A Critical Overview of Food Supply Chain Risk Management

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Abstract. Due to the increasing occurrence of disruptive events caused by both human and also natural disasters, supply chain risk management has become an emerging research field in recent years, aiming to protect supply chains from various disruptions and deliver sustainable and long-term benefits to stakeholders across the value chain. Implementing optimum designed risk-oriented supply chain management can provide a privileged position for various businesses to extend their global reach. In addition, using a proactive supply chain risk management system, enterprises can predict their potential risk factors in their supply chains, and achieve the best early warning time, which leads to higher firms' performance. However, relatively little is known about sustainable risks in food supply chains. In order to manage the ever-growing challenges of food supply chains effectively, a deeper insight regarding the complex food systems is required. Supply chain risk management embraces broad strategies to address, identify, evaluate, monitor, and control unpredictable risks or events with direct and indirect effect, mostly negative, on food supply chain processes. To fill this gap, in this paper we have critically discussed the related supply chain risk management literature. Finally, we propose a number of significant directions for future research.

Keywords: Supply chain risk, Food supply chain risk, Sustainable development, Risk assessment.

1 Introduction

The global population has increased rapidly in the past few decades, which can have a direct effect on increasing demands for food products. Population growth can exert tremendous pressure on natural resources that contribute to global climate change and global warming [1] [2]. It also can reduce the level of sustainable development in different countries. Achieving the UN Sustainable Development Goals (SDGs) is crucial in order to harmonize key dimensions of industrial growth, economic growth, social involvement, and environmental protection [3]. One of the major sustainability challenges is food security noted as one of the Sustainable Development Goals (SDG 2) [4].

Considering specific characteristics of food commodities such as perishability and its dynamic system, food supply chains (FSCs) are far more complex than other industries such as manufacturing/service [5] [6]. Food is considered as the vital and most basic human need for survival. Through the years, FSCs have had to deal with massive challenges such as food price fluctuation, climate change, food wastage, food and nutrition security, governance problems, and value-distribution across FSCs [7] [8]. On the other hand, the food network is characterized by a dynamic environment with customers who have increasing demands for food safety and sustainable food commodities. Food consumers also have an intense concern regarding how food products are supplied [9]. The environmental performance of food supply chains is immensely affected by the downstream processes that frequently include elements such as distribution of food products through various channels or drop-off points. One of the critical success elements for improving the food distribution system is selecting efficient logistics strategies and adopting appropriate technologies [10].

In this paper, we examine food supply chain risks and security within the context of the UK food supply chain. The rest of the paper is structured as follows: Section 2 outlines a brief overview of Food Supply Chain Management. Section 3 discusses sustainable supply chains in the UK context. Sections 4 and 5 outline risk management within supply chains in general and food supply chains respectively. Section 6 provides a detailed review of literature on supply risk management. The paper is concluded in section 7.

2 Food Supply Chain Management (FSCM)

The food industry is characterized by a dynamic environment due to the changing demands of its customers [11] [12] [13]. Based on this characteristic of the food industry, companies should have the flexibility to promptly adjust their strategies and redesign their resources [14] [15] [16] [17]. Adopting mass production is another characteristic in food industries. In addition, the whole processes across the supply chains such as purchasing, manufacturing, financing, and sales and marketing have been affected by globalization conditions, and integrated in order to generate global chains [13].

To improve efficiency of operation and to provide necessities, FSC needs to recognize and identify characteristics in this industry. Moreover, Schmid et al. (2014) argue that the characteristics between two main categories of fresh food and long-life products are different [18]. Therefore, each of the categories requires its own specific strategy. Due to low-profit margins in food supply chains, product differentiation is the most common strategy adopted in the food industry [19]. One of the important factors deliberated in food markets as the differentiation strategy is product freshness [20].

Risk assessment is an essential method for minimizing waste in FSC and preventing food and resource wastage. It also supports organizations to establish resilient strategies to achieve food security. Christopher and Peck (2004) have argued that the contemporary challenges in the food businesses are about handling and mitigating risks using resilient supply chain principles in various enterprises [21]. Evaluating risks in FSCs

can lead to the improvement of other key aspects such as sustainability and performance [22].

In pursuance of supplying safe and reliable commodities, entire supply chain roles should be aware of different potential risks either within and outside their systems. Existing literature highlight that enterprises are required to follow an explicit design to recognize and evaluate risks within their supply chain. The risk evaluation ultimately supports organizations to implement a preventive and sometimes a reactive plan to turn strategies to actions and appropriately manage potential risks [23]. Reducing uncertainties and liability across supply chains are the expected results that aim to achieve a high level of supply chain performance [24].

3 Sustainable Food Supply Chain Management in the United Kingdom

In line with the growing concerns, sustainability has been examined by consumers in recent decades. Particularly the concept of organic food as well as fair trade are under the scrutiny of consumers. Due to the dynamic environment in the food supply chains, food safety and sustainable production, and distribution are considered as the most significant customers' expectations [9]. The UK Sustainable Development Commission [25], according to its strategy and various stakeholder's perspectives, has constructed an applicable international framework for high priority principles of sustainable food and farming industries (Table 1).

Table 1. UK Sustainable Development Commission Priorities [25]

UK Sustainable Development Commission Priorities	
1	Safe, healthy products, nutrition and information for consumer
2	Rural and urban economies and communities
3	Viable livelihoods from sustainable land management
4	Operate within biological limits of natural resources
5	Reduce energy consumption, minimize inputs, renewable energy (environmental performance)
6	Worker welfare, training, safety and hygiene
7	High standards of animal health and welfare
8	Sustaining resources for food production

4 Sustainable Chain Risk Management

George (1967) presented an alternative definition for risk to avoid basic faults in the previous definition which was offered by Insurance Terminology of the American Risk and Insurance Association in 1966 [26]. He defined risk. "not as uncertainty, but as the objective probability that the actual outcome of an event will differ significantly from the expected outcome." As noted in Table 2 there are other definitions that can characterize the following formulas for risk.

Table 2. Risk Definitions

Citation	Formula
[27]	Risk=Probability× Impact
[28]	Risk=Hazard+ State of the system+ Consequences
[29]	Risk Source= Hazard+ Vulnerability→ Disruption→ Consequences

The coherent and consistent services from suppliers are expected by customers throughout the world. However, due to the increasing complexity in the current competitive global market, it is challenging to guarantee seamless supply chains [30]. Given the existing supply chains susceptibility and disruptions' intensity, operations management practitioners and researchers have concentrated on investigating the phases of supply chain risk management (SCRM). According to the Business Continuity Institute survey in 2016, 73% of organizations noted that they intend to include risk management approaches over their supply chain processes [31]. Such a high rate indicates that there is significant amount of resources required in organizations to mitigate supply chain risks. The main reasons for supply chain disruptions are categorized into two specific internal and external groups. Some examples of external events include natural catastrophes, changes in legislation and regulation, and market development. Instances of internal events are fraud, accidents, theft, epidemic disease, and sabotage [32]. Financial stability, organization's reputation, and customers' desires are certainly affected by these disruptions [33]. The growing probability of disruptive events with significant impacts has directed organizations to employ diverse proactive and reactive strategies for risk mitigation. Figure 2 illustrates the most commonly adopted supply chain risk strategies for mitigating risks.

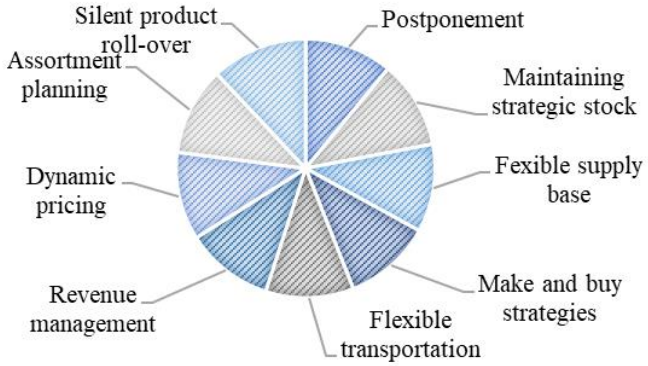

Fig. 1. Most commonly adopted supply chain risk strategies, adapted from [34]

Supply chain vulnerability is defined by [21] as disclosure to shocks emerging from within and outside of the supply chains. The vulnerability has been determined from three important characteristics including the tendency to risk, the ability to resist the shock, and strength-building [21]. Contrary to the vulnerability concept, resilience in supply chains is the ability to recover and resist disturbances (e.g., supplier failure,

inadequate demand prediction, etc.) and has a positive implication [35]. Resilience as a proactive approach aims to improve an organisation's ability to mitigate various risks [28].

Kumar et al. (2010) define supply chain risks as the possible deviations from the primary objective that, ultimately, target the reduction of value-added processes at various stages [36]. Zsidisin (2003) define risk in supply chains as "the probability of an incident associated with inbound supply from individual supplier failure or the supply market occurring, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety" [37].

Kern et al. (2012) have categorized risk into two main groups; Disruptive risks, and operational risks [38]. An example of an operational risk is the inappropriate or failed activities that can cause a supply-demand inconformity [39]. Equipment failure, supply failure, and strategy failure are other instances of operational risks. On the other hand, disruptive risks occur as a result of human-made or the natural catastrophe; such as terrorist attacks, natural disaster, and economic dilemma [40]. Disruptive risks are less controllable than operational risks. Another classification that has proposed by [41] is a) internal risk events occurring within a firm's supply chain and b) external risks arising from the environment surrounding a supply chain system.

5 Food Supply Chain Risk Management

Due to the dynamic market environment, the importance of achieving competitive advantages in the global trade, and complicate relationships among supply chain network actors (i.e. suppliers, producers, logistics providers, service providers, customers, etc.), FSCs are susceptible to various types of risks. Manuj & Mentzer (2008) argue that a risk management method incorporates three essential phases that are: risk identification, risk evaluation, and risk mitigation [42].

The empirical examination of supply chain risk management is broadly detailed in various literature [43] [44]. To provide a better understanding of risk in the context of supply chains, Rao and Goldsby (2009) offered a systematic classification of risks [45]. Tummala & Schoenherr (2011) developed a broad method to govern potential risks in supply chains by adopting a risk management procedure [46]. According to this management approach, risk identification is considered as the first stage in the risk analysis and is followed by risk assessment, and risk monitoring stages. The process of risk assessment is about identifying the most appropriate mitigation and proactive strategy based on the identified risks. The risk impacts on supply chain and their measurement techniques hinge on the architectural assessment "impact area" of various risks [47]. Supply chain risk management (SCRM) encompasses processes of risk recognition, risk measurement, risk handling, risk analysis, risk monitoring across the risk management framework [48].

The most cited and adopted supply chain risk classification in different research studies is conducted by [49]. He analyzed more than 200 quantitative articles between 1964 and 2005 and classified supply chain risks into two major risk types that include disruption and operational risks. Disruption risks are affected by man-made and natural

failure (i.e. terrorist violations, hurricanes, earthquakes, storm, economic disaster [40]. Operational risks emerge during the business procedure execution or different supply chain practices [39]. Heckmann et al. (2015) argued that operational risks in FSCs include supply failure, demand fluctuation and uncertainty, price variance in the market, and cost growth due to machine/equipment failure or management failure [50].

Risk classifications in the supply chain are also provided in SCRM literature such as [21] [45]. Olson & Dash (2010) suggested that for simplifying supply chain risks, such risks can be classified into three main groups [51]. These groups include: internal to firm, external to firm but internal to supply chain network. and external to network. Totally, with their sub-categories, five categories that can be generated include the internal process, internal control, demand and supply in supply chain network, and environmental risks. Christopher and Peck (2004) defined processes as sequences of value-adding activities adopted by various firm; they also argued that the internal process risks can disrupt these processes in focal firms [21]. They also stated that internal control risks are arising from misapplication of policies, rules, and procedures for controlling processes in firms. In terms of demand risks in supply chains, they argue that it is related to potential disruptions that have negative effects on the downstream flows in supply chains such as materials, cash, and information. On the other hand, supply risks have adverse impacts on upstream flows of supply chains. Various focal firms, upstream and downstream supply chains, and even market places are affected by the final category which is the environmental risks. According to a research review by Goh et al. (2007), most risks are categorized based on their source, which are typically within supply networks or their external environment [52]. Many recent studies are focusing on supply chain risks due to the number of related occurrences causing disruption and lowering organizational performances [22] [53].

According to the research undertaken by several researchers (e.g. [54] [55]), there is another classification for risks in food supply chains. It is believed that risks are mainly emerging from sources such as weather, natural disaster, biological and environmental-elements, market-related elements, logistical and infrastructure factors, political factors, public policy and institutional elements, and management and operational influences (Table 3).

Table 3. Main classification of risks emerging in agri-food supply chains, adapted from [56]

Risk	Definition
Weather related risk	Result of hail and wind catastrophe and to immense humidity or extreme rain that can increase the possibility of pests and diseases
Natural disaster risks	Extensive typhoons, droughts, cyclones, hurricanes, earthquakes, floods, and volcanic activity
Biological and environmental related risks	The biological risk can be from various sources such as bacteria, plants, in-sects, viruses, birds, animals, and humans. Some of these risks frequently have

	negative impacts on the quantity of production and postharvest, but some of these may have an effect on the quality of products as well. Environmental-related risks are caused by environmental degradation such as soil erosion or factory pesticide or sewerage flow into water sources.
Market-related risks	Mainly, market risks are caused by reasons such as demand fluctuation, price change, change in quality standards, short in supply and access to various desirable products and services.
Logistical and infra-structure risks	Lack of reliable and affordable transport, inappropriate communication management and information sharing, high energy consumption due to improper route planning and transportation mood selection can cause logistics and infra-structure risks
Political risks	Political risks are related to politico-social vulnerability inside or outside of a country, trade disruptions due to contention with other neighboring countries or traders, seizure of the asset due to dispute or regulation changes by foreign countries and investors
Public policy and institutional risks	Changing monetary, uncertain financial policies (e.g., credit, savings, insurance) and tax policies; changing regulatory and legal procedures are major causes of public policy and institutional risks
Management and operational risks	Weak system management regarding making decisions about capital and asset allocation, sources selection, quality control, planning, and forecasting, using the high capacity of machines and equipment and maintaining those, and communication and leading labor and employees are the main sources of management and operational risks

Performance measurement has many overlaps with the risk management field, and many scholars consider risks as major sources for compromising performance in supply chains (e.g., [55] [57]). In order to provide further insights and offer integration among supply chain actors as well as to generate useful information for ideal decision making,

performance management is considered as an effective suite of techniques and tools [58]. The main performance measurements suggested in previous studies include financial, especially total cost, level of responsiveness to customers, flexibility, food safety, and quality time, particularly lead time, and processes [57].

5.1 Sustainable Supply Chain Risk Management

Due to severe pressure from various stakeholders, organizations around the world are concentrating on the sustainability of their product/service and their operation, and the triple bottom line framework (i.e. environmental, social, and economic performance) has become a focal point [59]. Many current analytical and empirical studies are now focused on sustainable operations. Sustainable operations are related to concepts such as innovation and adopting new technology, remanufacturing, supply chain analysis and design, product development, reverse logistics, and applying appropriate inventory management methods to minimize waste. Nevertheless, a few research works [16] [60] have attempted to evaluate the linkage between sustainable practices adoption and supply chain risks with a view to assessing those risk by different methods. According to Carter and Rogers (2008), sustainability is one of the capabilities in organizations to identify and mitigate social, economic, and environmental risks across the SC [61]. Other studies in finance and strategy have also investigated the linkage between Social Responsibility (SR) and risk management in firms (i.e. evaluate concerning stock market efficiency and performance) [62]. Taylor and Vachon (2018) argued that the value and importance of sustainability can inform supply chain risk mitigation approaches [60].

6 Review of Supply Chain Risk Appraisal Approach

Risk assessment is defined as an explicit, systematic process that is both complicated and evolving. In line with this evolvement, adopting comprehensive quantitative risk assessments is more common in recent literature. However, various firms, specifically small and medium-size organizations, encounter many difficulties within their quantitative risk assessment implementations. The main reasons for these difficulties include lack of proficiency, knowledge, scheduling and time management, motivation, engagement, and capital. In addition, due to the lack of access to quantitative data and an applicable model with appropriate parameters, quantitative risk assessments are not always usable [63].

According to [64], when risk managers are struggling with the aforementioned problems, they can adopt qualitative risk assessment for prioritizing risks, setting appropriate strategies and policies, and risk resource allocation. In order bridge the gap between the two different approaches (i.e. qualitative and fully quantitative), various semi-quantitative scoring systems and other techniques such as decision trees have also been introduced e.g. by [65] [66].

In the past decade, there have been growth in studies concentrated on supply chain risk assessment. Gaudenzi & Borghesi (2006) suggested an AHP-based framework for examining supply chain risks [67]. Chang et al. (2015) introduced an exploratory

technique to develop optimum decisions for minimizing risk in FSCs [68]. In order to present a comprehensive system thinking approach in the SCRM field, Ghadge et al. (2012) conducted a systematic literature review [69]. There are a few significant contributions to the field of SCRM. Hossein Nikou & Selamat (2013) presented a literature review on supply chain risk management to evaluate the potential risks across the Malaysian FSCs [70]. Manning & Soon (2016), in order to drive SC agility and stability in various organizations, designed a resilience model for FSCs [71]. Fearne et al. (2001) focused on the mitigation approaches for the risks related to fresh beef supply chains [72]. There are other studies such as [73] that evaluated the relationship between potential risks and organizational performance in food supply chains, particularly for fresh food retailer networks. Ding et al. (2014) measured indicators of quality performance in the FSCs in the Australian beef processing sector [74]. Various risk impacts on food processing performance are also highlighted in [75]. Dani & Deep (2010), conducted a research review on various risk response development approaches [76]. Wang et al., (2012) established a new risk assessment methodology for studying aggregative food safety risks in the food supply chain using fuzzy set theory and AHP [77]. The main important literature focusing on food supply chain risk assessment is provided and examined in Table 4.

Table 4. Summary of the SCRM assessment literature

Source	Aim	Risks involve	Method
[78]	To establish a ranking for suppliers based on aspects determined by micro/macroeconomic features	1. Food quality 2. Corruption 3. Environmental sustainability 4. Logistics 5. Price 6. Production volume 7. Economic growth	Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Elimination et Choix Traduisant la Realité (ELECTRE), Cross-Efficiency (CE)
[79]	To develop sustainable framework to minimize food waste.	1. Lack of skilled personnel Poor leadership 2. Failure within the IT system 3. Capacity 4. Poor customer relationship	Pareto analysis Decision-Making, Trial and Evaluation Laboratory (DEMATEL)
[53]	To evaluate the impact of possible demand disruptions in FSCs	1. Demand disruption	Game theory
[80]	Review the mathematical models	1. Seasonality	Review Paper

	generated in agricultural business	2. Supply 3. Lead-times 4. Perishability	
[40]	Risk assessment with two different approach and creating novel approach for assessment	1. Macro level risks 2. Operational risks external to the firm 3. Internal risks	Hierarchical holographic modelling and FL
[81]	To model a government-manufacturer-farmer game for FSCs risk management	1. Society health risks from chemical additive	Game theory
[39]	Reduce the occurrence of the food safety issues and ensure the quality of the people's life	1. Safety risk	Fuzzy AHP
[82]	Develop a model by adopting AHP approach for supply chain risk assessment	1. Earthquake 2. Financial Crisis 3. Supply interruptions 4. Inaccurate demand forecasts 5. Technology upgrades 6. Machine breakdowns	Orders-of magnitude and AHP
[50]	A critical review of supply chain risk	1. Network risk 2. Process risk	Review Paper
[34]	A literature review regarding supply chain risk management	1. Macro risk factors 2. Micro risk factors 3. Demand risk factors 4. Manufacturing risk 5. Supply risk factors	Review Paper
[83]	Examine the research literature related to food supply chain risk assessment for realizing progress in this area	1. Planning 2. Quality of raw materials 3. Resource allocation 4. Production 5. Specification change 6. Delay 7. Defects 8. Reputation 9. Contract risks	Review Paper and survey

		10. Supply	
[84]	Propose an incentive scheme include two contracts (i.e. wholesale-market-clearance and wholesale-price-discount sharing) for eliminating ‘‘double marginalization’’ in three-tier supply chain	1. Poor logistics contracts	SIM
[85]	Managing and mitigating risks in food supply chain	1. Macro level risks 2. Demand management risks 3. Supply management risks 4. Product/service management risks	ISM Modelling
[86]	Qualitatively examine the various types of uncertainty effecting on transport operations instead of evaluating the each involve risk	1. Delays 2. Delivery constraints 3. Lack of coordination 4. Variable demand 5. Poor information	Review Paper
[87]	To examine risks in FSCs	1. The quality risks 2. The logistics and inventory control risks 3. The structural risks 4. The information risks 5. The cooperation risks 6. The market risks 7. The environmental risks	System dynamics
[45]	SCRM review	1. Environmental factors 2. Industry factors 3. Organisational factors 4. Problem-specific factors and 5. Decision-maker related factors	Review Paper
[88]	Identify the relationship between	1. Information	Fuzzy Interpretive Structure

	cold chain and developing economies in India	2. Communications technology	Modelling (FISM) approach
[49]	Perspectives in supply chain risk management	1. Operational risk 2. Uncertain cost 3. Disruption risk 4. Natural and man-made disasters 5. Economic crises	Review Paper
[89]	Model for inbound supply risk	1. Internal risk 2. Quality risk 3. External risk 4. Demand risk 5. Natural or man-made disaster 6. Security	AHP
[67]	Proposed a method to assess supply chain risks according to supply chain objectives	1. Transport/distribution 2. Manufacturing 3. Order cycle 4. Warehousing 5. Procurement	AHP
[41]	To understand the business needs for (SCRM) from a practitioner overview.	1. Loss of IT 2. Fire 3. Loss of site 4. Employee health and safety 5. Customer health and product safety 6. Industrial action 7. Loss of suppliers 8. Terrorist damage 9. Pressure group	Exploratory quantitative survey and qualitative focus group discussions
[47]	Managing risk to avoid supply chain breakdown	1. Supply risk 2. Strategic risk 3. Regulatory risk 4. Customer risk 5. Operations risk 6. Impairment asset risk 7. Competitive risk 8. Financial risk 9. Reputation risk	Supply chain risk tool

[90]	Managing complex problems associating with both operational and supply chain risk for minimising the costs	1. Length of harvest season 2. Crop size under climatic variations	SP

7 Conclusion and Future Research

We have provided a detailed narrative extraction on key literature related to food supply chain risk management. We believe that the future direction of research for food supply chain risk management embrace the capabilities offered by technologies such as Artificial Intelligence (AI). Breakthroughs in advance digitization, information systems, robotics, technological development, and Artificial Intelligence (AI) will be the driving force of the "fourth industrial revolution" [91]. AI for instance, can provide a distinctive ability in which machines obtain intelligence for making decisions through minimizing human intervention. Machine Learning (ML) is one of these methods, which is the key to unlocking meaning from the dataset through learning from experience [92]. It has revealed in the literature that the machines could possess higher level accuracy in final results compared by human being's outputs in many fields throughout the decision-making processes [93], for instance prediction of cancer [94], drug discovery and development [95], big data [96], and genomics [97].

Despite enthusiasm regarding AI in recent years, there a few vendors in the food industry that apply machine learning in their system. Most early AI applications are mainly adopted by industries such as pharmaceutical, healthcare, cosmetics and, retail. One future research direction in the field is to investigate the possibility of applying ML methods to develop predictive analytics for sustainable supply chain risk management. The research in this spectrum is still at its initial stages, providing purely theoretical schemes that have not been thoroughly tested or applied in real-world contexts.

Through applying machine learning approaches, we could pave the way for automating prediction by training datasets for such predictive analytics tools. The automation will enable organizations to predict supply chain risks, mitigate those, and put measures in place to develop resilience. Subsequently, the negative impacts of events such as unprecedented weather and supply chain shock (e.g. COVID-19) will be greatly reduced. It also can support organizations to provide sustainability to the sector and other intangible benefits (i.e., social value).

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