A conceptual framework for improving effectiveness of risk management in supply networks

Abstract:

Purpose: The purpose of the paper is to develop a conceptual framework for improving the effectiveness of risk management in supply networks following a critical literature review.

Methodology: A critical review of 91 scholarly journal articles published between 2000 and 2018 supports the development of an integrated conceptual framework.

Findings: The findings emphasize that supply chain integration (SCI) can have both a positive and negative impact on the effectiveness of risk management in supply networks. It is possible to have a positive effect when SCI can be used to develop competencies in joint risk planning within the organization and with wider supply network members and, in turn, to develop collaborative risk management capabilities. Supply network characteristics can influence whether and the extent to which SCI has a positive or negative impact on risk management effectiveness.

Research implications: The conceptual framework can be used to empirically assess the role of SCI for effective risk management. Dynamic evaluation of the effectiveness of risk management and potential redesign of the supply network by considering other contingent factors are some future research avenues.

Practical implications: There is a need for developing specific competencies in risk planning within organizations and joint risk planning with supply network members which, in turn, can help develop collaborative risk management capabilities to improve the effectiveness of risk management in supply networks. Network characteristics will influence whether and the extent to which SCI results in the effectiveness of risk management.

Originality value: Moving beyond recent (systematic) reviews on supply chain risk management, this study develops a novel conceptual framework interlinking supply chain integration and the effectiveness of risk management while considering network characteristics.

Keywords: Supply chain risk management; Supply chain integration; Supply network characteristics; Conceptual framework

1. Introduction

Supply chain risk management (SCRM) is characterized by a coordinated approach amongst supply chain members involving cross-company collaboration between partners (Norrman and Jansson, 2004; Tang, 2006; Thun and Hoening, 2011). However, risk management processes appear to remain mostly restricted within focal firms (Fan and Stevenson, 2018). Such a single-firm approach may not be effective for SCRM (Cheng and Kam, 2008) as multiple risks may originate and propagate across different tiers in the supply chain network (Ghadge et al., 2013; Heckmann et al., 2015). Effectiveness of risk management could be measured in terms of reduced risk (Tse et al., 2011), better preparedness (Li et al., 2006; Jüttner and Maklan, 2011), better response (Sheffi, 2001), higher resilience (Pettit et al, 2010) and overall decrease in probability of occurrence and severity of risks (Lavastre et al., 2014).

Supply chain integration (SCI) can be considered as a key enabler of effective risk management across networks; however, only a few studies have investigated its role as an enabler for SCRM (Pettit et al., 2010; Jüttner and Maklan, 2011). Transparency and visibility along the supply chain increase the capability to identify and manage risks (Faisal et al., 2006; Wagner and Silveira-Carmagos, 2012). Apart from ensuring visibility of risk, there is a need by supply network members to incorporate the acquired information into the risk management decision-making process. Hence, successful SCRM is dependent on the firms' learning orientation across traditional intra- and inter-firm boundaries to effectively deploy business intelligence and to mitigate the effects of supply chain disruptions (Sheffi and Rice, 2005; Manuj and Mentzer, 2008). Lavastre et al. (2014) found that managing SCRM at a strategic level with supply chain partners ensured the success of SCRM. Wiengarten et al. (2016) show that companies can complement and strengthen the impact of their supplier integration practices through SCRM. More recently, Revilla and Saenz (2017) found that firms pursuing an inter-organizational orientation (collaborative and integral) faced the lowest levels of supply chain disruption. Carefully managed sharing of information, expertise and priorities between public and private sector organizations and between key players can develop collaborative and trusted relationships, which are imperative for pre-disruption preparation and post-disruption rapid response (WEF, 2012).

Christopher et al. (2011) note that while companies take steps in implementing risk mitigation strategies, network strategies like collaboration were overlooked. However, SCI can have both benefits and disadvantages. Multiple authors have noted that integration among firms in the supply network will lead to an increased dependency and, in effect, higher risk exposure (Wieland and Wallenburg, 2013; Hallikas et al., 2004), as risks in one link are likely to affect other links in the network (Norrman and Jansson, 2004; Waters, 2011). Moreover, managing multiparty collaboration in a complex supply network is, itself, very difficult as each member will have their own objectives (Jain et al., 2008) and may have different capabilities (Singh, 2011). Also, security concerns of shared data may have a negative impact on SCI (Kache and Seuring, 2014). Colicchia and Strozzi (2012) highlight the need to consider the impact of risks arising out of network collaboration. This fact highlights how such integration practices could represent sources of risks (Zhao et al., 2013). Following this perspective, Wieland and Wallenburg (2013) propose that future research should examine the advantages and disadvantages of integration. In fact, surprisingly, Kache and Seuring (2014) do not find any strong relationship of integration to their construct of supply chain risk.

Despite the above findings, there is limited understanding on which competencies and capabilities companies need to develop for increasing the positive effect while minimizing the negative effect of SCI on risk management effectiveness. A large number of reviews have been conducted on SCRM (e.g., Tang, 2006; Rao and Goldsby, 2009; Tang and Musa, 2011; Colicchia and Strozzi, 2012; Ghadge et al., 2012; Sodhi et al., 2012, Bandaly et al., 2013; Heckmann et al., 2015; Ho et al., 2015; Zhu et al., 2017; Fan and Stevenson, 2018; Friday et al., 2018). The above reviews play an important role in synthesizing the large body of knowledge on SCRM by identifying and classifying all types of risks, their underlying factors, the various risk management approaches and the methodologies used. Nevertheless, these reviews do not specifically address how the effectiveness of risk management can be improved by increasing the positive effect while minimizing the negative effect of SCI. Clearly this is an evident gap in the SCRM literature, aptly identified by Fan and Stevenson (2018). Zhu et al. (2017) focus on how SCI can secure performance maintenance or improvement but do not explore how SCI can improve the effectiveness of SCRM. Friday et al. (2018) identify the capabilities required for collaborative risk management and its theoretical underpinnings but lack exploring the impact of collaborative risk management on improving the effectiveness of risk management. Fan and Stevenson (2018) also note that empirical evidence is needed to examine how collaborative practices can be effectively integrated into SCRM. Thus, there is an increasing need to understand the use of a collaborative approach to risk management and to specify the role of SCI on the effectiveness of risk management. In order to develop this understanding, the literature on SCI for effective SCRM is synthesized to define the constructs and develope a conceptual model.

The paper raises the following research questions to provide answers to the above identified research gap:

(RQ1) How can SCI positively influence the effectiveness of risk management in supply networks?

(RQ2) How can SCI negatively influence the effectiveness of risk management in supply networks?

(RQ3 a) How will SCI have a direct effect on risk management effectiveness?

RQ 3b) How will SCI have an indirect effect on risk management effectiveness, mediated through collaborative risk management capabilities?

(RQ4) How will network characteristics influence the positive and negative effect of SCI on risk management effectiveness?

Following a critical review, the study develops an integrated framework which provides directions for future research and insights to practitioners on using SCI for improving the effectiveness of risk management. In the next section the key concepts are defined, followed by a description of the methodology in section 3. Section 4 answers the research questions and develops a conceptual framework in section 5. The concluding section discusses key contributions to theory, limitations and future research avenues.

2. Concepts of SCI and SCRM

2.1 Supply Chain Integration (SCI)

SCI is the degree to which an organization collaborates with its supply chain partners and manages intra and inter-organization processes with the objective of providing the maximum value to the end-customer (cf. Zhao et al., 2008, p. 374). SCI includes both internal and external integration. Internal integration refers to "*the degree to which a manufacturer structures its own organizational strategies, practices and processes into collaborative, synchronized processes, in order to fulfill its customers' requirements and efficiently interact with its suppliers*" (Flynn et al., 2010). Danese and Romano (2013) define customer integration as the degree to which a firm exchanges information, works closely and interacts for feedback with its customers; whereas supplier integration involves core competencies related to coordination with critical suppliers (Flynn et al., 2010). Thus, it is important to note that information sharing and collaboration are pre-requisites for and are subsumed within the broader concept of SCI (Richey and Autry, 2009; Adams et al., 2014; Michalski et al., 2017).

Organizations form partnerships by sharing information and linking their information systems to achieve unique synergies. Buyers and suppliers signal their own trustworthiness through the willingness to share information (Dyer, 1997). Collaboration involves information sharing but goes beyond that to include proactive planning and synchronization of processes. It is characterized by a higher level of interaction and requires shared investments for the achievement of collective goals (Mentzer and Kahn, 1995). Collaboration is also a process of decision-making across functions within an organization, which needs to be implemented at strategic and tactical levels (Barratt, 2004). This process is based on the creation of long-term relationships, the development of complementary capabilities and engagement in joint planning. Cross-functional activities, process alignment and joint decision making extends the focus to include not only a passive exchange of information between the partners but, also, a more proactive approach through shared planning and synchronization of activities and business processes (Jagdev and Thoben, 2001; Barratt et al., 2004; Qazi et al., 2018). Thus, while analyzing the effect of SCI on risk management effectiveness, the paper will consider the role of both information sharing and collaboration as manifested through joint risk planning both within and outside the organization.

2.2 Supply Chain Risk Management (SCRM)

SCRM can be defined as ''*the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity*'' (Tang, 2006). To mitigate supply chain risks, Tang (2006) suggests that firms can coordinate or collaborate with upstream partners to ensure the efficient supply of materials; and with downstream partners to influence demand. Similarly, the supply chain partners can improve their coordinated or collaborative effort if they can access private information that is available to individual supply chain partners. Ho et al. (2015) note that though definitions of SCRM have emphasized collaboration with supply chain partners, some of the limitations are related to their focus on specific elements of SCRM and their lack of spanning the SCRM processes in their entirety. Hence, they define SCRM as: "an inter-organizational collaborative endeavour utilising quantitative and qualitative risk management methodologies to identify, evaluate, mitigate and monitor unexpected macro and micro level events or conditions, which might adversely impact any part of a supply chain" (Ho et al., 2015). Though these suggestions inherently assume the positive effect of SCI on SCRM, firms have followed the steps for risk management, i.e., identification, assessment and evaluation, selection of appropriate risk management strategies and implementation of those strategies (Manuj and Mentzer, 2008) within the firm.

3. Methodology

The paper follows a critical literature review approach, as authors have a broad understanding of the SCRM area and the study goes beyond a mere description of the systematic process and degree of analysis, typically followed in systematic literature review (Grant and booth, 2009; Robinson and Lowe, 2015). Recent work published by Heckmann et al. (2015), Dubey et al. (2017), Diaz-Balteiro et al. (2017) and Ivanov et al. (2017) in the leading operations, logistics and supply chain management provides strong support for acceptance of a critical review approach.

For data screening, the following key search strings were identified. "*supply network*" AND "*risk management*" AND "*supply chain integration*" OR "*collaboration*" OR "*information sharing*"

ABI Inform ProQuest and Scopus databases were selected for conducting the review. The search was restricted to the academic journal articles published between 2000 and 2018 and restricted to the subject areas of "supply chain management", "manufacturing", "information sharing" and "collaboration". This resulted in total hit of 13591 in ABI Inform and 621 hits in Scopus (excluding open access journals). In the second step, we examined the total hits with the scope to identify the relevant papers (Cooper, 2009). The first 500 hits were considered in ABI-Inform as the search showed that papers beyond the first 500 were largely irrelevant, while all 621 hits were considered for Scopus. Search journals appearing in the broad domain of Operations Research/Management Science/Production and Operations Management and 'Journal Quality list' 2016 were considered. The papers that met these criteria were chosen for the next round of shortlisting. In the next round, only papers appearing in at least two of ABDC 2016, FNEG 2016, CNRS 2017, ABS 2018 and VHB 2015 rankings were filtered. The list of selected journals (with number of papers) is reported in Table 1. Using the given shortlisting criteria for the shortlisted journals and removing duplicates, 392 papers were selected for the next round. These 392 papers were divided into 4 sets of 98 papers each. A pair of authors, to ensure reliable categorizations, read each set of papers. The following inclusion criteria were used for this second stage filtering process for selection of papers for full review:

- Covers "*supply chain integration*" while discussing supply chain risk management
- Covers "*risk management*" while discussing supply chain integration
- Covers the role of network characteristics on supply chain risk management

Papers were included in the full review only if at least one of the above criteria was met. This resulted in the rejection of 32 papers and selection of 79 papers. An additional 12 papers, found from the references of the 79 papers, were found to be relevant (and also met the criteria) and were included in the final selection, resulting in a final list of 91 papers. The distribution of selected articles is shown in Table 1.

Table 1: List of journals covered in the review

Name of the journal	Frequency
Supply Chain Management: An International Journal	17
International Journal of Logistics Management	12
International Journal of Operations and Production Management	8
Journal of Supply Chain Management	8
International Journal of Production Economics	7
International Journal of Physical Distribution and Logistics Management	6
International Journal of Production Research	5
Industrial Management & Data Systems	5
Journal of Business Logistics	4
Journal of Manufacturing Technology Management	4
Information System Frontiers	2
Business Process Management Journal	2
Management Science	1
Journal of Operations Management	1
Decision Sciences	1
European Journal of Operational Research	1
Journal of Enterprise Information Management	1
Information Technology and Management	1
The Journal of the Operational Research Society	1
European Journal of Information Systems	1
Production and Operations Management	1
Integrated Manufacturing Systems	1
MIT Sloan Management Review	1

The papers were coded based on pre-defined research questions, as they attempted to help with several answers. Papers which mentioned and explained the positive and negative effects of SCI on risk management effectiveness (shown in table 2) were collated. Similarly, papers which mentioned about the competencies and capabilities needed to improve risk management effectiveness (shown in table 3); network characteristics (shown in table 4); and analysis of the effect of network characteristics on the relationship between SCI and risk management effectiveness (shown in table 5) were classified. In this research, following the guidelines provided by Tranfield et al. (2003), realist synthesis is used to summarize the findings following pre-defined research questions. This helps us in identifying the key elements of SCI, which can lead to the effectiveness of risk management through the mechanisms of acquired collaborative risk management capabilities. The contingency effects of network characteristics to explain the above relationships are also captured. The synthesis of the findings is presented in section 4.

4. Positive and negative effects of SCI on risk management effectiveness in supply networks

4.1 Direct positive effects of SCI on risk management effectiveness

The reviewed papers were analysed and eight SCI competencies, which can improve effectiveness of risk management, were identified and coded by two of the authors. The other two authors reviewed the coding and naming of the individual items which formed the competencies and helped organize the 8 individual items into two broad competency groups - information sharing and joint risk planning with supply network members and internal risk planning within the organization.

a) *Information sharing and joint risk planning with supply network members*

Responding to RQ1, the critical review showed that information sharing can improve the effectiveness of risk management by alerting a disruption at an upstream stage, determining early warning time, facilitating decision making to offset the impact of the disruption (Li et al., 2006) and by improving overall disaster preparedness and response (Sheffi, 2001; Wieland and Wallenburg, 2013). Communication and information exchange with supply chain partners are most effective in minimizing risks (Lavastre et al., 2014). This helps in reducing product- and performance-related errors and number of defects (Tse et al., 2011), prevents quality failure (Zu et al., 2012) and reduces supplier perception of unethical behavior by the counterpart (Eckerd and Hill, 2012). Increased information sharing between the supplier and buying firm is rewarded by a perception of decreased unethical activity exhibited by the buying firm, potentially reducing risks for the supplier (Eckerd and Hill, 2012). Sharing of risk-related information leads to increased supply chain risk avoidance (Lavastre et al., 2012).

Under conditions of supplier capacity uncertainty, it is demonstrated that information sharing between partners in a multi-echelon supply chain helps in reducing risks and builds resilience (Li et al., 2017). Information-sharing indeed provides the transparency needed to detect and respond to upstream and downstream disruptions (Scholten and Schindler, 2015). Information from first-tier suppliers and other actors within the supply chain, NGOs, unions, government, media, or other actors adjacent to the supply chain enable buying firms to identify hotspots related to supply chain sustainability risks (Busse et al., 2017). Sharing information about disruption also enables other supply chain members to quickly find solutions that minimize the effects of the disruption (Li et al., 2006). Information sharing allows organizations to identify bottlenecks and other potential risks and enables them to take mitigating action before a disruption occurs (Brandon-Jones et al., 2014). Reducing information asymmetry could also help supply chain partners to proactively develop and improve the level of situation awareness in anticipating disruptions (Ali et al., 2017). Monitoring contingencies from various risk sources through information sharing and joint risk planning (Jüttner and Maklan, 2011) can thus be considered as a key competency to improve risk management effectiveness. However, information sharing between partners alone may not be enough to improve risk management effectiveness. Companies need to practice joint planning with supply chain members and within the organization to reap the full benefits of SCI. The key factors in reducing uncertainty and improving the ability to deal with disruptions are risk sharing through joint business continuity plans (Jüttner and Maklan, 2011) and joint decision making (Jüttner and Maklan, 2011; Cantor et al., 2014).

There is, indeed, a need for joint planning in order to realize the benefit of risk mitigation activities (Manuj and Mentzer, 2008). An inter-organizational risk analysis may help companies in comparing and sharing knowledge about the causes and effects of risks and uncertainties (Hallikas et al., 2004). Such a joint risk planning process increases the value of risk mitigation activities (Hallikas et al., 2004; Craighead et al, 2007; Manuj and Mentzer, 2008; Cantor et al., 2014). Joint definitions and co-management of goals by buyers and suppliers improve the ability of supply chain networks to meet the expectations of final consumers and, thus, avoid risks (Zu et al., 2012). Strong social relationships can also improve trust and can dampen the detrimental effects caused by the opportunism risk (Cruz and Liu 2011). Companies, engaged in joint processes, rather than working individually, can take advantage of partners' strategic resource to enhance their own operations and, hence, improve resilience of the supply chain (Zeng and Yen, 2017).

Similarly, continuous and systematic diffusion of knowledge and know-how across the entire supply chain network indeed enhances the expertise of suppliers, logistic operators and customers; improving the quality of both supplies and final product, reducing risks upstream and downstream (Biotto et al., 2012). Close interaction between a 3PL and its logistics collaborators also facilitates information sharing, preparation, planning thereby helping to build resilience (Liu and Lee, 2018).

b) *Risk planning within the organization*

Firms can consider having cross functional teams responsible for identifying and managing global sourcing risks, as suggested by Christopher et al. (2011). Better coordination between designers, supply chain personnel and suppliers in the early stages of new product development helps in avoiding the risk of obsolescence and misunderstanding consumer trends (Khan et al., 2012). Multiple risk sharing contracts can be explored to better plan for future risks (Wakolbinger and Cruz, 2011; Ghadge et al. 2017). Proactive as well as reactive risk planning approaches need to be followed. For a third party logistics service provider (3PL), internal integration can help it to adapt and cope with changes brought about by a disruption and provide quick response to disruptions.

4.2 Direct negative effects of SCI on risk management effectiveness

When companies share information, engage in joint planning and integrate processes through SCI, it exposes companies to the risks of others (Hallikas et al., 2004). Higher intensity of SCI contributes to the 'snowball' effect of propagation disruptions in material flows in supply chains, as those can act as drivers of amplification of disruptions during transmission, while the span of integration may weaken the effect of such disruptions (Swierczek, 2014; Swierczek, 2016).

Information and communication technology(ICT)-related risks exist in the data exchange process with supply chain partners; they will be willing to share data if they have confidence in the perceived security of supply chain information systems (Zhang and Li, 2006). Such risks may include information integrity issues in terms of adhoc data storage, information leakage due to personal conversations, disclosure of pricing information, etc. (Huong Tran et al., 2016). Such risks associated with inter-organizational information sharing can escalate as the volume of exchanged information increases (Anand and Goyal, 2009; Tan et al., 2015). Information sharing between partners can also have security threats (Bandopadhyay et al. 2010; Huong Tran et al., 2016).

Table 2: Positive and negative impact of SCI on effectiveness of risk managemen

SCI	Effectiveness of risk management
	Positive effects
Hallikas et al., 2004; Lockamy and McCormack, 2012	Minimizes occurrence of risk events
Sheffi, 2001; Wieland and Wallenburg, 2013; Zhu et al., 2017, Jüttner and Maklan, 2011; Zhu et al., 2017	Improves disaster preparedness and ability to deal with future disruptions
Enderwick, 2009; Tse et al., 2011; Chen et al., 2013; Zu et al., 2012; Cantor et al., 2014; Zsidisin et al., 2016	Avoids or reduces risks
Johnson et al, 2013; Simatupang and Sridharan, 2005; Scholten and Schilder, 2015; Dabhilkar et al., 2016	Enhances disaster response
Li et al., 2006; Wieland and Wallenburg, 2013; König and Spinler, 2016	Minimizes the effect of disruption, avoiding vulnerability from logistics outsourcing
Enderwick, 2009; Cruz and Liu, 2011	Reduces opportunism
Ponomarov and Holcomb 2009; Tukamuhabwa et al., 2015; Brusset and Teller, 2017; Zeng and Yen, 2017; Liu and Lee, 2018	Increases resilience
Busse et al., 2017	Identifies supply chain sustainability risks
	Negative effects
Hallikas et al., 2004; Lockamy and McCormack, 2012; Wever et al., 2012; Zeng and Yen, 2017	Increases dependence and exposure to risk of others
Bandyopadhyay et al., 2010; Huong Tran et al., 2016	Propagates information security risk

Swierczek, 2014; 2016	Causes snowball effect of propagation of disruptions

While communication networks and SCI facilitate optimization of traditional supply chain functions, they also exacerbate the information security risk: communication networks propagate security breaches from one firm to another and supply chain integration causes a breach in one firm to affect other firms in the supply chain (Bandopadhyay et al., 2010).

Furthermore, an inherent risk associated with SCI is the risk of increasing operational complexity. Operational complexity can increase when companies decide to integrate more closely (Sivadasan et al., 2010). For example, a company-supplier of two other companies, one a collaborator and other arms-length, may end up running two separate supply chains, which means duplication of effort in many cases. In particular, at the front of technology integration, many future collaborators are facing difficulties in integrating their systems. This increased complexity in technology integration can sometimes cause the termination of the collaboration (Matopoulos et al., 2007).

Through SCI, firms in a network also become more dependent on each other and this could create risk in networks. Cooperation between firms in a network is likely to increase dependency between the organizations and, hence, risk (Hallikas et al., 2004; Lockamy and McCormack, 2012; Wever et al., 2012). Such dependence has been viewed as a risk which is particularly high for small companies collaborating with big ones, especially when combined with the element of power. Thus, while SCI improves effectiveness of risk management on multiple dimensions, SCI also exacerbates the problem of managing risks, as it facilitates the propagation of risks across the network. Hence, SCI needs to be pursued with caution. Even if SCI helps in establishing knowledge-sharing routines and relation-specific assets, it can impede quick reaction, tie up capital, reduce flexibility (Wieland Wallenburg, 2013) and may not have a stronger impact on performance compared to information sharing (Wiengarten et al., 2010).

4.3 Indirect effects of SCI on risk management effectiveness mediated through collaborative risk management capabilities

Adopting Coates and McDermott's (2002, p. 436) definition, a competence is a "*bundle of aptitudes, skills and technologies that the firm performs better than its competitors, that is difficult to imitate and provides an advantage in the marketplace.*" Such competencies can lead to the development of capabilities which, in turn, impact performance. In this context SCI can be defined as a competency which consists of information sharing and joint risk planning with supply network members (akin to external integration) (Li et al., 2015); and risk planning within the organization (akin to internal integration) (Wiengarten et al., 2016). Firms possessing the above dimensions of SCI can develop collaborative risk management capabilities, which can support in improving effectiveness in risk management.

Thus, joint planning could help in assessing the need for risk mitigation programs and assess its benefits and potential gains more clearly. Firms which conduct joint planning activities with their suppliers are also able to have access to the information needed for their risk mitigation programs, perceive the benefits from risk mitigation programs and observe the potential gains in implementing risk mitigation programs (Cantor et al., 2014). In turn, suppliers may share risk management best practices with their own suppliers. Effective integration through the joint process of collaborative risk management (Hallikas et al., 2004; Cantor et al., 2014) can support SCRM programs between customers and suppliers (Lockamy and McCormack, 2012). Joint continuity plans also increase the willingness of supply chain partners to share risks (Jüttner and Maklan, 2011). Optimal incentive schemes between supply chain members to share the disruption information (Lei et al., 2012) can be developed based on joint risk planning activities, which can help in better understanding of each other's risks. Internal integration also has a positive effect on developing warning and recovery capabilities (Riley et al., 2016). Thus, it is argued that joint capacity and demand planning and joint risk assessment with suppliers, coupled with risk planning within the organization, can help in developing collaborative risk management capabilities and, specifically, decision synchronization, development of early warning systems and development of mechanisms for sharing risks and rewards.

We outline some collaborative risk management capabilities and their impact on risk management effectiveness.

a) Decision synchronization

Decision synchronization is essential for effective system-level disruption responses (Jüttner and Maklan, 2011; Scholten and Schilder, 2015). It is a capability which can be developed based on information sharing and joint risk planning with supply network members and within the organization. For example, operational risk planning in the delivery process should ensure that shipping schedules and replenishment of products are synchronized between the shipper, transporter and customer (Simatupang and Sridharan, 2005).

b) Development of early warning systems

Development of early warning systems is needed for identifying risks (Wiengarten et al., 2016). Information sharing can help in developing such early warning system capabilities, so that firms can be alerted about potential disruptions (Li et al., 2006; Wiengarten et al., 2016).

c) Development of mechanisms for sharing risk and rewards

Through risk sharing mechanisms, supply chain members use more formal policies and arrangements (e.g., agreements, contracts, etc.) to share the obligations and responsibilities in activities and/or resources relating to SCRM (Li et al., 2015). Thus, firms can engage in operational or strategic agreements with suppliers to share the supply chain risks, which can enable loss dispersion (Jüttner and Maklan, 2011). To successfully engage in such risk sharing arrangements, incentives between partners need to be aligned. Not all players in the supply network benefit equally from information sharing. Hence, appropriate risk-sharing contracts need to be designed. Sometimes such contracts and information sharing can complement each other in minimizing disruptions. In other cases, where there is a lack of information, such contracts can also safeguard the interest of different players faced with disruption (Wakolbinger and Cruz, 2011).

Incentive alignment can prevent opportunistic behaviour of individual parties and, thus, avoid the response capability of the whole system (Sheu et al., 2006). In markets where overseas buyers may face high uncertainty and high opportunism, Enderwick (2009) shows a successful relationship developed over a number of years could allay the fear of opportunism (Enderwick, 2009). Such relationships encourage risk-sharing in the form of investment in specialist assets.

From the review, the capabilities which can be developed through SCI resulting in improved risk management effectiveness are identified. We coded all the individual competencies, the capabilities and the risk effectiveness measure from the reviewed articles (shown as items in Table 3) and created two competency constructs - ‘joint risk planning with supply network members’ and ‘risk planning within the organization’. These competencies result in collaborative risk management capabilities.

Table 3: Competencies and capabilities for improving effectiveness of risk management

Constructs	Variables	References
Information sharing and joint risk planning with supply network	Joint capacity planning	Cantor et al.,2014
	Joint demand planning	Simatupang and Sridharan, 2005

members	Joint risk assessment	Hallikas et al., 2004; Pournader et al., 2016
	Joint risk mitigation planning	Hallikas et al., 2004; Craighead et al, 2007; Manuj and Mentzer, 2008; Cantor et al., 2014
	Joint business continuity planning	Jüttner and Maklan, 2011
	Information sharing, personal communication	Spekman and Davis, 2004; Brandon-Jones et al., 2014; Li et al., 2015; Huong Tran et al., 2016
	Knowledge sharing across the network and with external stakeholders	Manuj and Mentzer, 2008; Jüttner and Maklan, 2011; Biotto et al., 2012; Ellinger et al., 2015; Scholten and Schilder,2015; Tukamuhabwa et al., 2015; Dabhilkar et al., 2016; Zsidisin et al., 2016; Busse et al., 2017
	Joint problem solving with suppliers	Reimann et al., 2017
Risk planning within the organization	Collect data and intelligence on market trends and supply chain	Cantor et al., 2014; Ellinger et al., 2015
	Disseminate trends in supply chain with other functions	Cantor et al.,2014
	Scanning the environment for potential disruptions	Dabhilkar et al., 2016
	Notify other departments when something important happens with a key	Cantor et al., 2014; Ali et al., 2017

	supply chain member, education, training and learning	
Collaborative risk management capabilities	Decision synchronization	Simatupang and Sridharan, 2005; Scholten and Schilder, 2015
	Development of early warning system	Li et al., 2006; Wiengarten et al., 2016
	Development of mechanism for sharing risk and rewards	Manuj and Mentzer, 2008; Jüttner and Maklan, 2011; Wakolbinger and Cruz, 2001; Lei et al., 2012; Li et al., 2015
Effectiveness of risk management	Avoid risk	Tse et al., 2011
	Minimize occurrence of risk events	Hallikas et al, 2004; Lockamy and McCormack, 2012
	Improve disaster preparedness	Sheffi et al., 2001; Jüttner and Maklan, 2011; Wieland and Wallenburg, 2013
	Enhance response to disasters or risk events	Simatupang and Sridharan, 2005; Johnson et al., 2013
	Minimize effect of disruption	Li et al., 2006; Wieland and Wallenburg, 2013
	Reduce opportunism risks	Enderwick, 2009; Cruz and Liu, 2011
	Improve resilience	Ponomarov and Holcomb, 2009; Pettit et al, 2010; Ali et al., 2017

	Reduce unethical activities among network members	Eckerd and Hill, 2012

4.4 Role of supply network characteristics in influencing the positive and negative effects of SCI on effectiveness of risk management

Network characteristics in terms of network structure, network relationships and network complexity can impact how SCI will influence risk management effectiveness.

a) Network structure

A more concentrated or reduced supply base increases the risk of disruption; however, it facilitates collaboration. A network can also be open or closed. In a closed network, the buyer, the first and second tier of suppliers are interconnected and coupled with each other. However, this type of network requires additional effort for SCI (Mena et al., 2013). The degree of centrality of certain firms in a network has a role to play in the way SCI impacts the effectiveness of risk management in a network. A firm operating at the center of the network may have a higher influence on the other actors in terms of increasing product quality, while also decreasing costs and supply risks (Yan et al., 2015). Thus, buying firms need to assess the degree of centrality of suppliers and how many suppliers in a network have high network centrality. Nevertheless, it is important to distinguish between node level and network level disruptions, as not all node level disruptions may affect the network. Different network structures will play a role in how resilience can be achieved in the networks faced with disruptions (Kim et al., 2015).

b) Network complexity

Node complexity is determined by geographical dispersion of the supply chain (Stock et al., 2000), number of suppliers and differentiation of suppliers (Choi and Krause, 2006; Adenso Diaz et al., 2012) and the extent of flow of information among the actors. Complexity has a direct impact on coordination costs because more nodes and accompanying flows require greater effort at coordination (Craighead et al., 2007). A closed network is more stable and incurs less opportunism risk but requires higher efforts in SCI. An open network is less stable but requires fewer resources compared to a closed network (Mena et al., 2013). Node complexity has a strong negative effect on network reliability while flow complexity has a positive effect (Adenso-Diaz et al., 2012). Adenso Diaz et al. (2012) conducted an empirical analysis the of which results show that network density, node criticality and complexity are significant factors in reducing the reliability of supply networks. In particular, node complexity was found to have the strongest negative effect on network reliability followed by supplier complexity and density, while the strongest positive factor was source criticality (i.e., the level of redundancy of suppliers). Increasing the number of nodes in a network would reduce its reliability but increasing the number of connections would help to mitigate some of the negative effects (Adenso Diaz et al., 2012).

Complex supply networks require significant investments in SCI, but the benefits achieved in terms of improved resilience can also be justified compared to a simpler supply chain with a smaller number of suppliers, where the investments required may outweigh the benefits. For supply chains with moderate levels of complexity, moderate investment in supply chain visibility may be most appropriate, with the investments influenced by the type of complexity most prevalent in their supply chains (Brandon-Jones et al., 2014). Supply base complexity increases the probability of disruptions and increased visibility can help mitigate the effect of disruption (Brandon-Jones et al., 2015).

c) Network relationships

Building trustworthy relationships with suppliers and enhancing information and knowledge sharing in operations on a daily basis is at the heart of managing supply risks (Chen et al., 2016). The type and length of contracts (Lindroth and Norrman, 2001; Li et al., 2015) and the level of detail in the exchange of specifications determine the degree of coupling in the network. As relationship strength between supply network members improves due to increased efforts and investments in SCI opportunism may decrease. This may improve reliability but may also increase the probability of disruption due to increased transactions (Cruz and Liu, 2011).

Table 4: Items to capture network characteristics

Constructs	**Variables**	**References**
Network characteristics	Length and strength of relationship	Cruz and Liu, 2011; Li et al., 2015;
	Density or concentration of the supply network	Vachon and Klassen, 2006; Craighead et al., 2007
	Open or closed network	Mena et al., 2013
	Degree of centrality in the network	Yan et al., 2015

	Flow complexity	Adenso-Diaz et al., 2012
	Node complexity	Adenso-Diaz et al., 2012
	Degree of coupling	Skilton and Robinson, 2009

The degree of coupling, a measure for the strength of a relationship in a supply network, has an inverted U-shaped relationship with transparency, increasing to a point and then levelling off as coupling becomes increasingly tighter (Skilton and Robinson, 2009). Thus, a higher level of coupling and interdependence will help in transparency and visibility only up to a certain level (Skilton and Robinson, 2009). Power imbalances between network members can also be another network characteristic. With reduced power imbalances, risk-reward sharing imbalance reduces and more intense collaboration can be achieved (Matopoulos et al., 2007). In a complex network, the complexity of risk factors requires greater entrustment of risk management to secondary principals charged with the operation of sub-networks (Cheng and Kam, 2008). Thus, for example, OEMs who get supplied by multiple tiers of suppliers with some suppliers common for different OEMs, can entrust some of the risk management responsibility to first tier suppliers and also collaborate with each other on sharing risk information. Different relationship strengths between network members create different levels of risk exposure and provide different levels of flexibility in risk response. Hence, the decision about investment in supplier development programs or supplier integration can be continued or discontinued based on the suppliers' ability to deal with market and technology turbulence (Trkman and McCormack, 2009).

Table 4 shows the variables which can be used to capture network characteristics while table 5 summarizes how different network characteristics moderate the impact of SCI on effectiveness of risk management.

Table 5: Moderating effect of network characteristics on the impact of SCI on effectiveness of risk management

Network characteristics	Moderating effect on how SCI impacts effectiveness of risk management

Multiple tiers	Limit the positive impact of SCI on performance (Danese and Romano, 2013) (-)
Concentrated or small supply base	Facilitates collaboration (+) but increases disruption risk (-) (Vachon and Klasssen, 2006)
Closed network	Reduces opportunism risk (+) and requires additional resources for IS and collaboration (Mena et al., 2013)
Degree of centrality	Facilitates direct ties with suppliers while reducing supply risks (+) (Yan et al., 2015)
Length and strength of relationships	Lowers opportunism risk (+) but increases probability of disruptions due to increased transactions (-) (Cruz and Liu, 2011)
Higher level of coupling	Increases transparency and visibility up to a certain level(+), increases flow complexity(-) (Skilton and Robinson, 2009)
Power imbalance	Reduces risk-reward sharing imbalance and more intense collaboration can be achieved (+) (Matopoulos et al., 2007)
Node complexity	Reduces reliability and transparency, difficulty in IS, collaboration and SCI (Adenso-Diaz et al., 2012) (-)
Flow complexity	Improves network reliability (Adenso-Diaz et al., 2012)

(+) indicates positive effect, (-) indicates negative effect

5. Framework for effective risk management in supply networks

Moving beyond recent literature reviews on SCRM, this critical review enables the development of a conceptual framework for assessing the effect of SCI for effective risk management in supply networks. The review highlighted that SCI can be used to develop competencies in joint risk planning with supply network members and internal risk planning, which will result in collaborative risk management capabilities. Thus, we argue that the relationship of joint risk planning and internal risk planning competencies with effectiveness of risk management can be mediated by collaborative risk management capabilities and moderated by network characteristics. The network characteristics will have an influence on how the above capabilities will impact the effectiveness of network characteristics as complexity, number of tiers, and the length and strength of the relationships will make it easier or difficult to develop those capabilities. Hence, we develop an integrated framework that shows how competencies in risk planning within the organization and with supply network partners can improve the effectiveness of risk management by developing collaborative risk management capabilities while considering the influence of network characteristics.

Information processing theory (IPT) views organizations as information processing systems (Galbraith, 1973). Facing uncertainties and ambiguities, the primary function of an organization is to create the most appropriate configuration of work units to facilitate the effective collection, processing and distribution of information (Daft et al., 1987). These activities of information collection, processing and distribution are conceptualized as an organization's information processing capabilities and will be essential for both internal risk planning as well as for risk planning with network members. Using IPT, Fan et al. (2017) analyze the effect of risk information sharing on risk analysis, assessment and risk sharing, while Fan et al. (2016) show that a firm's capability in processing supply chain risk information can improve operational performance.

The dynamic capabilities view posits that competitive advantage arises when an organization is able to absorb information quickly and has the ability to respond to changes in its business environment. Using this ability, global supply chains can strengthen their inter-organizational relationships (Arnold et al., 2010). Thus, individual supply chain members should develop their own absorptive capacity which will enable them to acquire and assimilate information allowing them to participate in the joint exploitation of that knowledge along with other supply chain partners (Arnold et al., 2010).

Using IPT and dynamic capabilities as the theoretical foundation, the study proposes that firms in the supply network need to utilize SCI as a building block to develop competencies in joint planning with supply network members and risk planning within the organization. While IPT allows for effective collection, processing and distribution of information, the dynamic capabilities perspective ensures that firms are able to develop absorptive capabilities to process and synthesize information, strengthen relationships and use those for risk management. This leads to the development of collaborative risk management capabilities which will eventually influence the degree of effectiveness of risk management approaches. Such collaborative risk management capabilities include decision synchronization (Simatupang and Sridharan, 2005), development of early warning systems (Li et al., 2006), development of understanding of capacity constraints (Cantor et al., 2014) and development of mechanisms for sharing risks and rewards (Jüttner and Maklan, 2011; Li et al., 2015). Developing a collaborative risk management capability will incur costs related to resource deployment, monitoring, etc. Thus, network members should consider sharing the costs and benefits to reduce exposure to opportunistic and shirking behavior (Wever et al., 2012).

The proposed framework provides the theoretical basis for empirically validating the role of SCI on improving the effectiveness of risk management in supply networks. An integrated framework also has managerial implications for firms in the supply network. It recognizes that companies need to develop specific competencies in joint planning with supply network members and risk planning within the organization using SCI. Network characteristics need to be considered as contingent factors to tailor the collaborative risk management capabilities suited for the network. The dotted lines in the framework represent the feedback loop, which ensures that the companies need to monitor the effectiveness of risk management and take corrective actions to continuously improve the SCI competencies needed.

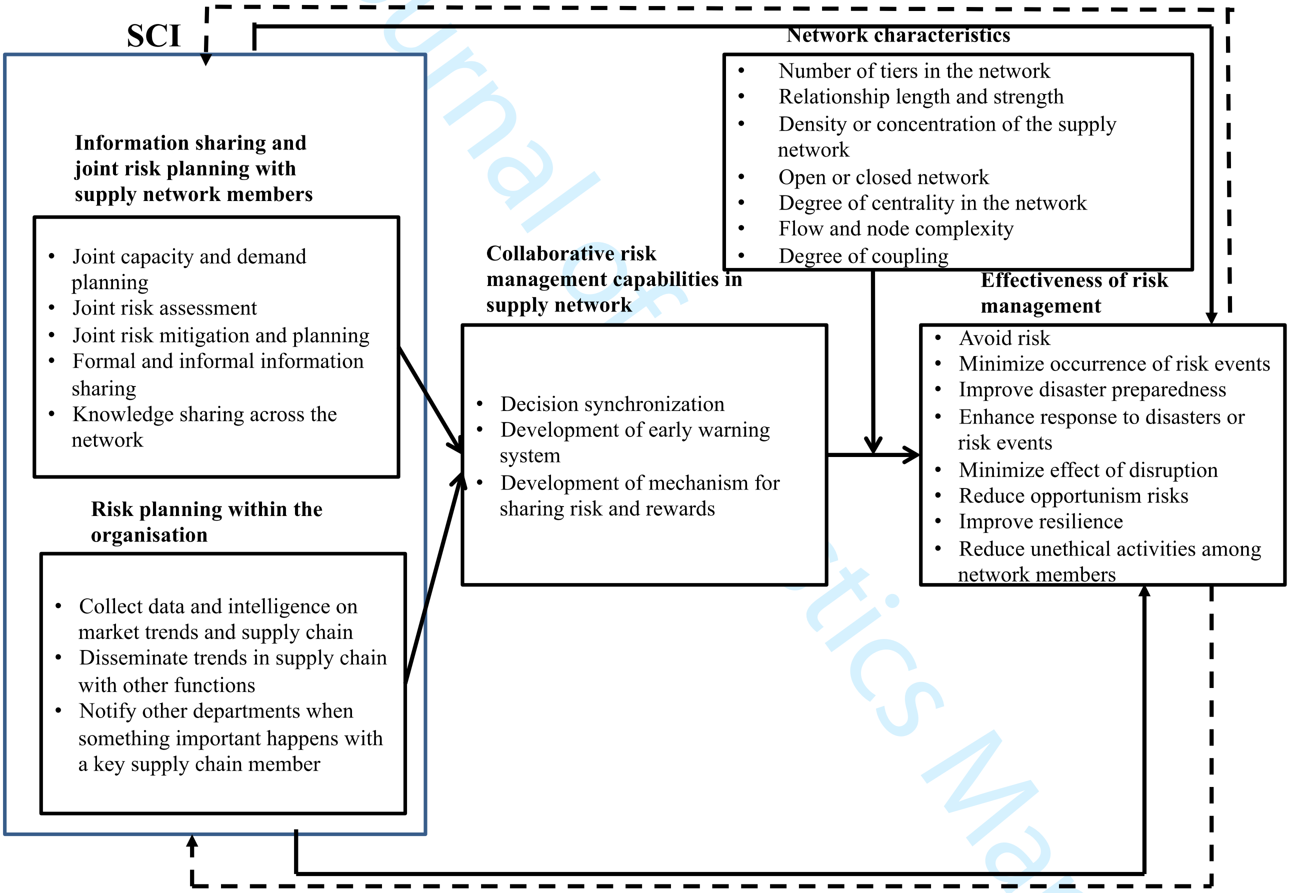

Figure 1: Conceptual framework for improving effectiveness of risk management in supply network

Such feedback loops are very important as the risk management process is dynamic rather than static. Hence, if effectiveness of risk management is not improved, firms should 1) invest in joint risk planning with other members and within the organization, 2) analyze whether adequate collaborative risk management capabilities are developed, and 3) take corrective actions if necessary. This may also result in redesign of the supply network, if needed. Figure 1 provides the conceptual framework for improving effectiveness of risk management in supply networks. Such conceptual frameworks have been used to synthesize insights from literature reviews and to provide directions for future research (Ali et al., 2017; Tachizawa and Wong, 2014; van der Vaart and van Donk, 2008).

6. Conclusion, limitations and future research directions

Following a critical review approach, articles published between 2000 and 2018 were carefully synthesized to answer the research questions. This paper makes two key contributions. First, the study has identified the positive and negative effects of SCI on risk management effectiveness in supply networks. Second, using IPT and dynamic capabilities as the theoretical foundation, a framework has been developed which organizations can use to further develop competencies and capabilities to improve effectiveness of risk management. Processes for sharing information, collaboration and integration between network members should take into account network characteristics (Wiengarten et al., 2010), willingness to share information (Arnold et al., 2010) and the degree of asymmetry in the behavior of supply chain partners (Michalski et al., 2017). Thus, we also cover the contingency effects of network characteristics.

Our proposed framework can potentially direct research to empirically validate the effect of SCI on improving the effectiveness of risk management considering network characteristics. In fact, there are limited empirical studies on analyzing how effectiveness of risk management can be improved using SCI. This study is the first step in that direction. It can also be extended to find out how competencies in risk planning within the organization and with supply network members can improve the effectiveness of risk management by developing collaborative risk management capabilities across each risk management stage, i.e., identification, assessment, mitigation and recovery. Dynamic evaluation of effectiveness of risk management and using that to improve risk management competencies and capabilities and potential redesign of the supply network can also be a research direction very relevant for improving risk management practices.

This study only considered network characteristics as a single contingent factor impacting the relationship between SCI and the effectiveness of risk management. Future research should also take into account other contingent factors which can explain the impact of SCI on risk management effectiveness; e.g., the type of product, product architecture, supplier characteristics (Trkman and

McCormack, 2009) and type of disruptions (Zhu et al., 2016). Other opportunities exist to develop and validate collaborative risk management processes and governance mechanisms in supply networks, with different characteristics to improve the effectiveness of risk management and performances of the network. Challenges for adopting a suitable technology infrastructure across the supply network also needs to be analyzed, as the level of penetration of information and communication technologies (ICT) is still not prevalent beyond tier I suppliers. Finally, there are opportunities for research on devising suitable coordination mechanisms to incentivize supply network members to collaborate for risk management (Reimann et al., 2017).

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