SUPPLY CHAIN MANAGEMENT

FOR SUSTAINABLE FOOD NETWORKS

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WILEY

Supply Chain Management for Sustainable Food Networks

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WILEY

This edition first published 2016

Registered Office
John Wiley & Sons, Ltd., The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Library of Congress Cataloging-in-Publication data applied for

ISBN: 9781118930755

A catalogue record for this book is available from the British Library.

Set in 10/12pt Times by SPi Global, Pondicherry, India

1 2016

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Preface

The agrifood industry is a sector of significant economic and political significance. It is one of the most regulated and protected sectors with significant implications for sustainability such as the fulfillment of human needs, the support of employment and economic growth, and its impact on the natural environment. According to the European Commission, the food and drink sector contributes to some 23% of global resource use, 18% of greenhouse gas emissions, and 31% of acidifying emissions.[1] Growing environmental, social and ethical concerns and increased awareness of the effects of food production and consumption on the natural environment have led to increased pressure by consumer organizations, environmental advocacy groups, policy-makers, and several consumer groups on agrifood companies to deal with social and environmental issues related to their supply chains within product lifecycles, from "farm to fork."

The agrifood industry is expected to grow in the next couple of years after a long period of recession. To that end the industry is facing new challenges that arise from:[2]

1. *New consumer trends.*
2. *The need to comply with stricter and often non-harmonized national regulatory interventions regarding product safety, quality and traceability.*
3. *Increased sources of risk throughout its supply chains.*

This book was motivated by a three-year leading research project (2012–2015) that was funded by the European Union (EU). Specifically, the Green-AgriChains Project has received funding from the EU's Seventh Framework Programme (FP7-REGPOT-2012-2013-1 under Grant Agreement No. 316167) and it involved eight leading EU universities along with four business clusters. To that effect, the gracious support of the European Commission is gratefully acknowledged.

This book intends to provide a holistic, up-to-date, interdisciplinary framework for designing and operating sustainable supply chains for agrifood products and it intends to add value to both practitioners and academics alike. The aim is to present

[1] http://www.euractiv.com/specialreport-prods-green-planet/cutting-food-waste-greening-diet-news-513731

[2] http://www.grant-thornton.co.uk/en/Publications/2013/Hunger-for-growth--Food-and-Beverage-looks-to-the-future/

sustainable practices that are unique for agriculture (such as organic products or precision farming), as well as practices that already have been implemented in other industrial sectors [such as transportation emissions control or corporate social responsibility (CSR)]. All book chapters include decision-making procedures and methodologies, most of which are quantitative. Even though we do discuss the most emerging state-of-the-art relevant technologies, our focus is more on the managerial dimension of the examined policies.

Chapter 1 is an introduction to *sustainable agrifood supply chain (AFSC) management.* The chapter summarizes the unique challenges for supply chain managers especially related to sustainability. These challenges are then further fine-tuned for the agrifood business. The purpose of this introductory chapter is to provide the basic managerial knowledge and motivation for the readers of the book, merging the worlds of operations management, supply chain management, and agriculture. It begins by presenting the generic system components along with the unique characteristics of AFSC networks that differentiate them from traditional supply chains. The authors then identify and discuss the most critical issues for the design and planning of AFSCs, along with the most relevant emerging technologies. They then present a critical synthesis of the related existing state-of-the-art literature efforts in order to identify major gaps, overlaps, and opportunities. These issues were further mapped accordingly on the recognized natural hierarchy of the relevant decision-making process and key findings and managerial insights are presented.

Chapter 2 discusses *knowledge-based farming.* The chapter covers the implementation of engineering management in agrifood production systems as a basis for the creation of a new generation of intelligent and sustainable processes by employing novel system approaches realized by embedded intelligent technologies for planning and controlling the use of all involved resources. It further demonstrates how robustly managed systems can address the inherent complexity and dynamic nature of bio-production systems. First, a general outline of Precision Agriculture (PA) as applied to crops is provided. Then, a general plan of its application describing the relevant data collection methods for capturing the variability of the fields and the crops is discussed. An account of the data analysis and the methods to use the data in the site specific management of the crops is provided. Several applications are presented indicating the potential of PA to lead to an optimization of the usage of resources such as fertilizers, chemicals, water, and energy leading to reduced inputs and minimizing adverse effects to the environment. In several applications the economic benefits to the farmers are also substantiated. PA can address the main components of agriculture sustainability. From an economic perspective PA can improve income to farmers, from a social perspective it can improve working conditions for farmers and the farming communities bringing the farmers to the cutting edge technological era, while from an environmental perspective the adverse effects on the environment are greatly addressed by reducing inputs and resource use.

Chapter 3 deals with *biomass from agricultural wastes.* Biomass logistics encompasses two parts, each different in scope. The first part involves the farm production of biomass and the dedicated transport system as the initial steps in the biomass supply chain. It is characterized as a low industrialized process, where

planning and execution remain very much implicit and internal with only a sparse tradition for using formalized planning tools. The other part involves the biomass processing facilities comprising the specific bio-energy production/processing; it is characterized as a highly industrialized process with a long tradition of explicit formalized planning and execution tools. The overall goal of this chapter is to identify research actions for improving the overall biomass waste logistics systems by extending the methods and technologies of industrial operations and production management to include a biologically constrained production system, while taking into account the sustainability (environmental, greenhouse gas emissions, energy balance) of the entire system.

Chapter 4's theme is *maintaining sustainability.* Stakeholders' demands have been suggested to affect the environmental and social activities of firms which in turn influence various performance dimensions. This chapter contributes to the analysis of this relationship by looking at the extent to which stakeholder demands are related to the integration of management activities within the firm, and by testing the hypotheses related to moderation effects of industry, firm type, and governance structures. Using data from the manufacturing sector in the UK and Germany, it examines the way in which stakeholder pressures are associated with management integration and economic as well as environmental performance, as defined by means of six sub-dimensions. Applying structural equation modeling it is documented that stakeholder pressure inevitably leads to economic and environmental performance integration, but that important moderation effects do exist.

Chapter 5 is an amalgamation of academic research efforts, offering *a review of quantitative optimization methodologies employed for evaluating the economic and environmental impacts of implementing green supply chain management (GSCM) decisions*. More specifically, the main GSCM decisions that may affect the economic and environmental performance of the three main physical drivers of a supply chain, namely products, facilities, and transportation, are identified, along with the quantitative optimization models employed for quantifying these impacts. Finally, these decisions are mapped into strategic, tactical, and operational decision phases accordingly and a critical synthesis of the academic research efforts is provided.

Chapter 6 discusses *safety, security, and traceability.* Traceability is a tool for sharing product related information among all members in the AFSC. It helps in terms of transparency of the network, contributing toward improved production and distribution management, promoting health, safety, and quality issues of agrifood product while mitigating associated risks in the entire chain. Overall, traceability can help in terms of product differentiation and provides significant financial benefits. The first part of the chapter deals with an extensive investigation of the most effective tracking and tracing systems that are already used in AFSCs. The aim of the second part of the chapter is to present new technologies, mainly based on information technology (IT) systems, for more sophisticated traceability systems, which can ensure the quality and safety of agrifood products in the entire chain.

Chapter 7 revolves around *IT in agrifood supply chains*. Nowadays, the emerging role of Information and Communication Technology (ICT) and farming technologies is recognized as a driver for change in the agrifood sector. Many researchers stress

the importance of adopting ICT and farming technologies by AFSC stakeholders, as these technologies are a major driver for innovation. The chapter intends to demonstrate the main technological trends that can be employed in the entire agrifood chain and their key role. A holistic approach is employed and an analysis of all available IT applications and techniques is conducted in all levels of the AFSC. Emphasis is given on the primary sector where a number of IT innovations has been employed (e.g., satellites, sensors for precision agriculture, etc.). IT has been a key enabler in the supply chain environment, acting as the power of process automation, the enabler of information sharing and collaboration or the supporter of management decisions and optimization logic. Especially in food supply chains, this role has been even more critical due to enhanced requirements for short life cycles and speed of response, traceability and food quality considerations, environmental constraints and sustainability. Ultimately, in the chapter, a contemporary view of this enabling role of IT in the supply chain environment is provided and a high-level IT architecture integrating the views of automation, information sharing/collaboration, and decision support is proposed. This architecture is then discussed in the context of current opportunities and challenges of food supply chains, namely radio frequency identification (RFID)-enabled supply chain management, carbon footprint monitoring and shared logistics. The chapter concludes with an overall discussion of the main barriers and drivers behind IT adoption in the supply chain and a future outlook on anticipated developments.

Chapter 8 deals with the much-debated *carbon footprint management.* Carbon footprint management has emerged as an issue of pivotal corporate importance that has led to its inclusion at both the design and management phases of contemporary AFSC networks, in which profitability and environmental impacts have to be balanced. This chapter aims at identifying the most significant carbon hot-spots that may arise across the entire AFSC, while providing sophisticated decision support management tools, both qualitative and quantitative, for "decarbonizing" the entire chain. More specifically, state-of-the-art tools for measuring the carbon footprint of agrifood products from cradle-to-grave are presented and practice-oriented low carbon interventions are proposed to aid the related decision-making process.

Chapter 9 discusses *quality management systems.* Ecolabel/Certification Quality management systems are very popular in the agrifood sector as they often demonstrate the company's ability to control food safety hazards in order to ensure that food is safe at the time of consumption. Nowadays, companies in the agrifood sector can develop and implement a number of available quality management systems (e.g., ISO22000:2005, ISO/TS 22004:2005, etc.). The main aim of the chapter is to present the key elements of the existing quality management systems available in the agrifood sector and to further investigate the employment of certain tools and techniques (e.g., trace and tracking systems) ensuring food quality and safety through the implementation of quality management systems.

Chapter 10's focus is on *risk management for agrifood supply chains.* Modern AFSCs are exposed to a wide variety of natural, technological, and humanitarian risks, such as natural disasters, adverse weather conditions (related or unrelated to global warming), biological incidents, market instability and fluctuation of food and raw materials' prices, logistical and infrastructural disruptions, public policy

interventions, and institutional reforms. These risks may inhibit their normal operations and provoke deviations, disruptions, or shutdowns to the supply chain's fundamental flows. Furthermore, despite the usually low probability of the associated triggering events, these risks may have a dramatic impact on their cost, efficiency, and reliability performance. To that end, there is a need for specific and efficient pre-, as well as post-, event risk mitigation and management strategies especially in the agrifood sector that becomes even more pressing due to the direct environmental impact of the sector.

Finally, **Chapter 11** deals with *regulatory policies/trends.* There are many researchers that have addressed the significant pressures from governmental regulators as one of the most important driving factors toward the sustainability of AFSCs. Regulatory interventions force AFSC stakeholders to adopt a high level of commitment to food safety and sustainable practices in the context of their CSR activities. On the other hand, the regulatory environment in the agrifood products is indeed rather complex. In many cases, the regulatory heterogeneity (indicatively, some impressive differences on import requirements among EU countries) on agrifood trade is a major challenge that AFSC stakeholders face. This chapter aims to demonstrate and analyze the main characteristics of the regulatory policies and their impacts on the various aspects of the AFSC (including, among others, food safety, quality, and implementation costs).

This book is aimed at both practitioners and academics alike. The potential audience includes researchers, C-level executives from throughout the food and beverage industry, supply chain managers, producers/manufacturers, farm managers/contractors, as well as stakeholders of AFSCs [producers, retailers, cooperatives, third-party logistics (3PL) companies, distributors, warehouse operators, policymakers and other administrative and technical personnel].

The information contained in this book will be core to the interested parties that have to deal with the entire hierarchical decision-making process for the field. Specifically, this book provides essential input to policy-makers and C-level executives that deal with strategic decision-making (including the design of AFSC networks), as well as to supply chain stakeholders and farmers that have to tackle issues of competitiveness at the tactical and operational levels. Readers who will find this book a "must-have" include practitioners from different fields related to agriculture and the agrifood industry. Moreover, practitioners from the logistics and supply chain management sector can use the book as a guideline. In academia, the book can be used as a textbook in both existing and emerging Master courses in relative graduate programs including, for example, Sustainable Production, Agriculture Production Management, Operations Management, Logistics and Supply Chain Management, and Business Administration. Additionally, readers who will find this book "nice-to-have" may include researchers in fields of Operations Management, Logistics and Supply Chain Management, Business Administration, and Agriculture Sciences, as well as undergraduate students close to completing their studies, who will find it an essential aid for conducting their senior theses.

Sustainable supply chain management for agrifood companies is clearly an evolving and critical subject that has not been comprehensively addressed in the

literature. While there are books that discuss the unique characteristics of AFSCs, they provide rather limited coverage on sustainability issues. Moreover, there are interesting books that address GSCM in general. We envision this new book to synthesize policies, practices, technologies and solutions offering a comprehensive, interdisciplinary, and customized paradigm. This condensed and targeted information will be of significant added value to leading executives and practitioners in the field, as well as researchers and interested academics.

Acknowledgments

This book consists of the collective work of many individuals from a wide range of organizations. It would not have been impossible to write and edit this book on sustainable food supply chains without the contributions and efforts of numerous scholars and practitioners. There are many individuals to thank, and we apologize in advance in case we have omitted anybody. First, we would like to thank the members, associates, and the EU's project officers (Mr Andrew Bianco and Mrs Carmen Madrid Gonzalez) affiliated with the Green-AgriChains project, a three-year leading research project (2012–2015) that was funded by the EU under the EU's Seventh Framework Programme (FP7-REGPOT-2012-2013-1 under Grant Agreement No. 316167). The project involved nine leading EU universities along with three business clusters. The academic partners include the Aristotle University of Thessaloniki (Greece), Brunel University (UK), INSEAD (France), Aarhus University (Denmark), International Hellenic University (Greece), University of Sheffield (UK), Alexander Technological Educational Institute of Thessaloniki (Greece), Karlsruhe Institute of Technology (Germany), and Erasmus University (Netherlands), while the business institutions include the world-class R&D logistics cluster EffizienzCluster (Germany), the Thessaloniki Innovation Zone (Greece), and the Organic Products Cluster (Greece).

Next, we would like to thank all of the authors who have contributed chapters to this book: Katerina Aggelopoulou, Jacqueline Bloemhof-Ruwaard, Fabrizio Dabbene, Rommert Dekker, Spyros Fountas, Paolo Gay, Theofanis A. Gemtos, Victor Guang Shi, Karen Hamann, Lorie Hamelin, Christos Keramydas, S.C. Lenny Koh, Sirpa Kurppa, Ioannis Mallidis, Ioannis Manikas, Felipe Montes, Jørgen E. Olesen, Konstantinos Papapanagiotou, Katerina Pramatari, Chen Qing, Anton Sentic, Sven G. Sommer, Agorasti Toka, Cristina Tortia, Jin M. Triolo, Marcus Wagner, and Jia Wei. If it was not for their diligent work, dedication, and ferocious commitment we would never have been able to have produced this book in the first place. We would also like to thank the numerous corporate organizations and the individuals who participated along with the authors in the various research projects on sustainable supply chains in the food sector. Their insights and their generosity of time allowed the authors of these chapters to conduct targeted research that formed the nexus of this book.

We would also like to thank the staff at Wiley (especially Mrs Liz Wingett) for their enthusiasm in supporting this effort from its very beginning and their impressive professionalism throughout the publication process. In addition, we

would like to thank Dr Naoum Tsolakis and the doctoral student Dimitrios Tsiolias for their tireless work in formatting this book. Finally, we would like to thank our families for all of their support during the writing and editing of this book. Without their support this project would never have been completed.

1

Sustainable Agrifood Supply Chain Management

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1.1 Introduction – Agrifood Supply Chain Management

The agrifood sector is one of the most regulated and protected sectors worldwide, with major implications for sustainability such as the fulfillment of human needs, the support of employment and economic prosperity, the environmental impact, the tackling of poverty, and the creation of new markets (Humphrey and Memedovic, 2006). Indicatively, the European Commission (EC) is promoting significant reforms to its Common Agricultural Policy (CAP) in order to respond to the plethora of internationally emerging agrifood supply challenges (EC, 2010; Scheherazade, 2014). Growing environmental, social as well as ethical concerns, and increased awareness

Supply Chain Management for Sustainable Food Networks, First Edition. Edited by Eleftherios Iakovou, Dionysis Bochtis, Dimitrios Vlachos and Dimitrios Aidonis.

of the impact of food production and consumption on the natural environment have led to increased pressures by consumer organizations, policy-makers, and environmental advocacy groups on agrifood companies to manage social and environmental issues across their supply chains (SCs) from "farm-to-the-fork" and along products' life cycles (Courville, 2003; Weatherell and Allinson, 2003; Ilbery and Maye, 2005; Maloni and Brown, 2006; Vachon and Klassen, 2006; Welford and Frost, 2006; Matos and Hall, 2007; Grimm, Hofstetter, and Sarkis, 2014).

In this context, designing appropriate effective global strategies for handling agrifood products to fulfill consumers' demand, while responding to ever-increasing changes of lifestyle and dietary preferences, has become quite a complex and challenging task. Specifically, adverse weather conditions, volatile global food demand, alternative uses of agricultural production and fluctuating commodities' prices have led to a volatile supply of agricultural products that is expected to exceed its capacity limit in the forthcoming years. To that effect, developed countries have been increasing their agricultural production in agrifood supply chain (AFSC) operations in order to respond to the projected rise of 70% on global food demand by 2050 (FAO, 2006, 2009; Nelson *et al*., 2010). At the same time, the value of family farms and the development of local food SCs is clearly recognized for both the developing and developed countries (FAO, 2014).

One of the most critical bottlenecks in agrifood production and distribution is the complexity and cost-efficiency of the relevant SC operations. Modern, global agrifood networks require multi-tier supply chain management (SCM) approaches due to the increased flows of goods, processes, and information both upstream and downstream the value chain. These increased requirements are related to the modern, emerging model of agrifood retailers (i.e., grocery retailers, fast-food and catering services' providers, etc.), the need for vertical and horizontal integration along the AFSCs, the plethora of differentiated product offerings, the market segmentation, the dominance of multinational enterprises in the food processing and retailing sectors, the need for limiting food waste and overexploitation of natural resources, as well as the branding of firms (van Roekel *et al*., 2002; Chen, Chen, and Shi, 2003; Mena *et al*., 2014).

Furthermore, SCM has been recognized as a key concept for the agrifood industry competitiveness. The rapid industrialization of agricultural production, the oligopoly in the food distribution sector, the advancement of Information and Communication Technologies (ICT) in logistics, customer concerns, and a divergence of governmental food safety regulations, the establishment of specialized food quality requirements, the emergence of modern food retailer forms, the increasing importance of vertical integration and horizontal alliances, as well as the emergence of a large number of multinational corporations, are just a few of the real-world challenges that have led to the adoption of SCM in the agrifood sector (Chen, 2006). To this end, SCM embraces the challenge to develop and deploy efficient value chains tailored to the specifications of the modern, uncertain environment, subject to the constraints of local and cross-regional conditions, with respect to logistics means and infrastructure, access to land and water resources, allocation of harvesting areas and the various processing and storing facilities, innovative and sustainable good-practice methods, regulatory and techno-economic environments, and rapid changes of food market characteristics.

In order to develop competitive and sustainable AFSCs, there are a few critical issues that have to be first recognized:

1. the unique attributes of AFSCs that differentiate them from other SC networks;
2. the decisions that should be made on the strategic, operational, and tactical levels;
3. the necessary policies to ensure sustainability of the agrifood chains; and
4. the appropriate innovative interventions, which are required to foster major advances and competitiveness within the evolving AFSC context.

Therefore, more frequent changes in AFSC designs are necessary and strategic actions should be taken to foster sustainability (Halldorsson, Kotzab, and Skjøtt-Larsen, 2009), and thus to achieve higher efficiency in logistics' operations performance and resource usage (e.g., Gold, Seuring, and Beske, 2010; Carter and Easton, 2011).

In general, an AFSC is encompassing a set of operations in a "farm-to-the-fork" sequence including farming, processing/production, testing, packaging, warehousing, transportation, distribution, and marketing (Iakovou *et al*., 2012). These operational echelons have to be harmonized in order to support five flow types, namely:

1. physical material and product flows;
2. financial flows;
3. information flows;
4. process flows; and
5. energy and natural resources' flows.

The aforementioned operations, services, and flows are integrated into a dynamic production–supply–consumption ecosystem of research institutions, industries, producers/farmers, agricultural cooperatives, intermediaries, manufacturers/processors, transporters, traders (exporters/importers), wholesalers, retailers, and consumers (van der Vorst, 2006; Matopoulos *et al*., 2007; Jaffee, Siegel, and Andrews, 2010). Moreover, the continuous evolution of AFSCs, and the overall complexity of the agrifood environment along with global market trends further highlight the need for integration of individual SCs into a unified AFSC concept. In such a structure, strategic relationships and collaborations among enterprises are dominant, while these organizations are further required to secure their brand identity and autonomy (Van der Vorst, da Silva, and Trienekens, 2007). A conceptual configuration of AFSCs is depicted in Figure 1.1.

The actors involved in the AFSC system can be generally partitioned into public authorities and private stakeholders. The former category includes mainly national governments and the associated ministries, administrative authorities (regional,

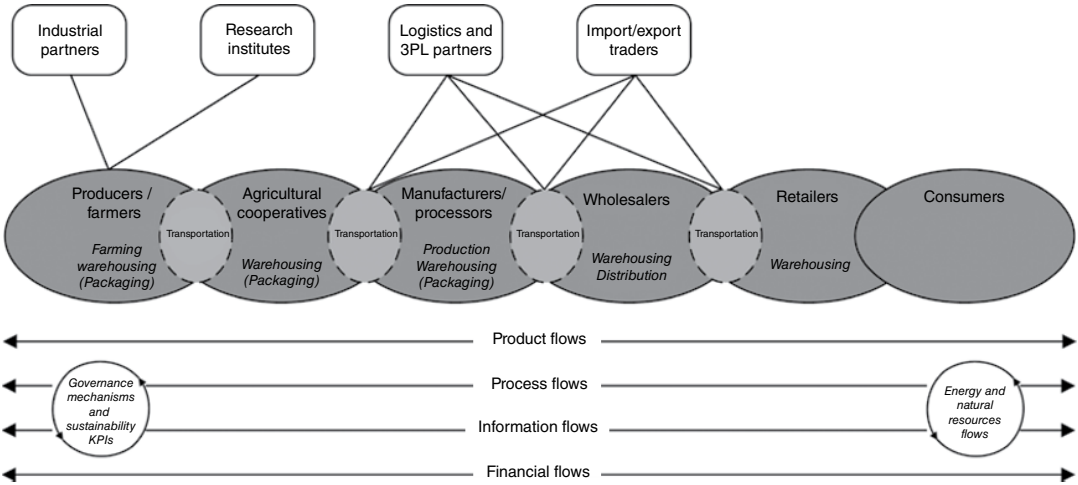

Figure 1.1 A typical agrifood supply chain. Adapted from Tsolakis et al., 2014a.