Food supply chain management: systems, implementations, and future research

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Abstract

Purpose – The purpose of this paper is to review the food supply chain management (FSCM) in terms of systems and implementations so that observations and lessons from this research could be useful for academia and industrial practitioners in the future.

Design/methodology/approach – A systematical and hierarchical framework is proposed in this paper to review the literature. Categorizations and classifications are identified to organize this paper.

Findings – This paper reviews total 192 articles related to the data-driven systems for FSCM. Currently, there is a dramatic increase of research papers related to this topic. Looking at the general interests on FSCM, research on this topic can be expected to increase in the future.

Research limitations/implications – This paper only selected limited number of papers which are published in leading journals or with high citations. For simplicity without generality, key findings and observations are significant from this research.

Practical implications – Some ideas from this paper could be expanded into other possible domains so that involved parties are able to be inspired for enriching the FSCM. Future implementations are useful for practitioners to conduct IT-based solutions for FSCM.

Social implications – As the increasing of digital devices in FSCM, large number of data will be used for decision-makings. Data-driven systems for FSCM will be the future for a more sustainable food supply chain.

Originality/value – This is the first attempt to provide a comprehensive review on FSCM from the view of data-driven IT systems.

Keywords Case studies, Food supply chain management, Review, Data-driven systems, Implementations, IT systems

Paper type Literature review

1. Introduction

Food industry plays an important role in providing basics and necessities for supporting various human activities and behaviors (Cooper and Ellram, 1993). Once harvested or produced, the food should be stored, delivered, and retailed so that they could reach to the final customers by due date. It was reported that about one-third of the produced food has been abandoned or wasted yearly (approximately 1.3 billion tons) (Manning *et al.*, 2006). Two-third of the wasted food (about 1 billion tons) is occurred in supply chain like harvesting, shipping and storage (Fritz and Schiefer, 2008). Take fruit and vegetables for example, such perishable food was wasted by 492 million tons worldwide in 2011 due to the

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inefficient and ineffective food supply chain management (FSCM) (Gustavsson *et al.*, 2011). Therefore, FSCM is significant to save our food.

FSCM has been coined to depict the activities or operations from production, distribution, and consumption so as to keep the safety and quality of various food under efficient and effective modes (Marsden *et al.*, 2000; Blandon *et al.*, 2009). The differences of FSCM from other supply chains such as furniture logistics and supply chain management are the importance reflected by factors like food quality, safety, and freshness within limited time, which make the underlying supply chain more complex and difficult to manage (La Scalia *et al.*, 2016). The complexities are significant in the case of perishable products where their traversal time through FSCM and the use warehouses or buffers against demand and transportation variability are severely limited. Additionally, as the coordination from worldwide scale, the complexities have been compounded, thus, the focus from a single echelon such as food production was shifted to the efficiency and effectiveness of holistic supply chain. That means the resources like trucks, warehouse facilities, transportation routes, and workers within the food supply chain will be used efficiently so as to ensure the food quality and safety through effective efforts such as optimization decisions (Wu, Liao, Tseng and Chiu, 2016).

As the development of cutting-edge technologies, FSCM has been widely recognized both by practitioners and academia. Information technology (IT) has brought dramatic improvements to FSCM in terms of automatic food processing like cleansing and packing as well as freshness storage (King and Phumpiu, 1996; Caswell *et al.*, 1998; Wang *et al.*, 2015). However, the discipline of FSCM is still incapable of addressing many practical real-life challenges satisfactorily. The reasons for the inadequacy are attributed to low operational levels from farmers (Folkerts and Koehorst, 1997), information obstacle among different stakeholders (Caswell *et al.*, 1998), and inefficient decision-making systems/models (Ahumada and Villalobos, 2009). Strategic decision-makers require comprehensive models to increase total profitability while data input into those models are usually ignored in most of traditional myopic models. In order to address current challenges, it is necessary to investigate better approaches to accommodate emerging global situations after taking a critical look at the current FSCM practices and conditions.

This paper selects total 192 articles from 1993 to 2017 by searching the key word "FSCM" in Google Scholar (until November 2016). Special concentration is placed upon the data-driven IT systems which are used for facilitating the FSCM with particular aims of re-designing and re-rationalizing current supply chain to a globally integrated fashion for food industry. Among these articles, there are seven reports from website, 25 papers are case studies, and the others are typical research papers related to FSCM. Most of these reviewed papers are from leading journals such as *International Journal of Production Economics* (19), *European Journal of Operational Research* (4), *Journal of Cleaner Production* (10), *Food Control* (13), *Supply Chain Management: An International Journal* (7), *Journal of Operations Management* (3), *British Food Journal* (4), etc. Figure 1 presents the selected papers in a yearly view. As demonstrated, there is only a few studies about data-driven IT systems in FSCM in early 1990s. Then, the related papers are fluctuated slightly from 2000 to 2014. Currently, as showing from the prediction curve, there is a dramatic increase of research papers related to this topic. Looking at the general interests on FSCM, the quantity can be expected to increase in the future.

This paper categorizes related topics in a hierarchical organization. Figure 2 presents the scope of the review that each focus is dissected to organize this paper. Section 2 talks about the supply chain management for food industry that covers three themes such as frameworks, models, and worldwide movement. Section 3 presents two major IT systems – traceability systems and decision-making systems for FSCM. Section 4 demonstrates FSCM implementations in terms of reported cases and data-driven applications. Section 5 summarizes the current challenges and future perspectives in

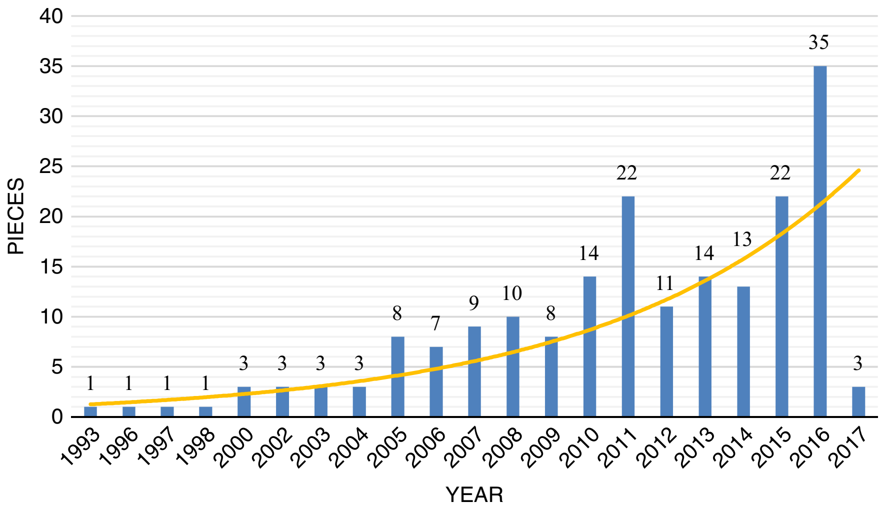

Figure 1. Number of articles in a yearly view

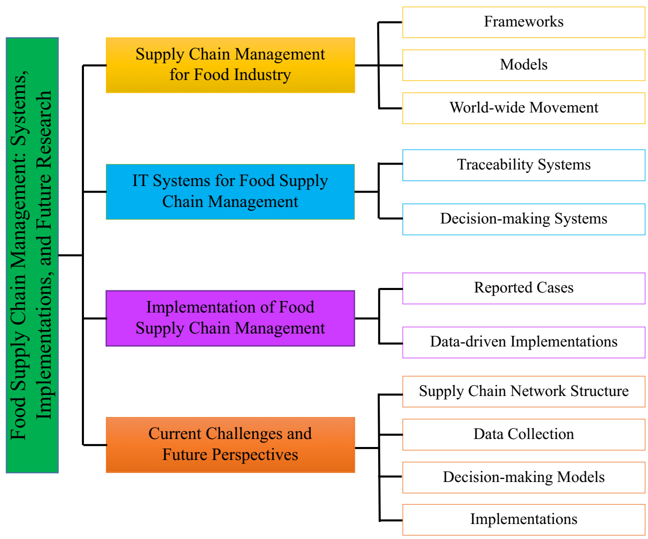

Figure 2. Organization of this review paper

four aspects: supply chain network structure, data collection, decision-making models, and implementations. Section 6 concludes this paper through identifying some insights and lessons from this investigation.

2. Supply chain management for food industry

2.1 Frameworks

A framework for FSCM is a basis for manufacturing, processing, and transforming raw materials and semi-finished products coming from major activities such as forestry, agriculture, zootechnics, finishing, and so on (Dubey *et al.*, 2017). In order to identify the relationships among different items, interpretive structural modeling (ISM) was used to establish a hierarchical framework (Faisal and Talib, 2016). This framework helps users to understand the interactions among logistics operators in a food supply chain. ISM-enabled framework was also used to support risk management in identifying and interpreting interdependences among food supply chain risks at different levels such as first-tier supplier, third-party logistics (3PL), etc. (Colin *et al.*, 2011). It is observed that this framework was proven as a useful method to structure risks in FSCM through a step-by-step process on several manufacturing stages. Information plays an important role in making FSCM more efficient. In order to assess the information risks management, an ISM based framework was proposed by twining graph theory to quantify information risks and ISM to understand the interrelationships in FSCM (Nishat Faisal *et al.*, 2007). As the global FSCM is emerging with international collaborations, ISM-enabled framework confines to explain causal relationships or transitive links among various involved parties. A total interpretive structural modeling was then introduced to analyze some enablers and barriers of FSCM (Shibin *et al.*, 2016). In this paper, ten enablers and eight barriers are examined by separate frameworks to further understand the interactions within a dynamic era of globalization FSCM.

Value chains play a critical role in FSCM to benefit the producers and consumers. Stevenson and Pirog (2008) introduced a value chain framework for strategic alliances between food production, processing and distribution which seek to create more value in the supply chain. The proposed framework concerns about food supply chain economic performance that correspond to the organization, structure, and practices of a whole supply chain. Food traceability has been widely used in the last few decades with large number applications. However, frameworks for a general or common implementation are scarcely reported. To label whether a framework with respect to food traceability application, Karlsen *et al.* (2013) observed that with a common framework, traceability is prone to be similar and implementation processes are more goal-oriented and efficient. Thus, Regattieri *et al.* (2007) presented a general framework and used experimental evidence to analyze legal and regulatory aspects on food traceability. They designed an effective traceability system architecture to analyze assessment criteria from alphanumerical codes, bar codes, and radio frequency identification (RFID). By integrating alphanumerical codes and RFID technology, the framework has been applied for both cheese producers and consumers.

Currently, coordination in the food supply chain from production to consumption is significant to ensure the safety and quality of various food. Take agri-food supply chain for example, Hobbs and Young (2000) depicted a conceptual framework to achieve closer vertical collaboration in FSCM using of contracting approaches. This work has critical impacts on transaction cost economics by developing a closer vertical coordination. In an international food supply chain, Folkerts and Koehorst (1997) talked about a framework which integrates the chain reversal and chain management model to make vertical coordination. In their framework, an analytical service designed particularly for benchmarking food supply chain projects is used so that an interconnected system of high performance and effectiveness are achieved as an integrated supply chain. Facing a global FSCM, strategic decision-making is important since the profitability of an entire chain could be increased by the holistic efforts from an efficient framework. To this end, Georgiadis *et al.* (2005) presented a system dynamics modeling framework for the FSCM. In this framework, end-users are able to determine the optimal network configuration, inventory management policy, supply chain integration, as well as outsourcing and procurement strategies. Collaboration is becoming more of a necessity than an option despite some barriers which deteriorate coordination among enterprises in food industry all over the world. Doukidis *et al.* (2007) provided a framework to analyze supply chain collaboration in order to explore a conceptual landmark in agri-food industry for further empirical research. It is observed that, from this framework, supply chain collaboration is of critical importance and some constraints such as time and uncertainties arise due to the nature of agri-food industry.

2.2 Models

Globalization of food production, logistics and consumption have resulted in an interconnected system for FSCM whose models play crucial role in ensuring food products of high and consistent safety and quality (Choi *et al.*, 2016). In this section, we present related work using various models for considering five major aspects like food quality, supply chain efficiency, food waste, food safety, and value chain analysis. An incomplete list of the leading authors covering these five aspects is shown in Table I. In order to better demonstrate the literature, key contributions for each paper are highlighted at the last column.

From Table I, it could be observed that food quality, supply chain efficiency and food safety are more concerned in these models. And multi-objectives are commonly considered, for example, food quality and safety are integrated in the decision models. However, food waste is specifically looked at without twining with other aspects. Recently, supply chain efficiency and value chain analysis are placed special emphasis since the global FSCM is becoming more and more significant.

2.3 Worldwide movement

Current movements on FSCM from major districts are presented in this section which covers Europe, North America, and Asia Pacific.

2.3.1 Europe. The food industry is the EU's largest sector in terms of employed people and value added. From one report about the data and trends of EU food and drink industry 2014-2015, the employment is 4.2 million people with 1.8 percent of EU gross value added and the turnover is €1,244 billion (FoodDrinkEurope, 2015). The turnover is increased by 22.32 percent compared with that from the year 2011 (€1,017 billion). Despite the significant increase of turnover, European Commission recently pointed out that the EU food industry is facing a decrease in competitiveness caused by a lack of transparency in food supply chain (European Commission, 2016). In order to enhance global competitiveness, in November 2011, 11 EU organizations like AIM, FoodDrinkEurope, European Retail Round Table (ERRT), CEJA, EuroCommerce, Euro Coop, Copa Cogeca, etc. signed a Supply Chain Initiative document which is based on a set of principles of good practice. After two years, seven EU level associations agreed to implement the principles which have been converted into 23 languages.

Retailers play important roles in FSCM since they are selling thousands of different products each of which has its own supply chain with distinct features and complexities. ERRT, an organization including the CEO's of Europe's leading international retail companies conducted a framework of the EU High Level Forum for a better food supply chain that often involves large number of business partners. Under the framework, leading retailers are going to build up a well-functioning and competitive supply chain in maintaining good relationships with their suppliers so as to bring the best and most innovative foods and drinks to the customers (ERRT, 2013). Retailers in EU are also aware that it is their environmental responsibilities to delivery of foods via a more sustainable model by contacting with consumers and suppliers. Thus, in March 2009, in response to the European Commission's Action Plan on Sustainable Consumption and Production, ERRT set up the Retailers Environmental Action Programme (REAP) which aims to reduce environmental footprint in the food supply chain. REAP not only facilitates the sustainability dialogue with food supply chain key stakeholders, but also stimulates retailers to adopt new FSCM models (European Commission, 2015).

Model	Food quality	Supply chain efficiency	Food waste	Food safety	Value chain analysis	Contributions
Caswell *et al.* (1998)	X	X				Proposes a Metasystems-enabled model Enhances product quality Considers the transaction costs and system efficiencies
Vorst (2000)		X				Introduces a KPIs-based model Assessment of the key impact factors in FSCM
Reiner and Trcka (2004)		X				Introduces an improved product-specific supply chain design model Enhances the performance
Gorris (2005)				X		Introduces a food safety objective model Concerns operational food safety management at different food chains
Beulens *et al.* (2005)	X	X		X		Introduces a network-based supply chain model Improves the products quality, safety and food chain transparency
Taylor (2005)			X		X	Applies lean value chain improvement Proposes a value stream analysis (VSA) model Uses a multi-echelon structures
Kim *et al.* (2006)			X			Presents a modified three-stage methane fermentation model Reduces the food waste
Manning *et al.* (2006)	X	X				Introduces an organizational business model Analyzes the efficiency in the integrated FSCM
Aramyan *et al.* (2007)		X				Illustrates a performance measurement Uses a balanced scorecard model Proposes applicable performance appraisal indicators
Trienekens and Zuurbier (2008)	X			X		Concern marginal costs and standards Revalue the cost/effectiveness of the food production
Oliva *et al.* (2008)	X					Introduces a system dynamic model Ensures the food quality
Akkerman *et al.* (2010)	X	X		X		Reviews the literature on related models in strategic network design, tactical network planning, and operational transportation planning
Ruiz-Garcia *et al.* (2010)	X		X			Establishes an architectural model Keep the quality and reduce waste
Parfitt *et al.* (2010)			X			Uses a data model Examines losses at immediate post-harvest stages
Marucheck *et al.* (2011)				X	X	Presents the operation management theory models and methodologies Examines food safety and values in FSCM
Garnett (2011)					X	Introduces a model to estimate food-related greenhouse gas emission Improves the total value of food supply chains

Table I.
List of models for FSCM

(*continued*)

Model	Food quality	Supply chain efficiency	Food waste	Food safety	Value chain analysis	Contributions
Wu and Pagell (2011)					X	Proposes a theory-building model Balances short-term profitability and long-term environmental sustainability
Gustavsson *et al.* (2011)			X			Introduces a hierarchical model Analyzes the food waste within a whole food supply chain
Rong *et al.* (2011)	X					Proposes a decision-making model Uses a mixed-integer linear programming model
Zarei *et al.* (2011)		X			X	Uses quality function deployment model Improves the efficiency and increases the food value chain
Zhang and Li (2012)				X	X	Analyzes an agri-food supply chain management Optimizes internal costs and productivities
Kummu *et al.* (2012)			X			Presents a data analytic model Conducts food waste Examines food wastes' influences on freshwater, cropland, and fertilizer usage
Zanoni and Zavanella (2012)		X				Proposes a joint effects model Considers different objective functions
Yu and Nagurney (2013)					X	Proposes a network-based FSCM model Increases the value chain
Aung and Chang (2014)	X			X		Presents an information-based traceability model Considers safety and quality in the food supply chain
Meneghetti and Monti (2015)				X	X	Introduces an optimization model Considers specific characteristics Increases the whole cold chain value
Chadderton *et al.* (2017)		X	X			Introduces a decision support model Considers site-specific capabilities and supply chain efficiency
Eriksson *et al.* (2016)			X			Proposes an environmental and economic model Enhances the biogas production from food waste

Table I.

Logistics is a bridge between food retailers and manufacturers. It was reported that, in 2012, there were 24 million people employed in the food supply chain and 21 percent of the employment comes from logistics-related companies (European Commission, 2016). European Logistics Association (ELA) is a federation with over 30 organizations from Central and Western Europe. Recently, in order to achieve green logistics, ELA developed a sustainable supply chain scheme for FSCM (ELA, 2012). From economic, environmental, and social perspectives, this scheme focuses on realistic financial structure, sustainable FSCM, and successful cases implementation which are should be truly sustainable. Take European Logistics Hub, Limburg – a province in the south of the Netherlands for example, high developed logistics facilities and modern logistics infrastructures offer an advanced logistics with lowest supply chain costs and environment impacts (Hemert and Iske, 2015).

Food production as source of FSCM is extremely important in Europe since about 9.12 million people were employed in agricultural industry including planting, harvesting, and so on. There are approximately 1,700 food manufacturers from 13 European countries. European Federation of Associations of Health Product Manufacturers (EHPM) aims to develop a sort of regulatory frameworks throughout the EU for health and natural food. Recently, EHPM is in support of producing the harmonization of health, safety, and qualified aspects for food supplements through an optimization of positive economic impacts on Food Supplements sector in the EU market (EHPM, 2013). Advanced technologies bring large benefit to food industry globally. A food Tech innovation Portal was launched by European Commission to apply innovative technology, such as biotechnology, nanotechnology and information and communications technology (ICT) to help food manufacturers to provide more health, safe, and natural foods (European Commission, 2014).

2.3.2 North America. North America is the second largest food industry in the world with a turnover of about €650 billion in 2013. Take USA for example, from an incomplete report in 2013, there were 40,229 grocery stores with $634.2 billion in revenues, 154,373 convenience stores with $165.6 billion annual sales, and 55,683 non-traditional food sellers with $450 billion turnover (Global Strategy, 2013). Consisting of multi-tiered food supply chains in North America, FSCM is both large and complex so that innovations are highlighted in food industry to meet the steady growing rate of 2.9 percent yearly.

Companies from North America are aggressively viewing new food market with large numbers of potential consumers. Thus, a far reaching and more sophisticated food supply chain is prone to risks caused by disrupted disasters, oil prices' fluctuations, and political upheavals, which greatly influence food production and transportation (Lan *et al.*, 2016). Using advanced technologies such as bio-tech and ICT, food production and harvesting are innovatively improved (Fraser *et al.*, 2016). Genetically modified organisms for instance with higher productivity and stronger anti-viruses are used in plants, mammals, fish, etc. (Hemphill and Banerjee, 2015).

For innovative warehousing of food, robotics and automation have been adopted in North America in food and beverage supply chain. Given the improved efficiencies in terms of sorting, packing, and processing, funding sources, in recent years, have invested in warehouse automation significantly. In 2012, the US Government granted $50 million to research institutes and universities for robotics aligning with creation of the next generation of collaborative robots from the Obama administration's National Robotics Initiative (Pransky, 2015). With the assistance from robots, warehouses for food and beverage are the most technologically advanced for facilitating FSCM.

Logistics and transportation are innovatively improved from improving the railroad, flight routes, marine and land roads. North America has the comprehensive and satisfactory logistics network. Currently, Genesee & Wyoming Inc. agreed to acquire Providence and Worcester Railroad Company (P&W) for approximately $126 million to meet customary closing conditions following the receipt of P&W shareholder approval in the fourth quarter of 2016 (BusinessWire, 2016). 3PL plays a major role in food supply chain. The top 3PL and cold storage providers in 2016 are AFN, Niles, Ill., Allen Lund Company, La Canada, Calif., and Americold, Atalanta, Ga. who are the top listed companies using latest technologies in transportation management systems, warehouse management systems (WMSs), and logistics scrutiny systems for a better food supply chain services.

2.3.3 Asia Pacific. China, as the third food and drink producer has a turnover of €767 billion in 2011 which is the largest food entity in this area (European Commission, 2016). As the biggest country in Asia pacific, China has around 400,000 food-related companies. Japan with €466 billion turnover between 2012 and 2013 employs 1.4 million workers.

India, Australia, South Korea, and New Zealand, as major food producers in this area, their turnovers (2012-2013) are 95, 62, 32, and 27 billion Euro, respectively. It is no debate that this area is the most important food and beverage supplier from its enormous turnovers. However, FSCM in this area is mainly based on sacrificing manpower, for example China used 6.74 billion employees to achieve the total turnover, which is one-third more people than that in the EU.

With small margins attainable in most links of food supply chain in Asia Pacific, consolidation across various food categories and levels of the FSCM was necessary to reduce cost and maximize profits. To this end, a robust logistics and FSCM network program was initiated to enhanced focus on food availability and growing number of organized retail outlets for food supply chain development (Simatupang and Sridharan, 2002). Take India for example, the government proposed a multi-tiered network design plan which upgrade current city/urban and rural supply chain to hyper/mega centers, urban, semi-urban, and rural structure in 2025 by full use of automation, verticalization, and lean principles as well as 3PL innovations (Venkatesh *et al.*, 2015). Thus, organizations in India are going to rethink their mega food center supply chain models so as to handle higher variety and faster transitions within food supply chain. Yeole and Curran (2016) used tomato post-harvest loses from Nashik district of India for example to demonstrate reduced intermediaries in the supply chain network will save the losses. Additionally, supply chain operations like improper packaging techniques and lack of cold storage facilitates are need to be improved for the network.

Chinese-made food products are prone to be low price, low quality, and low safety (Roth *et al.*, 2008). The main reason is the weak management in food supply chain. Despite China has the largest number of food companies, most of them are small and medium-sized enterprises (SMEs) which are extremely difficulty for the government to manage. Currently, Chinese Government proposed a set of regulations for ensuring the food safety from various aspects such as GB (Guo Biao – a national standard). Moreover, after some significant food scandals, Chinese Government put more efforts on the supervision of the food manufacturing and distribution (Lam *et al.*, 2013). Food logistics facilities are also concentrated on from both government and companies since China's connections to global food markets have important effects on food supply. Unfortunately, weak implementations are needed to be improved although the government has depicted to strength regulation, establish scrutiny systems, reform laws, and increase investment on basic infrastructures in FSCM. It is still far to say Chinese foods are low price, high quality and high safety.

Japan and South Korea always follow the strict monitoring within the total FSCM because they believe that their foods represent their culture. Thus, a food-obsessed country like Japan or South Korea uses national natural cuisine uniquely to reflect the pure environment. Since global integration of food supply chain, companies from both countries adopted supply chain strategies to improve relationship between diversification and a firm's competitive performance (Narasimhan and Kim, 2002). Food supply chain facilitates from both countries in production, warehouse, and distribution maybe the best in Asia Pacific. Take Japan for example, fishing industry plays an extremely crucial role in Japanese culture. Due to limited space for refrigerators and food storage spaces, its fish supply chain uses time-constraint multiple-layered supply chain network to guarantee freshness and quality (Watanabe *et al.*, 2003). Recently, these countries moved into a smart FSCM using advanced technologies such as Internet of Things (IoT). Different types of sensors are used to facilitate various operations within entire food supply chain (Park *et al.*, 2016).

Australia and New Zealand, as major food suppliers for the world, have mature FSCM in terms of consolidation of food industry partners and supply chain integrations. Australia proposed a green supply network where the consumers are able to seek to secure food

(Smith *et al.*, 2010). Recently, the Commonwealth Scientific and Industrial Research Organization launched a digital agriculture plan to help Australian farmers and food industry parties to improve productivity and sustainability. Smart solutions for modern farming and FSCM are placed on specific attention by developing information systems which are used for ingesting, processing, summarizing, and analyzing data from multiple sensor systems (Devin and Richards, 2016). New Zealand with its clean waters, fertile land, and excellent climate is a heaven for producing quality foods. This country is famous for its highly skilled workforce who is generating thousands of foods for the whole world with high standards in food quality and freshness (Campbell *et al.*, 2006). Besides skilled workers, efficient and effective FSCM also makes the great success of food industry which is the largest manufacturing sector in New Zealand. The Ministry for Primary Industries is the primary food safety regulating authority in New Zealand, aiming to ensure food quality, safety, and reduce risks. Currently, New Zealand planned to take the leading role in global food security by adopting cutting-edge technologies such as Auto-ID which is a key technology of IoT for tracking and tracing animal products like cows and sheep (Ghosh, 2016). As a result, food products from this country could be monitored from sources to consumption phase, which makes real total lifecycle management for each food.

3. IT systems for FSCM

It is no debate that IT systems are essential for FSCM where so many things can go wrong such as trucks, food suppliers, data entry, etc. This section takes the traceability and decision-making systems for FSCM as examples to review the state-of-the-art situations that are useful for practitioners when they are implementing IT-based solutions.

3.1 Traceability systems

Traceability of a food refers to a data trail which follows the food physical trial through various statuses (Smith *et al.*, 2005). As earlier as two decades ago, US food industry has developed, implemented, and maintained traceability systems to improve FSCM, differentiate foods with subtle quality attributes, and facilitate tracking for food safety (Golan *et al.*, 2004a). Some systems deeply track food from retailer back to the sources like farm and some only focus on key points in a supply chain. Some traceability systems only collect data for tracking foods to the minute of production or logistics trajectory, while others track only cursory information like in a large geographical area (Dickinson and Bailey, 2002).

This section analyzes total 19 key papers published from 2003 to 2017. Table II presents a categorized analysis in terms of tracing objects, technology, district, and features.

From Table II, it could be observed that food traceability is paid much attention from EU where people do care more about the food safety and quality. Associated technologies are developing fast so that cutting-edge techniques are widely used for various food tracing and tracking. Take RFID for example, 73.68 percent of the reviewed papers adopt this Auto-ID technology for food traceability. Moreover, agri-foods are placed special attention to trace and track because as the most important perishable products, their freshness and quality are eyed by the consumers.

3.2 Decision-making systems

Besides the traceability systems in FSCM, other decision-makings such as integration/collaboration, planning/scheduling, fleet management, and WMS are also widely used in food industry. This section presents a review of total 26 papers which are related to the above topics. Table III reveals these papers from 2005 to 2007 with specific decisions, countries/area (identified by the corresponding author), used technologies, and features.

Systems	Tracing objects	Technology	District	Features
Kelepouris *et al.* (2007)	Batched foods	RFID	UK	This paper outlines both an information data model and a system architecture that make traceability feasible in a food supply chain
Angeles (2005)	Biscuits, cakes, prepared foods	RFID	UK	Implementation guidelines for managers are summarized to conduct real-time visibility into supply chains
Opara (2003)	Agri-food	EID GIS	Oman	This paper introduces technological challenges in implementing traceable agricultural supply chain management
Hu *et al.* (2013)	Vegetable	UML RFID	China	A systematic methodology for implementing vegetable supply chain traceability is presented
Dabbene and Gay (2011)	Batched food	Barcode RFID ICT	EU	Novel criteria and methods for measuring and optimizing a traceability system are introduced
Bosona and Gebresenbet (2011)	Agri-food	Barcode EID Tag EDI GIS	EU	This paper points out that the full understanding of food supply chain is important to conduct food traceability
Hsu *et al.* (2008)	Fish	RFID CRM	Taiwan	A RFID-enabled traceability system for live fish supply chain is presented
Bertolini *et al.* (2006)	Durum wheat pasta	FMECA	EU	An industrial engineering tool "Failure Mode Effect and Criticality Analysis" (FMECA) is used for critical points tracing
Patterson *et al.* (2003)	Perishable food	RFID Barcode Geo-Coded	USA	This paper proposes a model to examine the key factors which are greatly influence the supply chain technology adoption
Regattieri *et al.* (2007)	Italian cheese	RFID Alphanumerical Codes, Barcode	EU	This paper provides a general framework for the identification of key mainstays in a traceability system
Golan *et al.* (2004b)	Agri-food	Electronic coding system	USA	This paper examines the US food traceability systems in agriculture supply chain management
Gianni *et al.* (2016)	Agri-food	BI IMS	EU	This paper proposes a business intelligence (BI) wise solution using integrated management systems (IMS) approach
Pizzuti *et al.* (2014)	Agri-food	RBV Communication	UK	This paper introduces a framework using resource based view (RBV) to examine strategic impacts of food traceability system technologies
Kondo (2010)	Fruits and vegetable	Machine vision Near infrared inspection	Japan	This paper presents an automation technology-based system for fruit and vegetable traceability
Choe *et al.* (2009)	Agri-food	Barcode RFID IT	South Korea	This paper presents an uncertainty mitigation approach in the context of the food traceability system
Thakur *et al.* (2011)	Fish	EPCIS UML	Norway	EPCIS framework and UML statecharts are used for modeling traceability information in FSCM
Badia-Melis *et al.* (2015)	Wheat flour	RFID Cloud Computing	EU	This paper introduces latest technological advancements in food traceability systems
Muñoz-Colmenero *et al.* (2017)	Candies	PGM PCR-CS	EU	This paper uses Ion Torrent Personal Genome Machine (PGM) in analyzing candies supply chain
Dabbene *et al.* (2016)	Agri-food	RFID Barcode Big Data	EU	This paper introduces a latest technologies for food traceability systems

Table II. Traceability systems for FSCM

Systems	Decisions	Technologies	Area	Features
Vorst *et al.* (2005)	Logistics network integration	ICT	The Netherlands	Innovative developments of physical means, human skills and competences are integrated with ICT for enhancing logistics network integration
Henson and Reardon (2005)	Supply chain coordination	Internet-based IT	Canada	For ensuring private food safety and quality, an internet-based system is designed to achieve supply chain coordination
Maloni and Brown (2006)	Supply chain co-operation	Internet-based framework	USA	An internet-based framework using corporate social responsibility is used in the food supply chain for various co-operation
Taylor and Fearne (2006)	Planning scheduling	Data-based framework	UK	A data-enabled framework is built to improving demand management within a number of food supply chain
Attaran (2007)	Transportation Fleet	RFID Internet	USA	An RFID-enabled system is used to improve the food retailer supply chain
Baker *et al.* (2007)	Fleet Scheduling	Optimization Heuristic	Australia	A fleet optimization system is proposed to satisfy the constraints in FSCM
Bottani and Rizzi (2008)	Logistics Warehouse	RFID EPC	Italy	This paper introduces an RFID and EPC system for fast-moving consumer goods (FMCG) supply chain management
Tsoulfas and Pappis (2008)	Supply chain performance	Modeling	Greece	A model based decision system is proposed to analyze the environmental performance indicators in FSCM
Vorst *et al.* (2009)	Logistics integration	Simulation	The Netherlands	A new simulation environment is introduced to support integrated food supply chain to deal with uncertainties
Peidro *et al.* (2009)	Planning	Fuzzy model	Spain	A fuzzy model is introduced for food supply chain planning by considering supply demand and process uncertainties
Kuo and Chen (2010)	Warehouse distribution	Internet Mobile APP RFID	Taiwan	A logistics service based on the advancement of multi-temperature joint distribution system (MTJD) is proposed for food cold chain
Hsiao *et al.* (2010)	Supply chain outsourcing	Hierarchical framework	Taiwan	A system for supply chain outsourcing decision-making is introduced for food manufacturers
Ali and Kumar (2011)	Supply chain collaboration	ICT	India	ICT is used in enhancing the decision-making across the agricultural supply chain
Knemeyer and Naylor (2011)	Logistics integration	Behavioral model	USA	A behavioral system is used to make logistics and supply chain decisions to achieve integrated FSCM
Wang and Li (2012)	Warehouse Logistics	Data-based modeling Tracing	UK	An information system is used for perishable food supply chains by using data captured from trace technologies
Trienekens *et al.* (2012)	Transparency Logistics	Integrated information	The Netherlands	An integrated information system using intensified data exchange is used in complex dynamic FSCM
Kannan *et al.* (2013)	Supplier selection	Fuzzy technique	Denmark	An integrated approach with fuzzy multi attribute utility theory and multi-objective modeling is proposed for decision-making in FSCM
Zheng and Ling (2013)	Planning	Fuzzy Optimization	China	A multi-objective fuzzy optimization system is proposed for transportation planning in FSCM

Table III.
Decision-making systems for FSCM

(*continued*)

Systems	Decisions	Technologies	Area	Features
Validi *et al.* (2014)	Distribution	Multi-objective GA	Ireland	A distribution system is proposed using optimization demand for two-layer FSCM
Agustina *et al.* (2014)	Vehicle scheduling Logistics	Modeling Optimization	Singapore	A distribution system is presented for food supply chains to make vehicle scheduling and routing decisions
Sitek and Wikarek (2015)	Logistics sustainability	Hybrid Modeling Optimization	Poland	A system uses hybrid framework and optimization approaches for sustainable FSCM
Kilger *et al.* (2015)	Collaborative planning	Multi-objective Modeling Internet	Germany	A planning system is introduced for the food supply chain to achieve collaborative processes
Govindan and Sivakumar (2016)	Supplier selection Coordination	Fuzzy Multi-objective Modeling	Denmark	A fuzzy technique based system is used for supplier selection in FSCM to achieve coordinated operations
Wang *et al.* (2016)	Sustainability Logistics	Trial-based Modeling	China	A system using decision-making trial and evaluation laboratory approach is used for FSCM
Pizzuti *et al.* (2017)	Logistics Integration	Ontology	Italy	An ontology-based system is used for supporting meet logistics management
Gunasekaran *et al.* (2017)	Sustainability Resilience	Big Data Framework	UK	A Big Data Analytics system is used for examine resilience in FSCM

Table III.

We selected two typical publications in each year for forming Table III from which several observations could be achieved. First, European countries are prone to be more use of systems to assist decision-makings in FSCM. Second, systems used in earlier stage are based on internet solutions. Currently, model-based systems using advanced technologies are widely reported in FSCM decision-makings. Third, focuses of decision-making shift from supply chain integration in earlier years to sustainable and specific problem solving cases in recent years.

4. Implementation of FSCM

4.1 Reported cases

Case studies from implementing various IT systems in FSCM are significant to get some lessons and insights, which are meaningful for industry practitioners and research academia. This section reports several cases using different systems for facilitating their operations or decision-makings in food supply chain from 2007 to 2017. They are categorized in the following Table IV which includes key information like company name, district, system, and improvement.

From the reported cases, it could be observed that, European countries have much more successful cases on using various IT support systems in FSCM. While, cases from Australia, China, etc. are scarcely presented. Another interesting finding is that before 2010, IT systems are used for optimization or supply chain coordination decision-makings. However, currently, companies are more concentrating on the sustainability and environmental performance in the food supply chain. For example, environmental influences like CO_2 emissions and waste reduction are widely considered.

4.2 Data-driven implementations

Data, usually used for decision-makings, have been considered in FSCM for various purposes. Data-driven implementation in FSCM is categorized into two dimensions in this paper.

Company	District	System	Improvement	Case
Tronto Valley	Italy	ARIS	Reduction of 3 types of costs Enhanced traceability	Bevilacqua *et al.* (2009)
A medium size company	Turkey	Risk management system	Order fulfilled on-time increases to 90.6% Risk mitigation increases 9.9%	Tuncel and Alpan (2010)
Parmigiana Reggiano	Italy	Traceability system	Improved traceability Enhanced customer satisfaction	Regattieri *et al.* (2007)
A tomato Firm	The Netherlands	Performance measurement system	Improved efficiency and flexibility Improved food quality Quicker responsiveness	Aramyan *et al.* (2007)
A food manufacturer	Japan	Customer co-operation system	Improved customer co-operation Enhanced internal environment management	Zhu *et al.* (2010)
Pizza restaurants	USA	TQM Lean/JIT	Improved information sharing Better quality Increased logistics efficiency	Pagell and Wu (2009)
Convenience stores	Taiwan	RFID-based food traceability system	Improved operations Strengthened tracking Better operational efficiency	Hong *et al.* (2011)
FoodRet	UK	Distribution management system	Improved corporation network Enhanced efficiency Reduced fuel consumption	Walker *et al.* (2008)
A leading retailer of food	USA	Risk management system	Improved risk management ability Consolidated coordination	Oke and Gopalakrishnan (2009)
Chicken and potato supply chains	UK	Sustainability assessment system	Improved supply chain efficiency Improved sustainability	Yakovleva (2007)
A fresh producer	Belgium	Food safety management system	Improved food quality Better risk management ability	Jacxsens *et al.* (2010)
SustainPack integrated project	Spain	Lifecycle management system	Reduced WIP Enhanced packaging Improved efficiency	Dobon *et al.* (2011)
Sanlu Group	China	Quality control system	Improved safety inspection More efficient control mechanisms	Chen *et al.* (2014)
A single company	Italy	LCA system	Higher specific production Improved ecoprofile of the crops	Cellura *et al.* (2012)
Agri-food supply chain	Australia	H&S food decision-making system	More healthy diet More environmental sustainability	Friel *et al.* (2014)
The Emilia-Romagna FSC	Italy	Distribution management system	Sustainable food chain Environmental food packaging	Accorsi *et al.* (2014)
6 Firms	Italy	FSCM system	Energy saving Avoided disposal cost Improved productivity	Sgarbossa and Russo (2017)
A beef logistics company	Netherland	Logistics network system	Reduced transportation emissions Sustainable logistics	Soysal *et al.* (2014)
A chestnuts company	Italy	Value chain management system	Improved sustainability Reduced CO_2 emission Increased value chain	Savino *et al.* (2015)
A mushroom manufacturer	The Netherlands	Supply chain management system	Increase total profitability by 11% Improved environmental performance	Banasik *et al.* (2017)

Table IV.
Reported cases using IT systems in FSCM

First is the simulation-based modeling which focuses on adopting different data for FSCM optimization or decision-making. The other is data collection from practical implementations for supporting IT systems for various purposes such as traceability, risk assessment, and so on.

For simulation-based modeling, studies mainly focus on establishing various simulation models which adopt different types of data such as product quality, customer demand for different decision-makings and predictions. In order to meet increasing demand on food attributes such as integrity and diversity, Vorst *et al.* (2009) proposed a simulation model which is based on an integrated approach to foresee food quality and sustainability issues. This model enables effective and efficient decision support on food supply chain design. FSCM is becoming more complex and dynamic due to the food proliferation to meet diversifying and globalizing markets. To make a transparent food supply chain, Trienekens *et al.* (2012) simulated typical dynamics like demand, environmental impacts, and social aspects to enhance the information sharing and exchanging. It is found that food supply chain actors should provide differentiated information to meet the dynamic and diversified demands for transparency information. As a wide application of Auto-ID technology for tracking and tracing various items (Zhong, Dai, Qu, Hu and Huang, 2013; Zhong, Li, Pang, Pan, Qu and Huang, 2013; Qiu *et al.*, 2014; Guo *et al.*, 2015; Scherhaufl *et al.*, 2015), traceability data plays an important role in supporting FSCM. Folinas *et al.* (2006) introduced a model which uses the traceability data for simulating the act guideline for all food entities in a supply chain. The assessment of information underlines that traceability data enabled by information flow is significant for various involved parties in food supply chain to ensure food safety. Wong *et al.* (2011) used a model to evaluate the postponement as an option to strengthen food supply chain performance in a soluble coffee manufacturer. The simulation model shows that cost savings including reduction of cycle stock are obtained by delaying the labeling and packaging processes. Bajželj *et al.* (2014) simulated the food demand to examine the impacts of food supply chain on climate mitigation. This paper proposes a transparent and data-driven model for showing that improved diets and reduced food waste are critical to deliver emissions reductions. Trkman *et al.* (2010) used a structural equation model based on data from 130 companies worldwide to examine the relationship between analytical capabilities in FSCM. It is observed that the information support is stronger than the effect of business process orientation in food supply chain. Data-driven model was also proposed by developing a measure of the captured business external and internal data for food productivity, and supply chain value (Brynjolfsson *et al.*, 2011). This paper obtains 179 firms' data from USA where 5-6 percent increase in their output and productivity by using IT solutions. Low and Vogel (2011) used a national representative data on local food market to evaluate the food supply chain where small and medium-sized farms dominate the market. This paper finds that direct-to-consumer sales of food are greatly affected by climate and topography which favor perishable food production. Akhtar *et al.* (2016) presented a model by using data collected from agri-food supply chains to examine adaptive leadership performance in FSCM. This paper thus depicts that how global food supply chain leaders can use data-driven approach to create financial and non-financial sustainability. Hasuike *et al.* (2014) demonstrated a model to simulate uncertain crop productions and consumers' demands so as to optimize the food supply chain profit. This simulation model is based on stochastic programming that accommodates surplus foods among stores in a local area. Manning *et al.* (2016) used a quantitative benchmarking model to drive sustainability in food supply chain. Li and Wang (2015) based on networked sensor data worked out a dynamic supply chain model to improve food tracking. Recently, Big Data is emerging as a crucial IT for instructing decisions in food supply chain. In order to differentiate and identify final food products, Ahearn *et al.* (2016) simulated environmental sustainability and food safety to improve food supply chain by using the consumer demands big data. This paper features a sustainability metric in agricultural production.

For practical data-driven system, various data are captured and collected to decision-makings in FSCM. Papathanasiou and Kenward (2014) produced a top level environmental decision support system by using the data collected from European food supply chain. It is found that socio-economic aspects have more influences on effective environmental decision support than technical aspects. Martins *et al.* (2008) introduced a shelf-life dating complex systems using sensor data to monitor, diagnose and control food quality. As the increasing focus on healthy diet, food composition and dietary assessment systems are significant for nutrition professionals. Therefore, Pennington *et al.* (2007) developed a system using the appropriateness of data for the intended audience. Most food and nutrition professionals will be beneficial from educating themselves about the database system. Perrot *et al.* (2011) presented an analysis of the complex food systems which are using various data such as supply chain dynamics, knowledge, and real-time information to make different decisions in FSCM. Tatonetti *et al.* (2012) illustrated a data-driven prediction system which is used for drug effects and interactions that US Food and Drug Administration has put great effects on improving the detection and prediction. Ahn *et al.* (2011), given increasing availability of information from food preparation, studied a data-driven system for flavor network and food pairing principles. Jacxsens *et al.* (2010) using actual microbiological food safety performance data designed a food safety management system to systematically detect food quality. The diagnosis is achieved in quantitative to get insight in the food businesses in nine European companies. Karaman *et al.* (2012) presented a food safety system by full using of data from plants where white cheese, fermented milk products and butter are produced. A case study from a Turkish dairy industry is demonstrated the feasibility and practicality of the presented system. In order to assess the lifecycle for sewage sludge and food waste, a system based on anaerobic codigestion of the organic fraction of municipal solid waste and dewatered sewage sludge was introduced (Righi *et al.*, 2013). Environmental performances of various scenarios in the NE Italy case studies are evaluated to show energy saving using the data-driven system. Jacxsens *et al.* (2011) introduced a sort of tools for the performance examination and improvement of food safety management system by the support of food business data. These tools are able to help various end-users to selection process, to improve food safety, and to enhance performance. Food safety management systems usually use traceability and status data to examine food quality and freshness. Tomašević *et al.* (2013) took the Serbian meat industry for example to report food safety management systems implementation from 77 producers. Laux and Hurburgh (2012) reported a quality management system using food traceability data like maintain records for the grain scrutiny. A traceability index is used to quantify a lot size of grain in an elevator in this paper. Herrero *et al.* (2010) introduced a revisiting mixed crop-livestock system using farms' data to achieve a smart investment in sustainable food production. By carefully consider the inputs of fertilizer, water, and feed, waste and environmental impacts are minimized to support farmers to intensify production. Tzamalis *et al.* (2016) presented a food safety and quality management system used in 75 SME by using the production data from the fresh-cut producing sector. This paper provides a best practice score for the assessment to ensure food quality and safety.

5. Current challenges and future perspectives

This section summarizes current challenges and highlights future perspectives in supply chain network structure, data collection, decision-making models, and implementations.

5.1 Supply chain network structure

Food quality and safety heavily rely on an efficient and effective supply chain network structure. As the increasing globalization demands for more healthy and nutritious food, current structure is facing several challenges. First, the concentration of design and development of a food supply chain network structure is placed upon a sole distribution system or a WMS. Mixed-integer linear programming models are widely used to suggest proper locations and distribution network configurations (Manzini and Accorsi, 2013). An entire and global structure is necessary. Second, optimizations are always considered within a network structure. However, the common considerations are planning, scheduling, profit and cost. Environmental impacts and sustainable performance are omitted. As increasing consumptions of various resources, a sustainable supply chain network structure considering waste reduction and greenhouse gas emissions is needed. Third, with the development of advanced technologies such as IoT, traditional network structure is no longer suitable for facilitating the food supply chain operations because large number of digital devices, sensors, and robots are equipped along the supply chain. Thus, an innovative and open structure for FSCM is required.

Future structure for food supply chain network will be focused on the following directions so as to address current challenges and meet future requirements:

- An integrated global architecture: the final goal of this architecture is to control global food chain in both optimal and interdependent levels to make involved stakeholders for a closed-loop management and scrutiny. For achieving this purpose, new conceptual frameworks, effective supporting tools, integrated models, and enabled technologies are needed further investigation (MacCarthy *et al.*, 2016; Talaei *et al.*, 2016).
- Sustainable food supply chain: in the future, sustainable business in food industry can be harvested by reducing the environmental impacts, enhancing food waste recycling, and strengthening facilities sharing. New mechanisms and coordinated development along with other industries like manufacturing and economy are basic supports for achieving the sustainability (Green *et al.*, 2012; Irani and Sharif, 2016; Lan and Zhong, 2016).
- Physical internet (PI) for FSCM: PI is an open global logistics system by using encapsulation, interfaces, and protocols to convert physical objects into digital items to achieve operational interconnectivity (Montreuil, 2011). Using the PI principle, FSCM for food handling, movement, storage, and delivery could be transformed toward global logistics efficiency and sustainability.

5.2 Data collection

Data-enabled decision-making plays an important role in FSCM so that without an approachable data collection method, it is difficult to carry out data-based analytics. Despite wide adoption of data collection approaches used in food supply chain, several challenges still exist so that data-driven decision-makings are confined. In the first place, manual and paper-based operations are common in food supply chain, especially in agri-food logistics. Data from these approaches are usually prone to be inaccurate and incomplete. As a result, decisions based on such data are unreasonable (Zhong *et al.*, 2016). Moreover, various data collection devices such as sensors, smart phones, and GPS have different data formats that are usually unstructured and heterogeneous. Integration and sharing of these data among the food supply chain are extremely difficult (Pang *et al.*, 2015). Finally, current data collection system cannot deal with huge number of data capturing in a simultaneous fashion. Due to the limited central calculation capacity and signal transmission methods, data collisions and jams could be happened occasionally.

Future data collection for food supply chain will be focused on the following dimensions which are featured by smart/intelligent devices:

- IoT-enabled smart data collector: this type of data collection method is based on IoT technologies like smart Auto-ID and smart sensors which are designed with multi-functional ability. They are able to collect data under different situations such as temperature-sensitive condition for perishable products or wines. Thus, they are designed in a wearable or flexible way to be easily deployed and operated (Wu, Yue, Jin and Yen, 2016). A certain learnable ability is built upon each collector which is central managed and controlled by a knowledge-enabled super computer that works as human brain to coordinate vast number of collectors.
- Adaptive smart robot: these data collectors are specially designed by twining robotics and smart sensors so that they are able to fulfill some operations and capture data in parallel. They are useful in some extremely hazardous environment like super low temperature for ice cream or frozen seafood. Such adaptive smart robot is based on advanced technologies which make it to perform like a human (Zhong *et al.*, 2016). It can sense environment and adaptively make decisions based on real-time data from the environmental variations.

5.3 Decision-making models

As more and more data aggregated in food supply chain, decision-making models require associated knowledge from such data for more precise and systematic resolutions. Traditional approaches packaged or embedded into decision-making models are not able to deal with Big Data challenges. First of all, decision-making models in FSCM need various data for different purposes such as optimization of planning and scheduling, reduction of waste, etc. However, computational time will be so long that immense data are input into these models. Second, data-driven decision models used for food supply chain optimization do not have evaluation criteria to validate their effectiveness since numerical studies are commonly used in literature (Meneghetti and Monti, 2015). Such approaches may not be suitable under Big Data era. Third, current models are focusing on a specific problem driven by a single company or a particular food supply chain. Multi-functional models are scarcely reported. By making full use of food industry Big Data, multi-objective and generic models could be achieved.

To this end, future decision-making models for FSCM will be implemented as follows:

- Multi-functional models: these models are able to make full use of Big Data from food supply chain. Some advanced and intelligent models or algorithms like deep machine learning will be integrated into these models so that multi-objectives could be defined (Balaji and Arshinder, 2016). They are capable of selecting associated data for different objective functions through training, learning, and calculating.
- Smart decision models: future decision models can work collaboratively in a smart way. With the intelligent learning capability based on Big Data, a number of models will be created to perform smart decisions on real-time basis (Zhong *et al.*, 2015). Advanced hierarchical or parallel frameworks for these models are required, thus, smart models are able to invite other models for seamless co-operation.

5.4 Implementations

FSCM implementations from real-life industries are based on cutting-edge technologies which are used for addressing some issues faced by food supply chain. Reported cases from literature mainly concentrated on verifying some hypothesis and presenting the improvements after using an IT system (Canavari *et al.*, 2010; Soto-Silva *et al.*, 2016). Few studies highlighted the natural characteristics of food supply chain or generic issues summarized from a set of companies so that the essence of FSCM could be figured out. After that, suitable technologies can be picked up to work out the solutions for the company or involved parties in food supply chain. Regarding the complexity of food supply chain, some important issues involving waste, re-use of resources, facility sharing, greenhouse gas emissions, and holistic lifecycle management are still unaddressed (Genovese *et al.*, 2017). Take food waste for example, about 40 percent of total food produced in the USA goes as waste yearly which is equivalent of $165 billion (Pandey *et al.*, 2016). Such vast wasted food not only physically influences our environment by polluting the water, but also significantly increases the CO_2 emission since large number of pollution will be generated when they are deteriorating. Thus, reduction of food waste requires the actions at different echelons within food supply chain like food production, delivery, storage, retailing, and recycling. Regarding different echelons, associated solutions such as food production management system, WMS, logistics management system, etc. should be highly integrated in terms of data sharing and seamless synchronization.

Emerging cutting-edge techniques may contribute to system integration in the near future. First, Cloud technology has been used to integrate segregated sector using minimum resources. It allows involved stakeholders to access various services via software as a service, platform as a service, and infrastructure as a service (Singh *et al.*, 2015). Through Cloud-enabled solution, the information sharing and collaborative working principle could be achieved by using basic computing and internet equipment. Second, IoT technologies like Auto-ID and smart sensors have been widely implemented in manufacturing and aerospace industry (Zhong, Li, Pang, Pan, Qu and Huang, 2013; Whitmore *et al.*, 2015). IoT-based solutions for FSCM are able to provide an entire product lifecycle management via real-time data capturing, logistics visibility, and quality traceability. Additionally, within an IoT-based environment, every objects with sensing, networking and calculating ability can detect and interact with each other to facilitate logistics operations and decision-making in a fashion that is ubiquitous, real-time, and intelligent. Third, Big Data Analytics for FSCM has received increasing attention since it is able to deal with immense data generated from food supply chain. Big Data Analytics can help food companies to make graphical decisions with more accurate data input by excavating hidden and invaluable information or knowledge which could be used for their daily operations. With such information, ultimate sustainable food supply chain could be realized by optimal decisions.

In the future implementation, giant companies play important roles in leading the food supply chain toward a green and sustainable direction. To this end, collaborations with green relationships could lead to a win-win situation that large companies will get the economic benefits, and in turn the food supply chain members like SMEs could also be benefited. That green relationship is based on the joint value creation by using new business models in terms of internal and external green integration which will be enabled by advanced technologies (Chiou *et al.*, 2011; Gunasekaran *et al.*, 2015). So these companies may take initial actions to be equipped by advanced IT systems, while up-stream and down-stream parties within food supply chain can follow up for a green future.

Finally, the implementations need the involvement of government bodies which are going to work out strategic plans for guiding and supporting various enterprises toward a better future. Thus, Big Data Analytics is extremely important for these bodies to figure out up-to-data statistics report, current status of a food supply chain, and industrial feedbacks. Further to identify the strategies, they can use advanced prediction models or data-driven decision-making systems for assisting deeper analysis. As a result, each individual end-user could be beneficial from future implementation.

6. Conclusions

As the increasing awareness of food quality, safety, and freshness, FSCM is facing ever pressure to meet these requirements. How to upgrade and transform current FSCM to suit the ever increasing demands in the future? This paper presents a state-of-the-art review in FSCM from systems, implementations, and worldwide movements. Current challenges and future perspectives from supply chain network structure, data collection, decision-making models, and implementations are highlighted.

Based on the reviewed papers, some ideas and observations are significant for academia and industrial practitioners:

- advanced technologies like Big Data Analytics, Cloud Computing, and IoT will be employed to transforming and upgrading FSCM to a smart future;
- data-driven decision-makings for FSCM would be adopted for achieving more sustainable and adaptive food supply chain; and
- FSCM implementations will be facilitated by the cutting-edge technologies-enabled solutions with more user friendliness and customization.

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