An Up-to-date Critical Synthesis of Supply Chain Risk Mitigation Strategies

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Abstract
Globalization and technological innovations associated with critical socioeconomics changes have been exposing supply chain networks into a plethora of risk forms thus eroding severely supply chain performance. Consequently, today supply chain risk management sits at the C-level executive agenda of all leading multinational organizations. In response, a multitude of risk mitigation strategies have been developed to prevent, dampen, or negate altogether the negative effects of the various types of risk and to safeguard the operations of supply chains worldwide. In this work, we present an up-to-date critical synthesis and a taxonomy of the strategies that have been proposed both in literature and in practice. Following that, we identify gaps, overlays and opportunities for meaningful research, while further outlining the contextual framework for contemporary research in the field of supply chain risk management.

Keywords: supply chain risk management, risk mitigation strategies, critical synthesis.

JEL classifications: D81

Introduction

Over the past few years, supply chains (SCs) have been constantly evolving into multi-national, multi-echelon networks including complex relationships among stakeholders with conflicts of interests (Simchi-Levi, Kyratzoglou, & Vassiliadis 2013). Additionally, SCs are being exposed to multiple risks, ranging from traditional sources, such as natural disasters (e.g. recently the volcanic eruption in Iceland in 2010, and the tsunami in Japan in 2011, and environmental-related issues to emerging threats, such as economic instability, information technology outages/cyber-attacks, and social inequity (Supply Chain Risk Leadership Council 2013). Typical characteristics of modern commercial networks such as globalization, offshore sourcing, and worldwide-based customers have stretched SCs thin, increasing their vulnerability and proneness to disruptions (Colicchia, Dallari & Melacini 2010). Furthermore, even technically non-disruptive events (e.g. legislation or regulatory changes) have disruption-like impacts on organizations for the time it takes to adjust to a new status quo.

As a result and given the increased complexity and vulnerability of the modern SCs dynamic structure, the aforementioned risks have considerable impacts on the performance of the organizations, and thus have to be adequately and timely managed (Glendon 2011). Therefore, several proactive risk mitigation strategies rose naturally in order to shield enterprises against these risk impacts and mitigate their results (Knemeyer, Zinn & Eroglu 2009; Sheffi 2007). Finally, managers have to decide on the appropriate one, which in turn should be further tailored to their company's needs.

In this manuscript, we present an up-to-date critical synthesis and a taxonomy of the strategies that have been proposed both in literature and in practice. Following that, we identify gaps, overlays and opportunities for meaningful research, while further outlining the contextual framework for contemporary research in the field of supply chain risk management.

Supply Chain Risk Mitigation Strategies

Although supply chain risk has been universally recognized as a key factor in global supply chains' viability and performance, research on the subject has been proven inadequate. Additionally, it is more heavily focused on risk itself and not on mitigation practices (Bromiley et al. 2015). Rajesh & Ravi (2015) identify the enablers of risk mitigation as a Flexible supply base, Flexible supply contracts, Collaborative partner relations, Supply chain visibility, Supply chain velocity, Strategic risk planning, Dynamic assortment planning, Accurate demand forecasting, Information security, Technology adaptation, Postponement strategies, Flexible processes, Strategic Stocking, Responsive pricing strategies, and Integrated supply chains and propose a framework for evaluating their value, their relationships, and ranking them in terms of usefulness in designing a supply chain risk mitigation portfolio. On the other hand, literature reviews indicate a shift of risk management research from reactive to proactive risk mitigation strategies (Tang & Nurmaya Musa 2011). Over the past years, many strategies have emerged as first choice among industry leaders as evidenced by MIT and PwC's 2013 report on Supply Chain and Risk Management (Simchi-Levi, Kyratzoglou, & Vassiliadis 2013). The findings of the report are summarised in Figure 1.

Based on these findings, this paper attempts a critical exploration of these risk mitigation strategies and the relevant literature, often in combination where it is deemed necessary, in the following paragraphs.

Business Continuity Planning (BCP)

Business continuity planning (or business continuity and resiliency planning) is the process of creating systems of prevention and recovery to deal with potential threats to a company (Elliot, Swartz, & Herbane 1999). Herbane, Elliott & Swartz (2004) report that "organizations create value, business continuity focuses on preserving it" and stress the strategic importance of BCP as early as 2004 in a relatively stable business environment. Early frameworks have been proposed (Devargas 1999; Gibb & Buchanan 2006) comprising of sets of different steps. In modern practice generally BCP can be summarized in six separate stages identified as follows:

Stage 1: Risk Mitigation Management.
Stage 2: Business Impact Analysis (BIA).

Stage 3: Supply Chain Continuity Strategy Development.
Stage 4: Supply Chain Continuity Plan Development.
Stage 5: Supply Chain Continuity Plan Testing.
Stage 6: Supply Continuity Plan Maintenance.

Figure 1: Actions companies take to mitigate supply chain risk and their level of adoption from the industry (adapted from Simchi-Levi, Kyratzoglou, & Vassiliadis 2013.

However, these stages act more as general guidelines, rather than direct solutions. In consequence of this lack of a clear definition and standardization of practices, although BCP is recognized as crucial in a firm's performance in today's volatile environment, it has not penetrated top-level priorities (Ernest-Jones 2005). In that aspect, Lindström, Samuelsson, & Hägerfors, (2010) propose an explanatory framework for the embedment of BCP in an organization's culture and underline that BCP needs to be more than a checklist provided by generic and vague standards.

BCP is a crucial part of Integrated Management Systems (Maier et al. 2011) and the modern focus on innovation and disruptive technologies that have high associated risks underlines the importance of BCP (Blos, Hoeflich & Miyagi 2015). Law (2014) highlights the importance of BCP in disaster recovery by reviewing recommendations by highly acclaimed US institutions, such as The Federal Reserve Board, the Office of the Comptroller of the Currency, and the Securities and Exchange Commission, the Securities and Exchange Commission and Wall Street West. Further, Nemzow (1997) highlights key issues in implementing a BCP further stressing its key role in minimizing disruption impacts

However, a common misconception about BCP is that it is merely a means to facilitate efficient disaster recovery. It has been pointed out that many practitioners forget that, as the title of the strategy suggests, business continuity – the sustained performance and resiliency of supply chain operations is the primary target and recovery is only a part of the overarching concept (Heng 1996). BCP falls on the context of good business practice that enables agility,

efficiency and visibility and provides a sense of security to all SC stakeholders (Stanton 2005). This notion is supported by case studies, such as Castillo's (2004) thorough exploration of the practices at Boeing, the aerospace industry giant, proving the benefits for SC members and customers alike.

Finally, it is commonly pointed out that the sixth fundamental stage of BCP, Supply Continuity Plan Maintenance is rarely observed. Cerullo & Cerullo's (2004) analysis of industry surveys indicates that although BCP is implemented, it is not maintained and updated. It also stresses that BCP should be integrated into IT security planning as IT becomes more important. Ghandour (2014) carries out a novel approach to how BCP is perceived by practitioners themselves through analyzing the terminology they use. It concludes that practitioners focus on the preparedness and planning for disaster recovery.

Dual Sourcing (DS), Emergency Sourcing (ES) and Safety Stock

Although coming in a close second in adoption, Dual Sourcing is perhaps the most commonly researched risk mitigation strategy, owing to its straightforward openness to quantitative study. The archetypical dual sourcing problem formulation consists of deciding the optimal supply mix between an unreliable cheap supplier and a reliable costly one (indicatively in Shu et al 2015) in the face of supply chain risk, with the tradeoffs between total cost and service level being examined (Sawik 2014). Based on that concept, research has expanded into several directions to include a multitude of variables and factors such as delivery time and distance, collaboration, demand uncertainty, price volatility and so forth. Additionally, an extreme case of DS, namely Emergency Sourcing, that consist of maintaining emergency suppliers that are only activated in the case that the main supply route is disrupted is commonly studied in tandem. The main body of literature on the subject usually concentrates on the comparison between alternate supply-oriented strategies, such as single sourcing (which usually consist of the baseline scenario), dual sourcing, emergency sourcing, safety stock and spot market procurement (which in itself is an emergency sourcing variant with no reservation cost but with price volatility).

Indicatively, Silbermayr & Minner (2014) prove the superiority of dual sourcing over single sourcing in the presence of disruptions and examines the tradeoffs between dual sourcing, safety stock and emergency sourcing, while Song et al. (2014) explore the benefits of DS while factoring in resource availability, demand uncertainty, price variability and lead time. Silbermayr & Minner (2015) indicate that under learning conditions (the increase of performance through continued partnership) Dual Sourcing is optimal and Song, Dong & Xu (2014) illustrate the trade-offs between managing risk, inventory, and reducing the supplier base.

Emergency Sourcing on the other hand is studied comparatively to DS in Huang & Xu (2015), and to Spot Market procurement in Merzifonluoglu (2015) and Inderfurth, Kelle & Kleber (2013). Iakovou et al (2015) indicate that a relatively small portion of regular supply capacity is needed to be reserved in order to adequately counter the effects of a disruption. Zeng & Xia (2015) explore the conditions under which Backup Supply can be beneficial, highlight revenue sharing contracts as an effective tool and accentuate the importance of building a

mutually beneficial relationship with backup suppliers and its positive effect on countering a disruption.

Raising Safety Stock still remains one of the most commonly practiced strategies, despite being in stark contrast with the modern concepts of lean supply chains and just-in-time, usually because it incurs comparatively less cost and doesn't demand a high level of supply chain risk management sophistication. Although a great body of literature exists targeted to determining optimal safety stock levels (indicatively van Donselaar & Broekmeulen (2013), Stößlein et al. (2014), Braglia, Castellano & Frosolini (2014), Zhong & Zhang (2015), Inderfurth & Vogelgesang (2013), Osman & Demirli (2012), Li & Jiang (2012), and Beutel & Minner (2012)), it is often compared unfavorably to DS and ES, owing to the high holding costs and the added risk of maintaining high inventory levels.

As a general remark, the main body of literature on the subject mainly consists of presenting DS and the associated alternative strategies in a comparative context, with the end result being insights as to the conditions warrantying the application of one strategy over another. Roadmaps are drawn to assist in the decision-making process, but most of the recommendations are case-specific with no strategy dominating over the others.

Regional and Global Strategy

This strategy in modern practice is mostly referred to as the concept of "glocalization". Glocalization (a portmanteau of globalization and localization) is a term that describes the adaptation of international products around the particularities of a local culture in which they are sold. Put more simply, it is the practice of conducting business combining the idea of globalization with that of local considerations. It has emerged as a vital concept in modern supply chains that transcend local boundaries and are targeted to a worldwide clientele. In a risk management context it is translated as the need to design and implement strategies that take local parameters and risks into consideration. A centralized risk mitigation approach can often prove inadequate if area-specific pitfalls are not taken factored in.

The concept of glocalization is explored in Drori, Höllerer & Walgenbach (2014), who attempt to specify the relevant dimensions of complexity and multidimensionality by constructing a framework of three sets of analytic conceptualizations: the identification of three axes of glocalization (vertical, horizontal, and temporal), the extraction of three core themes of glocalization ("what", "who", and "how"), and naming several sequenced components of glocalization (abstraction, construction of equivalency, and adoption and adaptation). Ultimately, it is widely accepted that differences between culture, geography, trading formats and distribution practices should be taken into account to achieve uninterrupted supply chain operations in a global context (Fernie 1995). Additionally, the concept of international presence exhibits the added benefit of risk decentralization and negates dependence on a single market (Schmitt et al. 2015).

Supplier Collaboration

Supply chain collaboration in general has been highlighted as a critical factor of success and resilience ever since supply chains

outgrew vertical integration and started expanding to include multiple echelons and numerous stakeholders in locations spread all over the globe. In that context, continued collaborations both upstream and downstream are characteristic of supply chain excellence and resilience (Ramanathan & Gunasekaran 2014; Ramanathan 2014; Sandberg 2007).

Modern supply chains are often host to multiple suppliers in their most upstream locations, mostly raw material suppliers and OEM's, both of which are highly contested areas. Supplier collaboration refers to the continued efforts of organizations to pursue joint operations between these first and second tier echelons, in order to cement a streamlined flow of goods further down the chain. Supplier collaboration is theorized to have positive effects on supply chain performance by many researchers, while there is an emphasis on the need for more research on the topic (Rich et al. 2006; Barratt 2004).

Technological uncertainty is a moderating factor in supplier capabilities (Oh & Rhee 2008) and partnerships alleviate uncertainty and improve stability through information sharing (Chicksand 2015). Collaborations have been proven especially helpful in reducing risk associated with new product development, safeguarding a supply chain in its infantile stage (Melander & Lakemond 2015). In general, collaborations offer increased process efficiency and flexibility, which are key enablers in countering risk (Cao & Zhang 2010). Additionally, supplier collaboration enhances both a firm's performance in already established markets and its ability at penetrating new ones, thus enhancing a supply chain's adaptability and resilience (Ho& Lu 2014). Overall, supplier collaboration has been demonstrated to incur a positive effect on the overall supply chain service level and stability in contrast to a decentralized decision-making approach (Fu & Piplani 2004; Min et al. 2005).

Demand Collaboration

As the strategy of Supplier Collaboration discussed previously can prove vital in alleviating supply uncertainty, the strategy of Demand Collaboration has been put forth as a means to safeguard the downstream nodes of the supply chain. Demand Collaboration refers to the tactics employed to strengthen demand forecasts and the incentives presented to customers in order to express demand in a more timely and organized manner. Sahay (2003) and Vereecke & Muylle (2006) highlight the key role of demand collaboration in supply chain stability and call for more continued relationships with customers.

Sheu, Yen & Chae (2006) identify ten critical social and technical variables (supply chain interdependence, duration and supply chain employee stability, trust, long-term orientation, communication and information sharing, inventory systems, information technology capabilities, supply chain coordination structure, supplier-retailer collaboration, and supplier-retailer performance) that enhance the impact of demand collaboration on supply chain performance. Supply chain customer integration is proven to have a positive impact on performance from a contingency perspective (Flynn, Huo & Zhao 2010) and joint collaboration planning greatly enhances an organization's flexibility (Hadaya & Cassivi 2007). Moreover, supplier collaboration has been shown to enhance the effects of other risk mitigation strategies when employed in tandem. For example, in a Dual Sourcing setup, demand forecast updating is proven to lead to the selection of

the supplier mix that offers the best stability, and therefore to a more profitable solution (Cheaitou et al. 2014).

In recent years, the rise of e-commerce has been a key enabler in demand collaboration giving birth to practices such as Continuous Replenishment Program (CRP), Vendor Managed Inventory (VMI), and Collaborative Planning, Forecasting and Replenishment (CPFR) (Pramatari, Doukidis & Kourouthanassis 2005). The role of IT in demand collaboration is further underlined as crucial and its positive impact on operational performance demonstrated by Iyer (2011). In general, manufacturer performance is shown to be enhanced by a collaborative buyer-supplier relationship, safeguarding supply chain stability (Yang 2012).

Forward Buying/Hedging

Forward buying as a strategy can take two forms: on the one hand, it is utilized by firms that either trade or utilize a great volume of commodities, such as oil and grains, in order to protect against price volatility in world markets. On the other hand, it refers to s practice used by both wholesalers and retailers involving the stocking up of specific products that are offered by a particular product manufacturer at a lower price. Both practices see a lot of application in today's fast moving markets where commodity price volatility is at an all-time high. At the same time, suppliers and manufacturers often offer price markdowns and promotions in the interest of Demand Collaboration (see paragraph 2.5). Taušer & Čajka (2014) concentrate on wheat prices to compare and evaluate different hedging strategies, namely futures contracts, forward contracts, "plain vanilla" options, and option strategies. Overall, forward buying of commodities is underlined as crucial in countering demand uncertainty and price volatility, both of which constitute major sources of supply chain risk (Manikas & Kroes 2015.

Table 1: Summary of supply chain risk mitigation strategies literature review

Risk mitigation Strategy	**Works**
General Risk Management	Bromiley et al. 2015, Heckmann, Comes & Nickel 2014, Rajesh & Ravi 2015, Tang & Nurmaya Musa 2011, Zailani et al. 2015, Simchi-Levi, Kyratzoglou & Vassiliadis 2013
Business Continuity Planning (BCP)	Elliot, Swartz & Herbane 1999, Maier et al 2011, Devargas 1999, Gibb & Buchanan 2006, Ernest-Jones 2005, Stanton 2005, Blos, Hoeflich & Miyagi 2015, Herbane, Elliott & Swartz 2004, Cerullo & Cerullo 2004, Ghandour 2014, Law 2014, Nemzow 1997, Lindström, J., Samuelsson & Hägerfors 2010, Heng 1996, Castillo 2004

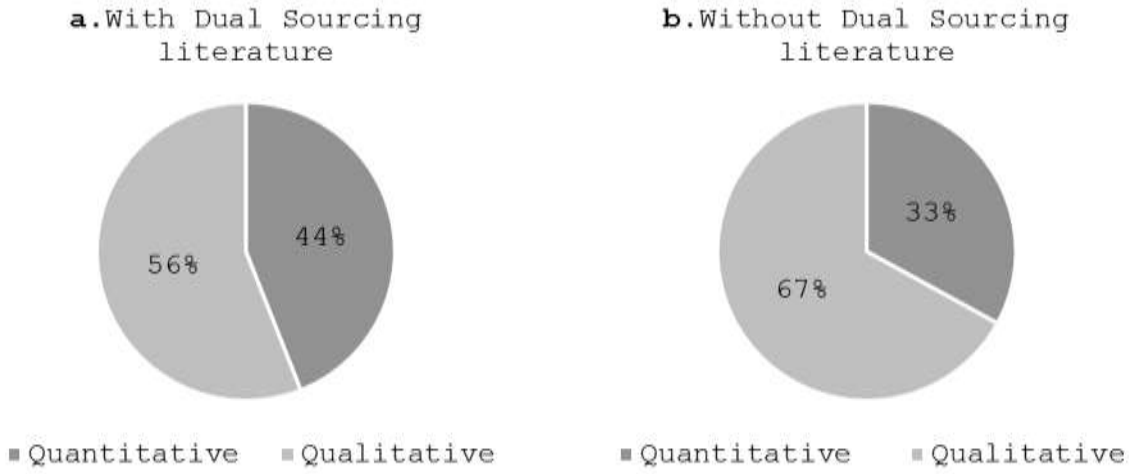
Risk mitigation Strategy	**Works**
Dual Sourcing (DS), Emergency Sourcing (ES) and Safety Stock.	Merzifonluoglu 2015, Huang & Xu 2015, Zeng & Xia 2015, Sawik 2015, Song, Dong & Xu 2014, Silbermayr & Minner 2015, Sawik 2014, Song et al. 2014, Inderfurth, Kelle, & Kleber 2013, Silbermayr & Minner 2014, Shu et al. 2015, van Donselaar & Broekmeulen 2013, Stößlein et al. 2014, Braglia, Castellano & Frosolini 2014, Zhong & Zhang 2015, Inderfurth & Vogelgesang 2013, Osman & Demirli 2012, Li & Jiang 2012, Beutel & Minner 2012, Iakovou et al. 2015
Regional and Global Strategy	Schmitt et al. 2015, Fernie 1995, Drori, Höllerer & Walgenbach 2014
Supplier Collaboration	Chicksand 2015, Melander & Lakemond 2015, Cao & Zhang 2010, Ho & Lu 2014, Cao & Zhang 2011, Fu & Piplani 2004, Ramanathan & Gunasekaran 2014, Ramanathan 2014, Oh & Rhee 2008, Min et al. 2005, Sandberg 2007, Rich et al. 2006, Barratt 2004
Demand Collaboration	Cheaitou et al. 2014, Flynn, Huo & Zhao 2010, Ramanathan & Gunasekaran 2014, Ramanathan 2014, Yang 2012, Sahay 2003, Sheu, Yen & Chae 2006, Vereecke & Muylle 2006, Hadaya & Cassivi 2007, Iyer 2011, Pramatari, Doukidis, & Kourouthanassis 2005
Forward Buying/Hedging	Manikas & Kroes 2015, Taušer & Čajka 2014
Near Shoring Manufacturing	Habermann, Blackhurst, & Metcalf 2015, Bock 2008, Tate et al. 2014, Fratocchi et al. 2014, Ellram, Tate & Petersen 2013, Miller et al. 2014, Iakovou, Vlachos & Chatzipanagioti 2010, Tate 2014,
Component Substitution	Hernández & Catya 2015

Component Substitution

It is common practice today, especially with electronics manufacturers and the automotive industry, for products to be designed with interchangeable parts, or based on a common platform. As a consequence, manufacturing procedures are simplified and streamlined

with families of components serving many different end products. Component substitution demonstrates the added benefit of reducing safety stock and thus enabling risk pooling and minimizing risk exposure (Hernández & Catya 2015). This strategy can also act complimentary to the Regional and Global strategy discussed in paragraph 2.3, with component substitution enabling customization of products tailored to a specific geographic area's individual characteristics and challenges.

Figure 2: Distribution of literature in qualitative and quantitative works



Conclusions

In this paper we attempted a first approach at a critical taxonomy of supply chain risk mitigation strategies. We reviewed 78 papers of the relevant literature, and explored the most often deployed (as reported by supply chain companies) practices worldwide. The review is summarized in Table 1, while Figure 2 demonstrates the distinction between qualitative and quantitative works.
Overall, the key implications extracted from this research can be summarized as following:

- Most companies do not implement only a single risk mitigation strategy. As a result most of them are studied in tandem.
- A big gap exists in quantitative academic research in risk mitigation strategy. Although Figure 2a may suggest otherwise, most of the quantitative works focus on a single strategy, namely that of Dual Sourcing (see Figure 2b). A large portion of research focuses on the identification, the classification and the conceptualization of mitigation strategies, while a small amount addresses them in a more practical context.
- A fair amount research consists post-evaluation of applied strategies, meaning that up until now research mostly follows practice.
- There is an emergent need for standardization of risk mitigation strategies in order to facilitate a critical examination and evaluation (Zailani et al. 2015).
- While most research highlights the positive impacts of the strategies under study in supply chain performance, it does so outside of a risk context. The crucial role of some of these

strategies in safeguarding supply chains in the modern turbulent business environment is mostly ignored.

- The application of risk mitigation strategies is case specific, heavily tied to the particular conditions and constraints of each supply chain and the environment it operates in.

Future research will continue to incorporate the ever-expanding body of supply chain risk mitigation strategies literature. Risk management has been established as one of the most critical fields of supply chain management in the modern volatile business environment where global chains have to effectively safeguard their operations in order to be able to continue to accomplish their goals of producing and delivering value worldwide in an efficient and profitable manner.

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