Supply Chain Management for the Agri-food Sector: A Critical Taxonomy

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Abstract

Globalization along with rapid demographic changes have led to an ever increasing demand for agri-food products. In this context, the design, implementation and operation of effective agri-food supply chains have emerged as of key importance. However, the volatility of weather conditions, the perishability of goods, the complex regulatory environment concerning food safety, environmental protection and trade, the changing lifestyles, and consumers' needs for diversified agri-food products pose significant challenges for the development of efficient supply chains and logistics networks within the agri-food sector. In this manuscript, we present a critical taxonomy of the state-of-the-art literature and practices that apply to all major issues that stakeholders need to address for the design and the management of Agri-food Supply Chains (AFSCs). More specifically, we first present the generic system components along with the unique characteristics of AFSCs that differentiate them from conventional supply chain networks. Following this, we recognize and present the most critical issues for the design and planning of AFSCs, while we provide a respective classification of the related research efforts. These key issues are further mapped on the underlying natural hierarchy of the decision-making process. Finally, we wrap-up and discuss major gaps and overlaps in the existing literature, while propose a future research agenda.

Keywords: Supply chain management, agri-food sector, hierarchical decision-making, taxonomy.

1. Introduction

Agricultural products play a pivotal role in the global strategies for fulfilling consumers demand and responding to the increased lifestyle changes in the dietary domain. However, diverse weather conditions, alternative uses of agricultural production, volatile global food demand and instability of commodities' prices lead to a fragile supply of agricultural products that is expected to exceed its capacity limit in the forthcoming years. Agri-food supply (AFS) has emerged as a critical issue for the international community. Developed countries are expected to increase their agri-cultural production
and effectiveness in the agri-food supply chain (AFSC) operations in order to respond to the anticipated rise of 70% on the global food demand by 2050 (FAO, 2006; FAO, 2009; Nelson et al., 2010). At the same time, AFS as one of the most regulated and protected sectors in the European Union (EU) has significant implications for sustainability such as the fulfillment of human needs, the support of employment and economic prosperity through export-led growth, the environmental impact, the eradication of poverty and the creation of new markets as dictated by the United Nations Industrial Development Organization (Humphrey and Memedovic, 2006). Furthermore, the European Commission (EC) is promoting great reforms to its Common Agricultural Policy (CAP) in order to respond to the plethora of the internationally emerging AFS challenges (EC, 2010).

One of the most critical bottlenecks in agri-food sector is the complexity and cost-efficiency of the logistics operations. Modern, global agri-food networks require multi-level supply chain management (SCM) approaches due to the increased flows of goods and information both upstream and downstream in the value chain and vice versa. These increased requirements are related to the emerging model of agri-food retail outlets (i.e. key grocery retailers, fast food and catering services providers etc), the need for vertical and horizontal integration, the great market segmentation, the plethora of differentiated product offerings, the diversification of market needs, the presence of multinational enterprises in the food processing and retailing sector, and the branding of firms (Roekel et al., 2002; Chen et al., 2003). To this end, SCM embraces the challenge to develop and deploy efficient policies tailored to the specifications of the modern, uncertain environment and subject to the constraints of local and cross-regional conditions with respect to logistics infrastructure, access to land and water resources, allocation of harvesting and processing areas, innovative and good-practice approaches, regulatory and techno-economic environments, and rapid transformation of market characteristics.

Specifically, for building modern and competitive AFSCs, a number of critical issues need to be tackled in order to create added value for all the involved stakeholders with respect to:

- The unique characteristics of AFSCs that differentiate them from traditional networks.
- The decisions that should be made on the strategic, operational and tactical levels.
- The policies which are required to achieve sustainability of the agri-food systems.
- The innovations that need to be promoted to the changing agri-food supply chain context.

In this paper, we discuss the most critical agri-food supply chain management issues and provide a first-effort review both in academia and business of the relevant existing state-of-the-art research and practices. Specifically, in Section 2 we present the structure of AFSCs along with the particular moduli that differentiate them from traditional supply chain (SC) networks. Following in Section 3, we identify and present thirteen key emerging issues for the design and management of modern AFSCs along with the respective literature. Finally, we wrap-up with summary and
conclusions in the last Section, while we further propose future research steps.
2. Supply Chains for the Agri-food Sector

It was only in the previous decade that the agri-food industry recognized and started embracing SCM as a key concept for its competitiveness. Rapid industrialization of agriculture, concentration of food distribution, expansion of information and logistics technologies, customer and governmental food safety concerns, establishment of specialized food quality requirements, emergence of modern retailer forms (e.g. supermarkets, fast-foods), ever-increasing usage of vertical integration and horizontal alliances, and the emergence of a plethora of multinational corporations were just few of the real-world challenges that have motivated stakeholders in considering the overall agri-food sector from a supply-chain perspective (Chen, 2006).

In general, an Agri-Food Supply Chain is comprised by a set of sequential operations such as the input supply, production, postharvest, storage, processing, marketing distribution, food services, and consumption following a sequence of operations from ‘farm-to-the-fork’ (Jaffee et al., 2010). These operations are designed to provide adequate logistical, financial, and technical services, and support three fundamental flow types, i.e. material and product flow, financial flow, and information flow. Moreover, they transcend all the echelons of the SC, including in general: input suppliers, producers, intermediaries, processors, exporters, retailers, and consumers (Matopoulos et al., 2007; Jaffee et al., 2010; van der Vorst, 2006). Actually, the continuous evolution of AFSCs, and the overall complexity of the agri-food environment along with global market trends highlight the need of integration of individual AFSCs in a unified AFSC concept. In such a structure, there are dominant strategic relationships and collaborations among enterprises, while the latter maintain their brand identity and autonomy (van der Vorst, 2007).

Figure 1. A typical Agri-Food Supply Chain structure (Jaffee et al., 2010)

The involved stakeholders acting within the presented AFSC framework, either on national or international level, could generally be clustered into public authorities and private organizations. The former category includes mainly national governments and the associated ministries (agriculture, finance), administrative authorities (regional, district, urban), as well as
international organizations (e.g. Food and Agriculture Organization), while the latter category encompasses farmers/growers, food traders, food stores and supermarket chains, agro-industries and processors, as well as financial institutions (banking, insurance) (Jaffee et al., 2010). In this context, highly concentrated agro-industrial enterprises and retailers have developed recently into dominant players of the agri-food field, while the public sector has emerged as a key-governance factor (Bachev, 2012).

Although SC configuration as described above is rather common for a traditional SC, AFSCs exhibit a set of unique characteristics that differentiate them from classical supply chain and raise an imperative need for special managerial capabilities. Van der Vorst (2000; 2006) highlights these particular features according to each associated SC partner, as listed below.

- **Overall**: (i) raw materials shelf-life constraints, intermediates and products perishability, and product quality changes across the SC, (ii) materials recycling requirements.
- **Growers/ Producers**: (i) long production times, (ii) production seasonality.
- **Auctions/ Wholesalers/ Retailers**: (i) quality and quantity variability of supply, (ii) global sourcing requirements due to seasonal product supply restrictions, and (iii) conditioned transportation and storage requirements.
- **Food Industry**: (i) quality and quantity variability of supply, (ii) high volume and low variety production, (iii), specialized and high technology machinery and intensive capacity utilization, (iv) process yield variability (quality, quantity) due to biological, seasonal, weather, etc. reasons, (v) quarantine issue (quality tests), (vi), storage-buffer capacity restrictions and special storage condition requirements, (vii) specialized regulations and legislation regarding environmental protection and consumer-related issues, (viii) complementarity of agricultural inputs, (ix) physical (e.g. taste, size, etc.) and specialized additional (convenience of ready-to-eat meals) product features, (x) product safety and traceability and customers’ quality perception.

Finally, AFSCs are dynamically evolving over time in order to follow the incessant changes within the broader agri-food sector environment. Today, the major challenges underway encompass: rapid urbanization, growth of domestic food markets, domestic and global factors and markets liberalization, decrease of public sector funding, demographic changes, income changes, consumers’ demand and preferences, and emergence of global SCs. Therefore, the recognition of the most critical issues that need to be addressed by all AFSCs stakeholders towards an integrated decision-making process emerges as a prerequisite for managing such complex, multi-tier supply chains and ensuring their overall efficiency and sustainability.

### 3. Critical Issues for the Design and Management of AFSCs

Designing, managing and operating AFSCs involves a complex and integrated decision-making process. This is even more complicated when
AFSCs deal with fresh, perishable and seasonable products that lead to high volatile of supply and demand. Planning of AFSCs in general should capture issues such as crops’ planning, harvesting practices, food processing operations, marketing channels, logistics activities, vertical integration and horizontal cooperation, risk and environmental management, food safety and sustainability assurance.

Based on our preliminary experience with the “GREEN-AgriChains” REGPOT program under the title “Innovation Capacity Building by Strengthening Expertise and Research in the Design, Planning and Operations of Green Agri-food Supply Chains”, a European Union FP7 funded project (2012-2015) encompassing a number of EU leading companies and research institutions, we have identified key issues for modern AFSCs that need to be addressed. These are further mapped on the strategic, tactical and operational level of the underlying hierarchical decision-making process (Table 1), while the existing state-of-the-art related literature is presented accordingly. As this taxonomy is only a first effort, it is not submitted as an exclusive list, as the size of a comprehensive list would exceed the scope of the hosting conference.

Table 1. Key issues for the Design and Management of AFSCs mapped in the hierarchical decision-making process

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Symbols: S for strategic, T for Tactical, and O for operational

3.1 Selection of Farming Technologies

During the industrialization period, agricultural mechanization evolved as a means to respond to the increased demand for mass production. Today, the variability in machinery cost, the need for diversified crops, the regulations regarding environmental impact and food safety, and the biological and meteorological implications indicate the need for the development of scientific models for the optimal selection of farm machinery (Poulsen & Jacobsen, 1997).

Several quantitative models that deal with the optimal mechanization level regarding economic efficiency and capacity utilization have been
developed in literature (e.g., Søgaard and Sørensen, 2004; Parmar et al., 1996; Glen, 1987). The main parameters that affect farm machinery selection are the machinery cost (including also operational, labor, and timelines cost) and the machinery size with regard to: (i) total crop area, (ii) available labor, (iii) tillage practices, (iv) crop mix and (v) weather (Edwards, 2009).

Today, the outsourcing of the harvesting machinery to individual contractors emerges as a meaningful option. However, comprehensive models that evaluate the financial scope of either utilizing privately owned machinery or hiring an external contractor for coping with the harvesting of mixed crops during a multi-period yield have not been adequately developed yet.

3.2 Financial Planning & Investments

The greatest peril in the development of effective and cooperative AFSCs usually lies within the local suppliers that lack the desired professionalism, know-how and financial resources to comply with the rigid standards for quantity, quality and price, as set by global retailers. Nowadays, within the context of the rapidly changing scenery of the agricultural sector and the dawn of the agro-industrialization era investments in technological R&D, the spread of radical knowledge, as well as novel services are crucial drivers for innovation in the AFSCM domain (World Bank, 2008; Reardon and Barrett, 2000). In this context, certain authors examine the impact of investments in the AFSC performance in current literature.

From a financial perspective, Turvey and Baker (1990) elaborated stochastic programming to investigate farmers’ decision for hedging through futures and options. They demonstrate how the regulated farm programs reduce financing risks incurred to the farmers, while they reveal that high-debt farms select hedging as a means of liquidity. Additionally, Belaya et al. (2012) demonstrate that Foreign Direct Investments (FDIs) on the farming, food processing and retailing sectors influence positively the performance of an entire AFSC. They highlight that FDIs are even more important for non-western countries, where Multinational Enterprises (MNEs) need to cooperate with local enterprises. The latter need FDIs in order to respond to the quality and information sharing standards set by the international retailers and remain in the supply chain. Finally, the issue of ownership structure and power authority along the agri-food value chain, in relevance to the investments for the optimization of AFSC performance, has also been discussed in literature (indicatively, Yu, 2010; Hendriske and Bijman, 2000).

From a social-oriented perspective, Hebebrand (2011) underlines the need for innovative financing plans and farm investments in rural, developing communities. The author claims that the integration of local agricultural smallholders to international AFSCs could promote reduction of poverty and creation of knowledge in developing countries. On the corporate side, the author emphasizes the need of public-private partnerships to stimulate shared-market development and profit maximization for all stakeholders in the AFSC whereas she consults MNEs to substantially invest in developing countries and adopt a long-term perspective on the anticipated investment returns.
From a technical aspect, Ekman (2000) proposed a stochastic program for determining the optimal investment on farming machinery to deal with the uncertain time constraints of tillage, with respect to the unpredictable nature of the weather. Towards this direction, Berge ten et al. (2000) formulated a multi-objective linear program for the determination of the equipment that maximizes the economic returns while at same time minimizes the environmental impact in terms of pesticides and fertilizers’ utilization. From another perspective, Tan and Fong (1988) developed a linear programming (LP) model for the selection of the optimal mix for perennial crops in terms of maximizing revenues. The authors assess the model on multiple periods given the sensitiveness of crop prices. Towards the same direction of maximizing the net present value from crop planning, Stoecker et al. (1985) developed an LP model to define the optimal structure of capital expenditure funding with respect to single-period cropping plans and multi-period groundwater exploitation. The authors articulate their problem based on the factors of crop production, drilling policies, scheduling of irrigation area and allocation of water sources.

3.3 Supply Chain Partners’ Relationships

Modern AFSCs in general are structured in multiple echelons encompassing a significant number of stakeholders with common but also conflicting objectives that need to build robust and long-term relationships. Into this context, one of the key factors towards the development of sustainable and efficient AFSCs is collaboration as “collaboration can be more effective than competition as a general organizational mode to achieve economic efficiency” (Fischer and Hartman, 2010).

Effective relationships among SC stakeholders are of vital importance for sustaining high-performance of AFSCs and should be based on clear understanding of the “inter-organizational relationships” scheme, including concepts such as integration, collaboration, coordination, cooperation, and contracts among partners. The issue of SC partners’ relationships is rather common in the relevant SC literature, and thus few indicative papers are presented below in order to figure out the field framework and current trends.

Initially, a point of interest that rises through real-world practice is the dynamics of the relationships between producers and retailers in the global sourcing and retail chain context, where Burch and Goss (1999) identify the emerging rivalry between retail channels capital and manufacturing capital. Moreover, a critical consumer-driven issue that concerns the majority of the AFSCs stakeholders is the assurance of food safety and quality, as well as the transparency and traceability throughout the SC, with Beulens et al. (2005) pointing out the relevant challenges and the need for cooperation among SC networks.

Contracting among AFSC partners is another vital issue that affects directly the AFSC level of efficiency and sustainability. Fischer et al. (2009) highlight these market, industry, and enterprise characteristics that influence the relevant contractual selection process (contract type), as well as the enterprise-level factors that affect the sustainability of relationships. Ligon (2003) deals with the optimal risk mitigation in agricultural contracts.
Moreover, Hovelaque et al. (2009) employ Monte-Carlo simulation to discuss the effects of constraint supply on agricultural cooperatives, as well as the impacts of price contracts in such an environment. Da Silva (2005) discusses contract farming as a critical component of an agri-food system development and chain governance strategy. Finally, from a technical aspect, Zanoni and Zavanella (2007) deal with perishable goods, providing models and heuristic algorithms for an integrated transport and inventory control system, while Higgins et al. (2004) present a framework for integrating transport and harvesting systems.

Integration of SCs, and especially AFSCs, is yet another substantial concept for designing and operating the entire chain. In this direction, van der Vorst et al. (2009) propose a simulation model for the integrated design of food SCs, in terms of logistics, product quality, and sustainability decision-making procedures. Mintcheva (2004) presents an approach of indicators to the concept of integrating the environmental policy for a food SC. The concept of risk management integration is addressed by Shepherd et al. (2006) involving stakeholders in determining the interfaces and processes that are necessary to communicate risks. Moreover, end-to-end integration is recognized by Netland et al. (2008) as a prerequisite for developing lean AFSCs that add value to final products, while they emphasize on the significance of close coordination among manufacturing teams, customers, and farmers. Karantininis et al. (2010) point out the role of vertical integration and contractual arrangements in enhancing firms’ innovative behavior.

The cooperation among stakeholders is a prominent characteristic of optimal AFSC performance (Wever et al., 2009). Hobbs and Young (2000) propose a framework for analyzing the changes of vertical co-ordination of AFSCs along with the relevant driver forces such as product characteristics, transactions characteristics and cost changes. Additionally, Cechin and Bijman (2009) discuss how agricultural cooperatives respond to this vertical coordination concept in a SC context, emphasizing in generating high quality attributes. Finally, the pivotal importance of the SC collaboration concept is denoted by Matopoulos et al. (2007) along with the relevant constraints that arise due to the nature of the specific structure of the agri-food sector, while the authors point out that collaboration is rather limited to operational issues and logistics activities.

3.4 Supply Chain Network Configuration

The design of a SC is a vital issue for the overall operation and efficiency of the SC in the long-term, and encompasses a set of critical strategic decisions affecting the materials, products and information as well as the associated costs. These decisions include amongst others sourcing, procurement, purchasing, allocation and capacity of intermediate warehouses, allocation of processing facilities, transportation network design, retailers’ network design and market selection along with the associated capacity limitations and uncertainties. The objective is to minimize chain costs including harvesting, collection or purchasing costs, facility (storage, handling and fixed) and inventory holding costs, and transportation costs, while assuring an adequate level of flexibility in order to be able to adapt to potential future changes.
Despite the significance of the aforementioned decisions and the plethora of papers that address them in the general SCM context, the relevant agri-food specialized literature is rather poor, probably due to difficulties imposed by the structure and relationships complexity of the entire agri-food chain and the incoming uncertainties that characterize this particular type of SCs. To this end, since very few aspects of ASFCs management have been addressed in literature, only an indicative selection of papers with a focus on transportation network design is presented following. Boudahri et al. (2011) propose a model for the design and optimization of the transportation network of an AFSC, and implement this model on a chicken meat SC. Additionally, Higgins et al. (2004) propose a framework for integrating harvesting and transport systems for sugar production. Burch and Goss (1999) discuss the global sourcing issue for retail chains and its impact on the agri-food system. It appears that there is plenty of room for practical and academic contributions in the field of agri-food supply chain network design and the tailoring of the relevant general SC decision-making methodologies to the increased requirements of modern AFSCs is a challenging research field of emerging importance.

3.5 Performance Measurement

Real-world practice has indicated thus far that in order to ensure an organization’s success in the long-term, managers should insightfully consider the measurement of the SC performance (Neely et al., 2005; Caplice and Sheffi, 1994). A Performance Measurement System (PMS) allows for monitoring and evaluating the overall SC efficiency, while providing up-to-date information to support the relevant comparison, benchmarking, decision-making and revision processes. In general, measuring the performance of SCs is a challenging process that becomes even more complicated in the case of modern AFSCs as they exhibit few particular characteristics that require additional technical and managerial capabilities (Aramyan et al., 2006).

In this context, Aramyan et al. (2007) propose a novel conceptual framework for the integrated AFSC performance measurement based on the categorization of the performance indicators into four main categories, i.e. efficiency, flexibility, responsiveness, and food quality. Additionally, Aramyan et al. (2006) present a review of the key-performance indicators and the models that are employed in the existing AFSC performance measurement. Van der Vorst (2006) emphasizes on the role of collaboration among SC partners in measuring performance, and presents a framework for the development of AFSC networks employing four structural elements: network structure, business processes, network and chain management, and resources. Finally, in the general SC performance measuring literature, there are many papers proposing frameworks (Gunasekaran et al., 2004) and introduce widely applied KPIs (Beamon, 1999) and some papers tackling the critical issue of the overall PMS design and implementation (Lohman et al., 2004; Neely et al., 2005) that could be tailored to the modern AFSC needs for reliable and practical information.
3.6 Risk Management

During the last two decades, there is a continuously growing interest of governments, international authorities, financial institutes, consumer organizations, and other national and international stakeholders for managing risk in the agricultural and food sectors. Globalization of the economy, food-safety issues, and climate changes are just few of the concerns that motivate this interest. At the same time, triggering events such as food safety crises (e.g. avian influenza, China’s milk scandals, etc.), fluctuation of food and prices of raw materials (grains and vegetable oils in Europe and Central Asian countries within the period 2006-2008) and climate change effects (e.g. Katrina hurricane in 2005) highlight the need for risk management in the agri-food sector.

Modern AFSCs experience a wide variety of risks of natural, technological and human origin, namely weather-related, natural disasters, biological and environmental, market-related, logistical and infrastructural, public policy and institutional (Jaffee et al., 2009). These risks threat the AFSCs with deviations, disruptions or shutdowns of the SC fundamental flows (see Section 2), and may have dramatic impact on costs, efficiency, and reliability of the involved activities and operations. The literature thus far has focused on few critical aspects of the entire agri-food risk management concept including cross-border transaction risks (Ameseder et al., 2009), chemical and biological risks (Bachev, 2011), agricultural contracts (Ligon, 2003), catastrophic/disaster risk management (RPDRM, 2012; Anton et al. 2011), income risk management (OECD, 2000), climate risk management (Wall et al., 2004), and insurance schemes (Diaz-Caneja et al., 2009).

The core aims of the relevant decision-making process are to shield the overall AFSC against the afore-mentioned risks with respect to low-risk and low-cost restrictions, and eliminate simultaneously its vulnerability under two critical constraints regarding the efficiency and sustainability of the adopted strategies. In this context, the holistic approach has been recognized by main stakeholders as the most appropriate in order to achieve these outcomes (OECD, 2009; Bachev, 2012). In this direction, the Agricultural Risk Management Team of the World Bank proposed a methodology for a Rapid Agricultural Supply Chain Risk Assessment (RapAgRisk), based on three axis: risk sources, partners’ strategies, and government policies. The main factors that guide the relevant decision-making process are: (i) risk characteristics, (ii) agent characteristics (personal and behavioral), (iii) institutional environment, (iv) dimensional characteristics of activities and transactions, (v) progress in science and technology, and (vi) natural environment (Bachev, 2012).

The core risk-related decisions are the selection of the appropriate risk governance mode and risk mitigation strategy. The former includes the options of market, private and public governance; the failures of the first two in real-practice reinforce the role of public intervention. Therefore, the level of public intervention and the implementation of hybrid models (public-private coordination) were added to the decision-making agenda. The latter decision concerns the adopted risk mitigation policy including technology development and adoption, enterprise management practices, financial instruments,
investments in infrastructure, policy and public programs, and private collective action (OECD, 2009).

Finally, the nature of the overall decision-making process is twofold, definitely stochastic and pure dynamic, as it unfolds in real time within an uncertain environment that changes continuously, breeding new challenges and opportunities. Consequently, the decisions along with the associated implemented strategies should be monitored and subject to reconsideration in order to ensure the entire long-term AFSC efficiency and sustainability.

3.7 Sustainability

Sustainability emerges as an issue of pivotal importance that has to be taken into account when designing and operating supply chain networks in which profitability and environmental impacts are balanced (Linton et al., 2007; Neto et al., 2008; 2009; Hassini et al., 2012; Securing and Muller 2008). Agri-food supply chain stakeholders are called to adopt a certain level of commitment to sustainability practices in the context of their Corporate Social Responsibility (CSR) activities, mainly due to pressure from government regulators, non-governmental organizations (NGOs), community activists, and global competition (Maloni and Brown 2006; Marsden and Smith 2005; Marsden et al. 1999; Mariani 2007; Vorley 2001). Klerkx et al. (2012) discuss the increasing importance of the adoption of CSR practices for exporting agri-food firms, concluding that the concept of corporate environmental friendliness has not been adequately developed especially in emerging economies. Stonehouse (2003) proposes an integrated educational program that could be adopted in higher agricultural education in order to cultivate the environmental awareness of the field experts.

The sustainability of supply chains of perishable food products in general has been addressed by several authors in literature (e.g. Higgins et al. 2010; van der Vorst et al. 2009; Leat et al. 2011). Most activities that take place in AFSCs can be responsible for a significant proportion of the total energy use and the environmental impacts that arise in the agri-food sector, like traffic generation, vehicle emissions, vehicle noise, visual intrusion and health and safety of workers and the public. Such activities include harvesting with various types of equipment using fuels, transportation with many vehicle movements, storage of perishable products for long time period and final production through technologies more or less friendly to the environment. Van der Vorst et al. (2009) argue that investments in food supply chain design should not only be aimed at improving logistics performance, but also at the conservation of food quality and environmental sustainability. The authors propose a new simulation model for the design of perishable food supply chains that includes food quality models and sustainability indicators. Mintcheva (2005) argues that environmental issues cannot be dealt with separately at each step of a food supply chain and proposes a set of indicators that good be embedded into an integrated environment policy framework for such supply chain networks.

Other related research papers address either the reduction of product waste (e.g., Van Donselaar et al. 2006) or the greenhouse gas emissions related to the business processes in the supply chain network (e.g. Edwards-
Estimates of the carbon footprint of a food system depend both on the definition of the system boundary and the utilized carbon accounting methodology (Buckwell, 2005). The spatially distributed sources of agricultural products along with their often bulky nature require the development of extensive logistical infrastructure and significant transport capacities for the design of eco-friendly agri-food supply chain networks. Transportation is considered to have the most important impact on the environment and thus decisions regarding vehicle selection, routing and scheduling should be taken with respect to the total emissions estimated to be released during the networks lifetime. Sustainable fleet management, as well as coordination of available equipment (e.g. optimized unloading procedures) could contribute in less traffic and fewer trips, more adequate co-ordination of transport vehicles and site-specific accumulation of goods, and controllable machinery use for decreasing energy costs (Auernhammer, 2001). According to Allen et al. (1998), public perception is often a significant factor in the acceptability and future development of an industrial or commercial activity and can influence location choices, land-use and transport planning decisions.

3.8 Quality Management

The terms of quality management systems and standardization of products are strongly connected to food safety. Standards and norms provide state-of-the-art specifications regarding products, services, procedures and processes, helping firms to be more competitive.

In 2005, ISO (International Organization for Standardization), which is the world’s largest developer of voluntary International Standards, established the food safety management system ISO 22000:2005. The above specifies the minimum requirements for the development and implementation of a food safety management system. The minimum requirements for an organization in the food chain, include the demonstration of the organization’s ability to control food safety hazards in order to ensure that food is safe at the time of human consumption (ISO 22000:2005, 2005; ISO/TS 22004:2005, 2005; Oger et al. 2010).

Moreover, Global Food Safety Initiative (GFSI) standards address a large number of issues related to food safety from producers to end users. GFSI-benchmarked food safety standards include among others: Global Good Agricultural Practices (GlobalGAP), Safe Quality Food (SQF), and British Retail Consortium (BRC).

GlobalGAP has established a number of voluntary standards (e.g. Integrated Farm Assurance Version 4, Compound Feed Manufacturing (CFM) Standard, Plant Propagation Material (PPM) Standard, e.t.c.) for the certification of production processes of agricultural products of the primary food sector, linking developing country farmers to international retailers (Henson et al. 2011; Tipples and Whatman 2010; Asfaw et al. 2009).

SQF, an Australian initiative, is a comprehensive food safety and quality management certification system for food manufacturers, wholesalers, and distributors, applied in all levels of SCM (Trienekens and Zuurbierl, 2008). The SQF provides two standards based on the type of food supplier: SQF 1000 for primary producers and SQF 2000 for manufacturers and distributors.
SQF standards combine management quality system (e.g. ISO 9000) and a food safety system (e.g. Good Handling Process - GHP, Good Manufacturing Process - GMP, Hazard Analysis and Critical Control Points - HACCP) with requirements for tracking and tracing (Lee, 2006; Fulponi, 2006).

The British Retail Consortium has developed a number of BRC Standards for Food Safety for suppliers and global retailers (e.g. Global Standard for Food Safety Issue 6, Global Standard for Packaging and Packaging Materials Issue 4, Global Standard for Storage and Distribution Issue 2 etc.). As in the case of SQF, the BRC Standards are based, among others, on the GHP/GMP principles, the HACCP system and the ISO 9000 standard facilitating standardization of quality, safety, operational criteria and manufacturers’ fulfillment of legal obligations (Knaflewska and Pospiech, 2007). Nowadays, the implementation of BRC Standards is rather common, as there are more than 16,000 certified suppliers in 90 countries.

3.9 Transparency, Food Safety & Traceability

Ensuring transparency both upstream and downstream in AFSCs is a crucial constituent that can guarantee production control, promote food safety and quality, ensure customer trust, support product differentiation and claim financial benefits. Nowadays, the issue is even more prominent due to the complexity of AFSCs and the recent worldwide food scandals (Bánáti, 2011).

The term ‘transparency’ can be viewed from different perspectives. Within the supply chain framework we adopt the following definition: “… is the extent to which all its stakeholders have a shared understanding of, and access to, the product-related information that they request, without loss, noise, delay and distortion” (Hofstede et al., 2005; Deimel et al., 2008). In this context, the need for transparency is incumbent upon all the partners in a food chain (including the suppliers of raw materials, the farmers, the food processors, the packaging and transportation intermediaries) in order to facilitate flow of information and cooperation. To this end, the strategic decision of adopting common regulatory environment, comprehensive key performance indicators and compatible information technology infrastructure among the actors of an AFSC is pivotal.

Transparency is closely related to traceability. Nowadays, food safety has become a critical factor for the management of modern AFSCs. Different methods and techniques have to be employed in order to ensure high levels of food safety in all levels of the supply chain. According to Regulation (EC) No. 178/2002, “It is necessary to ensure that a food or feed business including an importer can identify at least the business from which the food, feed, animal or substance that may be incorporated into a food or feed has been supplied, to ensure that on investigation, traceability can be assured at all stages”. Members States in the European Union have adopted a number of Regulations and Directives aiming at harmonizing food safety policies and traceability systems.

Wilson and Clarke (1998) define traceability as the necessary information that describes the history of food production, along with any subsequent transformations or processes, from the grower to the final consumer. The key elements of traceability systems are tracing and tracking.
Tracing refers to the upstream examination along the supply chain providing information prior the consumption of the product, while tracking is the downstream examination providing information about product's origin, location, and possibly prior movements (Agriculture and Agri-food Canada, 2007).

The key benefits of traceability systems are outlined in a numerous scientific papers in the relevant literature body, such as:

- Minimization of information costs for consumers (Hobbs, 2006; Sanderson and Hobbs, 2006; Meuwissen et al., 2003; Buhr, 2003).
- Minimization of the public and private costs of a problem (Hobbs, 2006; Golan et al. 2003; Hobbs et al., 2005).
- Implementation of product’s differentiation strategies (Sanderson and Hobbs, 2006; Smith et al, 2005; Golan et al., 2004).
- Enhancement of consumers’ confidence and liability (Hobbs et al., 2009; Hobbs, 2003; Golan et al., 2003).
- Accessibility to international markets and enhancement of industry competitiveness (Hobbs et al., 2009).
- Ability to respond to emergencies (Hobbs et al., 2009).
- Improvements to production management (Agriculture and Agri-food Canada, 2007).
- Reduction of risks (Agriculture and Agri-food Canada, 2007).

The scientific works that examine decisions related to transparency in food chains are numerous and rooted back in the previous decades (e.g., Deasy, 2002; Moe, 1998; Cheng and Simmons, 1994). More recently, Beulens et al. (2005) provided a relevant empirical study on traceability in the egg industry and stressed the importance of establishing effective tracking and tracing systems that can secure pro-active monitoring in each node of the AFSC that enables product recalls in the case of quality deficiencies. They conclude that even if information communication technology (ICT) and quality systems can be easily installed and configured by each partner of the SC, the most significant peril in the whole effort refers to the lack of coordination on a physical unit’s level. As a response, the adoption of RFID technology can secure the visibility requirements along the supply chain partners (Zhang and Peichong, 2012).

Except for the ICT systems and the safety/quality standards, Trienekens et al. (2012) provide a taxonomy of the appropriate governance mechanisms (organizational arrangements) tailored to the transparency demands of the different SC partners (the government, food companies and consumers).

Regardless of the qualitative research in the field, thus far integrated transparency in terms of information exchange, governance mechanisms and safety standards is achieved only in small, closed supply chains. Thus, implementing transparency in complex AFSCs where customization is dominant is a challenging new research field.

3.10 Harvest Planning

AFSCs are mainly characterized by a single major problem: The balance between the supply and demand sides. To this end, the effect of harvesting planning implications on the performance of the entire AFSC is of pivotal
importance. One of the most critical issues that need to be tackled is the extreme volatility of harvesting planning to disruptions like unstable weather and poor sunlight, plant diseases, poor soil performance, etc. The problem is even more complex in the case of perishable agri-food products, where time is a critical dimension that affects the whole planning in all echelons of an AFSC.

From a strategic perspective, the location of farms according to the overall AFSC planning, the matching of soil types with the desired crops, the design of crop rotations, the irrigation development and fallow systems are key capital dependent decisions in order to deploy effective and sustainable AFSCs (Glen and Tipper, 2001; Visagie et al., 2004; Kaiser et al., 1993; Tan and Fong, 1988; El-Nazer and McCarl, 1986; Schönhart et al., 2011). More specifically, Higgins et al. (2004) provide an insightful empirical study of the Australian sugar industry and demonstrate the significance of the coordination among local agri-food associations (including growers, harvest contractors and milling representatives) towards effective cost reductions.

On tactical level, factors like labor scheduling, timing of planting, planting varieties, fertilizer applications and the resource management among competing crops are important for the successful completion of the growers objectives, namely the minimization of cost, the maximization of profit etc. (Higgins et al., 2004; Ahumada and Villalobos, 2011).

Finally, at the operational level, relevant activities refer to pre-harvesting treatment, irrigation scheduling, harvesting frequency, post-harvest actions, packing and storing, labor management and delivery (e.g., Recio et al., 2003; Bin Deris and Ohta, 1990). Especially, Higgins et al. (2004) stress that harvesting scheduling is closely related to fleet management, both at the level of farming machines as well as from the aspect of logistics operations between farmers and food processors. Their study reveals the significance of routing of the harvesting equipment (i.e. optimized crossing loops between farm paddocks and field haulouts) to minimize waste, cost and utilization of the transport system.

3.11 Logistics Operations

Managing the flow of goods in compliance with performance criteria and regulations in modern AFSCs highlight the need for sophisticated agri-food logistics operations. According to van Beek et al. (1993), it is vital to discriminate between the logistics operation in two levels:

(i) Transformation level. At this stage the transformation of the agricultural goods to forms that can be easily handled and transported takes place. Operations like unitization of goods, packaging, stacking, bundling, wrapping and unstacking occur here. The goods are transformed to smaller, final or intermediate products with desirable characteristics and shape so as to be transported to the next echelon of the AFSC.

(ii) Transportation level: In this level we refer to the preservation of goods along their flow through the entire AFSC. Inventory control is a key operation.

Notably, the logistics operations are greatly affected by the decisions made in other strategic levels such as transparency, food safety and
traceability. However, the combination of product flows is an emerging issue since it could lead to increased lead-times and logistics cost. The issue of logistics operations in the agri-food sector needs to be further elaborated as the research on the field is limited, especially when it comes for perishable goods.

3.12 Waste Management & Reverse Logistics

Integrated waste management in AFSCs is a new research field composed by practices from the agricultural and the food sector. Both scientific fields have been subject to research in literature and provide useful findings that could be adopted in agri-food supply chain management. Waste from agriculture and food processing can become one of the most serious sources of pollution (Di Blasi et al., 1997).

Research on food and in general organic waste management extends over a very wide generic spectrum in the literature (e.g. Schaub and Leonard, 1996; Hall and Howe, 2012; Polprasert, 2007; Bernstad and Jansen, 2012). Agricultural waste management regards the systemic and organized use of by-products of agricultural production with sustainable methods that preserve or even enhance the quality of air, water, soil, plant, and animal resources. An agricultural waste management system in general consists of six basic operations, namely production, collection, storage, treatment, transfer and utilization, which often imply high logistics costs and complex planning (US Department of Agriculture, 2012). Agricultural waste can be handled either by controlled disposal or by further utilization as value-added by-product (e.g. for animal feed, field fertilizers, energy production and other). Ajila et al. (2012) provide an overview of state-of-the-art sustainable practices for agro-processing waste management, presenting both conventional methods (like land filling / dumping in open sites, incineration and composting) and applied modern solutions (like microbial or extraction technologies for the production of valuable organic compounds or processing technologies for the production of animal feed). Waste reduction is considered to be an action of first priority that could provide financial and environmental benefits in agricultural waste management, in conjunction with other recommended practices such as waste re-use, on-farm or off-farm incineration with or without energy recovery, composting, and recycling (EA-UK, 2001). Several scientific papers in literature address waste management issues of agri-food by-products (indicatively, Briassoulis et al., 2012; Thanarak, 2012; Iakovou et al. 2012; El Haggar, 2007; Nagendran, 2011; Kosseva, 2011).

3.13 Fleet Management, Vehicle Planning and Scheduling

Fleet management on tactical level, as well as vehicle planning and scheduling on operational level of decision-making transcend all the echelons of the agri-food supply chain, since transportation is one of the key logistics operations that determines the operational efficiency, the effectiveness, the cost and the environmental impact of the system. The optimization of the transport system of AFSCs has been addressed by many researchers in literature. For example, Higgins et al. (2004) propose a modeling framework
to improve the efficiency of both the harvesting and transport operations, while they present two real-world case studies motivated by the Australian sugar industry. Higgins (2006) developed a mixed integer programming model for scheduling road transport vehicles in sugarcane transport, while Han and Murphy (2012) developed an optimization model to solve a truck scheduling problem for transporting four types of woody biomass in western Oregon. Ravula et al. (2008b) simulated the transportation system of a cotton gin, using a discrete event simulation model, to determine the operating parameters under various management practices, while they provide a comparison between two policy strategies for scheduling trucks in a biomass logistics system (Ravula et al., 2008a).

More specifically, agricultural fleet management regards resource allocation, scheduling, routing, and real-time monitoring of vehicles and materials that is mostly undertaken by farmers or machine contractors. Intensive agricultural production systems involve complex planning and coordination of field operations, mainly due to uncertainties associated with yield, weather and machine performance. The planning of such operations in general involves four highly interconnected stages, namely harvesting, out-of-field removal of biomass, rural road transportation and public road transportation, supported by a corresponding machinery system (harvesters, transport units, medium and high capacity transport trucks, unloading equipment) (Sørensen and Bochtis, 2010). Current scientific research has contributed to the development of models for scheduling of field operations involving fleets of agricultural machines, with off-line management systems (e.g. Busato et al., 2007; Berruto and Busato, 2008; Higgins and Davies, 2005), with on-line planning (e.g. Bochtis and Vougioukas, 2007) or based on methods from other scientific areas (e.g. Guan et al. 2008). Indicatively, Sørensen and Bochtis (2010) propose a conceptual model of fleet management in agriculture that embeds amongst others on-line positioning of vehicles, machine monitoring/tracking, improved general knowledge of the production process and management, coordination of multiple machines, route and path guidance, etc. Jensen et al. (2012) present a path planning method for transport units in agricultural operations involving in-field and inter-field transports.

Vehicle routing in agricultural sector also constitutes a new challenging research field that has been implemented for the transportation of agricultural products (e.g. Sigurd et al., 2004; Ahumada and Villalobos, 2011; Zannoni and Zavanella, 2007), in food logistics applications (Tarantilis and Kiranoudis, 2004) analogous to other general commodities, or for in-field operations (Bochtis and Sørensen, 2009; 2010).

4. Summary & Conclusions

Supply chain management has emerged as an area of critical importance for the agri-food sector, since stakeholders involved in both the design and the execution of AFSCs are called to address systemically an array of decisions spanning all levels of the natural hierarchical decision-making process. To that effect, we first presented the generic system components along with the unique characteristics of agri-food supply chain networks that differentiate
them from traditional supply chains. Following that, we identified and discussed the most critical issues for the design and planning of AFSCs, as well as presented a taxonomy of the related existing state-of-the-art literature to identify major gaps and overlaps. These issues were further mapped accordingly on the natural hierarchy of the decision-making process.

This paper captures both the associated challenges and the complexity of the decision-making process for the design and planning of AFSCs. Our analysis demonstrates that supply chain management on the agri-food sector is a rapidly evolving research field currently tackling rather myopically key issues instead of adopting an integrated systemic approach that transcends all the echelons of the AFSC network.

More specifically, research on the selection of farming technologies has been quite significant. However, modern needs for maximization of mixed crop yield with parallel minimization of the incurred costs imply that further research in multi-period problems needs to be undertaken. Regarding financial planning and investments, an impressive number of scientific models using various mathematical approaches have been developed. However, the respective optimization criteria should be more clarified and embedded in a more generalized framework, since the provided research findings are mostly case-dependent.

Significant attention has been paid thus far to relationships among AFSC partners as well as to the relevant integration, coordination, collaboration, and contracting issues. More targeted research should be dedicated to the AFSC Supply Chain Network Configuration starting with tailoring the already developed general SC methodologies to AFSCs. In the field of AFSC Supply Chain Partners’ Relationships, there is a need for more practice-oriented integrated solutions that emphasize on the design of performance measurement systems and the communication of the obtained information. On the contrary, risk management in agri-food supply chains has attracted considerable attention and it appears that most of the contemporary risks have been tackled.

Regarding the transparency, traceability and food safety sector, ongoing, targeted research has been developed further supported by ICT innovation. Harvesting planning and fleet management have attracted academic scrutiny throughout all levels of the decision-making process. Finally, a significant gap in literature refers to the logistics operations (packaging, vehicle routing etc.) of agri-food-products, where a more in-depth research needs to be developed, especially for perishable goods.

We envision that the presented in this manuscript key issues along with the respective taxonomy will provide a guiding systemic framework for researchers and practitioners alike, in their evolving efforts towards the efficient development and management of AFSCs.

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