UNIVERSITAT DE BARCELONA

An analytical study about the relationship between Green Supply Chain Management practices and Organizational Performance

Keivan Amirbagheri

RSITAT DE
ELONA

2019

Keivan Amirbagheri | PhD in Business

UNIVERSITAT DE
BARCELONA

PhD in Business

An analytical study about the relationship between Green Supply Chain Management practices and Organizational Performance

Keivan Amirbagheri

LIBERTAS PERFVNDET
OMNIA LVCE

UNIVE
BARC

Tamaño final abierto: 353 mm × 240 mm | Ancho total [formato cerrado]: 170 mm | Lomo: 13 mm

Generado por HurryCover 2.027 (9-9-2019)

PhD in Business

Thesis title:

An analytical study about the relationship between Green Supply Chain Management practices and Organizational Performance

PhD student:
Keivan Amirbagheri

Advisors:
Laura Guitart-Tarrés
Ana Núñez-Carballosa

Date:
September 2019

Universitat de Barcelona

Dedicated to my best friends,

My beloved family

تقدیم به پدر و مادرم

Acknowledgement

Doing this Ph.D. dissertation has been the most valuable opportunity that I had throughout my life. Although it was very challenging in its each step, but I would not be able to fulfill this mission without the precious help of my supervisors, my family, my colleagues and my friends.

Firstly, I would like to express my special appreciation and thanks to my dear advisors Dr. Laura Guitart-Tarrés and Dr. Ana Núñez-Carballosa. You have been the best mentors for me. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. Your advice on both research as well as on my career have been priceless.

Many thanks to Dr. José María Merigó Lindahl for his wonderful help and support during my visiting stay at University of Chile. Undoubtedly, I learned a lot from him.

A special thanks to my fantastic family. Words cannot express how grateful I am. To my mother, my father and my brother for all the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far.

To the individuals and organizations that provided the possibility to implement my interviews. First, Cesar Castillo and Fundación ICIL that your help was inevitable during this way. To Xavier Rius especially for his great support.

Many thanks to many individuals of the University of Barcelona that were really like my family. To Dr. Mercè Bernardo for her support and Paloma Miravitlles Matamoros, Martí Sagarra, Yuliya Kasperkaya, Fariza Achcaoucaou Iallouchen and Elio Shijaku for their motivating ideas. Finally, to Dr. Esther Hormiga for her efforts in coordinating the Ph.D. program in Business.

I am also grateful to Joana Rafecas and Jordi Roca for their unfailing support and assistance that made this program more pleasing.

Thanks to my dear Ph.D. colleagues to their valuable support and academic comments, especially to my dearest friend Agustin Torres Martinez that during these all years was always by my side, Jaime Alexander López Guauque, Magaly Gaviria Marin, Hugo Baier Fuentes, Helen Castellón Orozco, Cristian Granados Sanchez, Alfonso Hernandez, Alina Fesenko, Lijue Lu, Ryan Armstrong, Aleida Lopez, Nina Magomedova, Adeline Abou Ali, Liz Arroyo Carrasco, Behnoush Kangarlou, Vahid Minaei and many others.

Hani Amiri who cannot read these lines or share this special moment that we always dream of, but I will be eternally grateful to life, for having her in my way and transmitting so many positive things to me.

And finally, to my dearest friends, Ali, Amin, Alireza, Behnam, Carolina and Behrad for their great support.

LIST OF CONTENT

Chapter 1. Introduction

Chapter 2. Research on green supply chain: a bibliometric analysis

Chapter 3. Green supply chain practices and organizational performance: A case study in Spain

Chapter 4. OWA operators in the calculation of the average green-house gases emissions

Chapter 5. Conclusions

Annexes

List of tables

List of figures

List of abbreviations

GSC ……..	green supply chain
GHG ………………………………	green-house gases
GSCM ………………………………	green supply chain management
OWA ………………………………	ordered weighted average
SSC …………………………………	sustainable supply chain
SSCM ………………………………	sustainable supply chain management
WoS ……...	Web of Science
OR/MS ……......................................	operational research/ management science
POM ………………………………..	production and operational management
ENMs ……………………………….	engineering nanomaterials
JCR …………………………………	journal citation reports
OP …………………………………..	organizational performance
IOWGA …………………………….	induced ordered weighted geometric averaging
GIOWA …………………………….	generalized induced ordered weighted averaging
WA …………………………………	weighted averaging
HWA ……………………………….	hybrid weighted averaging
OWAGE ...………………………….	ordered weighted averaging GHG emission
IOWAGE …....................................	induced ordered weighted averaging GHG emission
OWAWAGE	ordered weighted averaging weighted average GHG emission
OWAWAGE	ordered weighted averaging weighted average GHG emission
IOWAWAGE ... ………………………..	induced ordered weighted averaging weighted average GHG emission
POWAWAGE ………………………….	probabilistic ordered weighted averaging weighted average GHG emission
IPOWAWAGE	induced probabilistic ordered weighted averaging weighted average GHG emission
GOWAGE …..	generalized ordered weighted averaging GHG emission

A-IOWA ………………………………. arithmetic-IOWA

GM …………... generalized mean

CHAPTER 1

Introduction

1.1 Introduction

Over the last decades, enterprises have begun to apply for environmental management programs, and green supply chain practices, help them to compete in the markets. At the same time, the number of studies on the green supply chain (GSC) has significantly increased during this period.

As a comprehensive definition to apply in this work, I use what Srivastava (2007) presents i.e. "integrating environmental thinking into supply-chain management, including product design, material sourcing, and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life."

In addition, organizational performance can be measured on a variety of dimensions and refers to the financial and non-financial performance of the organization (Walker and Ruekert, 1987).

In addition, it is very important to mention that within the exceptionally later decades, since of a gigantic development of the population and the need to supply nourishment for them from one hand and the other hand an immethodical utilization of fossil fuel, our planet is experiencing an unexampled growth in terms of greenhouse gases (GHG) emission such as CO_2, CH_4 and N_2O in its atmosphere that cause an ascending number of global warming, year by year and a drastic climate change (Hastings et al. 2010; IPCC, 2007; Stewart et al. 2013). Aggregation operators in the related literature with the aim of decision making are diverse and each of them can be used to collect the information (Belaikov et al. 2007; Merigó and Casanova, 2010).

1.2 Motivation, objectives, methodologies and research questions

1.2.1 Motivation and objective

The very first objective of this dissertation is to investigate comprehensively the world of green supply chain management to obtain a profound insight into the world of GSCM and its practices via bibliometric analysis as a powerful tool.

The scholars agree that bibliometric analysis is the research field of library and information sciences that studies bibliographic material with quantitative methods (Broadus, 1987; Pritchard, 1969). Vast applicability of this

methodology among the various fields of science made it popular among scholars.
During the last couple of decades, the growth of environmental concerns from one side and institutional and non-institutional pressures from the other side causes the topic of green supply chain management (GSCM) gain high importance. Besides, it is noteworthy to mention that in terms of diversity, in comparison with the past decades, now there is a bigger number of countries (both developed and developing) that are interested in implementing GSCM. Many scholars have presented different definitions for this concept. Each of them analyzes GSCM from a unique point of view. One of the most comprehensive works is the research of (Ahi and Searcy, 2013) that collects 22 definitions of GSCM. As an example, Handfield et al. (1997) believe that green supply chain management refers to applying the environmental management principles to the full set of activities across the whole customer order cycle. Albino et al. (2009) assume the GSCM as a strategic approach to extend environmental measures to the whole supply chain. Lakhal et al. (2007) use a metaphoric concept to describe the green supply chain. They state that the green supply chain practices are five like the five circles of the Olympic flag. These elements are zero emissions, zero waste in activities, zero waste of resources, zero use of toxic substances and zero waste in product lifecycle. In addition, Kim et al. (2011) emphasize that the GSCM practices intend to effect control and support environmental performance by allocating possible human material resources and redefining organizational responsibilities and procedures. Finally, Andiç et al. (2012) recommend that the GSCM is minimizing or eliminating the effect of the supply chain on the environment. As a very simple definition, green supply chain management refers to integrate environmental thinking into supply chain management (Chin et al. 2015; Sarkis, 2012).
There are many works that review the related literature to green supply chain management. Govindan et al. (2015) focus on the methodology among the GSCM papers, Islam et al. (2018) and Igarashi et al. (2013) have dedicated their effort to analyze specific practices. Also, Srivastava (2007) addresses a broader aspect of green supply chain management in his work (Tseng et al. 2019).

From the other hand, one major and fundamental concept to this study is organizational performance. Yamin et al. (1999) believe that organizational performance refers to the quality of achievement of one organization in its market-based goals and financial ones. Zhang (2010), Vickery et al. (1999) and Stock et al. (2000), use these two criteria for measuring organizational performance. But some other studies (Testa and Iraldo, 2010; Zhu and Sarkis, 2004; Nakano and Hirao, 2011) express that the organizational performance refers to other items such as environmental performance as well. Based on the consideration of this doctoral thesis, organizational performance refers to a combination of these items that are environmental, financial, marketing and business performance.

Several investigators have done studies to analyze the relationship of the green supply chain management practices on the performance in general (Green et al. 2012; Lee et al. 2012; Yu et al. 2014; Vijayvargy et al. 2017; Diab et al. 2015). In average almost all these studies have detected a positive influence of green supply chain management practices on the performance. In this doctoral thesis, the fundamental objective of is **to investigate the relationship between Green Supply Chain Management practices and Organizational Performance** based on a thorough literature review to obtain the GSCM practices from one side and the organizational performance factors from the other side.

As mentioned before in the work of Lakhal et al. (2007) zero-emission is one of the fundamental aspects of the GSCM that every company seeks that. Some studies dedicate their works to this issue (Jaggernath and Khan, 2015; Rehman et al. 2016). In this work also green-house gases emission also has detected as one of the major concerns of the companies that by implementing GSCM practices they try to improve its situation.

In this sense, the last objective of this doctoral thesis comes after the core objective of this work that is proposing a quantitative analysis of the obtained outputs. To this end, I applied the concept of ordered weighted average (OWA) operators to decide about the green-house gases emission as a critical concern of the companies. This phenomenon during the last couple of decades has experienced enormous growth. So, it seems necessary to dedicate a significant section of this work to this item. OWA operators provide a parametrized family of aggregation operators between the minimum and the maximum, weighting the data according to the attitudinal character of the decision-maker. Besides, it seems necessary to mention that this chapter of work is the output of the previous section and the results of the interviews and among various methodologies, I applied this methodology to express that as better as possible.

1.2.2 Research methodology

With the intention of responding to the objectives of this doctoral thesis, in this study, I applied three diverse methodologies to pursue the objectives of this thesis.

At the very first stage of this work and with the aim of gaining a comprehensive image about the world of green supply chain management I conducted a bibliometric study. Nowadays, thanks to the enhancement of computer technology, using this methodology could prepare easily a quantitative report about the topic (Merigó et al. 2015).

By obtaining information about the GSCM, the next step was conducting a qualitative study through a group of interviews to analyze the level of GSCM implementation and its influence on organizational performance. The qualitative data provide more appropriate findings than quantitative ones (Creswell and Poth, 2017).

The last applied methodology is a quantitative approach by applying an ordered weighted average operator to analyze greenhouse gases emissions.

1.2.3 Research questions

In continuation of the previous section, it is important to form the research questions. As discussed, the core objective of this thesis is to study the green supply chain management practices and their influence on organizational performance. In addition, without gaining a profound insight about GSCM concept, the work cannot be complete. From the other point of view and after investigating the main issue of this work, is time to focus on the principle outputs of this objective.

So, to this end, this doctoral thesis, targets to prepare answers to the upcoming research questions:

RQ1: What is going on in the world of Green Supply Chain Management? What are the trends among countries, institutions, journals, etc.?

RQ2: What is the state of green supply chain management practices implementation?

RQ3: How can Green Supply Chain Management practices implementation have an influence on organizational performance?

RQ4: How ordered weighted averaging operators can be applied for the analysis of average gases emissions?

1.3 Thesis structure

This doctoral thesis is based on the academic articles that are listed as chapters **2**, **3** and **4** respectively. Each article from one side responds to the general objective of the thesis and from the other side based on their contributions, answers the above-mentioned research. The first article (**chapter 2**) is formed to respond to the first research question. This chapter through a bibliometric analysis presents a comprehensive insight and gives a general picture from the world of green supply chain management. The second article (**chapter 3**) prepares the answer to the second and the third research questions by applying a qualitative methodology. Finally, the last article (**chapter 4**) responds to the fourth research question by using the concept of OWA operators.

Figure 1.1 prepares a comprehensive understanding of each chapter and article.

Figure 1.1 An overview to chapters 2 to 4

Chapter 2

- **Title:** Research on green supply chain: A bibliometric analysis
- **Methodology:** Bibliometric methods
- **Contributions:** Provide useful insight for the policy-makers of the green supply chain field from one side and present a quick overview for the academic readers about this field of the investigation

Chapter 3

- **Title:** Green supply chain practices and organizational performance: A case study in Spain
- **Methodology:** Multiple and comparative case study – 6 companies and secondary data
- **Contributions:** Provide a comprehensive analysis in the situation of green supply chain management practices implementation in some Spanish-based companies and study the influence of those practices on the organizational performance

Chapter 4

- **Title:** OWA operators in the calculation of the average green-house gases emissions
- **Methodology:** OWA operators and fuzzy logic method
- **Contributions:** Provide new ordered-weighted average operators to calculate the average GHG emissions and present an illustrative example of the European countries

Chapter 2 is dedicated to the first paper of this thesis. Through this paper, I analyze all publications in the green supply chain from the very first year of its presence to 2017 by the help of bibliometric methodology. In this paper, I analyze the published papers in this area by various bibliometric indicators to obtain a thorough insight into this field. The main objective of this paper is to obtain a complete understanding of the green supply chain management world, the diverse trends among universities, countries, authors, keywords, and journals. As mentioned, bibliometric analysis is used to implement this study as a powerful tool that makes this analysis possible. Also, the graphical analysis was applied by VOS Viewer software to prepare a visual result to support the outputs from the bibliometric analysis. A general finding of this study demonstrates that among countries, although the USA is the most productive country, some Asian countries, especially China, are quickly improving their rankings. The same is happening among the Asian universities. **So, this chapter prepares a clear and comprehensive response to the first research question of this Ph.D. thesis**.

By answering this first research question and obtain a general insight about GSCM world, now it is a time entry to the next chapter to answer to the upcoming research questions.

The second paper (chapter 3) through a case study analysis and using qualitative data investigates the level of the implementation of green supply chain management practices in the companies. It also analyzes the possible influences of the implementation of these practices on the organizational performance in the cases of this study that are manufacturers and transportation and logistics operators. In this investigation, the organizational performance refers to *environmental, financial, business and marketing performances*. The findings of this study represent a prominent level of implementation of GSCM practices among the cases of the study on average. However, it is noteworthy to state that the influence of GSCM practices on the organizational performance is not the same and it varies in a wide spectrum of direct or indirect influence. **This paper answers to the second and third research questions of this thesis**.

One of the main concerns of the companies based on the results of the previous chapter is the emission of greenhouse gases (GHG) emission and tries to minimize it. So, the last paper (chapter 4) of this thesis presents a calculation of the greenhouse gases emission by using the OWA operators and give a practical example in the case of European countries.

The purpose of this study is to concentrate on the analysis of the use of the aggregation operators in the calculation of GHG emission with the aim of developing better decision-making techniques. I also analyzed the applicability of these approaches for the process of the decision-making problem in GHG emission. To achieve this aim, I implement an illustrative example regarding the calculation of the average of green-house gases emission among European countries. **This paper, responses to the very last research question of this study**.

The closing section (chapter 5), prepares a brief conclusion about the obtained results in the previous sections. Besides, it prepares some future lines of the investigation and mentions the limitations that I have been confronted during the process of investigation.

1.4 Results

This Ph.D. thesis is based on the articles, international conferences, and workshops that are explained here:

Chapter 2:

Published article

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L., and Merigó, J. M. (2019). Research on green supply chain: a bibliometric analysis. Clean Technologies and Environmental Policy, 21(3), 3-22, Impact factor: 2.337.

International conference

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L., and Merigó, J. M. (October 2018). *Research on green supply chain: a bibliometric analysis.* Paper presented at Operations Management: Manufacturers Meeting Service Innovation, POMS International Conference. Granada, Spain.

Chapter 3:

Under review

Amirbagheri, K., Núñez-Carballosa, A., and Guitart-Tarrés, L. Green supply chain practices and organizational performance: A case study in Spain. Under review in Journal of Cleaner Production, Impact factor: 6.395.

International conference

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L. (April 2016). *Green Supply Chain Management practices and Organizational Performance. An analytical study*. Paper presented at the 3rd International EurOMA Sustainable Operations and Supply Chains Forum. Lancaster, UK.

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L. (October 2018). *Green supply chain practices and organizational performance: A case study in Spain*. Paper presented at Operations Management: Manufacturers Meeting Service Innovation, POMS International Conference. Granada, Spain.

International Workshop

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L. (November 2017). *Green supply chain practices and organizational performance: A case study in Spain*. Paper presented at 10th EurOMA workshop on journal publishing in Operations Management. Sant Cugat, Spain.

Chapter 4:

Under review

Amirbagheri, K., Merigó, J. M., Guitart-Tarrés, L., and Núñez-Carballosa, A. OWA operators in the calculation of the average green-house gases emissions. Minor revision in Journal of Intelligent & Fuzzy Systems, Impact factor: 1.426.

National conference

Amirbagheri, K., Merigó, J. M., Guitart-Tarrés, L., and Núñez-Carballosa, A. (October 2018). *OWA operators in the calculation of the average green-house gases emissions*. Paper presented at XVIII Conferencia de la Asociación Española para la Inteligencia Artificial National Conference. Granada, Spain.

1.5 Conclusions

In this very last section of this chapter I conclude the obtained results of this study. This doctoral thesis follows up three main objectives and based on them tries to answer to four research questions. Both are listed below:

Objectives:

- To investigate comprehensively the world of green supply chain management via bibliometric analysis to gain a clear insight.
- To investigate the relationship between Green Supply Chain Management practices and Organizational Performance.
- Apply the concept of ordered weighted average (OWA) operators to decide about the green-house gases emission as a critical concern of the companies.

Research questions:

RQ1: What is going on in the world of Green Supply Chain Management? What are the trends among countries, institutions, journals etc.?

RQ2: What is the state of selected companies in terms of green supply chain management practices implementation?

RQ3: How can Green Supply Chain Management practices implementation influence on the organizational performance?

RQ4: How ordered weighted averaging operators can be applied for the analysis of average gases emissions?

The first objective of this thesis is related to the first research question. By applying the methodology of bibliometric analysis, the results and the findings to respond to this question are reflected in the academic paper that is addressed below:

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L., and Merigó, J. M. (2019). Research on green supply chain: a bibliometric analysis. Clean Technologies and Environmental Policy, 21(3), 3-22, Impact factor: 2.337.

This article is thoroughly reflected in **chapter 2** of this thesis.

The second objective of this thesis is related to the second and the third research questions of this thesis. To provide a comprehensive response, the upcoming paper has been written. It is noteworthy to mention that this paper is explained in **chapter 3**.

Amirbagheri, K., Núñez-Carballosa, A., and Guitart-Tarrés, L. Green supply chain practices and organizational performance: A case study in Spain. Under review in Journal of Cleaner Production, Impact factor: 6.395.

The final objective is related to the fourth research question. The next paper is designed to answer to this question that completely is described in **chapter 4** of this doctoral thesis.

Amirbagheri, K., Merigó, J. M., Guitart-Tarrés, L., and Núñez-Carballosa, A. OWA operators in the calculation of the average green-house gases emissions. Minor revision in Journal of Intelligent & Fuzzy Systems, Impact factor: 1.426.

On the other hand, Table 1.1 is prepared to support more graphically the obtaining of this work and to give a general overview of the entire process of this thesis.

Table 1.1 Objectives, research questions and outputs of thesis

Objective	Related research question(s)	Methodology	Output (paper)
To investigate comprehensively the world of green supply chain management via bibliometric analysis to gain a clear insight	What is going on in the world of Green Supply Chain Management? What are the trends among countries, institutions, journals etc.?	Bibliometric analysis	Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L., and Merigó, J. M. (2019). Research on green supply chain: a bibliometric analysis. Clean Technologies and Environmental Policy, 21(3), 3-22, Impact factor: 2.337
To investigate the relationship between Green Supply Chain Management practices and Organizational Performance	What is the state of selected companies in terms of green supply chain management practices implementation? How can Green Supply Chain Management practices implementation influence on the organizational performance?	Qualitative analysis	Amirbagheri, K., Núñez-Carballosa, A., and Guitart-Tarrés, L. Green supply chain practices and organizational performance: A case study in Spain. Under review in Journal of Cleaner Production
Apply the concept of ordered weighted average (OWA) operators to decide about the green-house gases emission as a critical concern of the companies	How ordered weighted averaging operators can be applied for the analysis of average gases emissions?	Quantitative analysis	Amirbagheri, K., Merigó, J. M., Guitart-Tarrés, L., and Núñez-Carballosa, A. OWA operators in the calculation of the average green-house gases emissions. Minor revision in Journal of Intelligent & Fuzzy Systems, Impact factor: 1.426

1.6 References

Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. Journal of cleaner production, 52, 329-341.

Albino, V., Balice, A., & Dangelico, R. M. (2009). Environmental strategies and green product development: an overview on sustainability-driven companies. Business strategy and the environment, 18(2), 83-96.

Andiç, E., Yurt, Ö., & Baltacıoğlu, T. (2012). Green supply chains: Efforts and potential applications for the Turkish market. Resources, Conservation and Recycling, 58, 50-68.

Beliakov, G., Pradera, A., & Calvo, T. (2007). Aggregation functions: a guide for practitioners (Vol. 221). Heidelberg: Springer.

Broadus, R. (1987). Toward a definition of "bibliometrics". Scientometrics, 12(5-6), 373-379.

Chin, T. A., Tat, H. H., & Sulaiman, Z. (2015). Green supply chain management, environmental collaboration and sustainability performance. Procedia Cirp, 26, 695-699.

Creswell, J. W., & Poth, C. N. (2017). Qualitative inquiry and research design: Choosing among five approaches. Sage publications.

Diab, S. M., Al-Bourini, F. A., & Abu-Rumman, A. H. (2015). The impact of green supply chain management practices on organizational performance: a study of Jordanian food industries. J. Mgmt. & Sustainability, 5, 149.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. Journal of Cleaner Production, 98, 66-83.

Green Jr, K. W., Zelbst, P. J., Meacham, J., & Bhadauria, V. S. (2012). Green supply chain management practices: impact on performance. Supply Chain Management: An International Journal, 17(3), 290-305.

Handfield, R. B., Walton, S. V., Seegers, L. K., & Melnyk, S. A. (1997). 'Green'value chain practices in the furniture industry. Journal of Operations Management, 15(4), 293-315.

Hastings, A. F., Wattenbach, M., Eugster, W., Li, C., Buchmann, N., & Smith, P. (2010). Uncertainty propagation in soil greenhouse gas emission models: an experiment using the DNDC model and at the Oensingen cropland site. Agriculture, ecosystems & environment, 136(1-2), 97-110.

Igarashi, M., de Boer, L., & Fet, A. M. (2013). What is required for greener supplier selection? A literature review and conceptual model development. Journal of Purchasing and Supply Management, 19(4), 247-263.

IPCC, (2007). Fourth Assessment Report (AR4) of Working Group 1: Chapter 2. Changes in atmospheric constituents and in radiative forcing. http:// www.ipcc.ch/pub/reports.htm.

Islam, M. S., Tseng, M. L., Karia, N., & Lee, C. H. (2018). Assessing green supply chain practices in Bangladesh using fuzzy importance and performance approach. Resources, Conservation and Recycling, 131, 134-145.

Jaggernath, R., & Khan, Z. (2015). Green supply chain management. World Journal of Entrepreneurship, Management and Sustainable Development, 11(1), 37-47.

Kim, J. H., Youn, S., & Roh, J. J. (2011). Green supply chain management orientation and firm performance: evidence from South Korea. International Journal of Services and Operations Management, 8(3), 283-304.

Y. Lakhal, S., H'Mida, S., & Islam, M. R. (2007). Green supply chain parameters for a Canadian petroleum refinery company. International journal of environmental technology and management, 7(1-2), 56-67.

Lee, S. M., Tae Kim, S., & Choi, D. (2012). Green supply chain management and organizational performance. Industrial Management & Data Systems, 112(8), 1148-1180.

Merigó, J. M., & Casanovas, M. (2010). Fuzzy Generalized Hybrid Aggregation Operators and its Application in Fuzzy Decision Making. International Journal of Fuzzy Systems, 12(1).

Merigó, J. M., Gil-Lafuente, A. M., & Yager, R. R. (2015). An overview of fuzzy research with bibliometric indicators. Applied Soft Computing, 27, 420-433.

Nakano, K., & Hirao, M. (2011). Collaborative activity with business partners for improvement of product environmental performance using LCA. Journal of Cleaner Production, 19(11), 1189-1197.

Pritchard, A. (1969). Statistical bibliography or bibliometrics. Journal of documentation, 25(4), 348-349.

Rehman, M. A. A., Aneyrao, T. A., Pachchhao, A. D., & Shrivastava, R. L. (2016). Identification of performance measures in Indian automobile industry: a green supply chain management approach. International Journal of Business Performance Management, 17(1), 30-43.

Sarkis, J. (2012). A boundaries and flows perspective of green supply chain management. Supply chain management: an international journal, 17(2), 202-216.

Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. International journal of management reviews, 9(1), 53-80.

Stewart, C. E., Zheng, J., Botte, J., & Cotrufo, M. F. (2013). Co-generated fast pyrolysis biochar mitigates green-house gas emissions and increases carbon sequestration in temperate soils. Gcb Bioenergy, 5(2), 153-164.

Stock, G. N., Greis, N. P., & Kasarda, J. D. (2000). Enterprise logistics and supply chain structure: the role of fit. Journal of operations management, 18(5), 531-547.

Testa, F., & Iraldo, F. (2010). Shadows and lights of GSCM (Green Supply Chain Management): determinants and effects of these practices based on a multi-national study. Journal of Cleaner Production, 18(10-11), 953-962.

Tseng, M. L., Islam, M. S., Karia, N., Fauzi, F. A., & Afrin, S. (2019). A literature review on green supply chain management: Trends and future challenges. Resources, Conservation and Recycling, 141, 145-162.

Vickery, S. N., Calantone, R., & Dröge, C. (1999). Supply chain flexibility: an empirical study. Journal of supply chain management, 35(2), 16-24.

Vijayvargy, L., Thakkar, J., & Agarwal, G. (2017). Green supply chain management practices and performance: the role of firm-size for emerging economies. Journal of Manufacturing Technology Management, 28(3), 299-323.

Walker Jr, O. C., & Ruekert, R. W. (1987). Marketing's role in the implementation of business strategies: a critical review and conceptual framework. Journal of marketing, 51(3), 15-33.

Yamin, S., Gunasekaran, A., & Mavondo, F. T. (1999). Relationship between generic strategies, competitive advantage and organizational performance: an empirical analysis. Technovation, 19(8), 507-518.

Yu, W., Chavez, R., Feng, M., & Wiengarten, F. (2014). Integrated green supply chain management and operational performance. Supply Chain Management: An International Journal, 19(5/6), 683-696.

Zhang, Q. (2010). Technology Infusion Enabled Value-chain Flexibility: A Learning and Capability-based Perspective. Lambert Academic Pub.

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. Journal of operations management, 22(3), 265-289.

CHAPTER 2

Research on green supply chain: a bibliometric analysis

Abstract

Recently, the emergent concept of green supply chain has received increasing attention. Although popular among scholars, many literature reviews have only examined GSC from a general point of view or focused on a specific issue related to GSC. This study presents a comprehensive analysis of the influence and productivity of research on GSC from 1995 to 2017 by reporting trends among authors, countries and institutions based on a bibliometric approach. To this end, the study analyzes around 1900 papers on GSC. This study uses the Web of Science Core Collection database to analyze the bibliometric data and the visualization of similarities viewer method to graphically map those data. The graphical analysis uses bibliographic coupling, co-citation, co authorship and co-occurrence of keywords.

Keywords: green supply chain, bibliometric approach, Web of Science, VOS viewer

2.1 Introduction

Over the last decades, enterprises have begun to apply environmental management programs and green supply chain practices, to help them compete in the markets. At the same time, the number of studies on green supply chain (GSC) has significantly increased during this period.

Numerous studies have reviewed the literature on GSC in the period surveyed in this study. Each of these works has analyzed the GSC literature from a different point of view. For example, Srivastava (2007) adopts an integrated and fresh approach to consider the field of green supply chain management (GSCM) because of the necessity to present a comprehensive reference of GSCM to help academicians, researchers and practitioners. Carter and Rogers (2008) provide a large-scale literature review and use conceptual theory to introduce the concept of sustainability to the field of supply chain management. They demonstrate the relationships among environmental, social and economic performance within the context of a supply chain management. Seuring and Müller (2008) offer a conceptual framework to summarize the research in the field of sustainable supply chain. Their paper also offers a literature review on sustainable supply chain management. Hassini et al. (2012) review the literature related to sustainable supply chain (SSC) and provide a framework for SSC and performance management, whereas Ahi and Searcy (2013) identify and analyze the published definitions of GSCM and sustainable supply chain management (SSCM). Tiwari et al. (2018) analyze big data analytics in supply chain management. On the other hand, Govindan et al. (2015) focus on green supplier selection, whereas Miemczyk et al. (2012) investigate the sustainability of a purchasing and supply chain. Fahimnia et al. (2015) present a comprehensive evolution of the field, focusing on forward green supply chain practices by implementing a bibliometric methodology. Although the abovementioned literature review as well as other works provides valuable information on the state of the literature on GSC, there is still much need for a comprehensive bibliometric approach to analyze this literature. Based on this reality, after 2012 that is the last year of the work by Fahimnia et al. (2015), the GSC area experiences a huge increasing trend so, our study tries to cover this growth and report it. Besides, I believe that Web of Science (WoS) as a comprehensive database could prepare more complete results that can help us to obtain a more thorough analysis of this area. Also, in our work the items not only from one aspect (no. of papers) but also based on many measurements such as total publications, total citation and *h-index* try to explore the trends and the different items.

The aim of the work is to provide a bibliometric overview of GSC by using a modern bibliometric approach that uses several bibliometric indicators and the VOS viewer software during a 22-year period from 1995 to 2017 by reporting trends among authors, countries and institutions. To present the results graphically, this paper uses VOS viewer software (Van Eck and Waltman 2010). To develop the mapping analysis (Merigó et al.2018), this study uses bibliographic coupling (Kessler 1963), co-citation (Small 1973), co-authorship and co-occurrence of keywords (Merigó et al. 2016).

This paper first briefly discusses concepts and bibliometric studies related to green supply chain and reviews the existing literature. The next section describes the bibliometric methods used throughout the paper. “Results” section presents the bibliometric results of the WoS Core Collection, and “Graphical analysis of GSC with VOS viewer” section develops a graphical analysis of the bibliographic materials. The closing section describes the paper’s findings and states its conclusions.

2.2 Background

2.2.1 Green supply chain

An important environmental concept that has gained attention among companies and scholars over recent decades is GSCM. At the same time, a diverse set of definitions has been suggested for GSCM. This concept, as Srivastava (2007) notes, can be defined in several ways such as green purchasing, integrated green supply chains flowing from supplier to manufacturer to customer or reverse logistics. As mentioned above, Ahi and Searcy (2013) propose a thorough framework of 22 definitions of GSCM and 12 definitions of SSCM. Tseng et al. (2016) present empirical evidence of firms' GSC capabilities while Tsireme et al. (2012) explore the reasons that affect the decisions of managers of firms to adopt management practices in GSCM. The main objective of GSCM is to reduce, as much as possible, harmful environmental influences such as air and water pollution and to improve the ability to manage waste of resources such as energy, materials and products (Rao and Holt 2005; Eltayeb et al. 2011).

Many studies are conducted to achieve these objectives. For instance, Sarkis (2012) provides a framework to understand and appreciate the relationships among various research streams and topics in the field. Kainuma and Tawara (2006) extend the scope of supply chains to include reuse and recycling of products and services throughout their life cycle and apply that extended notion in a setting to confirm its efficiency. Based on their technique, Kainuma and Tawara (2006) were able to measure environmental and managerial performance. In another study, Kumar et al. (2012) explore a simple model that companies may use to understand and improve supply chain sustainability practices. Besides, de Oliviera et al. (2018) present the GSCM practices from a comprehensive point of view and to analyze the subject's behavior through a bibliometric analysis from 2006 to 2016.

2.2.2 Antecedents

There are numerous definitions for the term bibliometrics in the literature. One of the very first definitions of this term provided by Pritchard (1969) is "the application of mathematics and statistical methods to books and other media communications." A more comprehensive definition suggested by White and Mccain (1989) is that "bibliometrics is the quantitative study of the literature as they are reflected in bibliographies." According to yet another definition proposed by Broadus (1987), bibliometrics is "the quantitative study of physical published units, or of bibliographic units, or of surrogates of either" (Hood and Wilson 2001). The power of bibliometrics to classify the various aspects of a publication and its reported results in an organized form made bibliometrics a popular method. Additionally, this methodology not only is possible to apply in all of the fields of science but also can be used to review the performance of different journals (Laengle et al. 2018; Martínez-López et al. 2018). By using a very powerful and multifunctional software, it is easy to analyze the results obtained through bibliometrics (Merigó et al. 2015). The traces of a bibliometric analysis can be detected in papers in operational research/ management science (OR/MS), production and operational management (POM), supply chain management (SCM), green supply chain (GSC) and some other environmental science disciplines.

In recent decades, the use of OR/MS within the scientific community has increased substantially (Merigó and Yang 2017). They present a bibliometric overview of research published in OR/MS to identify some of the most relevant studies in this field and some of the newest trends according to the information found in the Web of Science database. Chang and Hsieh (2008) evaluate the distribution of papers published by Asian authors in OR/MS journals from 1968 to 2006 based on a bibliometric analysis, whereas White et al. (2011) attempt to present an overall assessment of OR in developing countries. In another work, Mingers and Xu (2010) concentrate on citation counts of papers published in six well-known MS journals.

"The origin of operations management is closely linked with the birth of the company itself, as there has always been a need to produce goods and services to be managed" (Alfalla-Luque and Medina-López 2009). Several bibliometric studies have also been done in the field of POM. Pilkington and Liston-Heyes (1999) use a co-citations analysis to investigate the intellectual foundations of the POM literature and consider whether they are distinct from those commonly associated with rival fields. Hsieh and Chang (2009), based on papers published in 20 core POM journals, explore the global POM research. Moreover, most of the academic areas of management have performed studies based on bibliometric parameters. These areas range from accounting and business to technologies used in business and industry.

Supply chain management is a strategy for integrating the activities of a supply chain (Oliver and Webber 1982) on a day-by-day basis, which has gained popularity among academics, and its nature has been investigated in numerous studies (Shiau et al. 2015). For example, Wong et al. (2012) develop a systematic review of the cross-disciplinary literature on SCM. At the same time, numerous studies analyze supply chain management through a bibliometric perspective. Charvet et al. (2008) use a bibliometric approach to study the intellectual structure of supply chain management. In another work, Alfalla-Luque and Medina-López (2009) examine SCM and its influence on the needs of companies by analyzing the bibliometric studies of the main journals in the discipline. Also, Chen et al. (2017) conduct a systematic literature review and a quantitative bibliometric analysis to review the literature to find out about the items that are studied by the authors and the existing gaps in the body of knowledge.

Some of the bibliometric studies focus on specific issues of GSC such as performance measurement (Beske-Janssen et al. 2015), corporate social responsibility for supply chain management (Feng et al. 2017) or green innovation (Albort- Morant et al. 2017). For example, Fahimnia et al. (2015) present a comprehensive evolution of the field, focusing on forward green supply chain practices by implementing a bibliometric methodology; their findings provide a robust road map for further investigations in this field. Beske-Janssen et al. (2015) systematically review the academic literature on sustainability performance measurement for SSCM published in the last 20 years. In the other study, Thomé et al. (2016) offer a novel combination of systematic literature review and bibliometric analysis of sustainable new product development.

There are some bibliometric works that have done to study some environmental issues. As an example, Hu et al. (2010) did a bibliometric analysis to identify the global research related to lead in drinking water field from 1991 to 2007 or in another similar work, Fu et al. (2013) analyzed the same topic but during 1992 and 2011. Zhao et al. (2018) conduct a large-scale bibliometric analysis on the trends of the emerging contaminants: nano-adsorbents, nano-photocatalysts and related research topics from the literature during 1998–2017. In another study, Wang et al. (2014) carried out a bibliometric analysis to provide insights into research activities and tendencies of the global risk of engineering nanomaterials (ENMs) from 1999 to 2012. From the other point of view, Andrade et al. (2017) organized a bibliometric analysis to investigate and analyze the scientific production related to indoor air quality of environments used for physical exercise and sports practice. Ioana-Toroimac (2018) through a review of previous publications builds maps of scientific knowledge on the hydromorphology integration in the water framework directive. In a more general and comprehensive perspective, Khan and Ho (2012) identify the top-cited articles published

In environmental science journals listed in Journal Citation Reports (JCR). Finally, Dragos and Dragos (2013), with a help of bibliometric approach, analyze the factors affecting scientific productivity in environmental sciences and ecology.

2.3 Bibliometric methods

This study uses certain bibliometric indicators to organize the data in a more reader-friendly form. By implementing these indicators, the paper aims to show different results relating to the same variable (Cancino et al. 2017). Among other things, the study uses the total number of papers and citations to measure productivity and influence (Blanco- Mesa et al. 2017), cites per paper and *h*-index (Alonso et al. 2009; Hirsch 2005). In addition, the study uses citation thresholds and some other indicators such as institutions ranking, country ranking and publications per person (Laengle et al. 2017; Valenzuela et al. 2017).

The study provides the bibliometric data from WoS Core Collection database. The search process occurred in September 2017 by using the keyword "green and supply chain." Search results are for articles published by the end of 2017. The initial search identified 2440 papers which were later reduced to 1892 after removing any document not classified as article, review, letter or note. So, the final number of papers of the analysis is 1892. The documents have 58,785 citations in total resulting in 31.07 citations per paper. The *h*-index is 111, implying that out of the 1892 papers, 111 have 111 citations or more.

As a complementary analysis, this study also presents a graphical image of the bibliographic material using the VOS viewer software (Van Eck and Waltman 2010). This software collects data and generates maps based on bibliographic coupling, co-authorship, citation, co-citation and co-occurrence of keywords (Merigó et al. 2016; Wang et al. 2018). Bibliographic coupling (Kessler 1963) occurs when two papers cite the same third paper. Co-citation (Small 1973) measures the most cited paper; it occurs when two papers are cited by a third paper. Co-authorship measures the degree of co-authorship of the most productive authors. Citation analysis focuses on the degree of citations between two variables. The co-occurrence of keywords shows the most common keywords used by different papers, as well as which keywords usually appear below the abstract. Network connection visualizes the keywords that appear more frequently in the same papers (Cancino et al. 2017).

2.4 Results

2.4.1 Publication and citation structure of GSC

The very first paper on GSC was published in 1995. Since then, the number of papers published on GSC has grown. To better understand this trend, Table 2.1 reports the number of papers published on GSC and their total citations. Additionally, by defining some thresholds, Table 2.1 identifies the range of highly cited papers relative to those with one or five citations.

During the first 7 years of the period studied in this paper, the number of papers published on GSC had not exceeded one. After this period, there had been a slight growth in the number of papers published on GSC. Until 2012, the number of published papers had increased significantly relative to previous years. From 2012 to 2017, journals had published increasingly more papers; the highest number of published papers is in 2017 with 469 papers. It should be noted that 6.82% of the papers have received more than one hundred citations that is 129 out of 1892 papers. In addition, 15.54% of the papers have received more than 50 citations and 68.08% and 90.17% of the papers have received more than five and one citations, respectively.

The next step is to analyze the most cited published papers in various journals. Table 2.2 reports the results based on a list of the 50 most cited papers of all time. The most cited paper in the GSC area was published in 2008 by Stefan Seuring and Martin Mueller; this paper has received 1400 citations. Among the ten most cited papers, Joseph Sarkis and Qinghua Zhu are leading in the list with three and two papers, respectively.

Another interesting item involving several factors is the most cited papers by other papers published in the GSC field. To derive this output, this study applies the VOS viewer (Van Eck and Waltman 2010) which enabled us to generate the results for co-citation of papers. Table 2.3 shows the 30 most cited papers from the highest to the lowest. The first three papers on this list receive the highest number of citations among the papers listed in Table 2.2.

In addition, another interesting item is the journals that are citing GSC. Table 2.4 presents the 30 journals that publish the largest numbers of papers citing GSC. To gain a deeper insight into these results, we have divided them into four periods. The first period stretches from 1995 to 2002 and the last from 2013 to 2017. Journal of Cleaner Production is the leading journal on this list. In the last two periods (from 2008 to 2017), there has been a sharp increase in the number of published papers citing GSC. Interestingly, the third-ranked journal on this list, Sustainability, has published 30 papers during the last 5 years.

A valuable point of view is obtained by data on authors, universities and countries of papers citing GSC. This analysis provided us with essential information about the GSC literature. Table 2.5 shows the top 30. After Clark University, the next two universities are Asians universities: the Hong Kong Polytechnic University and Dalian University of Technology. The presence of a remarkable number of Asian universities among the top universities shows the high interest in GSC in this region. Besides, the presence of many Asian countries in the analysis of countries also indicates the importance of this research area in Asia. Note that in this table and the other ones, we considered China and Taiwan as one country and also as separated countries.

2.4.2 Leading institutions and countries of GSC

Table 2.6 reports valuable information about the active institutions in the field of GSC. This table was organized based on the largest number of papers published in the journal. In addition, this comprehensive source shows some valuable information such as cites per paper, *h-index* and number of papers in each journal among the top 50 most cited articles.

Table 2.1 Annual citation structure of GSC								
Year	TP	TC	≥100	≥50	≥20	≥10	≥5	≥1
1995	1	21	0	0	1	1	1	1
1996	1	300	1	1	1	1	1	1
1997	2	80	0	1	2	2	2	2
1998	1	244	1	1	1	1	1	1
1999	0	0	0	0	0	0	0	0
2000	3	235	1	1	2	2	2	3
2001	1	69	0	1	1	1	1	1
2002	6	620	2	2	4	5	6	6
2003	4	809	2	2	4	4	4	4
2004	11	1360	3	6	8	10	11	11
2005	10	2362	5	8	10	10	10	10
2006	9	1604	7	9	9	9	9	9
2007	20	3870	12	16	17	20	20	20
2008	35	5559	16	22	29	32	33	34
2009	30	2572	8	18	24	28	29	29
2010	69	3631	13	25	40	56	60	67
2011	81	5884	19	43	55	65	72	78
2012	150	7203	18	51	103	120	137	148
2013	141	5830	13	36	88	113	126	137
2014	206	5811	6	30	101	148	180	199
2015	283	5235	2	19	99	170	214	267
2016	359	3288	0	1	50	120	218	328
2017	469	2198	0	1	17	70	151	350
Total	1892	58785	129	294	666	988	1288	1706
%	100%		6.82%	15.54%	35.20%	52.22%	68.08%	90.17%

Abbreviations: TP and Tc = Total papers and citations; ≥100, ≥50, ≥20, ≥10, ≥5, ≥1 Number of papers with equal or more 100, 50,20, 10, 5 and 1 citations

The Hong Kong Polytechnic University is the most productive and influential institute on this list. Because the ranking is based on the level of productivity, some universities, such as the Dalian University of Technology, have a higher level of influence and a lower level of productivity than other institutions. Thus, although the Dalian University of Technology is ranked third, it has more citations relative to the University of Southern Denmark.

With the help of Table 2.7, it is possible to consider a more detailed view of the institutions during the period surveyed in this paper. According to the information shown in these tables, although a Danish university is the leader of the last period of this study, the presence of Asian universities and especially the Chinese one is an important fact. The vital message folded in these data is the presence of Asian universities among the top universities; for example, the Islamic Azad University is the fourth one or University of Tehran is the seventh university of the list in the last period of the study.

Table 2.8 which reports results on countries provides a general understanding of these results and some important general criteria and represents the same results through 5-year intervals. The USA in both the general and the 5-year-interval formats occupies the first position if I do not consider China and Taiwan as the same country. However, the table shows a rapid ascent of Asian countries to the top of the list.

Table 2.2 The 50 most cited documents in GSC

R	Journal	TC	Title	Author/s	Year	C/Y
1	JCP	1400	From a literature review to a conceptual framework for sustainable supply chain management	Seuring, S; Mueller, M	2008	140
2	IJMR	1079	Green supply-chain management: A state-of-the-art literature review	Srivastava, SK	2007	98.09
3	IJPDL	825	A framework of sustainable supply chain management: moving toward new theory	Carter, CR.; Rogers, DS	2008	82.50
4	JOM	783	Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises	Zhu, QH; Sarkis, J	2004	55.93
5	IJOPM	670	Do green supply chains lead to competitiveness and economic performance?	Rao, P; Holt, D	2005	51.54
6	POM	569	Sustainable operations management	Kleindorf, PR; Singhal, K; Van Wassenhove, LN	2005	43.77
7	JOM	558	Sustainable supply chains: An introduction	Linton, JD.; Klassen, RD; Jayaraman, V	2007	50.73
8	JCP	529	A strategic decision framework for green supply chain management	Sarkis, J	2003	35.27
9	IJPE	504	An organizational theoretic review of green supply chain management literature	Sarkis, J; Zhu, QH; Lai, KH	2011	72
10	IJPE	491	Environmental management and manufacturing performance: The role of collaboration in the supply chain	Vachon, S; Klassen, RD	2008	49.10
11	IJOPM	471	Extending green practices across the supply chain - The impact of upstream and downstream integration	Vachon, S; Klassen, RD	2006	39.25
12	JSCM	423	Building a more complete theory of sustainable supply chain management using case studies of 10 examples	Pagell, M; Wu, Z	2009	47
13	IJOPM	409	Green supply chain management in China: Pressures, practices and performance	Zhu, QH; Sarkis, J; Geng, Y	2005	31.46
14	IJPE	375	Confirmation of a measurement model for green supply chain management practices implementation	Zhu, QH; Sarkis, J; Lai, KH	2008	37.50
15	IJPDL	360	Sustainable supply chain management: evolution and future directions	Carter, CR.; Easton, PL	2011	51.43
16	JCP	354	Green supply chain management: pressures, practices and performance within the Chinese automobile industry	Zhu, QH; Sarkis, J; Lai, KH	2007	32.18
17	JCP	300	An inter-sectoral comparison of green supply chain management in China: Drivers and practices	Zhu, QH; Sarkis, J	2006	25.00
18	CMR	300	Lean and green: The move to environmentally conscious manufacturing	Florida, R	1996	13.64
19	IJPR	292	The moderating effects of institutional pressures on emergent green supply chain practices and performance	Zhu, QH; Sarkis, J	2007	26.55
20	DSS	288	A review of modeling approaches for sustainable supply chain management	Seuring, S	2013	57.60
21	IJOPM	285	Greening the supply chain: a new initiative in South East Asia	Rao, P	2002	17.81
22	EJOR	284	Quantitative models for sustainable supply chain management: Developments and directions	Brandenburg, M; Govindan, K; Sarkis, J; Seuring, S	2014	71
23	IJPE	266	A literature review and a case study of sustainable supply chains with a focus on metrics	Hassini, Elkafi; S, Chirag; SC	2012	44.33
24	ESA	262	A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers	Buyukozkan, G; Cifci, G	2012	43.67
25	IJPE	260	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms	Yang, MG; Hong, P; Modi, SB	2011	37.14
26	JCP	257	Mapping the green product development field: engineering, policy and business perspectives	Baumann, H; Boons, F; Bragd, A	2002	16.06
27	RCR	255	An analysis of the drivers affecting the implementation of green supply chain management	Diabat, A; Govindan, K	2011	36.43
28	ESA	253	A green supplier selection model for high-tech industry	Lee, AHI; Kang, HY; Hsu, CF; et al.	2009	28.11
29	MQ	248	Information systems innovation for environmental sustainability	Melville, NP	2010	31
30	EJOR	246	Operations Research for green logistics - An overview of aspects, issues, contributions and challenges	Dekker, R; Bloemhof, J; Mallidis, I	2012	41
31	EJOR	244	Evaluating environmentally conscious business practices	Sarkis, J	1998	12.20
32	JCP	224	A comparative literature analysis of definitions for green and sustainable supply chain management	Ahi, P; Searcy, C	2013	44.80
33	TRE	224	An integrated logistics operational model for green-supply chain management	Sheu, JB; Chou, YH; Hu, CC	2005	17.23
34	OIJMS	223	Network design for reverse logistics	Srivastava, SK	2008	22.30
35	POM	220	Collaboration and evaluation in the supply chain: The impact on plant-level environmental investment	Klassen, RD; Vachon, S	2003	14.67
36	DSS	216	A multi-objective optimization for green supply chain network design	Wang, F; Lai, X; Shi, N	2011	30.86
37	TRE	215	Green supply chain management implications for closing the loop	Zhu, QH; Sarkis, J; Lai, KH	2008	21.50
38	IJPE	212	Modeling carbon footprints across the supply chain	Sundarakani, B; de Souza, R; Goh, M; Wagner, SM; Manikandan, S	2010	26.50
39	SCMIJ	212	Corporate social responsibility in global supply chains	Andersen, M; Skjoett-Larsen, T	2009	23.56
40	TRE	209	Environmental purchasing and firm performance: an empirical investigation	Carter, CR; Kale, R; Grimm, CM	2000	11.61

Table 2.2 (continued)

R	Journal	TC	Title	Author/s	Year	C/Y
41	JOM	203	Balancing priorities: Decision-making in sustainable supply chain management	Wu, Z; Pagell, M	2011	29
42	SCMIJ	201	Use the supply relationship to develop lean and green suppliers	Simpson, DE; Power, DF	2005	15.46
43	JCP	200	Integration of artificial neural network and MADA methods for green supplier selection	Kuo, RJ; Wang, YC; Tien, FC	2010	25.00
44	ESA	199	Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain	Shaw, K; Shankar, R; Yadav, SS; Thakur, LS	2012	33.17
45	SCMIJ	199	Green supply chain management practices: impact on performance	Green, KW Jr.; Zelbst, PJ; Meacham, J; et al.	2012	33.17
46	SCMIJ	198	Drivers for the participation of small and medium-sized suppliers in green supply chain initiatives	Lee, SY	2008	19.80
47	OIJMS	193	Firm-level correlates of emergent green supply chain management practices in the Chinese context	Zhu, QH; Sarkis, J; Cordeiro, JJ; Lai, KH	2008	19.30
48	SCMIJ	191	Making connections: a review of supply chain management sustainability literature	Ashby, A; Leat, M; Hudson-Smith, M	2012	31.83
49	JSCM	190	Corporate social responsibility reports: A thematic analysis related to supply chain management	Tate, WL; Ellram, LM; Kirchoff, JF	2010	23.75
50	POM	188	Drivers and Enablers That Foster Environmental Management Capabilities in Small- and Medium-Sized Suppliers in Supply Chains	Lee, SY; Klassen, RD	2008	18.80

Abbreviations available in Table 2.1 except for: R = Rank; C/Y = Citations per year; JCP= Journal of Cleaner Production; IJMR = International Journal of Management Reviews; JOM = Journal of Operations Management; IJPLDL = International Journal of Physical Distribution & Logistics Management; IJOPM = International Journal of Operations & Production Management; IJPE = International Journal of Production Economics; JSCM = Journal of Supply Chain Management; IJPR = International Journal of Production Research; EJOR = European Journal of Operational Research; MQ = MIS Quarterly; TRE = Transportation Research Part E-Logistics and Transportation Review; ESA = Expert Systems with Applications; POM = Production and Operations Management; RCR = Resource Conversation and Recycling; OIJMS = Omega-International Journal of Management Science; DSS = Decision Support Systems; SCMIJ = Supply Chain Management-an International Journal; M&SOM = Manufacturing & Service Operations Management; JSCM = Journal of Supply Chain Management; JEM = Journal of Environmental Management.

Table 2.3 Most cited documents in GSC publications

R	cited reference	citations	TLS
1	Srivastava SK, 2007, Int J Manag Rev, v9, p53	388	381
2	Zhu QH, 2004, J Oper Manag, v22, p265	374	374
3	Seuring S, 2008, J Clean Prod, v16, p1699	348	346
4	Rao P, 2005, Int J Oper Prod Man, v25, p898	323	323
5	Vachon S, 2006, Int J Oper Prod man, v26, p795	242	241
6	Sarkis J, 2011, Int J Prod Econ, v130, p1	223	223
7	Sarkis J, 2003, J Clean Prod, v11, p397	220	219
8	Carter CR, 2008, Int J Phys Distr Log, v38	214	213
9	Vachon S, 2008, Int J Prod Econ, v111, p299	204	203
10	Zhu QH, 2005, Int J Oper Prod Man, v25, p449	203	203
11	Porter ME, 1995, Harvard Bus Rev, v73, p120	202	201
12	Hart Sl, 1995, Acad Manage Rev, v20, p986	200	200
13	Zhu QH, 2008, Int J Prod Econ, v111, p261	191	191
14	Bowen FE, 2001, Prod Oper Manag, v10, p174	187	187
15	Hervani AA, 2005, Benchmarking, v12, p330	170	170
16	LInton JD, 2007, J Oper Manag, v25, p1075	170	169
17	Kleindorfer PR, 2005, Prod Oper Manag, v14, p482	165	163
18	Zhu QH, 2006, J Clean Prod, v14, p472	158	158
19	Zhu QH, 2007, J Clean Prod, v15, p1041	156	156
20	Rao P, 2002, Int J Oper Prod Man, v22	154	154
21	Walker H, 2008, Journal Purchas Supply Manag, v14, p69	150	150
22	Min H, 2001, Int J Oper Prod Man, v21, p1222	139	138
23	Zhu QH, 2007, Int J Prod Res, v45, p4333	138	137
24	Klassen RD, 1996, Manage Sci, v42, p1199	125	125
25	Russo MV, 1997, Acad Manage J, v40, p534	123	123
26	Handfield R, 2002, Eur J Oper Res, v141, p70	121	120
27	Geffen CA, 2000, Int J Oper Prod Man, v20	120	120
28	King AA, 2001, Prod Oper Manag, v10, p244	120	120
29	Fornell C, 1981, J Marketing Res, v18, p39	117	116
30	ArmStrong JS, 1977, J Marketing Res, v14, p396	111	111

Abbreviations: TLS – Total Link Strength

Moreover, additional changes in the ranking of countries seem to be inevitable.

2.4.3 Graphical analysis of GSC with VOS viewer

The previous part focused on general results concerning leading authors, institutions and countries in the field of GSC. It is also useful, however, to examine such outputs as co-citation and co-occurrence of keywords. To this end, this study uses VOS viewer software (Van Eck and Waltman 2010).

To show co-citation, that is, two journals cited by a third journal, Fig. 1 reports the results of journals with a threshold of 100 citations and of papers with the 100 most representative co-citation connections. As it can be seen, different clusters of journals are separated by distinct colors. The Journal of Cleaner Production is in the center of this figure being a leading journal with the highest number of citations received in this field. Besides, another interesting item is the form of the dispersion of the journals. Normally, the clusters are formed based on the common subjects in the same area and cite the journals that are in their area although there are some exceptions also.

To gain a deeper insight into the results presented in Fig. 1, Table 2.9 shows the 50 most cited journals. This report is divided into two classifications: global and periodic. The periodic analysis allowed us to study the effects and evolution of each of these journals.

Another noticeable item is the bibliographic coupling of institutions. Figure 2 presents a visual report of data involving at least 100 papers and 300 bibliographic coupling connections. In addition, this figure shows how each of the leading institutions is connected to the other institutions. To interpret this figure and justify the obtained result, two items are important: 1. the proximity of the universities either in the same country or in the same continent and 2. The nationality of the authors. As it can be seen, normally the collaboration occurs between the universities that are in the same area or even those that have the same language. In addition, in many cases the authors of the universities do not have the same nationality as the university, and in some cases, it is observed that one author collaborates with a university from his nationality.

Figure 3 reports the type and level of co-authorship between authors who have published at least 80 papers. The lines between authors' labels show the co-authorship relationship. The more the lines there are, the higher the level of co-authorship. As it can be seen, among the clusters of this figure, there are three main clusters that their cores are the Sarkis, Govindan and Zhu that have the highest level of the co-authorship, respectively.

Figure 4 presents bibliographic coupling of countries that publish in GSC with a threshold of 50 papers. The size of the labels reflects the country's number of publications.

Table 2.4 Citing article of GSC: Journals

R	Journal	95-02	03-07	08-12	13-17	TP
1	J. of Cleaner Production	2	8	24	243	277
2	Int J. of Production Economics	-	3	38	91	132
3	Sustainability	-	-	-	74	74
4	Int J. of Production Research	-	6	20	46	72
5	Supply Chain Management an Int J.	-	2	15	29	46
6	Business Strategy and the environment	-	-	14	23	37
7	Transportation Research Part E Logistics and Transportation Review	1	1	10	23	35
8	Production Planning Control	-	-	6	25	31
9	Resources conservation and Recycling	-	-	10	21	31
10	Int J. of Physical Distribution Logistics Management	-	-	12	18	30
11	Computers & Industrial Engineering	-	-	3	26	29
12	Int J. of Operations Production Management	1	5	4	18	28
13	European J. of Operational Research	1	1	2	21	25
14	Industrial Management & Data Systems	1	-	4	15	20
15	Industrial Marketing Management	-	-	8	12	20
16	Expert Systems with Applications	-	-	9	9	18
17	Benchmarking an Int J.	-	-	-	17	17
18	Int J. of Logistics Management	-	-	4	12	16
19	J. of Purchasing and Supply Management	-	-	6	9	15
20	Int J. of Advanced Manufacturing Technology	-	-	2	11	13
21	OMEGA Int J. of Management Science	-	-	3	10	13
22	J. of Environmental Management	-	2	4	6	12
23	Renewable Sustainable Energy Reviews	-	-	-	12	12
24	Int J. of Logistics Research and Applications	-	-	4	7	11
25	J. of Supply Chain Management	-	-	3	8	11
26	Transportation Research Part D Transport and Environment	-	-	1	10	11
27	Int J. of Environmental Science and Technology	-	1	4	5	10
28	J. of Manufacturing Technology Management	-	-	-	10	10
29	Mathematical Problems in Engineering	-	-	-	10	10
30	Annals of Operations Research	-	-	-	9	9

Abbreviations available in Table 2.1 and 2.2 except: 95-96, 97-01, 02-06, 07-11, 12-16 – Number of papers published in GSC in the five-year period considered.

The USA is the most productive country, and China and the UK (England, Scotland, Wales and North Ireland) are the second and third most productive countries. Also, the links among the countries demonstrate the level of collaboration that based on what said before about the institutions, usually this collaboration happens among the countries with geographical proximity or language proximity.

The last item in this analysis is the most common keywords used by authors publishing in the field of GSC. To obtain the pertinent results, a co-occurrence of author keywords should be developed. Figure 5 presents a visual report of keywords that appear 100 times or more, as well as the 300 most frequent co-occurrences. The most common keywords are sustainability, green supply chain management and supply chain management. Table 2.10 reports the results of Fig. 5. This table shows the 40 most common keywords in the field of GSC both globally and periodically. This figure and this table disclose one interesting result that during the years of this study, the interest to various keywords changes. In the other words, some keywords do not exist during the very first years of the analysis but in the next years gain importance and vice versa. In addition, the relationship among the keywords somehow shows the approach of the publications in this area.

Table 2.5 Citing articles of GSC: Authors, universities and countries

R	Author	TP	Institution	TP	Country	TP
1	Sarkis J	3512	Clarck U.	3049	Peoples R China+Taiwan	3135
2	Zhu QH	2335	Hong Kong Polytechnic U.	2528	Peoples R China	2371
3	Seuring S	1862	Dalian U. Technology	2478	USA	2128
4	Lai KH	1706	U. Kassel	1879	UK	1186
5	Govindan K	1468	Western U. Western Ontario	1791	Taiwan	764
6	Klassen RD	1421	U. Southern Denmark	1514	Germany	695
7	Vachon S	1306	U. Montreal	895	India	684
8	Carter CR	1183	Worchester Polytechnic U.	803	Spain	659
9	Geng Y	848	Khalifa U. Science Technology	736	Italy	653
10	Pagell M	738	Erasmus U. Rotterdam	730	Australia	566
11	Diabat A	736	U. East Anglia	685	Canada	557
12	Wu ZH	667	National Cheng Kung U.	608	Malaysia	482
13	Kannan D	637	Aalborg U.	603	France	472
14	Searcy C	536	National Central U.	595	Iran	470
15	Lee SY	523	Chinese Academy of Sciences	569	Netherlands	457
16	Gunasekaran A	511	U. Tennessee Knoxville	531	Brazil	428
17	Chan HK	509	U. Estadual Paulista	525	Turkey	364
18	Jabbour CJC	508	National Taipei U. Technology	522	Denmark	329
19	Tseng ML	480	Wageningen U. Research	515	Sweden	323
20	Buyukozkan G	468	U. Nova de Lisboa	499	South Korea	292
21	Sheu JB	424	National Taiwan U.	499	Finland	195
22	Tate WL	418	National Taiwan U. Science and Technology	486	Japan	183
23	Hsu CW	407	U. Teknologi Malaysia	482	Portugal	169
24	Jabbour ABLD	347	Cardiff U.	475	Belgium	160
25	Cruz-Machado V	345	Esade Business School	458	Greece	158
26	Azevedo SG	340	Lunghwa U. Sci Technology	442	Switzerland	156
27	Kuo TC	332	U. Bath	438	Norway	150
28	Bai CG	319	Chung Yuan Christian U.	429	Singapore	149
29	Koh SCL	313	National Tsing Hua U.	400	Poland	132
30	Carvalho H	312	U. Nottingham	386	New Zealand	114

Abbreviations available in Tables 2.1 and 2.2.

Table 2.6 The most productive and influential institutions in GSC

R	Institution	Country	TP	TC	H	C/P	≥50	≥25	≥5	ARWU	QS	Top 50
1	Hong Kong Polytechnic U.	Peoples R China	60	4086	29	68.10	21	32	55	201-300	111	7
2	U. Southern Denmark	Denmark	53	2517	28	47.49	15	30	46	301-400	390	2
3	Dalian U. Technology	Peoples R China	37	5026	26	135.84	21	26	36	301-400	481-490	10
4	Clarck U.	USA	37	6172	31	166.81	29	34	37	601-700	471-480	12
5	Worcester Polytechnic Institute	USA	29	1029	16	35.48	4	10	22	701-800	601-650	1
6	U. Estadual Paulista	Brazil	26	678	13	26.08	3	8	21	-	-	-
7	Islamic Azad U.	Iran	23	321	10	13.96	1	3	18	-	-	-
8	U. Teknologi Malaysia	Malaysia	20	515	10	25.75	4	7	13	701-800	288	-
9	Wageningen U. Research	Netherlands	20	547	10	27.35	2	5	14	-	119	1
10	National Kaohsiung U. Science Technology	Peoples R China	20	240	7	12.00	2	3	9	301-400	85	-
11	U. Tehran	Iran	19	413	10	21.74	3	7	12	301-400	551-600	-
12	Aalborg U.	Denmark	19	796	10	41.89	6	7	13	201-300	374	-
13	U. Nova de Lisboa	Portugal	18	638	12	35.44	4	9	15	501-600	366	-
14	U. Sheffield	UK	18	413	11	22.94	3	6	15	101-150	84	-
15	U. East Anglia	UK	18	767	13	42.61	4	10	16	301-400	252	-
16	U. Kassel	Germany	17	2463	11	144.88	7	10	12	-	-	3
17	Cranfield U.	UK	17	263	9	15.47	-	5	13	-	-	-
18	Lunghwa U. Science and Technology	People R China	16	529	11	33.06	3	6	15	-	-	-
19	Chinese Academy of Sciences	Peoples R China	16	697	11	43.56	7	9	12	-	-	-
20	National Taiwan U.	People R China	16	540	8	33.75	4	4	10	-	-	1
21	Dongebi U. Finance Economics	Peoples R China	16	298	8	18.63	2	5	11	-	-	-
22	Indian Institute of Technology Kharagpur	India	15	244	8	16.27	2	4	9	-	185	1
23	Khalifa U. Science Tehnology	United Arab Emirates	15	1014	14	67.60	6	12	15	-	401-410	1
24	U. Nottingham	UK	15	421	11	28.07	2	7	11	101-150	75	-
25	Western U. Western Ontario	Canada	15	2724	14	181.60	11	13	14	-	198	7

Table 2.6 (continued)

R	Institution	Country	TP	TC	H	C/P	≥50	≥25	≥5	ARWU	QS	Top 50
26	National Tsing Hua U.	Peoples R China	15	428	9	28.53	2	4	11	48	151	-
27	U. Padua	Italy	14	288	9	20.57	1	6	11	151-200	-	-
28	U. Montreal	Canada	14	1062	9	75.86	5	6	11	151-200	126	2
29	Esade Business School	Spain	14	530	9	37.86	3	8	12	-	-	-
30	U. Bath	UK	14	519	13	37.07	3	10	14	501-600	159	-
31	Polytechnic U. Milan	Italy	14	306	8	21.86	2	5	11	201-300	183	-
32	CNRS	France	13	158	7	12.15	1	4	11	-	-	-
33	U. Tennessee Knoxville	USA	13	580	10	44.62	2	5	12	201-300	461-470	2
34	Chung Yuan Christian U.	Peoples R China	13	477	8	36.69	4	5	11	201-300	-	-
35	U. Electronic Science Technology of China	Peoples R China	12	129	8	10.75	-	1	8	201-300	-	-
36	U. Sao Paulo	Brazil	12	307	8	25.58	2	4	9	151-200	120	-
37	National Central U.	Peoples R China	12	754	9	62.83	1	2	9	-	411-420	-
38	Lund U.	Sweden	12	109	6	9.08	-	2	8	101-150	73	-
39	Cardiff U.	UK	12	521	9	43.42	4	6	9	99	140	-
40	U. Leeds	UK	12	257	9	21.42	1	4	11	101-150	93	-
41	U. Beira Interior	Portugal	12	400	8	33.33	1	6	9	-	-	-
42	Erasmus U. Rotterdam	Netherlands	12	769	9	64.08	4	7	9	101-150	183	1
43	U. Malaya	Malaysia	11	124	6	11.27	-	1	7	401-500	133	-
44	Tianjin U.	Peoples R China	11	121	5	11	-	2	6	301-400	481-490	-
45	National Taipei U. Technology	People R China	11	674	8	61.27	4	5	9	-	551-600	2
46	U. Sydney	Australia	11	263	8	23.91	2	4	9	83	46	-
47	U. Sains Malaysia	Malaysia	11	236	6	21.45	1	4	6	-	330	-
48	Ryerson U.	Canada	11	452	7	41.09	4	7	11	-	701	2
49	National Taiwan U. Science and Technology	People R China	11	532	8	48.36	3	5	11		243	1
50	U. Massachusetts Dartmouth	USA	11	363	10	33	2	7	11	-	-	-

Abbreviations available in Tables 2.1 and 2.2 except: H – h-index; C/P – Cites per year; ≥25 – Number of documents with equal or more than 25 citations; ARWU and QS – Ranking in the general ARWU and QS U. rankings; Top 50 – Paper among the fifty most cited publishes in GSC.

2.5 Conclusions

This study presents a bibliometric overview of publications on GSC from 1995 until 2017. The study uses the WoS Core Collection database to analyze publications in the abovementioned period. The results show a significant growth of publications on GSC during the years surveyed in this paper.

The work reports the leading institutions and countries of journals that have published papers on GSC. Although the USA is the most productive country, some Asian countries, especially China, are quickly improving their rankings. The most productive and influential institution is the Hong Kong Polytechnic University. To justify the rapid growth of countries' number of publications in GSC, there are many effective reasons such as economic, environmental and social (Lee et al. 2013). The companies found out that the key to improve the performance in various aspects is applying GSC practices, and from the other point of view, global and governmental obligations are the other items that can influence this item. During the years of the study, the developing countries including many Asian countries try to have a share in the studies around GSC from one side, and from the other side, their efforts are dedicated to improving the situation of some less-studied industries in terms of green supply chain issue.

By using the VOS viewer software, the study considers co-citations, bibliographic coupling, co-authorship and the co-occurrence of keywords. The graphic results confirm the table's outputs. The most important benefit of using a graphical representation is the ability to show the various connections among variables.

Note that this work provides a general overview of the publication and citation structure of GSC by using a wide range of indicators including the total number of papers and citations, *h*-index, cites per paper and several citation thresholds. Based on this methodology, I comprehensively reviewed published articles to uncover prominent works. The study includes all published papers from different countries by all authors working in the field, so the results are as accurate and complete as possible. In addition, by analyzing approximately 1900 papers, this study has reviewed more papers relative to previous works.

The paper is very useful for policymakers to understand the current trends in the field. Additionally, it is also very useful for Ph.D. students and newcomers to get a quick overview of the current trends of the journal.

Moreover, readers of the journal can complete their knowledge by reading these results. Usually, experts know well the field, but it is very common that due to specialization, they do not know the whole field of the journal, and therefore, by reading this paper, they can complement and/or improve their knowledge very well.

This work aims to present the data from different perspectives, so each reader can understand the data according to his or her interests and priorities. Nevertheless, many limitations exist due to the wide range of issues surveyed in this work, such as the use of Web of Science and the future evolution of the reported results over time. However, the expectations of the authors about the trend of the publications in this area following the trends during the past years are incremental. Additionally, it is important to say that after studying the trends, it seems that Asian countries and specially China will experience a better ranking in the future in terms of the publications in this area.

Table 2.7 Most productive institutions in GSC throughout time

	1995-2007			2008-2012			2013-2017		
R	Institution	TP	TC	Institution	TP	TC	Institution	TP	TC
1	Clark U.	9	3133	Hong Kong Polytechnic U.	26	2840	U. Southern Denmark	51	2237
2	Dalian U. Technology	7	2454	Clarck U.	20	2598	Hong Kong Polytechnic U.	32	722
3	Western U. Western Ontario	6	1686	Dalian U. Technology	15	2108	Worcester Polytechnic Institute	29	1029
4	Clarckson U.	3	850	Chung Yuan Christian U.	9	327	Islamic Azad U.	23	321
5	Aristotle U. Thessaloniki	2	245	National Chiao Tung U.	8	538	U. Estadual Paulista	23	545
6	Asian Inst Management	2	955	National Tsing Hua U.	8	388	Aalborg U.	19	796
7	Erasmus U. Rotterdam	2	287	National Kaoshiung U. Science Technology	7	161	U. Tehran	18	336
8	U. Montreal	2	271	Erasmus U. Rotterdam	6	432	U. Teknologi Malaysia	17	255
9	Hong Kong Polytechnic U.	2	524	Galatasaray U.	6	556	Dongbei U. Finance and Economics	16	298
10	Kansas State U.	2	44	National Cheng Kung U.	6	409	Dalian U. Technology	15	464
11	Michigan State U.	2	142	National Taipei U Technology	6	460	Lunghwa U. Science and Technology	15	519
12	Norwegian U. Science and Technology	2	82	Wageningen U. Research	6	344	U. Sheffield	15	261
13	U. California Los Angles	2	208	Western U. Western Ontario	6	894	Indian Institute of Technology Kharagpur	14	187
14	U. Melbourne	2	355	Esade Business School	5	349	U. Nottingham	14	392
15	York U. Canada	2	46	U. Montreal	5	658	Wageningen U. Research	14	203
16	Austral U.	1	3	Monash U.	5	227	Chinese Academy of Science	13	611
17	California State U. Northridge	1	23	National Taiwan U.	5	199	Cranfield U.	13	178
18	Carnegie Mellon U.	1	300	Oregon State U.	5	756	Khalifa U. Science Technology	13	684
19	Chalmers U. Technology	1	257	U. Nova de Lisboa	5	368	National Kaoshiung U. Science Tchnology	13	79
20	Chung Hua U.	1	19	U. East Anglia	5	498	U. Nova de Lisboa	13	270

Table 2.8 Temporal evolution of the publications classified by countries

		Total				1995-2002		2003-2007		2008-2012		2013-2017	
R	Country	TP	TC	H	C/P	TP	TC	TP	TC	TP	TC	TP	TC
1	China (Peoples R China+Taiwan)	467	14732	60	31.55	-	-	11	3020	100	6289	356	5423
2	USA	381	20445	73	53.66	7	854	24	5739	99	8882	251	4970
3	Peoples R China	323	10003	46	30.97	-	-	7	2454	45	3578	271	3971
4	UK	257	6665	46	25.93	3	112	6	456	53	2889	195	3208
5	Taiwan	161	5454	40	33.88	-	-	4	566	58	3102	99	1786
6	India	141	4525	32	32.09	-	-	1	1079	10	737	130	2709
7	Italy	100	1897	27	18.97	-	-	1	76	12	525	87	1296
8	Germany	94	4134	29	43.98	-	-	2	162	17	2151	75	1821
9	Canada	92	6005	35	65.27	1	21	10	2110	21	2378	60	1496
10	Denmark	88	3415	31	38.81	-	-	-	-	6	527	82	2888
11	Iran	80	1614	21	20.18	-	-	-	-	3	124	77	1490
12	Spain	78	2050	25	26.28	-	-	2	157	22	1105	54	788
13	Brazil	75	1172	19	15.63	-	-	-	-	6	236	69	936
14	France	75	2063	23	27.51	-	-	1	569	7	481	64	978
15	Australia	72	2323	23	32.26	1	24	2	355	18	1194	51	750
16	Netherlands	69	1851	23	26.83	2	287	4	110	14	716	49	738
17	Malaysia	66	1170	19	17.73	-	-	-	-	7	491	59	679
18	South Korea	45	1068	16	23.73	-	-	1	64	10	701	34	303
19	Turkey	42	1282	18	30.52	-	-	-	-	14	930	28	352
20	Sweden	38	886	15	23.32	1	257	1	11	10	364	26	254
21	U Arab Emirates	35	2023	17	57.80	-	-	1	670	4	550	30	803
22	Portugal	28	729	14	26.04	-	-	-	-	5	368	23	361
23	Japan	26	479	9	18.42	-	-	2	173	4	156	20	150
24	Singapore	21	676	12	32.19	-	-	1	6	6	419	14	251
25	South Africa	21	205	6	9.762	-	-	1	50	2	91	18	64
26	Belgium	20	331	10	16.55	-	-	1	71	1	66	18	194
27	Finland	20	306	10	15.30	-	-	-	-	2	91	18	215
28	Greece	20	997	12	49.85	-	-	2	245	7	558	11	194
29	Ireland	20	627	13	31.35	-	-	-	-	4	156	16	462
30	Switzerland	18	587	11	32.61	-	-	-	-	4	324	14	263
31	Poland	17	240	8	14.12	-	-	1	50	2	66	14	124
32	Austria	16	160	8	10	-	-	-	-	-	-	16	160
33	New Zealand	16	246	7	15.38	-	-	-	-	5	183	11	63
34	Thailand	15	121	5	8.067	-	-	-	-	2	22	13	99
35	Lithuania	14	215	8	15.36	-	-	-	-	1	6	13	209
36	Norway	12	368	8	30.67	-	-	3	150	2	79	7	139
37	Indonesia	11	150	7	13.64	-	-	-	-	1	21	10	129
38	Philippines	9	1314	8	146	1	285	1	670	-	-	7	359
39	Chile	8	149	5	18.63	-	-	1	90	-	-	7	59
40	Colombia	8	107	6	13.38	-	-	-	-	-	-	8	107
41	Mexico	8	42	4	5.25	-	-	-	-	-	-	8	42

Abbreviations available in previous tables.

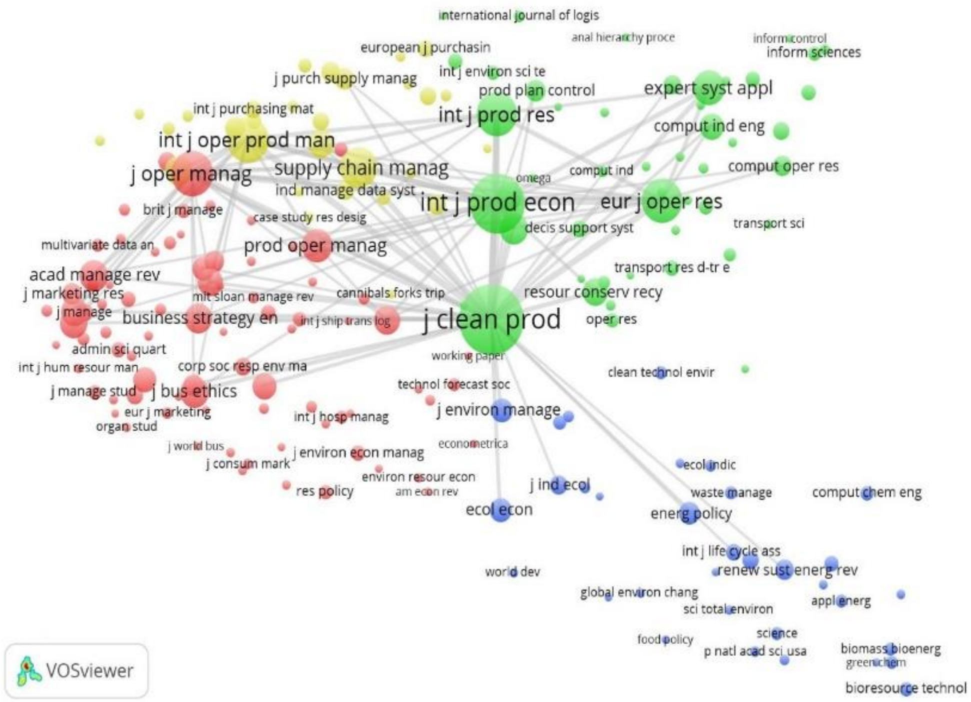

Figure 2.1 Co-citation of journals cited in GSC

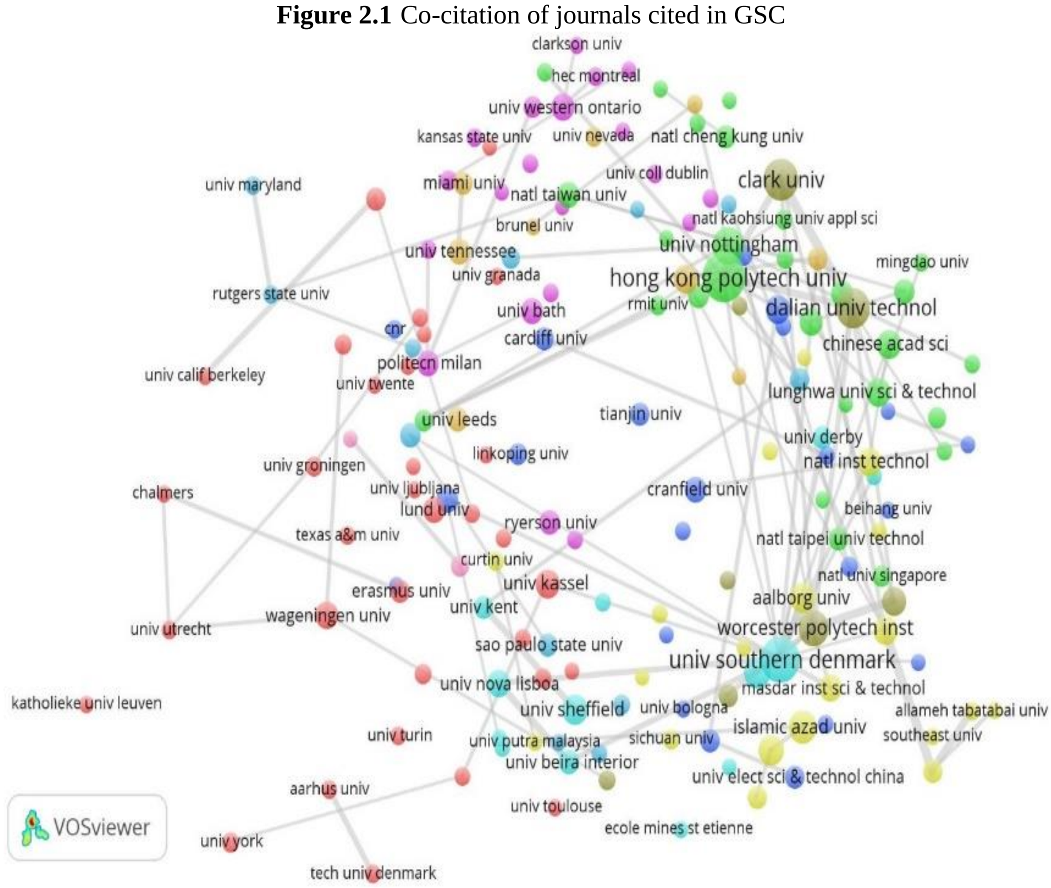

Figure 2.2 Bibliographic coupling of institutions that publish in GSC

Table 2.9 Most cited journals in GSC

R	Journal	Global		1995-2007		2008-2012		2013-2017	
		Cit	CLS	Cit	CLS	Cit	CLS	Cit	CLS
1	J Clean Prod	7404	6060.33	50	44.06	792	696.01	6562	5317.81
2	Int J Prod Econ	5101	4511.32	25	22.93	590	526.98	4486	3959.63
3	Int J Oper Prod Man	2851	2641.03	81	75.12	629	581.71	2141	1983.8
4	J Oper Manag	2757	2552.53	75	69.24	619	568.44	2063	1913.74
5	Eur J Oper Res	2670	2394.66	66	57	335	301.26	2269	2037.31
6	Int J Prod Res	2635	2403.18	23	21.97	359	336.87	2253	2044.1
7	Supply Chain Manag	2116	1996.12	22	21.39	206	196.3	871	828.76
8	Expert Syst Appl	1476	1317.44	-	-	113	95.67	1363	1223.85
9	Prod Oper Manag	1463	1369.9	97	77.53	384	361.39	982	931.82
10	J Bus Ethics	1223	1136.93	-	-	179	168.03	1043	967.3
11	Transport Res E-log	1177	1125.83	14	13.88	185	178.48	978	933.78
12	Acad Manage Rev	1152	1105.6	35	33.96	329	313.39	788	757.99
13	Business Strategy En	1108	1040.57	60	43.28	316	294.9	732	702.35
14	Acad Manage J	1107	1051.94	54	50.24	299	282.03	754	719.32
15	J Supply Chain Manag	1083	1031.46	6	5.96	206	196.3	871	828.76
16	Strategic Manage J	1035	983.18	35	32.89	277	262.4	723	687.45
17	Manage Sci	1023	954.94	42	38.33	255	235.65	726	680.16
18	Int J Phys Distr Log	931	890.93	-	-	85	82.65	846	807.96
19	Harvard Bus Rev	913	885.71	60	56.94	250	239.18	603	589.54
20	Resour Conserv Recy	909	871.03	10	9.46	85	80.03	814	781.61
21	Omega-Int J Manage S	876	850.49	12	11.8	171	164.43	693	674.15
22	Bus Strateg Environ	804	765.62	-	-	93	88.43	709	674.67
23	Comput Ind Eng	786	750.35	16	15.34	113	103.57	657	631.08
24	J Marketing	707	655.42	16	15.81	174	161.47	517	477.55
25	Ecol Econ	682	646.76	4	3.93	89	82.95	589	558.03

Table 2.9 (Continued)

R	Journal	Global		1995-2007		2008-2012		2013-2017	
		Cit	CLS	Cit	CLS	Cit	CLS	Cit	CLS
26	Ind Market Manag	677	641.46	7	6.96	127	117.46	543	516.54
27	J Environ Manage	649	635.32	4	4	102	98.3	543	531.54
28	Energ Policy	588	527.73	-	-	62	53.2	525	472.59
29	Calif Manage Rev	544	533.64	49	46.71	170	166.41	325	320.9
30	J Bus Res	521	506.42	6	5.87	93	90.55	422	409.9
31	J Purch Supply Manag	516	500.87	-	-	19	18.86	497	481.91
32	J Business Logistics	509	496.06	23	20.54	142	137.48	344	338.18
33	J Marketing Res	503	491.52	10	9.8	119	116.09	374	365.5
34	Prod Plan Control	500	476.89	-	-	32	31.17	468	445.75
35	Int J Manag Rev	467	465.93	-	-	82	81.97	385	383.96
36	Comput Oper Res	462	439.81	-	-	55	53.75	404	383.41
37	Renew Sust Energ Rev	443	378.91	-	-	19	18.47	424	359.07
38	Int J Adv Manuf Tech	426	410.52	-	-	20	19.95	406	390.72
39	Decision Sci	420	413.54	30	29.22	99	98.05	291	286.31
40	Ind Manage Data Syst	418	409.69	-	-	59	57.31	358	351.32
41	J Ind Ecol	385	365.24	24	23.48	95	92.93	266	250.67
42	Benchmarking	378	370.67	-	-	56	55.7	322	314.95
43	Environ Sci Technol	378	326.63	8	7.6	56	47.78	314	270.46
44	J Manage	376	370.89	-	-	67	66.08	307	302.74
45	Greener Management I	370	357.53	36	34.12	171	162.55	163	161.19
46	Int J Logist Manag	362	353.64	7	7	63	60.88	292	285.81
47	J Acad Market Sci	355	340.24	-	-	60	57.76	293	280.34
48	Corp Soc Resp Env Ma	351	344.26	-	-	38	37.76	313	306.42
49	Appl Math Model	332	321.15	-	-	16	15.84	316	305.43
50	Int J Purchasing Mat	330	323.13	36	33.99	113	109.96	181	179.21

Abbreviations: R = rank; Cit = Total citations in CIE; CLS = Co-citation links.

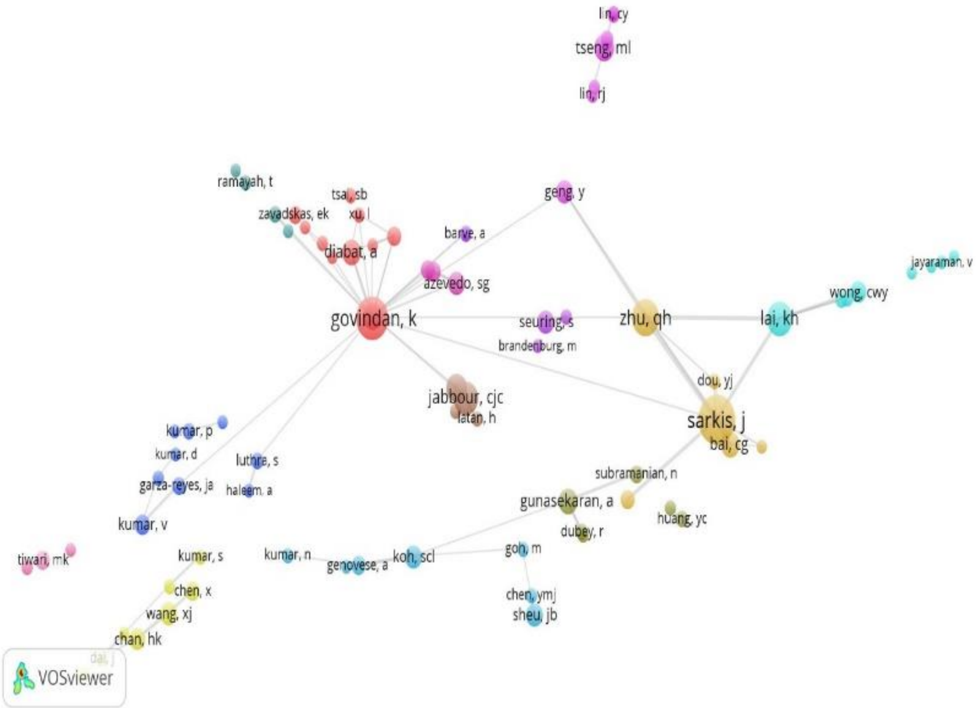

Figure 2.3 Co-authorship of authors

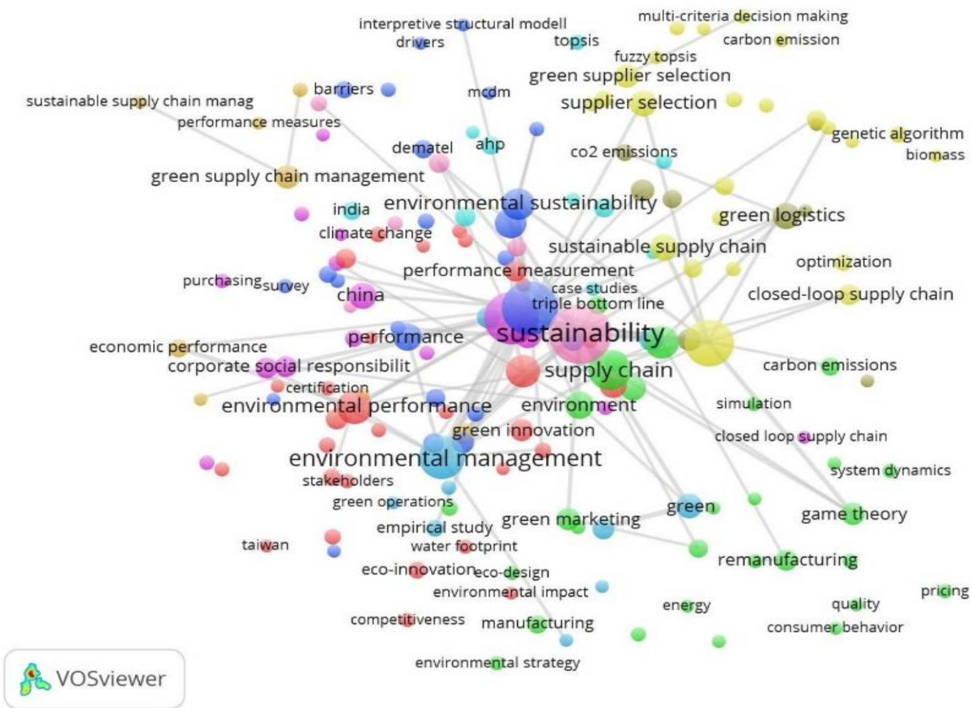

Figure 2.4 Bibliographic coupling of countries that publish in GSC

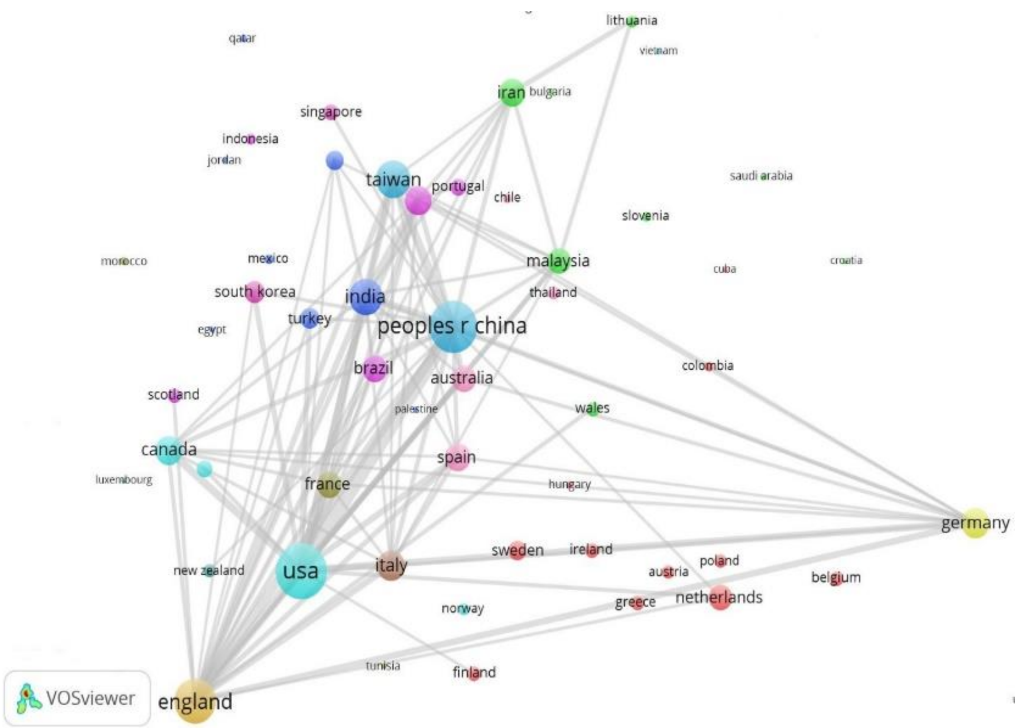

Figure 2.5 Co-occurrence of author keywords of documents published in GSC

Table 2.10 Most common author keyword occurrences in GSC

R	Journal	Global		1995-2007		2008-2012		2013-2017	
		Oc	Co	Oc	Co	Oc	Co	Oc	Co
1	Sustainability	229	208	4	4	41	40	184	164
2	Green supply chain management	176	150	5	5	36	27	135	118
3	Supply chain management	165	146	15	15	52	46	98	85
4	Green supply chain	128	88	3	3	30	18	95	67
5	Environmental management	106	94	12	12	43	36	51	46
6	Supply chain	96	83	8	8	16	13	72	62
7	Environmental performance	62	55	3	3	14	12	45	40
8	Reverse logistics	56	51	3	3	16	14	37	34
9	Sustainable development	56	47	1	1	18	14	37	32
10	Environmental sustainability	52	43	1	1	5	3	46	39
11	Sustainable supply chain management	48	42	-	-	5	5	43	37
12	Environment	40	37	1	1	12	11	27	25
13	Performance	40	37	1	1	3	3	36	33
14	Life cycle assessment	37	29	2	2	9	7	26	20
15	Literature review	37	35	-	-	3	3	34	32
16	Supplier selection	37	30	-	-	8	7	29	23
17	Sustainable supply chain	37	36	-	-	3	2	34	34
18	China	35	26	2	2	11	7	22	17
19	Green logistic	34	29	0	0	11	8	23	21
20	Green	30	28	1	1	3	3	26	24

Table 2.10 (Continued)

R	Journal	Global		1995-2007		2008-2012		2013-2017	
		Oc	Co	Oc	Co	Oc	Co	Oc	Co
21	Green supply chains	30	25	-	-	3	2	27	23
22	Green supplier selection	29	20	-	-	2	-	27	20
23	Green supply chain management (gscm)	28	25	-	-	4	4	24	21
24	Case study	27	23	1	1	2	1	24	21
25	Logistics	26	24	1	1	5	5	20	18
26	Automotive industry	25	24	1	1	5	5	19	18
27	Green innovation	25	22	-	-	2	1	23	21
28	Carbon footprint	24	21	-	-	10	8	14	13
29	Game theory	24	22	-	-	3	3	21	19
30	Green marketing	24	20	3	3	7	7	14	10
31	Corporate social responsibility	23	22	-	-	8	8	15	14
32	Green manufacturing	23	22	1	1	3	2	19	19
33	Institutional theory	23	23	1	1	7	8	15	14
34	Sustainable operations	23	18	1	1	3	1	19	16
35	Performance measurement	22	21	-	-	4	4	18	17
36	Remanufacturing	22	19	-	-	6	4	16	15
37	Closed-loop supply chain	21	17	-	-	11	8	10	9
38	Firm performance	21	15	1	1	3	2	17	12
39	Innovation	21	19	1	1	3	2	17	16
40	Lean	21	21	-	-	1	1	20	20

Abbreviations: R = Rank; Oc = Author keyword occurrences; Co = Author keyword co-occurrences links.

2.6 References

Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. Journal of cleaner production, 52, 329-341.

Albort-Morant, G., Henseler, J., Leal-Millán, A., & Cepeda-Carrión, G. (2017). Mapping the field: A bibliometric analysis of green innovation. Sustainability, 9(6), 1011.

Alfalla-Luque, R., & Medina-Lopez, C. (2009). Supply Chain Management: Unheard of in the 1970s, core to today's company. Business History, 51(2), 202-221.

Alonso, S., Cabrerizo, F. J., Herrera-Viedma, E., & Herrera, F. (2009). h-Index: A review focused in its variants, computation and standardization for different scientific fields. Journal of informetrics, 3(4), 273-289.

Andrade, A., Dominski, F. H., & Coimbra, D. R. (2017). Scientific production on indoor air quality of environments used for physical exercise and sports practice: bibliometric analysis. Journal of environmental management, 196, 188-200.

Beske-Janssen, P., Johnson, M. P., & Schaltegger, S. (2015). 20 years of performance measurement in sustainable supply chain management–what has been achieved? Supply chain management: An international Journal, 20(6), 664-680.

Blanco-Mesa, F., Merigó, J. M., & Gil-Lafuente, A. M. (2017). Fuzzy decision making: A bibliometric-based review. Journal of Intelligent & Fuzzy Systems, 32(3), 2033-2050.

Broadus, R. (1987). Toward a definition of “bibliometrics”. Scientometrics, 12(5-6), 373-379.

Cancino, C., Merigó, J. M., Coronado, F., Dessouky, Y., & Dessouky, M. (2017). Forty years of Computers & Industrial Engineering: A bibliometric analysis. Computers & Industrial Engineering, 113, 614-629.

Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. International journal of physical distribution & logistics management, 38(5), 360-387.

Chang, P. L., & Hsieh, P. N. (2008). Bibliometric overview of operations research/management science research in Asia. Asia-Pacific Journal of Operational Research, 25(02), 217-241.

Charvet F. F., Cooper M. C., & Gardner J. T. (2008). The intellectual structure of the supply chain management: a bibliometric approach. Journal of Business Logistics, 29, 47–53.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., & Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. International Journal of Production Economics, 194, 73-87.

de Oliveira, U. R., Espindola, L. S., da Silva, I. R., da Silva, I. N., & Rocha, H. M. (2018). A systematic literature review on green supply chain management: Research implications and future perspectives. Journal of cleaner production, 187, 537-561.

Dragos, C. M., & Dragos, S. L. (2013). Bibliometric approach of factors affecting scientific productivity in environmental sciences and ecology. Science of the Total Environment, 449, 184-188.

Eltayeb, T. K., Zailani, S., & Ramayah, T. (2011). Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. Resources, conservation and recycling, 55(5), 495-506.

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics, 162, 101-114.

Feng, Y., Zhu, Q., & Lai, K. H. (2017). Corporate social responsibility for supply chain management: A literature review and bibliometric analysis. Journal of Cleaner Production, 158, 296-307.

Fu, H. Z., Wang, M. H., & Ho, Y. S. (2013). Mapping of drinking water research: A bibliometric analysis of research output during 1992–2011. Science of the Total Environment, 443, 757-765.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. Journal of Cleaner Production, 98, 66-83.

Hassini, E., Surti, C., & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. International Journal of Production Economics, 140(1), 69-82.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. Proceedings of the National academy of Sciences, 102(46), 16569-16572.

Hood, W., & Wilson, C. (2001). The literature of bibliometrics, scientometrics, and informetrics. Scientometrics, 52(2), 291-314.

Hsieh, P. N., & Chang, P. L. (2009). An assessment of world-wide research productivity in production and operations management. International Journal of Production Economics, 120(2), 540-551.

Hu, J., Ma, Y., Zhang, L., Gan, F., & Ho, Y. S. (2010). A historical review and bibliometric analysis of research on lead in drinking water field from 1991 to 2007. Science of the Total Environment, 408(7), 1738-1744.

Ioana-Toroimac, G. (2018). Outcomes of the hydromorphology integration in the Water Framework Directive: a review based on science mapping. Journal of environmental management, 206, 1135-1144.

Kainuma, Y., & Tawara, N. (2006). A multiple attribute utility theory approach to lean and green supply chain management. International Journal of Production Economics, 101(1), 99-108.

Kessler, M. M. (1963). Bibliographic coupling between scientific papers. American documentation, 14(1), 10-25.

Khan, M. A., & Ho, Y. S. (2012). Top-cited articles in environmental sciences: Merits and demerits of citation analysis. Science of the Total Environment, 431, 122-127.

Kumar, S., Teichman, S., & Timpernagel, T. (2012). A green supply chain is a requirement for profitability. International Journal of Production Research, 50(5), 1278-1296.

Laengle, S., Merigó, J. M., Miranda, J., Słowiński, R., Bomze, I., Borgonovo, E., ... & Teunter, R. (2017). Forty years of the European Journal of Operational Research: A bibliometric overview. European Journal of Operational Research, 262(3), 803-816.

Laengle, S., Modak, N. M., Merigo, J. M., & Zurita, G. (2018). Twenty-five years of group decision and negotiation: a bibliometric overview. Group Decision and Negotiation, 27(4), 505-542.

M. Lee, S., Sung Rha, J., Choi, D., & Noh, Y. (2013). Pressures affecting green supply chain performance. Management Decision, 51(8), 1753-1768.

Martínez-López, F. J., Merigó, J. M., Valenzuela-Fernández, L., & Nicolás, C. (2018). Fifty years of the European Journal of Marketing: a bibliometric analysis. European Journal of Marketing, 52(1/2), 439-468.

Merigó, J. M., & Yang, J. B. (2017). A bibliometric analysis of operations research and management science. Omega, 73, 37-48.

Merigó, J. M., Gil-Lafuente, A. M., & Yager, R. R. (2015). An overview of fuzzy research with bibliometric indicators. Applied Soft Computing, 27, 420-433.

Merigó, J. M., Cancino, C. A., Coronado, F., & Urbano, D. (2016). Academic research in innovation: a country analysis. Scientometrics, 108(2), 559-593.

Merigó, J. M., Pedrycz, W., Weber, R., & de la Sotta, C. (2018). Fifty years of Information Sciences: A bibliometric overview. Information Sciences, 432, 245-268.

Miemczyk, J., Johnsen, T. E., & Macquet, M. (2012). Sustainable purchasing and supply management: a structured literature review of definitions and measures at the dyad, chain and network levels. Supply Chain Management: An International Journal, 17(5), 478-496.

Mingers, J., & Xu, F. (2010). The drivers of citations in management science journals. European Journal of Operational Research, 205(2), 422-430.

Oliver, R. K., & Webber, M. D. (1982). Supply-chain management: logistics catches up with strategy. Outlook, 5(1), 42-47.

Pilkington, A., & Liston-Heyes, C. (1999). Is production and operations management a discipline? A citation/co-citation study. International Journal of Operations & Production Management, 19(1), 7-20.

Pritchard, A. (1969). Statistical bibliography or bibliometrics. Journal of documentation, 25(4), 348-349.

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? International journal of operations & production management, 25(9), 898-916.

Sarkis, J. (2012). A boundaries and flows perspective of green supply chain management. Supply chain management: an international journal, 17(2), 202-216.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of cleaner production, 16(15), 1699-1710.

Shiau, W. L., Dwivedi, Y. K., & Tsai, C. H. (2015). Supply chain management: exploring the intellectual structure. Scientometrics, 105(1), 215-230.

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. Journal of the American Society for information Science, 24(4), 265-269.

Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. International journal of management reviews, 9(1), 53-80.

Thomé, A. M. T., Scavarda, A., Ceryno, P. S., & Remmen, A. (2016). Sustainable new product development: a longitudinal review. Clean Technologies and Environmental Policy, 18(7), 2195-2208.

Tiwari, S., Wee, H. M., & Daryanto, Y. (2018). Big data analytics in supply chain management between 2010 and 2016: Insights to industries. Computers & Industrial Engineering, 115, 319-330.

Tseng, M. L., Tan, K., & Chiu, A. S. (2016). Identifying the competitive determinants of firms' green supply chain capabilities under uncertainty. Clean Technologies and Environmental Policy, 18(5), 1247-1262.

Tsireme, A. I., Nikolaou, E. I., Georgantzis, N., & Tsagarakis, K. P. (2012). The influence of environmental policy on the decisions of managers to adopt G-SCM practices. Clean technologies and environmental policy, 14(5), 953-964.

Valenzuela, L. M., Merigo, J. M., Johnston, W. J., Nicolas, C., & Jaramillo, J. F. (2017). Thirty years of the Journal of Business & Industrial Marketing: A bibliometric analysis. Journal of Business & Industrial Marketing, 32(1), 1-17.

Van Eck, N., & Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523-538.

Wang, Q., Yang, Z., Yang, Y., Long, C., & Li, H. (2014). A bibliometric analysis of research on the risk of engineering nanomaterials during 1999–2012. Science of the Total Environment, 473, 483-489.

Wang, W., Laengle, S., Merigó, J. M., Yu, D., Herrera-Viedma, E., Cobo, M. J., & Bouchon-Meunier, B. (2018). A bibliometric analysis of the first twenty-five years of the International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 26(02), 169-193.

White H. D., & McCain K. (1989). Bibliometrics. Annual Review of Information Science and Technology, 24, 119–186.

White, L., Smith, H., & Currie, C. (2011). OR in developing countries: A review. European Journal of Operational Research, 208(1), 1-11.

Wong, C., Skipworth, H., Godsell, J., & Achimugu, N. (2012). Towards a theory of supply chain alignment enablers: a systematic literature review. Supply Chain Management: An International Journal, 17(4), 419-437.

Zhao, L., Deng, J., Sun, P., Liu, J., Ji, Y., Nakada, N., ... & Yang, Y. (2018). Nanomaterials for treating emerging contaminants in water by adsorption and photocatalysis: Systematic review and bibliometric analysis. Science of the Total Environment, 627, 1253-1263.

CHAPTER 3

Green supply chain practices and organizational performance: A case study in Spain

Abstract

Organizations gain a competitive advantage by improving environmental performance and reducing the negative environmental impacts of their products and services. But there is still a gap to study more about the relationship between green supply chain management and organizational performance. The purpose of this research from one side is to analyse the level of implementation of the green supply management practices among cases of the study and from the other side is to analyse these practices and their influence on the environmental, business, marketing and financial performance that they form the organizational performance. A qualitative method is applied among the medium and large manufacturing companies and logistics operators. The six cases have been selected with the criterion of trying to collect members of the entire supply chain to have a vision as global as possible. The obtained findings demonstrate an elevated level of green supply chain management practices implementation among the manufacturers but in comparison, this result is lower in logistics operators. From the other point of view, a meaningful influence of the implementation of green supply chain management practices on the organizational performance is detected although based on the opinions of the cases some of these influences are direct and the rest are indirect.

Keywords: green supply chain management, organizational performance, case study

Acknowledgment

We want to appreciate all the valuable help and guides of Fundación ICIL and its experts, also the interviewees that their expertise and their knowledge make us able to prepare this investigation.

3.1 Introduction

If supply chain actors in some countries were able to innovate in the supply chain, this would be because the legislative mechanisms in those countries, norms, and cultural-cognitive factors existing in organizational environments, are supporting the organizational arrangements. Because of the legal and cultural supports in those countries, local distributors and vendors often find it possible to conclude contracts and agree on ownership. In this way, activity and innovation will flourish in investment.

In global markets, it is inevitable to set up an outsourcing agreement or agreement. Therefore, it is necessary to explain the provisions related to innovation, ownership and social factors prior to the conclusion of the contract and ultimately specified the ability of the parties to innovate in the supply chain and the constraints of their organizational environments in each of them. Because every global business network differs significantly from other networks in terms of the cultural or consumer cultural background of other networks, characteristics of exchanges shape the investment and innovation activities. Due to the existence of specific business culture, one of the key challenges for business partners in the transition to a new organizational arrangement that involves international exchanges. As a result, international trading partners from different countries with different laws and different traditions are facing a lot of problems in creating a system of incentives for innovation in the supply chain.

Although these countries are continuous the decentralization and privatization policies, this trend is slowly moving due to instability of rules and regulations. Constraints and incentives created by governments, for example, in a country like China, have been shaping and supporting Chinese supply chain influence by restricting foreign companies (Bowersox, et al.2008).

Green supply chain management (GSCM) during the last couple of years, gains a considerable amount of attention from various investigators. In concordance with its development in length of the years they study diverse aspects of GSCM. Some of them analyze it through a literature review (Srivastava, 2007; Seuring and Müller, 2008; Sarkis et al. 2011; Ashby et al. 2012; Hassini et al. 2012; Govindan et al. 2015; de Oliviera et al. 2018), the other works apply case study approach to analyze different aspects and the level of GSCM application (Lee and Klassen, 2008; Pagell and Wu, 2009; Azevedo et al. 2011; Ubeda et al. 2011; Gopalakrishnan et al. 2012; Carballo-Penela et al. 2018; Petit et al. 2018) and in some studies the main issue is investigating the performance of the supply chain (Zhu et al. 2005; Foo et al. 2018; Dragomir, 2018; Maestrini et al. 2018) or the influence of GSCM implementation on performance as a general term (Carter et al. 2000; Rao and Holt, 2005; Zhu and Sarkis 2004; Yang et al. 2011). There are different definitions in the literature for the GSCM and each of them tries to cover some of these dimensions. To support this assertation, as an example, Ahi and Searcy (2013) find 22 definitions for GSCM in the literature. So, as a comprehensive definition to apply in this work, we use what Srivastava (2007) presents i.e. “integrating environmental thinking into supply-chain management, including product design, material sourcing, and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life.”

Organizational performance can be measured on a variety of dimensions and refers to the financial and non-financial performance of the organization (Walker and Ruekert, 1987).

There are some works that are dedicated to study the relationship of the green supply chain and performance (Zhu et al. 2008; Zacharia et al. 2009) but it still seems necessary to study more the relationship between GSCM and organizational performance. To that end, I must first identify a comprehensive collection of GSCM practices and factors that define organizational performance (OP). So, the two main objectives of this research are: 1) evaluate the level of GSCM practices implementation and 2) analyze the influence of these practices on the organizational performance that forms by four distinct categories of environmental, financial, marketing and business performance. For this, I have applied a case study approach in Spain in companies from all members of the supply chain that makes me able to explore more detailed insights about the above-mentioned relationship.

To this end, section 2 proposes a thorough research background. The third section is dedicated to describing the methodology of the study. The next section belongs to the data analysis and through the last section some discussion and suggestions will be given about the subject and I wrap the study with conclusions.

3.2 Research background

3.2.1 Green supply chain management

Many industries experience increasing globalization and a shifting focus on competition among networks of companies. Supply chain management becomes an important competitive approach for organizations in this context. In continue, GSCM emerged as an approach to balance these competitive requirements (Narasimhan and Carter, 1998). As stated, before there are various definitions for this concept that try to cover its myriad aspect. The very first of those definitions is establishes by Beamon (1999) as an "extension of traditional supply chains to include activities that aim to minimize the environmental impacts of a product throughout its entire life cycle, such as green design, resource saving, harmful material reduction and product recycle or reuse". Lee and Klassen (2008) integrate environmental issues into supply chain management to improve the environmental performance of the suppliers and customers and H'Mida and Lakhal (2007) highlight the dimensions of GSCM that relies on improving performance in the supply chain during the product's life cycle. Besides, to understand better the concept of GSCM and its identity, it is essential to define the practices of GSCM that form it. These practices are obtained from the literature of this concept. Zhu and Sarkis (2004) consider GSCM practices as internal environmental management, external GSCM, investment recovery and eco-design but in the next years Zhu et al. (2013) divide these practices into two general groups: internal and external. According to Mitra and Datta (2014) GSCM practices are internal environmental management, external practices, green purchasing, customer collaboration, and environmentally friendly product design. Azevedo et al. (2012) based on the green and lean upstream supply chain management that define, propose a theoretical framework to analyze the influence of these practices on the sustainable development of business. Ferreira et al. (2017) propose a classification that divide the GSCM practices to three groups: GSCM planning practices, GSCM operational practices and GSCM communication practices. This context is the fundamental of my work for the practices of GSCM, but besides, according to the literature review, I add some other factors to this set to enrich them for applying in this work. All these 8 items are reported in Table 3.1.

Table 3.1 GSCM practices

GSCM practices		References
External	Provide specifications to suppliers that include environmental requirements in the items purchased Evaluate whether second-tier suppliers carry out environmentally friendly practices Cooperate with the client for ecological design, cleaner production and ecological packaging	Ferreira et al. (2017), Govindan et al. (2013), de Sousa Jabbour et al. (2013), de Sousa Jabbour et al. (2014), Liu et al. (2012), Mitra and Datta (2014), Mohanty and Prakash (2014), Perotti et al. (2012), Zhu and Sarkis (2004), Zhu and Sarkis (2006), Zhu and Sarkis (2007), Zhu et al. (2008), Zhu et al. (2012), Zhu et al. (2013)
Return on Investment	Collect and recycle products and materials at the end of their useful life Establish a recycling system for used and defective products	
Internal environmental management	Train workers in relation to environmental issues Implement pollution prevention programs Apply the eco-labeling of products	Chien et al. (2012), Ferreira et al. (2017), Govindan et al. (2013), Green et al. (2012), de Sousa Jabbour et al. (2013), de Sousa Jabbour et al. (2014), Liu et al. (2012), Mitra and Datta (2014), Mohanty and Prakash (2014), Perotti et al. (2012), Zhu and Sarkis (2004), Zhu and Sarkis (2006), Zhu and Sarkis (2007), Zhu et al. (2008), Zhu et al. (2008), Zhu et al. (2012), Zhu et al. (2013)
Sustainable storage and construction	Implement water conservation (for example, plants and gardening materials that minimize water waste and the use of gray water in the system)	Ferreira et al. (2017), Perotti et al. (2012), Zhu and Sarkis (2004), Zhu et al. (2013)
Waste reduction and risk minimization	Reduce the consumption of hazardous and toxic materials Adopt the use of recyclable products whenever possible	Azevedo et al. (2011), Azevedo et al. (2012), Chien and Shih (2007), Chien et al. (2012), Espadinha-Cruz et al. (2011), Govindan et al. (2013), Green et al. (2012), de Sousa Jabbour et al. (2013), de Sousa Jabbour et al. (2014), Liu et al. (2012), Mohanty and Prakash (2014), Perotti et al. (2012), Zhu and Sarkis (2004), Zhu and Sarkis (2006), Zhu and Sarkis (2007), Zhu et al. (2008), Zhu et al. (2012), Zhu et al. (2013)
Reverse logistics	Reverse logistics and waste disposal Implement distribution, transport and execution strategies to redesign the logistics system for greater environmental efficiency Use the vehicles with low emissions and alternative fuels Consolidate and effectively use the full load capacity of the vehicles	Azevedo et al. (2011), Azevedo et al. (2012), Chien and Shih (2007), Espadinha-Cruz et al. (2011), Ferreira et al. (2017), Guide Jr and Li (2010), Jabbour et al. (2014), Mitra and Datta, (2014), Perotti et al. (2012)
Sustainable design	Design the products and / or manufacturing processes to avoid or reduce the use of dangerous products Design the products for the reuse, recycling, and recovery of materials and components	Azevedo et al. (2011), Azevedo et al. (2012), Chien and Shih (2007), Chien et al. (2012), Espadinha-Cruz et al. (2011), Govindan et al. (2013), Green et al. (2012), de Sousa Jabbour et al. (2013), de Sousa Jabbour et al. (2014), Liu et al. (2012), Mohanty and Prakash (2014), Perotti et al. (2012), Zhu and Sarkis (2004), Zhu and Sarkis (2006), Zhu and Sarkis (2007), Zhu et al. (2008), Zhu et al. (2012), Zhu et al. (2013)
GSCM communication practices	Prepare periodic environmental reports	González-Benito and González-Benito (2006)

The spectrum of GSCM practices in different sectors and companies is vast enough and each of them based on their necessity apply some of them. So, the analysis of the type of the applied practices from one side and the level of their implementation from the other side gives us a useful understanding. Therefore, I formulate the first investigation question as follows:

***IQ1*: On what level the green supply chain practices are implemented?**

3.2.2 Green supply chain management and organizational performance

There are some external or internal pressures that make companies to move toward greening their supply chain to accomplish to the economic, social and environmental objectives (Lee at al. 2013). To do so, the effort of the companies is directed to improve their performance in various fields by applying GSCM practices. In the body of literature there are studies that are dedicated to analyzing the influence of GSCM on the performance of the company. There is a group of investigations that analyze this effect from environmental point of view or financial point of view (Vachon and Klassen, 2008; Chiou et al. 2011; Green Jr. et al. 2012; Junquera et al. 2012; Ruiz-Benítez et al. 2018). My goal is detecting a set of the various form of performances in a same concept that is organizational performance. To this end, I categorize the organizational performance factors in 4 groups: *environmental performance, business performance, financial performance and marketing performance*.

In addition, based on this reality that the ultimate purpose of every company is a continuous improvement, knowing about the organizational performance and the effects of the GSCM practices on it could help the company holders to design different plans to enhance their performance. To do so, I formulate the second investigation question as follows:

***IQ2*: What is the level of influence of GSC factors on organizational performance?**

3.3 Methodology

3.3.1 Method and sample selection

This study tries to explore the relationship between GSCM practices implementation and organization performance. Based on Yin (2003), I selected the "case study" approach because it can answer clearly the questions of "what" and "why". In exploratory research projects, the researcher is looking for an "uncertain position" (Creswell, 2013).

There is not a precise criterion for determining the sample size or the number of cases. Nevertheless, factors such as the purpose of the sampling and the type of sampling are effective in determining the sample size. One possibility is to use the chain or snowball criterion: the first interviewee is usually chosen in a straightforward way, and then the researcher invites him or her to suggest other possible participants that the interviewee considers to be involved with the subject of the investigation (Biernacki and Waldorf, 1981). Eisenhardt (1989) and Yin (2003) also state that in the qualitative researches by interview, the interviewees are asked if they can propose some other candidates that can help to make progression in the research process. The selection should be guided by the diversity and the potentiality of the cases to contribute to the objectives of the research rather than by simple randomness.

To do so, I contacted two institutions that are experts to select the companies with a great level of sensitivity toward GSCM practices: Fundación ICIL (a Spanish important institute for careers and innovation in logistics and supply chain) and Institut Cerdà (a Spanish foundation dedicated to promoting the sustainability, innovative infrastructure and offering consultation to the public administration). The selected cases were national and international companies located in Spain from different sectors and sizes, and some of them are members of Global Compact LEAD, that refers to a group of highly engaged companies from across all regions and sectors that represent the cutting edge of the United Nations Global Compact and they are recognized annually for demonstrating ongoing commitment to its Ten Principles for responsible business. Besides, I studied different members of the supply chain to get a deeper insight.

After doing six interviews I obtained a theoretical saturation (Eisenhardt, 1989; Yin, 2003) that means that some type of pattern has been identified and the contribution of each new case to the investigation follows a decreasing proportion.

Table 3.2 reflects more details about these companies. To keep confidentiality of the interviews I used the acronyms instead of the company names.

3.3.2 Unit of study: greening process of supply chain

The unit of this study is green supply chain as a significant challenge not only in the companies but also among the countries as a global concern. Vachon (2007) and Tate et al. (2010) speak about the pressure on the manufacturers from the governments and the stakeholders to develop greener products that cause a new demand of these companies to their suppliers and customers to find an innovative solution to respond to the environmental concerns. Multinational enterprises establish global networks of suppliers that take advantage of country-industry specific characteristics to build a competitive advantage (Dunning and Lundan, 2010). Besides, the influence of green supply chain on the performance of company (Lee et al. 2012) and analyze it, reveals the necessity of doing more analyze in a data-based approach to gain more insights. So, one of the requirements of the selection was that the selected interviewees were managers of the companies that have a vast range of information and a broad perspective about the green supply chain.

3.3.3 Data collection and interview protocol

The obtained data of this work were collected between May 2017 and March 2018 by doing open-ended interviews and complementing with secondary data (such as websites and reports) to have a full access to needed data for responding to the investigation issues (Annex 1).

All the interviews were done in Barcelona (Spain). The duration of the interviews was between one hour and a half and two hours. To ensure the reliability of the research, they were always carried out by two or three interviewers.

The interview guide that was designed included eight GSCM practices and four main factors of the organizational performance. Finally, as a part of the interview, I ask the interviewees to evaluate the items based on their experience in a scale from 1 to 5 that 1 shows the lowest level of implementation *(in association with IQ1)* or the weakest influence *(in association with IQ2)* and in the same way 5 shows the highest level of implementation or the strongest influence. This interview guide was validated by some experts from Fundación ICIL.

During this period besides performing the open-ended interviews the interview-guide were sent to each of the interviewees by e-mail to fill them up with the aim of obtaining more precise outputs, and through phone calls any valuable detail was double or triple controlled. In this work I follow the suggestions of Lofland and Lofland (1984), Yin (2003) and Ritchie et al. (2013) about implementing a qualitative research.

3.4 Findings

In this section I report the findings of my research process and I present the output of the software and analyze it. I summarize the results of the interviews in two tables that specifically describe the activities of the companies and interviewee’s opinions upon the asked items. Besides, in an accumulated graphic I demonstrate the overall relationship between implementing green supply chain management practices and organizational performance.

Table 3.2 Cases characteristics

Case	Annual sales (million €)	Number of employees	Sector	Interviewee position
Manufacturer 1 (Man 1)	948	1196	Food and Nutrition	CSR Manager Public Affairs
Manufacturer 2 (Man 2)	1995	4285	Food and Nutrition	Responsible Sourcing
Manufacturer 3 (Man 3)	511	451	Consumer Goods	Logistic Manager
Transportation 1 (Tra 1)	98	107	Transportation and Logistic Activities	Innovation and Business Solutions Director
Transportation 2 (Tra 2)	36	68	Land, Maritime and Rail freight Transportation	Empowered Representative
Transportation 3 (Tra 3)	5	6*	National and International Freight Transport by Road, Logistics Operators.	General Manager

* This company outsource many of its duties, so this number is only the employees of the central office

As mentioned before, I defined eight practices for green supply chain management but to make them measurable it seems logical to define those practices based on a group of sub-practice in each of them. These sub-practices formed the questions of the interview. And from the other side I defined organizational performance as the form that mentioned in previous part. According to these practices and factors, I ask the interviewees to evaluate the influence of the GSCM practices and organizational performance factors based on a scale of 1 to 5, that 1 implies to the lowest influence possible and 5 expresses the highest influence.

Among a range of factors that I consider as OP, the implementation of practices of GSCM has a direct or indirect influence on it. Indirect practices refer to those items that by influencing on some other factors can have an effect on organizational performance factors. In addition, as a general finding of the items, those that are related to the suppliers, have the greatest influence on the organizational performance in total. The other output of this figure is the adopting of using recyclable products that has an enormous influence on business performance and marketing performance.

3.4.1 GSCM analysis in Spain

Empirical investigation makes us able to obtain understanding on the influences that implementing GSCM can cause on organizational performance. To achieve these outputs, table 3.3 and table 3.4 are prepared to present the findings of the investigation on each factor. Table 3.3 presents those factors that focus on the implementation of green supply chain management practices that are: *external practices*, *return on investment, internal environmental management, sustainable storage and construction, waste reduction and risk minimization, reverse logistics, sustainable design and communication practices*, this table encloses the approach of each company in confronting with every single practice of green supply chain management.. Table 3.4 on the measurements of organizational performance that are: *environmental, business, financial and marketing performance*.

3.4.2 Actions and approaches

3.4.2.1 External practices and companies' approach

Among the companies of this work, for all manufacturers and one of the transportation companies, this item has the high importance and priority while this level of importance for the other two is medium. As it can be seen, there are various plans and programs to conduct the activities of the providers or even the transporters to respect to the environmental issues and those tasks that belong to the social responsibility. As an example, for all manufacturers, there is a sensitivity to increase the greenness of packaging through these plans. However, the same situation is not valid among the transporters. Only the Tra1 applies specific standards and plans to achieve a cleaner condition. In addition, as table 3.3 reports, for Tra2 implementing this practice is not merely for the environmental aims:

> *Tra2: "Our providers are autonomous, and we ask them to respect some standards, but this decision is first for the security aims and being greener is not the first priority"*.

Tra3 also states that in Spain the lack of organization in the case of utilizing the logistic infrastructure exists and could be improved:

Table 3.3 Findings of GSCM practices implementation

	External practices	Return on investment	Internal environmental management	Sustainable storage and construction	Waste reduction and risk minimization	Reverse logistics	Sustainable design	Communication practices
Man 1	**High**	**High**	**High**	**High**	**-** **Not significant/not mentioned**	**High**	**High**	**High**
Man 2	**High**	**High**	**High**	**High**	**High**	**High**	**High**	**High**
Man 3	**High**	**Medium**	**High**	**-** **Not significant/not mentioned**	**Medium**	**High**	**Medium**	**High**
Tra 1	**High**	**High**	**Medium**	**-** **Not significant/not mentioned**	**Medium**	**High**	**-** **Not significant/not mentioned**	**High**
Tra 2	**Medium**	**High**	**Medium**	**-** **Not significant/not mentioned**	**Low**	**High**	**-** **Not significant/not mentioned**	**Low**
Tra 3	**Medium**	**Medium**	**High**	**Medium**	**Low**	**High**	**Medium**	**High**

Source: Own elaboration

Tra3: "In Finland, logistics operators and transporters collaborate in the last mile transport. In Spain we should learn. It is not logical for two multinational logistic operators (say two companies) to make the same journey in a city with various products between two same supermarkets. Here there is a way to go and improve. It is necessary for companies in the same market to share logistic infrastructures and for routes to be shared for the sake of sustainability and efficiency. The cities will end up demanding it. It is a matter of organization."

3.4.2.2 Return on investment and companies' approach

Return on investment in average has a high importance among the companies of the study and there are several plans to optimize it. In general, the manufacturers companies of this study as well of as the transporters have a comprehensive plan to recycling the recyclable machines and products based on a well-defined program. Although same as the last part (external practices), especially among the transporters companies when comparing with the foreigner countries, there are some limitations that makes harder the process in Spain.

3.4.2.3 Internal environmental management and companies' approach

Although in general this item receives a prominent level of attention, but in some cases it has not the high priority that deserves. All manufacturers companies of the study stablish a complete pollution prevention programs and consecutively are giving information to their workers about the environmental issues. In addition, for Tra3 because their major customer are Scandinavian countries, and based on this fact that for them, an important criterion for the selection of suppliers is the environmental aspects, so the company must respect their environmental standards. While, the existence of these kind of plans especially among the transporters is based on the necessity. As Tra2 expresses:

"There is not a comprehensive plan but in general we follow some programs to prevent the pollution such as substitution trucks with railway transportation as much as possible"

3.4.2.4 Sustainable storage and construction and companies' approach

Sustainable storage and construction imply to the practices such as use of alternative energy sources, water conservation and use of thermal insulation. Deepen more in this item shows that among the companies of the research half of them state that based on its certainty, they consider it as a routine practice, and it does not seem necessary to them to implement the practices related to it. However, in some cases such as Man1, there are strict programs to reuse the water in the cycle of the processes:

> *"By implementing recirculation, we try to use the water again that is used before with a percentage around 100%"*

3.4.2.5 Waste reduction and risk minimization and companies' approach

The focus of the companies is to reduce toxic and hazardous materials such as CO_2 from their procedures as much as possible and by applying a list of toxic materials, they try to prevent to use them. One important situation among the cases of this study is Tra3 that from one side should follow the requisites of its customers that are Scandinavians and form the other side Spanish standards. Besides, it is noteworthy to mention that based on the type of the industry and the materials that the companies deal with them, this item could lose its weight in comparison with the others, such as Man2 says:

> *"Because our main focus is on food material, so we do not have issues in the area of hazardous or toxic materials"*

3.4.2.6 Reverse logistics and companies' approach

The situation of reverse logistics practice among the companies of study is good and all of them have comprehensive plans. Some of them prevent to have empty truck, some others use electrical vehicles and the others use alternative fuels for their vehicle, but among these policies, the main concentration is to avoid having empty trucks. Although it is noteworthy to mention that this achievement is not easily accessible as such Man2 states:

> *"We fight for it, but it's a direct cost issue. Reverse logistics has a cost. A policy is the non-refoulement premium. Suppliers are offered a discount so that they do not return the product. The cost of going to find the product,*

classify it and destroy it is greater. We have it with the main clients", "the company has an agreement with a car rental company to use sustainable and electrical vehicles"

3.4.2.7 Sustainable design and companies' approach

Sustainable design refers to design the products for reuse, recycle, recovery of materials and component parts also design the products that need less energy and material. This practice for the transporters based on their natures is not significant at all but for the manufacturer as reflects in the table 3.3, is important enough to obtain the attention. Although this fact, however, some other issues could also be a cause of implementing this practice as Man2 expresses:

"Because of the health image of the company, some acts related to this item are eliminated, but it is not a matter of sustainability, but of image"

3.4.2.8 Communication practices and companies' approach

Communication practices refers to the periodical environmental reporting. Five out of six companies of the study, motivate their workers that based on a precise timing, fill the related forms and assume these reports as a powerful tool to enhance the environmental issues in the company. Only Tra2 states that:

"We don't have any plan for a periodic environmental reporting"

So, based on these obtained findings and to respond to IQ1, the average level of green supply chain management practices implementation among the companies of the study is upper than medium level.

In this section of the work, I report the influences that companies observe after implementing the green supply chain management practices on diverse types of organizational performance. To this end, next four sub-sections are dedicated to this item and are reported thoroughly in Table 3.4 that responds to RQ2.

3.4.2.9GSCM practices and environmental performance

As expected, and according to the literature, by implementation of green supply chain management practices, environmental performance experiences a significant improvement. In this study also all companies, unanimously confirms that they observe this above-mentioned improvement and by implementing these practices, the level of CO_2 emission reduces sharply. Tra3 states that:

> *"Customers are given, for each order, three possible budgets with 3 routes and types of transport used. For each option, price, transit time and Co2 emissions"*

Table 3.4 Findings of GSCM practices implementation of Organizational performance

	Environmental performance	Business performance	Financial performance	Marketing performance
Man 1	**High**	**Medium**	**Medium**	**High**
Man 2	**High**	**High**	**Medium**	**High**
Man 3	**High**	**High**	**Medium**	**High**
Tra 1	**High**	**High**	**Medium**	**High**
Tra 2	**High**	**Medium**	**Medium**	**High**
Tra 3	**High**	**Medium**	**High**	**Medium**

Source: Own elaboration

3.4.2.10 GSCM practices and business performance

Business performance as a part of an organization performance, refers to the competitive position, profitability and the use of assets. According to the interviews, Man1 and Man3 detect an indirect relationship between implementation of green supply chain management practices and business performance (although they expressed distinct levels of influence), while based on the opinions of the rest this relationship is a positive one toward an improvement. Based on them, this implementation caused some better results in terms of business performance factors.

3.4.2.11 GSCM practices and financial performance

All the companies agree what is not neglectable is that implementation of green supply chain management needs spending money. So, from this point of view, make the company greener can impose costs. However, two manufacturers and one transportation company could not detect a direct (based on the outputs of the interviews) relationship between implementing GSCM practices and the financial performance.

3.4.2.12 GSCM practices and marketing performance

Marketing performance is defined by the items such as: the average market share, the average sales volume and average sales in euro. Man1, Man2, Man3 and Tra1 are detected an indirect relationship between GSCM practices and marketing performance.

So, to respond to IQ2 it is important to mention that the companies of the research, believe that implementation of GSCM practices influence on organizational performance in general.

3.5 Discussion and suggestions

The existing literature expresses that the implementation of the GSCM practices can improve the performance of the company (Zhu et al. 2017; Mumtaz et al. 2018; Susanty and Sari, 2018; Zhu et al. 2008). This study confirms the existing literature that effectively, the GSCM practices can improve the performance of the company. Based on the facts of Table 3.2 and Table 3.3 I found some critical points and positive influences mentioned by the cases of my study.

The level of the implementation of green supply chain management practices among the manufacturer companies of the study as the obtained findings demonstrate, is high. Logistics operators have a prominent level of implementation in some very specific respects such as reverse logistics, but in general they have a lower degree of implementation in most practices. This happening could be based on this reason that the transportation companies generally are traditional. Besides, it is noteworthy to state that the logistic operators of this study are selected companies with years of experience, and they demonstrate innovative practices related to GSCM practices. In addition, some of them work with Nordic countries that have a high demand with such subjects.

According to the findings of this study, the companies in terms of implementation of green supply chain management have a suitable situation that represents the high importance of this item for them.
From the other side, the findings of the interviews demonstrates a meaningful influence of GSCM practices on different aspects of the organizational performance, directly or indirectly, thus as I state before, to respond to IQ2 it is important to mention that the companies of the research, believe that implementation of GSCM practices influence on organizational performance in general. Although in some cases an indirect influence and relationship is detected, but the rest items show a strong direct and positive relationship among the GSCM practices and organizational performance.

3.6 Conclusions

This study searches the responses of two main questions. These two are: a comprehensive analysis of the implementation of green supply chain management practices in the cases of this work and besides, analyze the influence of the implementation of these practices on the organizational performance factors that forms from, business performance, financial performance, environmental performance and marketing performance. To this end and to respond to these issues, based on the literature review that was done the practices of green supply chain management also the factors of the organizational performance were selected to form the structure of the investigation and the questions that could lead us toward my purpose. So, based on this foundation, I conduct six interviews to investigate these obtained factors. As a complement of the results of the interviews, the secondary data such as websites and reports had helped us.

The table 3.5 according to the table 3.3, summarizes the obtained findings of this study about the level of GSCM practices implementation in the cases. As it is understandable, based on a spectrum from low to high and a classification of the manufacturers and the logistic operators and transportation companies, these practices are located.

Table 3.5 Level of GSCM practices implementation

+ ←→					-	
	High	High-Medium	High-Low or High-Not significant	Medium-High	Low-Medium or Not significant-Medium	Low
Man	• External practices • Internal environmental management • Reverse logistics • Communication practices	• Return on investment • Sustainable design	• Sustainable storage and construction			
Tra	• Reverse logistics	• Return on investment	• Communication practices	• External practices • Internal environmental management	• Sustainable storage and construction • Waste reduction and risk minimization • Sustainable design	

Source: Own elaboration

Among these practices, "*waste reduction and risk minimization*" cannot be in on exact cell of the table among manufacturers. The reason of this, could be related to the level of the importance this practice among that companies.

As reported in Table 3.5, according to the nature of the cases of this study that can be classified in two general groups of manufacturers and logistic operators and transportation companies, every practice has its unique influence on the organizational performance. Some of them such as reverse logistic practices have a high positive influence on the organizational performance in all cases of the study in average while some other practices such as external practices although have a high positive influence on the organizational performance of the manufacturers, but the influence of this item on the logistic operators and transportation companies' organizational performance can be classified as a medium-high influence.

I believe that the findings of this study could be useful not only for the scholars but also for the decision makers and the managers of the companies according to the four reasons. First, a comprehensive set of elements give a clear insight to the scholars to follow the same line in the future researches and apply them in the similar studies. Second, I renovate and expand the boundaries of the investigation on the issue of GSCM and organizational performance. Third, I demonstrate the relationship of the elements of my work and their level of influence on each other through the output of the software analysis. Fourth, the findings of this research can give a clear clue to the decision makers also the managers to understand those milestones that need to be improved or the practices that could be created for their industry.

This study like the other researches experiences has limitations. The first limitation of this study is the habitual limitation of qualitative investigation based on the case study that is the obtained findings of this study maybe are not suitable for the other cases, in other words, they are not generalizable. The second limitation is the level of the diversity of the selected cases. In this study I believe that the three sectors (*Food and nutrition, Consumer goods and Transportation and logistics*) could answer my questions and could prepare the possibility to make the comparisons. For the further research it could be advisable to apply the structure of this study in the other sectors. The final proposed option for the future research is making a comparison between the findings of this study and the similar ones to gain an in-depth insight.

3.7 References

Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. Journal of cleaner production, 52, 329-341.

Ashby, A., Leat, M., & Hudson-Smith, M. (2012). Making connections: a review of supply chain management and sustainability literature. Supply Chain Management: An International Journal, 17(5), 497-516.

Azevedo, S. G., Carvalho, H., & Machado, V. C. (2011). The influence of green practices on supply chain performance: a case study approach. Transportation research part E: logistics and transportation review, 47(6), 850-871.

Azevedo, S. G., Carvalho, H., Duarte, S., & Cruz-Machado, V. (2012). Influence of green and lean upstream supply chain management practices on business sustainability. IEEE Transactions on Engineering Management, 59(4), 753-765.

Beamon, B. M. (1999). Designing the green supply chain. Logistics information management, 12(4), 332-342.

Biernacki, P., & Waldorf, D. (1981). Snowball sampling: Problems and techniques of chain referral sampling. Sociological methods & research, 10(2), 141-163.

Bowersox, D. J., Mentzer, J. T., & Speh, T. W. (2008). Logistics leverage. Journal of Business Strategies, 25(2), 85.

Carballo-Penela, A., Mateo-Mantecón, I., Alvarez, S., & Castromán-Diz, J. L. (2018). The role of green collaborative strategies in improving environmental sustainability in supply chains: Insights from a case study. Business Strategy and the Environment, 27(6), 728-741.

Carter, C. R., Kale, R., & Grimm, C. M. (2000). Environmental purchasing and firm performance: an empirical investigation. Transportation Research Part E: Logistics and Transportation Review, 36(3), 219-228.

Chenail, R. J. (2011). Interviewing the investigator: Strategies for addressing instrumentation and researcher bias concerns in qualitative research. The qualitative report, 16(1), 255-262.

Chien, M. K., & Shih, L. H. (2007). An empirical study of the implementation of green supply chain management practices in the electrical and electronic industry and their relation to organizational performances. International Journal of Environmental Science and Technology, 4(3), 383-394.

Chien, M. K., Chang, T. M., & Kuo, W. C. (2012, June). Applying Grounded Theory to study green supply chain management practices in Taiwan's industry. In International Technology Management Conference (pp. 129-136). IEEE.

Chiou, T. Y., Chan, H. K., Lettice, F., & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. Transportation Research Part E: Logistics and Transportation Review, 47(6), 822-836.

Creswell, J. W., & Poth, C. N. (2013). Qualitative inquiry and research design: Choosing among five approaches. Sage publications.

de Oliveira, U. R., Espindola, L. S., da Silva, I. R., da Silva, I. N., & Rocha, H. M. (2018). A systematic literature review on green supply chain management: Research implications and future perspectives. Journal of cleaner production, 187, 537-561.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Govindan, K., Kannan, D., Salgado, M. H., & Zanon, C. J. (2013). Factors affecting the adoption of green supply chain management practices in Brazil: empirical evidence. International Journal of Environmental Studies, 70(2), 302-315.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Latan, H., Teixeira, A. A., & de Oliveira, J. H. C. (2014). Quality management, environmental management maturity, green supply chain practices and green performance of Brazilian companies with ISO 14001 certification: Direct and indirect effects. Transportation Research Part E: Logistics and Transportation Review, 67, 39-51.

Dragomir, V. D. (2018). How do we measure corporate environmental performance? A critical review. Journal of cleaner production, 196, 1124-1157.

Dunning, J., & Lundan, S. M. (2010). Multinational enterprises and the global economy. Transnational Corporations, 19(3), 103-106.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of management review, 14(4), 532-550.

Ferreira, M. A., Jabbour, C. J. C., & de Sousa Jabbour, A. B. L. (2017). Maturity levels of material cycles and waste management in a context of green supply chain management: an innovative framework and its application to Brazilian cases. Journal of Material Cycles and Waste Management, 19(1), 516-525.

Foo, P. Y., Lee, V. H., Tan, G. W. H., & Ooi, K. B. (2018). A gateway to realising sustainability performance via green supply chain management practices: a PLS–ANN approach. Expert Systems with Applications, 107, 1-14.

Global Compact LEAD. Retrieved from https://www.unglobalcompact.org/take-action/leadership/gc-lead.

González-Benito, J., & González-Benito, Ó. (2006). A review of determinant factors of environmental proactivity. Business Strategy and the environment, 15(2), 87-102.

Gopalakrishnan, K., Yusuf, Y. Y., Musa, A., Abubakar, T., & Ambursa, H. M. (2012). Sustainable supply chain management: A case study of British Aerospace (BAe) Systems. International Journal of Production Economics, 140(1), 193-203.

Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A. B. L. D. S., & Jabbour, C. J. C. (2013). Analysing green supply chain management practices in Brazil’s electrical/electronics industry using interpretive structural modelling. International Journal of Environmental Studies, 70(4), 477-493.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. Journal of Cleaner Production, 98, 66-83.

Green Jr, K. W., Zelbst, P. J., Meacham, J., & Bhadauria, V. S. (2012). Green supply chain management practices: impact on performance. Supply Chain Management: An International Journal, 17(3), 290-305.

H'Mida, S., & Lakhal, S. Y. (2007). A model for assessing the greenness effort in a product supply chain. International journal of global environmental issues, 7(1), 4-24.

Hassini, E., Surti, C., & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. International Journal of Production Economics, 140(1), 69-82.

Jacob, S. A., & Furgerson, S. P. (2012). Writing interview protocols and conducting interviews: Tips for students new to the field of qualitative research. The qualitative report, 17(42), 1-10.

Junquera, B., del Brío, J. Á., & Fernández, E. (2012). Clients' involvement in environmental issues and organizational performance in businesses: an empirical analysis. Journal of Cleaner Production, 37, 288-298.

Lee, S. Y., & Klassen, R. D. (2008). Drivers and enablers that foster environmental management capabilities in small-and medium-sized suppliers in supply chains. Production and Operations management, 17(6), 573-586.

Lee, S. M., Tae Kim, S., & Choi, D. (2012). Green supply chain management and organizational performance. Industrial Management & Data Systems, 112(8), 1148-1180.

M. Lee, S., Sung Rha, J., Choi, D., & Noh, Y. (2013). Pressures affecting green supply chain performance. Management Decision, 51(8), 1753-1768.

Liu, X., Yang, J., Qu, S., Wang, L., Shishime, T., & Bao, C. (2012). Sustainable production: practices and determinant factors of green supply chain management of Chinese companies. Business Strategy and the Environment, 21(1), 1-16.

Lofland, J., & Lofland, L. H. (1984). Analyzing social settings.

Maestrini, V., Luzzini, D., Caniato, F., Maccarrone, P., & Ronchi, S. (2018). Measuring supply chain performance: a lifecycle framework and a case study. International Journal of Operations & Production Management, 38(4), 934-956.

Mitra, S., & Datta, P. P. (2014). Adoption of green supply chain management practices and their impact on performance: an exploratory study of Indian manufacturing firms. International Journal of Production Research, 52(7), 2085-2107.

Mumtaz, U., Ali, Y., & Petrillo, A. (2018). A linear regression approach to evaluate the green supply chain management impact on industrial organizational performance. Science of the total environment, 624, 162-169.

Narasimhan, R., & Carter, J. R. (1998). Environmental supply chain management. Center for Advanced Purchasing Studies.

Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. Journal of supply chain management, 45(2), 37-56.

Perotti, S., Zorzini, M., Cagno, E., & Micheli, G. J. (2012). Green supply chain practices and company performance: the case of 3PLs in Italy. International Journal of Physical Distribution & Logistics Management, 42(7), 640-672.

Petit, G., Sablayrolles, C., & Yannou-Le Bris, G. (2018). Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study. Journal of cleaner production, 191, 135-143.

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? International journal of operations & production management, 25(9), 898-916.

Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (Eds.). (2013). Qualitative research practice: A guide for social science students and researchers. sage.

Ruiz-Benítez, R., López, C., & Real, J. C. (2018). The lean and resilient management of the supply chain and its impact on performance. International Journal of Production Economics, 203, 190-202.

Sarkis, J., Zhu, Q., & Lai, K. H. (2011). An organizational theoretic review of green supply chain management literature. International journal of production economics, 130(1), 1-15.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journal of cleaner production, 16(15), 1699-1710.

Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. International journal of management reviews, 9(1), 53-80.

Susanty, A., & Sari, D. P. (2018, April). Exploring the implementation of green supply chain with cluster and discriminant analysis: Case study: Furniture industry at Central Java Semarang. In 2018 5th International

Conference on Industrial Engineering and Applications (ICIEA) (pp. 526-530). IEEE.

Tate, W. L., Ellram, L. M., & Kirchoff, J. F. (2010). Corporate social responsibility reports: a thematic analysis related to supply chain management. Journal of supply chain management, 46(1), 19-44.

Ubeda, S., Arcelus, F. J., & Faulin, J. (2011). Green logistics at Eroski: A case study. International Journal of Production Economics, 131(1), 44-51.

Vachon, S. (2007). Green supply chain practices and the selection of environmental technologies. International Journal of Production Research, 45(18-19), 4357-4379.

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. International journal of production economics, 111(2), 299-315.

Walker Jr, O. C., & Ruekert, R. W. (1987). Marketing's role in the implementation of business strategies: a critical review and conceptual framework. Journal of marketing, 51(3), 15-33.

Yang, M. G. M., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. International Journal of Production Economics, 129(2), 251-261.

Yin, R. K. (2003). Case study research design and methods third edition. Applied social research methods series, 5.

Zacharia, Z. G., Nix, N. W., & Lusch, R. F. (2009). An analysis of supply chain collaborations and their effect on performance outcomes. Journal of business logistics, 30(2), 101-123.

zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. Journal of operations management, 22(3), 265-289.

Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China: drivers and practices. Journal of cleaner production, 14(5), 472-486.

Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. International journal of production research, 45(18-19), 4333-4355.

Zhu, Q., Sarkis, J., & Geng, Y. (2005). Green supply chain management in China: pressures, practices and performance. International Journal of Operations & Production Management, 25(5), 449-468.

Zhu, Q., Sarkis, J., & Lai, K. H. (2008). Confirmation of a measurement model for green supply chain management practices implementation. International journal of production economics, 111(2), 261-273.

Zhu, Q., Sarkis, J., & Lai, K. H. (2012). Examining the effects of green supply chain management practices and their mediations on performance improvements. International journal of production research, 50(5), 1377-1394.

Zhu, Q., Sarkis, J., & Lai, K. H. (2013). Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. Journal of Purchasing and Supply Management, 19(2), 106-117.

Zhu, Q., Feng, Y., & Choi, S. B. (2017). The role of customer relational governance in environmental and economic performance improvement through green supply chain management. Journal of Cleaner Production, 155, 46-53.

CHAPTER 4

OWA operators in the calculation of the average green-house gases emissions

Abstract

This study proposes, through weighted averages and ordered weighted averaging operators, a new aggregation system for the investigation of average gases emissions. I present the ordered weighted averaging operators gases emissions, the induced ordered weighted averaging operators gases emissions, the weighted ordered weighted averaging operators gases emissions and the induced probabilistic weighted ordered weighted averaging operators gases emissions. These operators represent a new way of analyzing the average gases emissions of different variables like countries or regions. The work presents further generalizations by using generalized and quasi-arithmetic means. The article also presents an illustrative example with respect to the calculations of the average gases emissions in the European region.

Keywords: Green-house gases emission, aggregation operators, decision making, ordered weighted average.

4.1 Introduction

Within the exceptionally later decades, since of an gigantic development of the population and the need to supply nourishment for them from one hand and the other hand an immethodical utilization of fossil fuel, my planet is experiencing an unexampled growth in terms of green-house gases (GHG) emission such as CO_2, CH_4 and N_2O in its atmosphere that cause an ascending amount of global warming year by year and a drastic climate change (Hastings et al. 2010; IPCC, 2007; Stewart et al. 2013).

There are many works that study the ways that can lead the GHG emission toward the minimization. Sorrentino et al. (2014) evaluate the potential influence of vehicle electrification on grid infrastructure and road-traffic green-house emission. Hammons (2006) Study the impact of electrical power generation on GHG emission in Europe, Flower and Sanjayan (2007) analyze green-house gases emission in concrete manufacture while there are some papers that focus on agriculture and farming (Bhattacharyya et al. 2012; Kristensen et al. 2011; Smith et al. 2010).

Besides, although these works exist but it seems vital to present a comprehensive forecast about the future of countries based on the experts' opinions to provide a clear plan and make a suitable decision to decrease this emission in any of the studied sectors and under various conditions.

Aggregation operators in the related literature with the aim of decision making are diverse and each of them can be used to collect the information (Beliakov et al. 2007; Merigó and Casanova, 2010a; Merigó and Casanova, 2010b; Merigó and Gil-Lafuente, 2009; Merigó et al. 2012). These techniques give importance to the variables according to certain available subjective or objective findings (Merigó et al. 2018; Merigó et al. 2017; Torra, 1997; Xu and Da, 2003; Yager, 1003).

A very popular aggregation operator is the weighted average. This aggregation operator is flexible to use in a wide range of problems. Another popular aggregation operator is the ordered weighted average (OWA) (Yager, 1988; Yu, 2015). The OWA operator provides a parametrized family of aggregation operators between the minimum and the maximum, weighting the data according to the attitudinal character of the decision-maker. Based on this operator and with the purpose of expanding it, many authors expand and generalize it (Emrouznejad and Marra, 2014; Kacprzyk and Zadrożn, 2009; Mesiar et al. 2015; Torra and Narukawa, 2010; Yu et al. 2016). There are several types for the concept of expanding and generalizing and the most important item is the form of integrating OWA operator with some key concepts such as, using the induced variables, the probability and the weighted average. Xu and Da (2003) propose some new aggregation operators such as the induced ordered weighted geometric averaging (IOWGA) operator, generalized induced ordered weighted averaging (GIOWA) operator, hybrid weighted averaging (HWA) operator.

The purpose of this work is to concentrate on the analysis of the use of the aggregation operators in the calculation of green-house gases (GHG) emission with the aim of developing better decision-making techniques. To this end, the paper studies several aggregation operators including the WA (Beliakov et al. 2007), OWA (Linares-Mustarós et al. 2019; Yager, 1988), OWAWA and IOWAWA (Merigó, 2011), IOWA (Yager and Filev, 1999), POWAWA and IPOWAWA operator (Merigó et al. 2012). With the use of each operator, a new operator for GHG emission is produced including the OWA GHG emission (OWAGE), induced OWA GHG emission (IOWAGE), ordered weighted averaging weighted average GHG emission (OWAWAGE), induced OWAWA GHG emission (IOWAWAGE), probabilistic OWAWA GHG emission (POWAWAGE) and induced probabilistic OWAWA GHG emission (IPOWAWAGE).

The work also presents further generalizations by using generalized and quasi-arithmetic means obtaining the generalized OWAGE (GOWAGE). The aim of this approach is to show a more general framework in the analysis of averages by using complex aggregations including with geometric and quadratic averages. The study presents a wide range of particular types of aggregations under this approach.

During the related literature there are several works dedicated to the application of these aggregation operators such as, demand analysis (Merigó et al. 2016a), economic growth analysis (Merigó et al. 2016b), portfolio selection (Laengle et al. 2017), support vector machines (Maldonado et al. 2018) and the average price Merigó et al. (2015). On the other hand, many works are dedicated to making decision in different fields to solve the problem. As an example, Casanova et al. (2016) with mixing induced OWA operators and Minkowski distances, try to present a method to decide in reinsurance. Chen and Chen (2003) present a new method for handling multi-criteria fuzzy decision-making problems by using FN-IOWA operators or in the other study, Herrera et al. (2003) analyze the origin and uses of the ordered weighted geometric operator in multicriteria decision making and Llamazares (2007) proposes a model for the best-suited OWA operators and Blanco-Mesa et al. (2017) by using bibliometric method review the contribution in fuzzy decision-making area. This work develops OWA operators in the analysis of the average green-house gases emissions.

The work presents an application regarding the calculation of the average gases emissions in Europe. For doing so, the paper considers a multi-expert aggregation problem where four experts analyze the expected average emissions of each European country for the next period. From, the analysis develops several aggregation methods based on the tools developed in the paper including the OWAGE, IOWG and OWAWAGE operators. The main advantage of the OWA operator is the possibility of under or overestimate the information according to the attitudinal character of the decision maker. Thus, depending on the degree of optimism or pessimism of the decision maker, the results may lead to different decisions and interpretations of the information.

This paper is organized as follows. Section 2 briefly reviews some basic OWA operators. Section 3 introduces the use of the OWA operator in the calculation of the average green-house gases emissions. Section 4 develops further generalization with generalized and quasi-arithmetic means. Section 5 presents an illustrative example regarding the calculation of average gases emissions with OWA operators. Section 6 ends the paper summarizing the main findings and conclusions of the paper.

4.2 Preliminaries

4.2.1 The induced OWA operator (IOWA)

The IOWA operator (Yager and Filev, 1999) is an extension of the OWA operator. The main difference between OWA and IOWA is that the reordering step is not developed with the values of the arguments a_i. In this case, the reordering step is carried out with order inducing variables. The IOWA operator also includes as particular cases the maximum, the minimum and the average criteria. It can be defined as follows.

Definition 1. An IOWA operator of dimension n is a mapping $IOWA: R^n \times R^n \rightarrow R$ that has an associated weighting vector W of dimension n with $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0,1]$, such that:

$$IOWA(\langle u_1, a_1 \rangle, \langle u_2, a_2 \rangle, \ldots, \langle u_n, a_n \rangle) = \sum_{j=1}^{n} w_j b_j \, , \tag{1}$$

where b_j is the a_i value of the IOWA pair $\langle u_i, a_i \rangle$ having the jth largest u_i . u_i is the order-ranking variable and a_i is the argument variable.

4.2.2 The ordered weighted averaging-weighted average (OWAWA)

The OWAWA operator (Merigó, 2011) is a new model that unifies the OWA operator and the weighted average in the same formula. Therefore, both concepts can be seen as a particular case of a more general one. It can be defined as follows.

Definition 2. An OWAWA operator of dimension n is a mapping $OWAWA: R^n \rightarrow R$ that has an associated weighting vector W of dimension n such that $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$, according to the following formula:

$$OWAWA(a_1, \ldots, a_n) = \sum_{j=1}^{n} \hat{v}_j b_j \tag{2}$$

where b_j is the jth largest of the a_i, each argument a_i has an associated weight (WA) v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, $\hat{v}_j = \beta w_j + (1-\beta) v_j$ with $\beta \in [0,1]$ and v_j is the weight (WA) v_i ordered according to b_j, that is, according to the jth largest of the a_i.

4.2.3 The probabilistic ordered weighted averaging-weighted average (POWAWA)

The POWAWA (Merigó et al. 2018) operator uses probabilities, weighted average and OWA in the same formulation. It unifies these three concepts by considering the degree of importance that each concept has in the aggregation, depending on the situation considered. The POWAWA operator is defined as follows.

Definition 3. A POWAWA operator of dimension n is a mapping $POWAWA: R^n \rightarrow R$ that has an associated weighting vector W of dimension n with $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$ such that:

$$POWAWA(a_1, a_2, \ldots, a_n) = \sum_{j=1}^{n} \hat{v}_j b_j \qquad (3)$$

where b_j is the jth largest of the a_i, each argument a_i has an associated weight v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, a probability p_i with $\sum_{i=1}^{n} p_i = 1$ and $p_i \in [0,1]$, $\hat{v}_j = C_1 w_j + C_2 v_j + C_3 p_j$, with C_1, C_2 and $C_3 \in [0,1]$, $C_1 + C_2 + C_3 = 1$ and v_j p_j are the weights v_i and p_i ordered according to b_j, that is to say, according to the jth largest of the a_i.

4.2.4 The induced probabilistic OWAWA operator

The IPOWAWA (Merigó et al. 2012) is an aggregation operator that extends POWAWA operator that uses order-inducing variables that represent complex reordering processes of an aggregation. Thus, it is an aggregation operator that uses induced variables, the probability, the weighted average and the OWA operator. Moreover, it can assess complex reordering processes by using order-inducing variables. Its main advantage is that it provides a more robust formulation than the POWAWA operator because it includes a wide range of cases. It can be defined as follows.

Definition 4. The IPOWAWA operator of dimension n is a mapping $IPOWAWA: R^n \times R^n \to R$ that has an associated weighting vector W of dimension n with $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$, such that:

$$IPOWAWA(\langle u_1, e_1 \rangle, \langle u_2, e_2 \rangle, \ldots, \langle u_n, e_n \rangle) = \sum_{j=1}^{n} \hat{v}_j b_j \tag{4}$$

where b_j is the a_i value of the IPOWAWA pair $\langle u_i, e_i \rangle$ having the jth largest u_i , u_i is the order-inducing variable, each argument a_i has an associated weight v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, a probability p_i with $\sum_{i=1}^{n} p_i$ and $p_i \in [0,1]$, $\hat{v}_j = C_1 w_j + C_2 v_j + C_3 p_j$, with C_1, C_2 and $C_3 \in [0,1]$, $C_1 + C_2 + C_3 = 1$, v_j and p_j are the weights v_i and p_i ordered according to b_j , that is to say according to the jth largest of the e_i .

4.3 Calculation of the average green-house gases (GHG) emission with OWA operators

The purpose of this paper is to calculate the average GHG emission. The average GHG emission represents a numerical value that reports the information of the GHG emission. To calculate this item, using many aggregation operators is possible likewise normal arithmetic mean. These possible aggregation operators could be WA, OWA, IOWA or a combination of them such as OWAWA, IOWAWA, etc. Through using them I prepare some possibilities for the future of GHG emission in different scenarios in a spectrum from the worst case to the best case based on experts' opinions.

The basic operator for analyzing a set of GHG emission is OWAGE. The OWAGE operator is an aggregation operator that analyses an average GHG emission under uncertainty situation. It can be defined as follows for the set of GHG emission $A = \{e_1, e_2, \ldots, e_n\}$:

$$OWAGE(e_1, e_2, \ldots, e_n) = \sum_{j=1}^{n} w_j f_j \tag{5}$$

where f_j is the jth largest of the e_i.

The other significant aggregation operator is the induced OWA (IOWA) that its reordering step is developed with order including variables. So, by using the IOWA operator I obtain IOWA GHG emission (IOWAGE) that can be defined as follows:

$$IOWAGE\left(\langle u_1,e_1\rangle,\langle u_2,e_2\rangle,\ldots,\langle u_n,e_n\rangle\right)=\sum_{j=1}^{n} w_j f_j \tag{6}$$

where f_j is the e_i value of the IOWA pair $\langle u_i, e_i\rangle$ having the jth largest u_i . u_i is the order-ranking variable and e_i is the argument variable.

It is important to mention that this operator is based on considering no extra information. One of the very important aspects of the average GHG emission is the importance of each of them and in other words, their weights in comparison with each other. To this end it is better to use some approaches of information aggregation that combine OWA operators and WA. In the literature there are some aggregation operators with this structure like, the WOWA operator (Torra, 1997), the hybrid average (Merigó and Casanova, 2010a) and the OWAWA operators (Merigó, 2011). In this work I apply OWAWA to obtain the OWAWA GHG emission (OWAWAGE) and it is defined as follows for a set of GHG emission $A=\{e_1,e_2,\ldots,e_n\}$:

$$OWAWAGE\left(e_1,e_2,\ldots,e_n\right)=\sum_{j=1}^{n} \hat{v}_j f_j \tag{7}$$

where f_j is the jth largest of the e_i , each argument e_i has an associated weight (WA) v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, $\hat{v}_j = \beta w_j + (1-\beta) v_j$ with $\beta \in [0,1]$ and v_j is the weight (WA) v_i ordered according to b_j , that is, according to the jth largest of the e_i .

To focus more deeply on my contributions, I implement IOWAWA which is a combination of IOWA operators and WA in the same formulation. By using the IOWAWA operator I obtain IOWAWA GHG emission (IOWAWAGE) that can be defined as follows:

$$IOWAWAGE\left(\langle u_1,e_1\rangle,\langle u_2,e_2\rangle,\ldots,\langle u_n,e_n\rangle\right)=\sum_{j=1}^{n} \hat{v}_j f_j \tag{8}$$

where f_j is the e_i value of the IOWAWA pair $\langle u_i, e_i\rangle$ having the jth largest u_i, u_i is the order including variable and e_i is the argument variable, each argument e_i has an associated weight (WA) v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, $\hat{v}_j = \beta w_j + (1-\beta) v_i$ with $\beta \in [0,1]$ and v_j is the weight (WA) v_i ordered according to f_j, that is, according to the jth largest u_i.

Besides, the other aspect that can be considered and leads results to a better form is probabilities in the attitudinal character of the decision-maker. For this reason, I apply POWAWA operator. By applying the Eq. (3) I could obtain the probabilistic OWAWA GHG emission (POWAWAGE). It can be defined as follows:

$$POWAWAGE(e_1, e_2, \ldots, e_n) = \sum_{j=1}^{n} \hat{v}_j f_j \tag{9}$$

where f_j is the jth largest of the e_i, each argument e_i has an associated weight v_i with $\sum_{i=1}^{n} v_i = 1$ and $v_i \in [0,1]$, a probability p_i with $\sum_{i=1}^{n} p_i = 1$ and $p_i \in [0,1]$, $\hat{v}_j = C_1 w_j + C_2 v_j + C_3 p_j$, with C_1, C_2 and $C_3 \in [0,1]$, $C_1 + C_2 + C_3 = 1$ and v_j p_j are the weights v_i and p_i ordered according to f_j, that is to say, according to the jth largest of the e_i.

Let us analyze the different families of IOWAWAGE and POWAWAGE in the following paragraphs

First, I am considering the two main cases of the IOWAWAGE operator that are found by analyzing the coefficient β. Basically:

- If $\beta = 0,$ we get the WA.
- If $\beta = 1,$ the IOWA operator.
- If $\beta = 1$ and the ordered position of u_i is the same than the ordered position of f_i such that f_j is the jth largest of e_i, the OWA operator.
- Note that when β increases, we are giving more importance to the IOWAGE operator and when β decreases, we give more importance to the WA.

Another group of interesting families are the maximum-WAGE, the minimum-WAGE, the step-IOWAWAGE operator and the usual average.

- The maximum-WAGE is found when $w_p = 1$ and $w_j = 0,$ for all $j \neq p,$ and $u_p = Max\{e_i\}.$
- The minimum-WAGE is formed when $w_p = 1$ and $w_j = 0,$ for all $j \neq p,$ and $u_p = Min\{e_i\}.$

The arithmetic-WAGE is obtained when $w_j = 1/n$ for all j, and the weighted average is equal to the OWA when the ordered position of i is the same as the ordered position of j. The arithmetic-WAGE (A-WAGE) can be formulated as follows:

$$A-WAGE\left(\langle u_1,e_1\rangle,\langle u_2,e_2\rangle,\ldots,\langle u_n,e_n\rangle\right)=\frac{1}{n}\beta a_i+(1-\beta)\sum_{i=1}^{n}v_i e_i, \tag{10}$$

Note that if $v_i = 1/n,$ for all i, then, we get the unification between the arithmetic mean (and simple average) and the IOWAGE operator, that is, the arithmetic-IOWAGE (A-IOWAGE). The A-IOWAGE operator can be formulated as follows:

$$A-IOWAGE\left(\langle u_1,e_1\rangle,\langle u_2,e_2\rangle,\ldots,\langle u_n,e_n\rangle\right)=\beta\sum_{j=1}^{n}w_j b_j+(1-\beta)\frac{1}{n}e_i. \tag{11}$$

Following the OWA literature (Merigó et al. 2012; Yager, 1988; Yager, 2004), we can develop many other families of IOWAWA operators such as:

- The olympic-IOWAWAGE operator $(w_1 = w_n = 0,$ and $w_j = 1/(n-2)$ for all others).
- The general olympic-IOWAWAGE operator $(w_j = 0$ for $j = 1,2,\ldots,k,n,n-1,\ldots,n-k+1;$ and for all others $w_{j*} = 1/(n-2k)$, where $k < n/2).$
- The S-IOWAWAGE (green-house gases emission) $(w_1 = (1/n)(1-(\alpha+\beta)+\alpha,$ $w_n = (1/n)(1-(\alpha+\beta)+\beta,$ and $w_j = (1/n)(1-(\alpha+\beta)$ for $j=2$ to $n-1$ where $\alpha,\beta \in [0,1]$ and $\alpha+\beta \le 1).$
- The centered-IOWAWAGE (if it is symmetric, strongly decaying from the center to the maximum and the minimum, and inclusive).

Now I consider the different families of POWAWAGE operators that are found in the weighting vector $\hat{V}$ and the coefficients C_1, C_2 and $C_3.$

If $w_1 = 1$ and $w_j = 0,$ for all $j \neq 1,$ the POWAWAGE operator becomes the maximum probabilistic weighted average GHG emission (Max-PWAGE) which is formulated as follows:

$$Max-PWAGE = C_1 Max\left\{b_j\right\}+C_2\sum_{i=1}^{n}v_i\left|x_{i-}y_i\right|+C_3\sum_{i=1}^{n}p_i\left|x_{i-}y_i\right| \tag{12}$$

If $w_n = 1$ and $w_j = 0,$ for all $j \neq n,$ the POWAWAGE becomes the minimum probabilistic weighted average GHG emission (Min-PWAGE), which is formulated in the following way:

$$Min-PWAGE = C_1 Min\{b_j\} + C_2\sum_{i=1}^{n} v_i |x_{i-}y_i| + C_3\sum_{i=1}^{n} p_i |x_{i-}y_i| \quad (13)$$

The arithmetic PWAGE (if $w_j = 1/n$, for all j):

$$ArithmeticPWAGE = C_1\left(\frac{1}{n}\sum_{j=1}^{n} b_j\right) + C_2\sum_{i=1}^{n} v_i |x_{i-}y_i| + C_3\sum_{i=1}^{n} p_i |x_{i-}y_i| \quad (14)$$

- The arithmetic POWAGE operator (if $v_i = 1/n$, for all i):

$$ArithmeticPOWAGE = C_1\sum_{j=1}^{n} w_j b_j + C_2\left(\frac{1}{n}\sum_{i=1}^{n} |x_{i-}y_i|\right) + C_3\sum_{i=1}^{n} p_i |x_{i-}y_i| \quad (15)$$

Many other particular cases can be studied by looking at different expressions of the weighting vectors and the coefficients C_1, C_2 and C_3. for example:

- If $C_1 = 1$, we obtain the OWAGE operator.
- If $C_2 = 1$, the weighted GHG emission (WGE).
- If $C_3 = 1$, the probabilistic GHG emission (PGE).
- If $C_1 = 0$, the probabilistic weighted averaging GHG emission (PWAGE).
- If $C_2 = 0$, the probabilistic OWA GHG emission (POWAGE).
- If $C_3 = 0$, the OWAWA GHG emission (OWAWAGE) (Merigó et al. 2017).

Example 1. Assume we have the following arguments $A = (60, 40, 70, 20)$ that represent a set of four different gases emissions and the following weighting vector $W = (0.50, 0.25, 0.15, 0.10)$. If we aggregate the WA aggregation, we get the following result:

$$WAGE = 0.50\times 60 + 0.25\times 40 + 0.15\times 70 + 0.10\times 20 = 52.50,$$

Now we assume the same arguments and the same weighting vector. If we aggregate OWA aggregation, we get the following result:

$$OWAGE = 0.50\times 70 + 0.25\times 60 + 0.15\times 40 + 0.10\times 20 = 58.$$

4.4 Generalizations with generalized and quasi-arithmetic means

Generalization of the OWA operators is possible to do by generalized and quasi-arithmetic averaging aggregation operators that as the most common one generalized OWA (GOWA) (Yager, 2004) and then quasi-arithmetic

OWA (Quasi-OWA) (Fodor et al. 1995) are formed. These functions apply a general framework including particular cases. The GOWA operator applied to the analysis of gases emissions is called GOWA gases emissions (GOWAGE) and is defined as follows.

Definition 8. A GOWAGE operator of dimension n is a mapping $GOWA: R^n \rightarrow R$ that has an associated weighting vector W of dimension n with $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0,1]$, such that:

$$GOWAGE(e_1, e_2, ..., e_n) = \left(\sum_{j=1}^{n} w_j b_j^{\lambda} \right)^{1/\lambda} \quad (16)$$

where b_j is the jth largest of the e_i, and λ is a parameter such that $\lambda \in (-\infty, \infty) - \{0\}$.

Like the section 3, this operator also has the particular cases of the maximum, the minimum and the generalized mean (GM). Besides, there are some cases that can be obtained by maneuvering on the values of λ, such as:

- If $\lambda = 1$, the usual OWAGE operator.
- If $\lambda \rightarrow 0$, the ordered weighted geometric average gases emissions (OWGAGE).
- If $\lambda = 2$, the ordered weighted quadratic average gases emissions (OWQAGE).
- If $\lambda = -1$, the ordered weighted harmonic average gases emissions (OWHAGE).
- Quasi-arithmetic OWA gases emissions (Quasi-OWAGE) operator is the other generalization that uses the quasi-arithmetic means instead of the generalized means. So, it replaces the parameter λ by a strictly continuous monotonic function g.

Table 4.1 European average GHG emission according to different scenario-expert 1

Country	Abbreviation	Population	Weight	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Albania	ALB	2,934,363	0.003959	0.21	0.18	0.26	0.25	0.31	0.19	0.24
Andorra	AND	76,953	0.000104	0.39	0.46	0.13	0.40	0.43	0.39	0.15
Austria	AUT	8,751,820	0.011808	0.13	0.25	0.15	0.31	0.26	0.22	0.22
Belarus	BLR	9,452,113	0.012753	0.36	0.27	0.30	0.45	0.32	0.42	0.13
Belgium	BEL	11,498,519	0.015515	0.47	0.44	0.32	0.39	0.21	0.27	0.46
Bosnia and Herzegovina	BIH	3,503,554	0.004727	0.23	0.34	0.38	0.14	0.44	0.28	0.24
Bulgaria	BGR	7,036,848	0.009495	0.15	0.22	0.37	0.35	0.44	0.15	0.25
Cyprus	CYP	1,189,085	0.001604	0.47	0.48	0.47	0.15	0.14	0.37	0.13
Czech R	CZE	10,625,250	0.014336	0.15	0.42	0.39	0.37	0.14	0.50	0.47
Denmark	DNK	5,754,356	0.007764	0.24	0.35	0.13	0.17	0.49	0.25	0.18
Estonia	EST	1,306,788	0.001763	0.49	0.31	0.27	0.27	0.15	0.36	0.46
Finland	FIN	5,542,517	0.007478	0.14	0.22	0.28	0.20	0.50	0.19	0.34
France	FRA	65,233,271	0.088017	0.19	0.23	0.23	0.43	0.20	0.18	0.46
Germany	DEU	82,293,457	0.111035	0.16	0.49	0.47	0.29	0.26	0.17	0.22
Greece	GRC	11,142,161	0.015034	0.32	0.46	0.45	0.42	0.29	0.29	0.22
Hungary	HUN	9,688,847	0.013073	0.18	0.34	0.26	0.47	0.37	0.37	0.16
Iceland	ISL	337,780	0.000456	0.34	0.41	0.22	0.39	0.22	0.24	0.19
R Ireland	IRL	4,803,748	0.006482	0.47	0.13	0.39	0.27	0.35	0.36	0.46
Italy	ITA	59,290,969	0.079999	0.44	0.14	0.50	0.20	0.49	0.19	0.23
Kosovo	RKS	1,808,698	0.002440	0.21	0.28	0.39	0.13	0.40	0.39	0.41
Latvia	LVA	1,929,938	0.002604	0.31	0.14	0.27	0.38	0.23	0.13	0.26
Liechtenstein	LIE	38,155	0.000051	0.46	0.27	0.33	0.43	0.16	0.27	0.35
Lithuania	LTU	2,876,475	0.003881	0.28	0.31	0.36	0.28	0.29	0.20	0.46
Luxembourg	LUX	590,321	0.000796	0.23	0.34	0.26	0.33	0.18	0.48	0.13
Macedonia	MKD	2,085,051	0.002813	0.18	0.33	0.37	0.14	0.41	0.25	0.43
Malta	MLT	432,089	0.000583	0.26	0.41	0.48	0.43	0.41	0.32	0.39
Moldova	MDA	4,041,065	0.005452	0.46	0.38	0.48	0.14	0.31	0.47	0.18
Monaco	MCO	38,897	0.000052	0.20	0.16	0.13	0.45	0.37	0.22	0.48
Montenegro	MNE	629,219	0.000849	0.28	0.47	0.19	0.13	0.20	0.18	0.44
Netherlands	NLD	17,084,459	0.023051	0.34	0.27	0.16	0.31	0.46	0.31	0.48
Norway	NOR	5,353,363	0.007223	0.23	0.27	0.36	0.18	0.32	0.28	0.35
Poland	POL	38,104,832	0.051413	0.50	0.27	0.19	0.44	0.20	0.13	0.26
Portugal	PRT	10,291,196	0.013886	0.38	0.33	0.30	0.30	0.32	0.35	0.50
Romania	ROU	19,580,634	0.026419	0.20	0.33	0.29	0.14	0.16	0.46	0.20
Russia	RUS	143,964,709	0.194246	0.17	0.30	0.18	0.26	0.18	0.45	0.36
San Marino	SMR	33,557	0.000045	0.50	0.36	0.17	0.43	0.30	0.49	0.37
Serbia	SRB	8,762,027	0.011822	0.23	0.30	0.16	0.45	0.19	0.23	0.32
Slovakia	SVK	5,449,816	0.007353	0.48	0.49	0.30	0.30	0.43	0.26	0.39
Slovenia	SVN	2,081,260	0.002808	0.25	0.25	0.50	0.18	0.15	0.49	0.45
Spain	ESP	46,397,452	0.062602	0.17	0.13	0.26	0.18	0.20	0.44	0.43
Sweden	SWE	9,982,709	0.013469	0.44	0.29	0.30	0.37	0.45	0.32	0.48
Switzerland	CHE	8,544,034	0.011528	0.21	0.42	0.27	0.50	0.41	0.41	0.25
Ukraine	UKR	44,009,214	0.059380	0.45	0.47	0.45	0.22	0.17	0.47	0.21
United Kingdom	GBR	66,573,504	0.089825	0.40	0.49	0.17	0.42	0.35	0.29	0.27
Vatican city	VAT	801	0.000001	0.23	0.28	0.16	0.27	0.37	0.23	0.18
European average		741,145,874	1	0.310	0.323	0.304	0.299	0.307	0.314	0.323

Table 4.2 European average GHG emission according to different scenarios-expert 2

Abbr.	1	2	3	4	5	6	7
ALB	0.22	0.48	0.39	0.27	0.17	0.35	0.26
AND	0.26	0.38	0.49	0.29	0.18	0.22	0.14
AUT	0.45	0.20	0.39	0.21	0.13	0.47	0.35
BLR	0.20	0.46	0.24	0.25	0.45	0.16	0.24
BEL	0.49	0.43	0.14	0.21	0.20	0.42	0.40
BIH	0.48	0.48	0.15	0.43	0.39	0.33	0.26
BGR	0.37	0.23	0.42	0.16	0.38	0.39	0.29
CYP	0.28	0.34	0.26	0.23	0.25	0.22	0.36
CZE	0.16	0.27	0.32	0.15	0.36	0.44	0.20
DNK	0.25	0.18	0.32	0.16	0.39	0.29	0.45
EST	0.18	0.50	0.22	0.28	0.14	0.40	0.18
FIN	0.30	0.49	0.29	0.41	0.38	0.50	0.35
FRA	0.34	0.25	0.19	0.34	0.50	0.20	0.26
DEU	0.13	0.44	0.24	0.31	0.32	0.44	0.13
GRC	0.17	0.26	0.16	0.43	0.17	0.43	0.31
HUN	0.48	0.21	0.20	0.50	0.44	0.41	0.38
ISL	0.21	0.33	0.24	0.42	0.34	0.44	0.13
IRL	0.13	0.38	0.13	0.23	0.25	0.50	0.25
ITA	0.47	0.35	0.34	0.30	0.26	0.33	0.34
RKS	0.45	0.46	0.18	0.35	0.34	0.25	0.45
LVA	0.25	0.15	0.33	0.50	0.42	0.34	0.27
LIE	0.35	0.37	0.15	0.16	0.26	0.27	0.29
LTU	0.20	0.42	0.17	0.17	0.29	0.48	0.50
LUX	0.32	0.33	0.13	0.24	0.27	0.34	0.49
MKD	0.40	0.16	0.41	0.46	0.45	0.38	0.45
MLT	0.46	0.22	0.20	0.23	0.35	0.19	0.32
MDA	0.45	0.22	0.24	0.39	0.39	0.44	0.25
MCO	0.45	0.32	0.24	0.50	0.26	0.42	0.28
MNE	0.24	0.23	0.39	0.40	0.20	0.27	0.32
NLD	0.39	0.13	0.19	0.27	0.44	0.13	0.27
NOR	0.23	0.20	0.28	0.32	0.44	0.28	0.26
POL	0.24	0.13	0.27	0.22	0.50	0.38	0.18
PRT	0.42	0.33	0.43	0.24	0.35	0.30	0.37
ROU	0.49	0.34	0.31	0.37	0.15	0.34	0.13
RUS	0.15	0.40	0.37	0.38	0.23	0.34	0.47
SMR	0.22	0.33	0.28	0.28	0.36	0.49	0.21
SRB	0.44	0.30	0.21	0.16	0.28	0.45	0.49
SVK	0.13	0.40	0.46	0.22	0.26	0.27	0.36
SVN	0.44	0.37	0.16	0.25	0.45	0.49	0.41
ESP	0.19	0.39	0.25	0.16	0.42	0.31	0.50
SWE	0.26	0.38	0.47	0.38	0.27	0.37	0.46
CHE	0.47	0.33	0.28	0.34	0.31	0.43	0.43
UKR	0.48	0.37	0.13	0.36	0.20	0.36	0.15
GBR	0.46	0.32	0.21	0.41	0.42	0.31	0.44
VAT	0.22	0.18	0.15	0.22	0.40	0.50	0.19
EA.	**0.319**	**0.321**	**0.267**	**0.301**	**0.320**	**0.357**	**0.316**

Abbr.: Abbreviation, EA.: Europen average

Table 4.3 European average GHG emission according to different scenarios-expert 3

Abbr.	1	2	3	4	5	6	7
ALB	0.29	0.31	0.37	0.21	0.17	0.35	0.26
AND	0.36	0.36	0.24	0.29	0.22	0.28	0.27
AUT	0.22	0.29	0.35	0.35	0.37	0.29	0.38
BLR	0.32	0.24	0.18	0.23	0.22	0.37	0.32
BEL	0.22	0.19	0.37	0.18	0.19	0.25	0.34
BIH	0.38	0.19	0.38	0.32	0.32	0.26	0.30
BGR	0.28	0.25	0.15	0.37	0.28	0.21	0.38
CYP	0.36	0.19	0.26	0.26	0.17	0.33	0.29
CZE	0.19	0.32	0.23	0.16	0.23	0.27	0.30
DNK	0.29	0.29	0.15	0.38	0.36	0.15	0.27
EST	0.22	0.20	0.36	0.23	0.33	0.26	0.35
FIN	0.24	0.36	0.32	0.16	0.33	0.34	0.33
FRA	0.35	0.34	0.24	0.36	0.28	0.17	0.26
DEU	0.38	0.34	0.38	0.37	0.15	0.28	0.34
GRC	0.21	0.20	0.28	0.18	0.31	0.17	0.25
HUN	0.25	0.26	0.38	0.22	0.38	0.17	0.37
ISL	0.23	0.18	0.16	0.22	0.37	0.18	0.24
IRL	0.28	0.21	0.38	0.33	0.28	0.30	0.36
ITA	0.18	0.34	0.23	0.16	0.38	0.16	0.28
RKS	0.36	0.16	0.34	0.17	0.17	0.21	0.20
LVA	0.31	0.19	0.20	0.24	0.15	0.26	0.30
LIE	0.26	0.32	0.31	0.22	0.36	0.27	0.26
LTU	0.22	0.24	0.32	0.15	0.28	0.36	0.33
LUX	0.17	0.21	0.19	0.21	0.23	0.29	0.21
MKD	0.29	0.35	0.35	0.25	0.16	0.35	0.27
MLT	0.22	0.34	0.23	0.25	0.18	0.29	0.16
MDA	0.32	0.20	0.26	0.16	0.23	0.23	0.34
MCO	0.32	0.17	0.32	0.36	0.27	0.38	0.20
MNE	0.15	0.26	0.18	0.24	0.24	0.31	0.28
NLD	0.18	0.18	0.22	0.30	0.32	0.20	0.34
NOR	0.19	0.17	0.29	0.18	0.26	0.28	0.22
POL	0.34	0.22	0.34	0.23	0.29	0.23	0.29
PRT	0.33	0.22	0.25	0.21	0.19	0.27	0.20
ROU	0.18	0.21	0.24	0.29	0.24	0.18	0.34
RUS	0.30	0.28	0.34	0.33	0.35	0.18	0.17
SMR	0.16	0.38	0.30	0.20	0.37	0.16	0.16
SRB	0.15	0.27	0.22	0.21	0.27	0.16	0.34
SVK	0.23	0.33	0.15	0.33	0.30	0.21	0.19
SVN	0.20	0.35	0.24	0.22	0.36	0.26	0.32
ESP	0.37	0.37	0.21	0.21	0.22	0.27	0.20
SWE	0.27	0.38	0.33	0.33	0.25	0.26	0.20
CHE	0.28	0.27	0.30	0.35	0.24	0.30	0.34
UKR	0.32	0.33	0.33	0.15	0.32	0.30	0.36
GBR	0.37	0.37	0.38	0.15	0.23	0.23	0.29
VAT	0.15	0.38	0.15	0.26	0.31	0.20	0.26
EA.	**0.264**	**0.271**	**0.276**	**0.248**	**0.270**	**0.254**	**0.281**

Definition 9. A Quasi-OWAGE operator of dimension n is a mapping Quasi-OWAGE: $R^n \rightarrow R$ that has an associated weighting vector W of dimension n with $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0,1]$, then:

$$Quasi-OWAGE(e_1, e_2, ..., e_n) = g^{-1}\left(\sum_{j=1}^{n} w_j g\left(b_{(j)}\right)\right) \quad (17)$$

where b_j is the jth largest of the e_i and g is strictly continuous monotonic function.

4.5 Illustrative example

In this section through a numerical example I try to show the applicability of OWA operators. This work concentrates on the calculation of different OWA operators' aggregation on green-house gases emission of European countries and makes a comparison on them to gain a clear decision about their possible future scenarios. To this end and with the purpose of giving a correct overview to solve the problem, a group of four experts analyses the information in seven scenarios. This step by step process can be explained as follows.

Table 4.4 European average GHG emission according to different scenarios-expert 4

Abbr.	1	2	3	4	5	6	7
ALB	0.33	0.36	0.28	0.25	0.29	0.34	0.19
AND	0.21	0.28	0.25	0.35	0.24	0.39	0.34
AUT	0.38	0.38	0.22	0.35	0.39	0.28	0.28
BLR	0.39	0.48	0.34	0.23	0.26	0.41	0.26
BEL	0.42	0.25	0.47	0.33	0.44	0.22	0.29
BIH	0.37	0.44	0.44	0.32	0.32	0.48	0.23
BGR	0.31	0.38	0.45	0.38	0.32	0.49	0.24
CYP	0.28	0.28	0.27	0.34	0.32	0.31	0.34
CZE	0.26	0.48	0.23	0.32	0.45	0.49	0.38
DNK	0.29	0.49	0.47	0.26	0.26	0.40	0.32
EST	0.32	0.36	0.42	0.27	0.34	0.26	0.33
FIN	0.48	0.38	0.26	0.45	0.47	0.39	0.34
FRA	0.38	0.28	0.29	0.39	0.37	0.40	0.46
DEU	0.24	0.26	0.22	0.26	0.27	0.27	0.45
GRC	0.48	0.32	0.37	0.27	0.28	0.41	0.45
HUN	0.44	0.36	0.23	0.26	0.34	0.25	0.27
ISL	0.31	0.29	0.32	0.39	0.19	0.27	0.28
IRL	0.46	0.22	0.30	0.29	0.30	0.43	0.48
ITA	0.31	0.38	0.40	0.41	0.42	0.28	0.41
RKS	0.22	0.34	0.31	0.25	0.32	0.37	0.39
LVA	0.31	0.49	0.35	0.30	0.42	0.31	0.38
LIE	0.43	0.22	0.31	0.29	0.45	0.22	0.22
LTU	0.49	0.35	0.42	0.29	0.32	0.40	0.34
LUX	0.36	0.25	0.30	0.29	0.36	0.41	0.28
MKD	0.44	0.31	0.40	0.37	0.46	0.39	0.42
MLT	0.41	0.34	0.32	0.35	0.36	0.44	0.43
MDA	0.43	0.35	0.43	0.49	0.37	0.44	0.39
MCO	0.44	0.19	0.37	0.36	0.26	0.29	0.18
MNE	0.34	0.32	0.27	0.14	0.28	0.32	0.41
NLD	0.30	0.37	0.35	0.38	0.49	0.35	0.22
NOR	0.49	0.25	0.39	0.40	0.41	0.32	0.38
POL	0.44	0.36	0.32	0.28	0.48	0.36	0.42
PRT	0.38	0.45	0.49	0.33	0.27	0.41	0.23
ROU	0.40	0.38	0.35	0.32	0.29	0.27	0.32
RUS	0.35	0.27	0.32	0.33	0.31	0.27	0.40
SMR	0.27	0.40	0.36	0.27	0.44	0.30	0.39
SRB	0.49	0.28	0.27	0.38	0.45	0.38	0.44
SVK	0.37	0.31	0.42	0.30	0.41	0.42	0.42
SVN	0.31	0.35	0.36	0.43	0.43	0.30	0.25
ESP	0.44	0.41	0.24	0.25	0.34	0.46	0.27
SWE	0.28	0.45	0.49	0.39	0.24	0.49	0.42
CHE	0.24	0.39	0.30	0.41	0.30	0.27	0.46
UKR	0.34	0.40	0.42	0.25	0.29	0.34	0.42
GBR	0.26	0.39	0.37	0.43	0.38	0.30	0.27
VAT	0.18	0.12	0.21	0.19	0.23	0.15	0.20
EA.	**0.366**	**0.348**	**0.342**	**0.330**	**0.359**	**0.353**	**0.351**

Step 1: Four experts analyze the green-house gases emission of European countries in seven possible scenarios in future based on the environmental and economic situation of the mentioned country. Table 4.1, 4.2, 4.3 and 4.4 represent the opinions of the experts. Table 4.2, 4.3 and 4.4 are the same as 4.1 but to avoid repeating, I summarized them to a short form.

Step 2: The next step belongs to unify the experts' opinions to achieve to a collective result that cover all the information. To this end, it is necessary to assign the degree of importance to each of the experts: $Z = (0.4, 0.35, 0.15, 0.1)$. Table 4.5 reports the collective results of each country.

Step 3: Based on the objective of this work it is necessary to assign weighting vectors to consider subjective and objective information and an attitudinal character that underestimates the results.

- OWA: $W = (0.1; 0.15; 0.1; 0.2; 0.15; 0.25; 0.05)$
- Weighted average: $V = (0.2; 0.15; 0.1; 0.15; 0.1; 0.1; 0.2)$
- Probability: $P = (0.1; 0.2; 0.1; 0.1; 0.2; 0.1; 0.2)$
- OWAWA: $\beta = 0.3$
- POWAWA: $C_1 = 0.2; C_2 = 0.4; C_3 = 0.4$
- $U = (0.6; 0.2; 0.4; 0.7; 0.3; 0.4; 0.8)$

Step 4: Present the obtained results of the average green-house gases for each country for the OWAGE, WAGE, OWAWAGE, IOWAGE, IOWAWAGE, POWAWAGE and IPOWAWAGE. Table 4.6 dedicates to the aggregated results.

Step 5: Rank the countries from the lowest to the highest in each of the operators to draw some conclusions. Table 4.7 presents the results of this ranking based on the abbreviation of the name of each country.

4.6 Conclusions

The purpose of this study is to concentrate on the analysis of the use of the aggregation operators in the calculation of GHG emission with the aim of developing better decision-making techniques. In this study I reviewed some of the important operators of the family of OWA. This review started with simple WA and continued with OWA operator. It is noteworthy to mention that the main mission of this study is present a general structure based on the various aggregation operators in GHG emissions and it is important to mention that the illustrative example has the role to show how these operators result based on different elements of their definitions.

Moreover, I also analyzed some operators that form by combination of two or more aggregation operators. So, these operators are, IOWAGE, OWAWAGE, IOWAWAGE, POWAWAGE and IPOWAWAGE.

In addition, through these formulations, I found some particular cases in either IOWAWAGE or POWAWAGE operators such as, olympic-IOWAWAGE, S-IOWAWAGE, centered-IOWAWAGE, maximum, minimum and arithmetic probabilistic weighted average, and arithmetic probabilistic ordered weighted average.

Furthermore, some other generalizations are developed by using generalized and quasi-arithmetic means obtaining the GOWAGE and the Quasi-OWAGE operators.

The study provides a simple example to review the function of two simple aggregations operators of average green-house gases emission. During this example I review weighted average gases emission (WAGE) and ordered weighted average gases emission (OWAGE) to represent the difference between the results of the calculation based on these operators.

Table 4.5 European average GHG emission according to different scenario-collective results

Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Albania	0.24	0.32	0.32	0.25	0.24	0.29	0.25
Andorra	0.32	0.40	0.28	0.34	0.29	0.31	0.18
Austria	0.28	0.25	0.27	0.29	0.24	0.32	0.30
Belarus	0.30	0.35	0.27	0.33	0.34	0.32	0.21
Belgium	0.43	0.38	0.28	0.29	0.23	0.31	0.40
Bosnia and Herzegovina	0.35	0.38	0.31	0.29	0.39	0.31	0.26
Bulgaria	0.26	0.24	0.36	0.29	0.38	0.28	0.28
Cyprus	0.37	0.37	0.35	0.21	0.20	0.31	0.26
Czech R	0.17	0.36	0.33	0.26	0.26	0.44	0.34
Denmark	0.26	0.30	0.23	0.21	0.41	0.26	0.30
Estonia	0.32	0.37	0.28	0.27	0.19	0.35	0.33
Finland	0.25	0.35	0.29	0.29	0.43	0.34	0.34
France	0.29	0.26	0.22	0.38	0.33	0.21	0.36
Germany	0.19	0.43	0.35	0.31	0.27	0.29	0.23
Greece	0.27	0.34	0.32	0.37	0.25	0.33	0.28
Hungary	0.32	0.28	0.25	0.42	0.39	0.34	0.28
Iceland	0.28	0.34	0.23	0.38	0.28	0.30	0.19
R Ireland	0.32	0.24	0.29	0.27	0.30	0.41	0.37
Italy	0.40	0.27	0.39	0.25	0.39	0.24	0.29
Kosovo	0.32	0.33	0.30	0.23	0.34	0.31	0.39
Latvia	0.29	0.19	0.29	0.39	0.30	0.24	0.28
Liechtenstein	0.39	0.31	0.26	0.29	0.25	0.27	0.30
Lithuania	0.26	0.34	0.29	0.22	0.29	0.34	0.44
Luxembourg	0.27	0.31	0.21	0.28	0.24	0.40	0.28
Macedonia	0.30	0.27	0.38	0.29	0.39	0.32	0.41
Malta	0.34	0.33	0.33	0.33	0.35	0.28	0.34
Moldova	0.43	0.29	0.36	0.27	0.33	0.42	0.25
Monaco	0.33	0.22	0.22	0.45	0.31	0.32	0.34
Montenegro	0.25	0.34	0.27	0.24	0.21	0.25	0.37
Netherlands	0.33	0.22	0.20	0.30	0.44	0.23	0.36
Norway	0.25	0.23	0.32	0.25	0.36	0.28	0.30
Poland	0.38	0.22	0.25	0.32	0.35	0.26	0.25
Portugal	0.39	0.33	0.36	0.27	0.31	0.33	0.38
Romania	0.32	0.32	0.30	0.26	0.18	0.36	0.21
Russia	0.20	0.33	0.28	0.32	0.24	0.35	0.37
San Marino	0.33	0.36	0.25	0.33	0.35	0.42	0.28
Serbia	0.32	0.29	0.20	0.31	0.26	0.31	0.39
Slovakia	0.31	0.42	0.35	0.28	0.35	0.27	0.35
Slovenia	0.32	0.32	0.33	0.24	0.31	0.44	0.40
Spain	0.23	0.29	0.25	0.18	0.29	0.37	0.40
Sweden	0.34	0.35	0.38	0.37	0.34	0.35	0.43
Switzerland	0.31	0.36	0.28	0.41	0.34	0.39	0.35
Ukraine	0.43	0.41	0.32	0.26	0.22	0.39	0.23
United Kingdom	0.40	0.40	0.24	0.38	0.36	0.29	0.33
Vatican city	0.21	0.24	0.16	0.24	0.36	0.31	0.20
European average	0.31	0.32	0.29	0.30	0.31	0.32	0.32

Table 4.6 European average GHG emission according to different scenario-aggregated results 1

Country	WAGE	OWAGE	OWAWAGE	IOWAGE	IOWAWAGE	POWAWAGE	IPOWAWAGE
Albania	0.274	0.268	0.267	0.267	0.267	0.269	0.269
Andorra	0.320	0.310	0.304	0.300	0.301	0.303	0.301
Austria	0.282	0.317	0.291	0.279	0.280	0.285	0.277
Belarus	0.317	0.333	0.308	0.307	0.300	0.306	0.301
Belgium	0.319	0.276	0.328	0.308	0.337	0.329	0.335
Bosnia and Herzegovina	0.330	0.339	0.328	0.330	0.325	0.329	0.327
Bulgaria	0.298	0.334	0.304	0.316	0.299	0.304	0.300
Cyprus	0.288	0.288	0.294	0.276	0.291	0.292	0.289
Czech R	0.322	0.280	0.292	0.310	0.301	0.300	0.306
Denmark	0.278	0.307	0.287	0.293	0.282	0.292	0.289
Estonia	0.302	0.304	0.307	0.284	0.301	0.304	0.300
Finland	0.331	0.320	0.320	0.339	0.326	0.328	0.332
France	0.286	0.315	0.306	0.294	0.299	0.304	0.300
Germany	0.303	0.287	0.285	0.286	0.285	0.291	0.290
Greece	0.318	0.270	0.295	0.304	0.305	0.297	0.304
Hungary	0.343	0.333	0.327	0.342	0.330	0.327	0.329
Iceland	0.303	0.281	0.280	0.284	0.281	0.280	0.280
Ireland	0.316	0.312	0.314	0.321	0.316	0.312	0.314
Italy	0.303	0.316	0.318	0.324	0.320	0.318	0.319
Kosovo	0.305	0.301	0.314	0.313	0.318	0.319	0.321
Latvia	0.284	0.337	0.300	0.293	0.287	0.291	0.282
Liechtenstein	0.289	0.286	0.300	0.284	0.299	0.297	0.296
Lithuania	0.303	0.317	0.318	0.307	0.315	0.322	0.320
Luxembourg	0.297	0.265	0.277	0.281	0.281	0.278	0.281
Macedonia	0.328	0.349	0.340	0.349	0.340	0.342	0.342
Malta	0.320	0.296	0.319	0.326	0.328	0.322	0.328
Moldova	0.344	0.304	0.323	0.344	0.335	0.323	0.330
Monaco	0.320	0.319	0.318	0.318	0.318	0.313	0.313
Montenegro	0.263	0.323	0.296	0.258	0.277	0.293	0.280
Netherlands	0.288	0.297	0.301	0.310	0.305	0.304	0.307
Norway	0.282	0.283	0.280	0.300	0.286	0.284	0.288
Poland	0.288	0.286	0.291	0.297	0.294	0.288	0.290
Portugal	0.324	0.325	0.337	0.329	0.338	0.336	0.337
Romania	0.289	0.289	0.280	0.269	0.274	0.274	0.270
Russia	0.304	0.301	0.300	0.294	0.298	0.302	0.300
San Marino	0.348	0.320	0.324	0.336	0.329	0.326	0.330
Serbia	0.293	0.292	0.304	0.289	0.303	0.303	0.302
Slovakia	0.321	0.290	0.320	0.322	0.330	0.329	0.335
Slovenia	0.335	0.364	0.342	0.337	0.334	0.341	0.336
Spain	0.285	0.294	0.291	0.290	0.290	0.295	0.294
Sweden	0.356	0.359	0.364	0.360	0.365	0.365	0.365
Switzerland	0.361	0.336	0.345	0.350	0.350	0.347	0.349
Ukraine	0.330	0.281	0.312	0.306	0.319	0.311	0.316
United Kingdom	0.342	0.354	0.353	0.333	0.347	0.351	0.347
Vatican city	0.264	0.283	0.251	0.265	0.246	0.252	0.249
European average	0.310	0.321	0.314	0.309	0.310	0.313	0.310

I also analyzed the applicability of these approaches for the process of decision-making problem in GHG emission. To achieve to this aim, I implement an illustrative example regarding the calculation of the average of green-house gases emission among European countries. To this end I collect the opinions of the four experts in this area in seven various scenarios in a multi-person analysis. Based on this example, and through five steps I obtain the final table that demonstrate comprehensively the situation of the European countries in a descending trend based on the results of different aggregation operators that can occur according to different scenarios between the minimum and maximum results.

In the future research, by using the different aggregation operators such as logarithmic (Alfaro-Garcí et al. 2018), heavy (León-Castro et al. 2018a; León-Castro et al. 2018b), Bonferroni (Blanco-Mesa et al. 2016) and prioritized (Avilés-Ochoa et al. 2018), I calculate the average GHG emission in a wide range of scenarios among the countries also among different continents.

Table 4.7 European average GHG emission according to different scenario-aggregated results 2

Rank	WAGE	OWAGE	OWAWAGE	IOWAGE	IOWAWAGE	POWAWAGE	IPOWAWAGE
1	MNE	LUX	VAT	MNE	VAT	VAT	VAT
2	VAT	ALB	ALB	VAT	ALB	ALB	ALB
3	ALB	GRC	LUX	ALB	ROU	ROU	ROU
4	DNK	BEL	ROU	ROU	MNE	LUX	AUT
5	AUT	CZE	NOR	CYP	AUT	ISL	MNE
6	NOR	UKR	ISL	AUT	ISL	NOR	ISL
7	LVA	ISL	DEU	LUX	LUX	AUT	LUX
8	ESP	NOR	DNK	LIE	DNK	POL	LVA
9	FRA	VAT	POL	EST	DEU	DEU	NOR
10	NLD	POL	ESP	ISL	NOR	LVA	DNK
11	POL	LIE	AUT	DEU	LVA	CYP	CYP
12	CYP	DEU	CZE	SRB	ESP	DNK	POL
13	ROU	CYP	CYP	ESP	CYP	MNE	DEU
14	LIE	ROU	GRC	DNK	POL	ESP	ESP
15	SRB	SVK	MNE	LVA	RUS	LIE	LIE
16	LUX	SRB	LIE	FRA	BGR	GRC	FRA
17	BGR	ESP	LVA	RUS	LIE	CZE	RUS
18	EST	MLT	RUS	POL	FRA	RUS	BGR
19	ITA	NLD	NLD	AND	BLR	AND	EST
20	LTU	RUS	AND	NOR	AND	SRB	AND
21	ISL	RKS	SRB	GRC	EST	BGR	BLR
22	DEU	EST	BGR	UKR	CZE	NLD	SRB
23	RUS	MDA	FRA	LTU	SRB	FRA	GRC
24	RKS	DNK	EST	BLR	NLD	EST	CZE
25	IRL	AND	BLR	BEL	GRC	BLR	NLD
26	BLR	IRL	UKR	NLD	LTU	UKR	MCO
27	GRC	FRA	IRL	CZE	IRL	IRL	IRL
28	BEL	ITA	RKS	RKS	RKS	MCO	UKR
29	AND	AUT	ITA	BGR	MCO	ITA	ITA
30	MCO	LTU	LTU	MCO	UKR	RKS	LTU
31	MLT	MCO	MCO	IRL	ITA	LTU	RKS
32	SVK	FIN	MLT	SVK	BIH	MLT	BIH
33	CZE	SMR	FIN	ITA	FIN	MDA	MLT
34	PRT	MNE	SVK	MLT	MLT	SMR	HUN
35	MKD	PRT	MDA	PRT	SMR	HUN	SMR
36	BIH	BLR	SMR	BIH	SVK	FIN	MDA
37	UKR	HUN	HUN	GBR	HUN	SVK	FIN
38	FIN	BGR	BIH	SMR	SVN	BEL	SVK
39	SVN	CHE	BEL	SVN	MDA	BIH	BEL
40	GBR	LVA	PRT	FIN	BEL	PRT	SVN
41	HUN	BIH	MKD	HUN	PRT	SVN	PRT
42	MDA	MKD	SVN	MDA	MKD	MKD	MKD
43	SMR	GBR	CHE	MKD	GBR	CHE	GBR
44	SWE	SWE	GBR	CHE	CHE	GBR	CHE
45	CHE	SVN	SWE	SWE	SWE	SWE	SWE

4.7 References

Alfaro-García, V. G., Merigó, J. M., Gil-Lafuente, A. M., & Kacprzyk, J. (2018). Logarithmic aggregation operators and distance measures. International Journal of Intelligent Systems, 33(7), 1488-1506.

Avilés-Ochoa, E., León-Castro, E., Perez-Arellano, L. A., & Merigó, J. M. (2018). Government transparency measurement through prioritized distance operators. Journal of Intelligent & Fuzzy Systems, 34(4), 2783-2794.

Beliakov, G., Pradera, A., & Calvo, T. (2007). Aggregation functions: a guide for practitioners (Vol. 221). Heidelberg: Springer.

Bhattacharyya, P., Roy, K. S., Neogi, S., Adhya, T. K., Rao, K. S., & Manna, M. C. (2012). Effects of rice straw and nitrogen fertilization on greenhouse gas emissions and carbon storage in tropical flooded soil planted with rice. Soil and Tillage research, 124, 119-130.

Blanco-Mesa, F., Merigo, J. M., & Kacprzyk, J. (2016). Bonferroni means with distance measures and the adequacy coefficient in entrepreneurial group theory. Knowledge-Based Systems, 111, 217-227.

Blanco-Mesa, F., Merigó, J. M., & Gil-Lafuente, A. M. (2017). Fuzzy decision making: A bibliometric-based review. Journal of Intelligent & Fuzzy Systems, 32(3), 2033-2050.

Casanovas, M., Torres-Martinez, A., & Merigo, J. M. (2016). Decision making in reinsurance with induced OWA operators and Minkowski distances. Cybernetics and Systems, 47(6), 460-477.

Chen, S. J., & Chen, S. M. (2003). A new method for handling multicriteria fuzzy decision-making problems using FN-IOWA operators. Cybernetics &Systems, 34(2), 109-137.

Emrouznejad, A., & Marra, M. (2014). Ordered weighted averaging operators 1988–2014: A citation-based literature survey. International Journal of Intelligent Systems, 29(11), 994-1014.

Flower, D. J., & Sanjayan, J. G. (2007). Greenhouse gas emissions due to concrete manufacture. The international Journal of life cycle assessment, 12(5), 282.

Fodor, J., Marichal, J. L., & Roubens, M. (1995). Characterization of the ordered weighted averaging operators. IEEE Transactions on Fuzzy Systems, 3(2), 236-240.

Hammons, T. J. (2006). Impact of electric power generation on greenhouse gas emissions in Europe: Russia, Greece, Italy and views of the EU Power Plant Supply Industry–a critical analysis. International Journal of Electrical Power & Energy Systems, 28(8), 548-564.

Hastings, A. F., Wattenbach, M., Eugster, W., Li, C., Buchmann, N., & Smith, P. (2010). Uncertainty propagation in soil greenhouse gas emission models: an experiment using the DNDC model and at the Oensingen cropland site. Agriculture, ecosystems & environment, 136(1-2), 97-110.

Herrera, F., Herrera-Viedma, E., & Chiclana, F. (2003). A study of the origin and uses of the ordered weighted geometric operator in multicriteria decision making. International Journal of Intelligent Systems, 18(6), 689-707.

IPCC, (2007). Fourth Assessment Report (AR4) of Working Group 1: Chapter 2. Changes in atmospheric constituents and in radiative forcing. http:// www.ipcc.ch/pub/reports.htm.

Kacprzyk, J., & Zadrożny, S. (2009). Towards a general and unified characterization of individual and collective choice functions under fuzzy and nonfuzzy preferences and majority via the ordered weighted average operators. International Journal of Intelligent Systems, 24(1), 4-26.

Kristensen, T., Mogensen, L., Knudsen, M. T., & Hermansen, J. E. (2011). Effect of production system and farming strategy on greenhouse gas emissions from commercial dairy farms in a life cycle approach. Livestock Science, 140(1-3), 136-148.

Laengle, S., Loyola, G., & Merigó, J. M. (2016). Mean-variance portfolio selection with the ordered weighted average. IEEE Transactions on Fuzzy Systems, 25(2), 350-362.

León-Castro, E., Avilés-Ochoa, E., Merigó, J. M., & Gil-Lafuente, A. M. (2018a). Heavy moving averages and their application in econometric forecasting. Cybernetics and Systems, 49(1), 26-43.

León-Castro, E., Avilés-Ochoa, E., & Merigó, J. M. (2018b). Induced heavy moving averages. International Journal of Intelligent Systems, 33(9), 1823-1839.

Llamazares, B. (2007). Choosing OWA operator weights in the field of Social Choice. Information Sciences, 177(21), 4745-4756.

Maldonado, S., Merigó, J., & Miranda, J. (2018). Redefining support vector machines with the ordered weighted average. Knowledge-Based Systems, 148, 41-46.

Linares-Mustarós, S., Ferrer-Comalat, J. C., Corominas-Coll, D., & Merigó, J. M. (2019). The ordered weighted average in the theory of expertons. International Journal of Intelligent Systems, 34(3), 345-365.

Mesiar, R., Stupňanová, A., & Yager, R. R. (2015). Generalizations of OWA operators. IEEE Transactions on Fuzzy Systems, 23(6), 2154-2162.

Merigo, J. M. (2011). A unified model between the weighted average and the induced OWA operator. Expert Systems with Applications, 38(9), 11560-11572.

Merigó, J. M., & Casanovas, M. (2010a). Fuzzy Generalized Hybrid Aggregation Operators and its Application in Fuzzy Decision Making. International Journal of Fuzzy Systems, 12(1).

Merigo, J. M., & Casanovas, M. (2010b). The fuzzy generalized OWA operator and its application in strategic decision making. Cybernetics and Systems: An International Journal, 41(5), 359-370.

Merigó, J. M., & Gil-Lafuente, A. M. (2009). The induced generalized OWA operator. Information Sciences, 179(6), 729-741.

Merigo, J. M., Lobato-Carral, C., & Carrilero-Castillo, A. (2012). Decision making in the European Union under risk and uncertainty. European Journal of International Management, 6(5), 590-609.

Merigo, J. M., Palacios-Marques, D., & del Mar Benavides-Espinosa, M. (2015). Aggregation methods to calculate the average price. Journal of Business Research, 68(7), 1574-1580.

Merigó, J. M., Palacios-Marqués, D., & Soto-Acosta, P. (2017). Distance measures, weighted averages, OWA operators and Bonferroni means. Applied Soft Computing, 50, 356-366.

Merigo, J. M., Yang, J. B., & Xu, D. L. (2016). Demand analysis with aggregation systems. International Journal of Intelligent Systems, 31(5), 425-443.

Merigo, J. M., Peris-Ortiz, M., Navarro-Garcia, A., & Rueda-Armengot, C. (2016). Aggregation operators in economic growth analysis and entrepreneurial group decision-making. Applied Soft Computing, 47, 141-150.

Merigó, J. M., Zhou, L., Yu, D., Alrajeh, N., & Alnowibet, K. (2018). Probabilistic OWA distances applied to asset management. Soft Computing, 22(15), 4855-4878.

Smith, W. N., Grant, B. B., Desjardins, R. L., Worth, D., Li, C., Boles, S. H., & Huffman, E. C. (2010). A tool to link agricultural activity data with the DNDC model to estimate GHG emission factors in Canada. Agriculture, ecosystems & environment, 136(3-4), 301-309.

Sorrentino, M., Rizzo, G., & Sorrentino, L. (2014). A study aimed at assessing the potential impact of vehicle electrification on grid infrastructure and road-traffic greenhouse emissions. Applied energy, 120, 31-40.

Stewart, C. E., Zheng, J., Botte, J., & Cotrufo, M. F. (2013). Co-generated fast pyrolysis biochar mitigates green-house gas emissions and increases carbon sequestration in temperate soils. Gcb Bioenergy, 5(2), 153-164.

Torra, V. (1997). The weighted OWA operator. International Journal of Intelligent Systems, 12(2), 153-166.

Torra, V., & Narukawa, Y. (2010). Some relationships between Losonczi's based OWA generalizations and the Choquet–Stieltjes integral. Soft Computing, 14(5), 465-472.

Xu, Z., & Da, Q. L. (2003). An overview of operators for aggregating information. International Journal of intelligent systems, 18(9), 953-969.

Yager, R. R. (1988). On ordered weighted averaging aggregation operators in multicriteria decisionmaking. IEEE Transactions on systems, Man, and Cybernetics, 18(1), 183-190.

Yager, R. R. (1993). Families of OWA operators. Fuzzy sets and systems, 59(2), 125-148.

Yager, R. R. (2004). Generalized OWA aggregation operators. Fuzzy Optimization and Decision Making, 3(1), 93-107.

Yager, R. R., & Filev, D. P. (1999). Induced ordered weighted averaging operators. IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), 29(2), 141-150.

Yu, D. (2015). A scientometrics review on aggregation operator research. Scientometrics, 105(1), 115-133.

Yu, D., Li, D. F., Merigó, J. M., & Fang, L. (2016). Mapping development of linguistic decision-making studies. Journal of Intelligent & Fuzzy Systems, 30(5), 2727-2736.

CHAPTER 5

Conclusions

5.1 Principle conclusions

According to the content of this Ph.D.thesis, green supply chain management has gained a sharp increasing attention during the very last years among academicians, managers and policymakers. In the related literature to this topic, there are several works that are dedicated to its identity and many more aspects of that (Srivastava, 2007; Zhu et al. 2008; Chiou et al. 2011; Tseng et al. 2019; Yildiz Çankaya and Sezen, 2019). In this dissertation my effort is to enhance the knowledge about green supply chain management through diverse methods.

To this end, this thesis has three main chapters that each of them dedicates to an academic paper and its contributions address one question of the thesis. With the help of these chapters I can accomplish to the objectives of this work. Table 5.1 presents a summary of the contributions of each chapter.

The first paper (chapter 2) has conducted a comprehensive bibliometric analysis, with the aim of investigating the world of green supply chain since the very first publication to pursue the diverse trends of many items such as the leading journals, countries, institutions etc.

Following this chapter and after a thorough literature review on green supply chain management and organizational performance, the second paper (chapter 3) has conducted a qualitative study based on the interviews to focus on two issues. From one side, analyzing how GSCM practice in the companies of this study are implemented and from the other side, investigating the influence of this implementation on the organizational performance.

The last paper (chapter 4) is focused on one of the main concerns of the companies of the previous chapter. In this paper, I investigated de green-house gases emissions and proposed a new aggregation system for the investigation of average gases emissions.

Thanks to these three chapters, both theoretical and empirical, I have enlightened more the concept of green supply chain management.

Table 5.1 Conclusions presented in the main chapters

Main contributions	
Chapter 2 (Paper 1) Research on green supply chain: A bibliometric analysis	The work reports the leading institutions and countries of journals that have published papers on GSC. Although the USA is the most productive country, some Asian countries, especially China are quickly improving their rankings. Besides, Asian universities also are experiencing a meaningful leadership among others.
Chapter 3 (Paper 2) Green supply chain practices and organizational performance: A case study in Spain	According to the nature of the cases of this study that can be classified in two general groups of manufacturers and logistic operators and transportation companies, every practice has its unique influence on the organizational performance. Some of them such as reverse logistic practices have a high positive influence on the organizational performance in all cases of the study in average while some other practices such as external practices although have a high positive influence on the organizational performance of the manufacturers, but the influence of this item on the logistic operators and transportation companies' organizational performance can be classified as a medium-high influence.
Chapter 4 (Paper 3) OWA operators in the calculation of the average green-house gases emissions	The study provides an example to review the function of two simple aggregations operators of average green-house gases emission. I also analyzed the applicability of these approaches for the process of decision-making problem in GHG emission.

Finally, the fact of having used three totally different methodologies for the analysis of the chapters (bibliometric study, case study and OWA operators) based on the search for the answers of the research questions initially posed, confer an additional added value to this work as a whole. In this sense, the bibliometric study allowed an overview of the previous literature very stimulating as the beginning of the investigation. Subsequently, the case study allowed an in-depth analysis of what the literature establishes in the companies analyzed. Finally, make a very specific contribution on the calculation of green-house emission gases.

In the next three subsections, I explain more deeply the conclusions of each chapter.

5.1.1 Conclusions of chapter 2 (paper 1)

As expressed in previous parts, this chapter provides a comprehensive and deep understanding about the concept of green supply chain management. To this end, I apply bibliometric analysis as a very powerful tool to make possible the study. This study is conducted in a period between 1995 and 2017. Besides, VOS viewer software also was used to support graphically the obtained results from the bibliometric analysis. Thanks to this research, I can classify the obtained results in various categories. The main results of this study are reporting the structure of the publications in the world of green supply chain management based on the number of publications and the citations that they received. Also, this work prepares a vast vision of the leading countries and institutions. Finally, the article gives a clear image about the main keywords used by the authors and their trends during the years of investigation.

During the period of this research, the authors with an increasing steep have published 1892 papers with a total number of 58785 citations.

The work also reports the leading institutions and countries in the world of GSCM. The main conclusion of this section is a rapid movement of the Asian countries and institutions specially China and Chinese universities in comparison with the US and American institutions. The companies found out that the key to improve the performance in various aspects is applying GSCM practices and from the other point of view global and governmental obligations are the other items that can influence on this item.

In addition, the paper enters in the analysis of the keywords used in the whole package of papers. Such that, this finding gives an insight in a whole period and in the periods of 10 and five years to makes the reader able to understand how the investigation on GSC has changed during the years. As an example, sustainability that is leader of the keywords in total, during the very first years of the research, was not among the top ones. The very first period of this table reports that environmental management as a general keyword alongside supply chain management was the leader, but after that more specific keywords were entered in the group of keywords that were used by authors.

This paper is very useful for policy makers to understand the current trends in the field. Additionally, it is also very useful for Ph.D.students and newcomers to get a quick overview of the current trends of the journal. Moreover, readers of the article can complete their knowledge by reading these papers. Usually, experts in the field know well the field but it is very common that due to specialization, they do not know the whole field of the journal and therefore, by reading this paper they can complement and/or improve their knowledge very well.

5.1.2 Conclusions of chapter 3 (paper 2)

The third chapter of this doctoral thesis is devoted to the second paper. This paper studies two main questions: a comprehensive analysis of the implementation of green supply chain management practices. Besides, analyze the influence of the implementation of these practices on the organizational performance factors that forms from, business performance, financial performance, environmental performance and marketing performance.

The table 5.2 reports comprehensively the level of the implementation of each practice of GSCM in the companies of this study.

Table 5.2 Level of GSCM practices implementation

	+ ◄					-
	High	High-Medium	High-Low or High-Not significant	Medium-High	Low-Medium or Not significant-Medium	Low
Man	External practices Internal environmental management Reverse logistics Communication practices	Return on investment Sustainable design	Sustainable storage and construction			
Tra	Reverse logistics	Return on investment	Communication practices	External practices Internal environmental management	Sustainable storage and construction Waste reduction and risk minimization Sustainable design	

As reflexed in this table, based on a spectrum from low to high and a classification of the manufacturers and the logistic operators and transportation companies, these practices are located.

Some of them such as reverse logistic practices have a high positive influence on the organizational performance in all cases of the study in average while some other practices such as external practices although have a high positive influence on the organizational performance of the manufacturers, but the influence of this item on the logistic operators and transportation companies' organizational performance can be classified as a medium-high influence.

This study is useful for the scholars and the decision makers of the companies. The findings of this research give a potential fundamental to the scholars for the future research, besides, the obtained results make the decision makers able to improve their future decisions.

5.1.3 Conclusions of chapter 4 (paper 3)

The third paper of this thesis that is explained in the fourth chapter is dedicated to the ordered weighted average (OWA) operators in the calculation of the average green-house gases emissions.

According to the concern of the companies obtained from previous section, I conducted this study to propose the use of the aggregation operators in the calculation of green-house gases (GHG) emission with the aim of developing better decision-making techniques. To this end I review many important operators of the family of OWA. Besides, I also analyzed some operators that form by combination of two or more aggregation operators. So, these operators are, IOWAGE, OWAWAGE, IOWAWAGE, POWAWAGE and IPOWAWAGE.

I also analyzed the applicability of these approaches for the process of decision-making problem in GHG emission. To achieve to this aim, I implement an illustrative example regarding the calculation of the average of green-house gases emission among European countries. To this end I collect the opinions of four experts in this area in seven various scenarios in a multi-person analysis. Based on this example, and through five steps I obtain the final table that demonstrate comprehensively the situation of the European countries in a descending trend based on the results of different aggregation operators that can occur according to different scenarios between the minimum and maximum results.

5.2 Academic and scientific contribution

With the contributions of each chapter, it seems necessary on what level these findings can lead the literature toward an advanced step.

The findings and implications of this doctoral thesis are first, analyze the literature related to green supply chain management and organizational performance with the purpose of classifying it based on the identity of these two concepts, investigating the potential influence between them and form a complete list of the items that define each of them.

This thesis secondly provides a clear and comprehensive image of the world of green supply chain management and gives a thorough analysis about various trends in this field.

The final contribution of this work is combining one of the key issues in green supply chain management with the OWA operators to make it calculable.

I believe these contributions makes an enhancement both in theoretical and empirical fields.

The centric objective of this study is performing a comprehensive investigation on the green supply chain management practices and their influence on the organizational performance. To this end, the results of the various analyzes and the comparison and measurements contained in the contributions have made it possible to achieve the overall objective. So, table 5.3 presents a clear picture of the achievements with the initially set objectives.

5.3 Research implications

Throughout this doctoral thesis, it has been exposed that there are many challenges and difficulties in the management and implementing of supply chain and in some cases still exists a long way to greening it. So, this thesis besides talking about the importance of these items, gives some implications and suggestions to improve the situation.

Based on the information obtained from the different analyzes, comparisons and academic contributions derived from the results of this research, some implications for both academics and professionals are suggested.

From the professional point of view, this work presents a clear and comprehensive image of the green supply chain management and the practices that are linked to this process. The obtained findings help the companies to modify their practices and in addition implement those practices that can improve their performance and are not implemented yet. Some companies have some incomplete environmental plans, but they do not answer the requirements of having a green supply chain. Besides, through the results of this Ph.D.thesis it is observable that the implementation of GSCM practices effectively improves the performance of the companies. So, it seems necessary to modify every practice of company and make it targeted toward the objective of being greener.

Table 5.3 Achievements of the objectives set

	Objectives	Chapter
Objective 1	To investigate comprehensively the world of green supply chain management via bibliometric analysis to gain a clear insight.	***2***
Objective 2	To investigate the relationship between Green Supply Chain Management practices and Organizational Performance.	***3***
Objective 3	Apply the concept of ordered weighted average (OWA) operators to decide about the green-house gases emission as a critical concern of the companies.	***4***

5.4 Limitations and future lines of research

To conclude this thesis and with the purpose of continuing to deepen the study of the relationship between green supply chain management and organizational performance, the main limitations of this work are presented below, as well as some potential future lines of research.

Like any research process developed with specific scientific interests and in a specific context, this doctoral thesis has faced different limitations. Some of them, which however will serve as a stimulus to be overcome and improve future work, are the following:

The very first limitation of this thesis appears in the first paper. This refers to the use of Web of Science as a data base to perform the search. Besides, there are some other bibliometric measures that can be applied to analyze the GSCM concept form the other point of view. As a suggestion for the future research, it seem necessary to continue the period of performing the research. Based on the results of the chapter two that report a sharp increasing trend of the publication in GSCM area, it seems necessary to follow the analysis after the period of the paper one of this dissertation.

The next limitation of this thesis comes from the second paper that refers to the habitual limitation of qualitative investigation based on the case study that is the obtained findings of this chapter maybe are not suitable for the other cases, in other words, they are not generalizable. The other limitation is the level of the diversity of the selected cases. In this thesis I believe that the three sectors (Food and nutrition, Consumer goods and Transportation and logistics) could answer my questions and could prepare the possibility to make the comparisons. For the further research it could be advisable to apply the structure of the chapter three in the other sectors. The final proposed option for the future research is making a comparison between the findings of this study and the similar ones to gain an in-depth insight. The next limitation of this thesis is that the second paper, only includes the companies that operate in Barcelona, so the geographical situation and the volume of operations that can be had in Barcelona can condition the results.

As a future line of research, I propose to apply a questionnaire-based study from one side conducted in various countries and from the other side, in various industries to have a comparative list of results.

The final limitation of this work refers to the selection of experts for this work. As a very last suggestion for the future research, in the chapter four of this doctoral dissertation, by using the different aggregation operators such as logarithmic (Alfaro-García et al. 2018), heavy (León-Castro et al. 2018a; León-Castro et al. 2018b), Bonferroni (Blanco-Mesa et al. 2016) and prioritized (Avilés-Ochoa et al. 2018), it it's possible to calculate the average GHG emission in a wide range of scenarios among the countries also among different continents.

5.5 References

Alfaro-García, V. G., Merigó, J. M., Gil-Lafuente, A. M., & Kacprzyk, J. (2018). Logarithmic aggregation operators and distance measures. International Journal of Intelligent Systems, 33(7), 1488-1506.

Avilés-Ochoa, E., León-Castro, E., Perez-Arellano, L. A., & Merigó, J. M. (2018). Government transparency measurement through prioritized distance operators. Journal of Intelligent & Fuzzy Systems, 34(4), 2783-2794.

Blanco-Mesa, F., Merigó, J. M., & Kacprzyk, J. (2016). Bonferroni means with distance measures and the adequacy coefficient in entrepreneurial group theory. Knowledge-Based Systems, 111, 217-227.

Chiou, T. Y., Chan, H. K., Lettice, F., & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. Transportation Research Part E: Logistics and Transportation Review, 47(6), 822-836.

León-Castro, E., Avilés-Ochoa, E., Merigó, J. M., & Gil-Lafuente, A. M. (2018a). Heavy moving averages and their application in econometric forecasting. Cybernetics and Systems, 49(1), 26-43.

León-Castro, E., Avilés-Ochoa, E., & Merigó, J. M. (2018b). Induced heavy moving averages. International Journal of Intelligent Systems, 33(9), 1823-1839.

Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. International journal of management reviews, 9(1), 53-80.

Tseng, M. L., Islam, M. S., Karia, N., Fauzi, F. A., & Afrin, S. (2019). A literature review on green supply chain management: Trends and future challenges. Resources, Conservation and Recycling, 141, 145-162.

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

Zhu, Q., Sarkis, J., & Lai, K. H. (2008). Confirmation of a measurement model for green supply chain management practices implementation. International journal of production economics, 111(2), 261-273.

Annexes

Interview protocol, Interview guide (chapter 3)

Annex 1. Interview protocol

First, I appreciate for the time that you dedicated to this interview. This research pursues two main objectives that are: *A comprehensive analysis of the level of the implementation of green supply chain management practices in the company* and *investigating the possible influences of these practices on the organizational performance*. With the aim of not missing the interview's content, I will record the interview and will take notes. Do you agree with that?

Objective of the investigation:

This research pursues the completion of a doctoral thesis within the framework of the Doctorate in Business Program of the University of Barcelona. Its academic objective is to establish the activities related to the management of the green supply chain influence the results of the company. To do this, I have identified the factors that the literature establishes as favoring these practices. The empirical part of the work shows that these factors are considered influential, which is why in a first phase a series of interviews with the companies that approve this type of practices can be carried out.

General information:

About the company:

- Sector
- Number of workers
- (Primary products)
- The placement of your company in the supply chain

About the interviewee:

- Your workplace
- Your work limitations

Green supply chain management practices

Rate, on a scale of 1 to 5, the degree to which the following actions contribute to making your supply chain more ecological (where: 1-little or no contribution to 5-very high contribution):

- Provide specifications to suppliers that include environmental requirements in the items purchased.
- Evaluate whether second-tier suppliers carry out environmentally friendly practices.
- Cooperate with the client for ecological design, cleaner production and ecological packaging.
- Collect and recycle products and materials at the end of their useful life.
- Establish a recycling system for used and defective products.
- Train workers in relation to environmental issues.
- Implement pollution prevention programs.
- Apply the eco-labeling of products.
- Implement water conservation (for example, plants and gardening materials that minimize water waste and the use of gray water in the system).
- Reduce the consumption of hazardous and toxic materials.
- Adopt the use of recyclable products whenever possible.
- Reverse logistics and waste disposal.
- Implement distribution, transport and execution strategies to redesign the logistics system for greater environmental efficiency.
- Use the vehicles with low emissions and alternative fuels.
- Consolidate and effectively use the full load capacity of the vehicles.
- Design the products and / or manufacturing processes to avoid or reduce the use of dangerous products.
- Design the products for the reuse, recycling, and recovery of materials and components.
- Prepare periodic environmental reports.
- Other actions (please specify):
  ____

Organizational performance measures

From the following measures of organizational performance, which do you think best reflects the influence of green supply chain management practices on organizational performance?

- Environmental performance
  - The emission of air has reduced
  - Wastewater has reduced
  - Etc.
- Business performance
  - The use of assets has improved
  - The competitive position is stronger
  - Etc.
- Financial performance
  - The average return on investment in the last three years has improved
  - The average benefit in the last three years has increased
  - Etc.
- Marketing performance
  - The average market share in the last three years has grown
  - The average sales volume in the last three years has grown
  - Etc.

Influence of Green's practices on organizational performance:

If there is a positive relationship when the practice increases the measures of organizational performance and a negative relationship when the practice decreases organizational performance measures.

Indicate what relationships you think exist between green practices and organizational performance, indicating whether they are positive or negative, and the corresponding intensity of the relationship, using a scale of 1 (no relation) to 5 (strong relation).

Green practices \ Organizational performance	Environmental performance		Business performance		Financial performance		Marketing performance	
	+	-	+	-	+	-	+	-
Provide specifications to suppliers that include environmental requirements in the items purchased								
Evaluate whether second-tier suppliers carry out environmentally friendly practices								
Cooperate with the client for ecological design, cleaner production and ecological packaging								
Collect and recycle products and materials at the end of their useful life								
Establish a recycling system for used and defective products								
Train workers in relation to environmental issues								
Implement pollution prevention programs								
Apply the eco-labeling of products								
Implement water conservation (for example, plants and gardening materials that minimize water waste and the use of gray water in the system)								
Reduce the consumption of hazardous and toxic materials								
Adopt the use of recyclable products whenever possible								
Reverse logistics and waste disposal								
Implement distribution, transport and execution strategies to redesign the logistics system for greater environmental efficiency								
Use the vehicles with low emissions and alternative fuels								
Consolidate and effectively use the full load capacity of the vehicles								
Design the products and / or manufacturing processes to avoid or reduce the use of dangerous products								
Design the products for the reuse, recycling, and recovery of materials and components								
Prepare periodic environmental reports								