Proceedings of the 2015 International Conference on Industrial Engineering and Operations Management
Dubai, United Arab Emirates (UAE), March 3 – 5, 2015

Supply Chain Risk Management:

Systematic literature review and a conceptual framework for capturing interdependencies between risks

Abroon Qazi, John Quigley
Department of Management Science
University of Strathclyde
Glasgow, UK
(abroon.qazi, j.quigley)@strath.ac.uk

Alex Dickson
Department of Economics
University of Strathclyde
Glasgow, UK
alex.dickson@strath.ac.uk

***Abstract*—The purpose of this research is to conduct a comprehensive and systematic review of the literature in the field of 'Supply Chain Risk Management' and identify important research gaps for potential research. Furthermore, a conceptual risk management framework is also proposed that encompasses holistic view of the field. 'Systematic Literature Review' method is used to examine quality articles published over a time period of almost 15 years (2000 - June, 2014). The findings of the study are validated through text mining software. Systematic literature review has identified the progress of research based on various descriptive and thematic typologies. The review and text mining analysis have also provided an insight into major research gaps. Based on the identified gaps, a framework is developed that can help researchers model interdependencies between risk factors.**

Keywords—Supply chain risk management; Systematic literature review; Text mining; Risk management framework, Holistic approach

I. INTRODUCTION

Supply chain risk management (SCRM) is gaining an increasing interest from researchers [1-3]. A number of researchers have conducted literature reviews and consolidated important research findings [1, 4-7] but only a couple of researchers have conducted Systematic literature review [3, 8]. Systematic literature review (SLR) presents an effective technique to discover research gaps through a methodological process. We have followed the process adopted by Tranfield, et al. [9] who devised a strategy to transform the established technique in the field of Medical Science to its application in Management Science.

Through SLR, we have conducted review of quality articles published over a period of almost 15 years. SLR differs from narrative review in terms of providing transparent and replicable results through evidence based knowledge management [8, 9]. Data mining and text mining are used for collecting, retrieving and analyzing huge scientific data. We have used NVivo 10 (qualitative data analysis software) for validating the results of systematic literature review. Based on analysis of the review, important research gaps are identified and a holistic model is developed for capturing linkages across these future research areas. We have also developed a conceptual model for management of supply chain risks that is claimed to be a better modeling technique in comparison with most of the currently used methods treating risks as independent events.

Basic concepts related to the field of SCRM are discussed in Section II. Process of conducting systematic literature review is described in Section III followed by enumeration of findings resulting from the descriptive and thematic analysis of the review. Moreover, identified research gaps are also discussed in detail. A conceptual framework for modeling interdependencies between supply chain risks is developed and presented in Section IV to help researchers model global supply chain risks in a holistic manner.

II. SUPPLY CHAIN RISK MANAGEMENT

Risk has been defined as a chance of danger, damage, loss, injury or any other undesired consequence [10]. According to Knight [11], risk is something measurable in a way that probabilities of the outcomes can be estimated whereas, uncertainty is not quantifiable and the probabilities of the possible outcomes are not known. After analyzing concept of risk in different disciplines, Manuj and Mentzer [12] found the presence of following three components in all conceptualizations of risk:

- Potential losses in case of realization of risk
- Probability (likelihood) of the occurrence of an event that leads to realization of the risk
- Significance of the consequences of losses

Supply chain risk is characterized by both the probability of an event and its severity given that an event occurs [13]. According to Tang [14], "SCRM is the management of supply chain risks through coordination or collaboration amongst the supply chain partners so as to ensure profitability and continuity". According to Jüttner, et al. [7], "SCRM aims to identify the potential sources of supply chain risk and implement appropriate actions to avoid or contain supply chain vulnerability". Vulnerability is defined as an exposure to serious disturbances from risks within the SC as well as risks external to the SC [15]. Supply chain risk is an event that may cause disruption to the flow of activities within the supply chain.

Manuj and Mentzer [16] conducted an extensive literature review and a qualitative study comprising interviews and focus group meeting in order to develop a grounded theory for understanding global supply chain risks. According to them, "Global supply chain risk management is the identification and evaluation of risks and consequent losses in the global supply chain, and implementation of appropriate strategies through a coordinated approach among supply chain members with the objective of reducing one or more of the following – losses, probability, speed of event, speed of losses, the time for detection of the events, frequency, or exposure – for supply chain outcomes that in turn lead to close matching of actual cost savings and profitability with those desired". Recently, there has been a shift in the interest of researchers towards exploring impact of disruption on global supply chains. Global sourcing and lean operations are the main drivers of supply chain disruptions [17].

Risk management is an established field in some areas of organizational life like finance but it is still a developing theme within the realm of supply chain management [1]. Though there is an ongoing debate on the objective and subjective nature of risk, there is a consensus among researchers on treating the risk management as a process comprising three stages of risk identification, risk estimation and risk evaluation [18].

III. Research Methodology

We adopt research methodology of conducting systematic literature review. In contrast to traditional narrative reviews, the systematic reviews adopt replicable and transparent process that minimizes the bias by providing an audit trail of the reviewers' plan of action [19]. The systematic review and its associated procedure, meta-analysis, play an important role in evidence-based practices. Systematic review is conducted for identifying major contributions to a research field whereas meta-analysis provides a statistical procedure for synthesizing key findings [9].

Systematic review differs from the narrative review in terms of following a comprehensive and an unbiased search. Though systematic reviews necessitate investing plethora of time and great deal of commitment, the results are deemed as of high quality and most efficient [20]. The complete process of conducting a systematic literature review is shown in Fig. 1.

A. *Identification of Research*

The first step in conducting a systematic literature review is to identify the keywords and search terms that result from the scope of research, literature and discussion within the review team. One key aspect is to report the search terms in detail for replication in future. The searches should not only be confined to the published journals rather unpublished reports, conference papers and other working papers must also be taken into consideration. The search phase results into an identification of a detailed listing of articles and papers for further consideration.

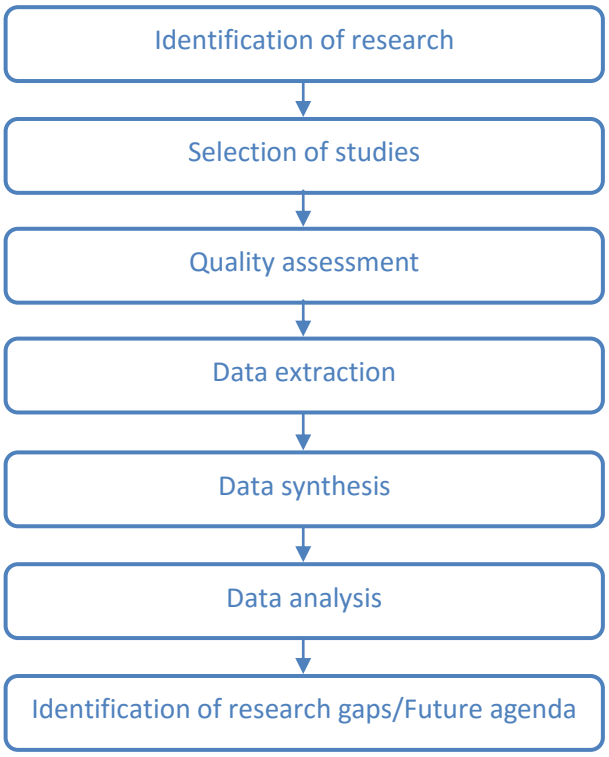

Fig. 1. Systematic literature review process [9].

Following the guidelines of systematic literature review process, a panel of three researchers conducted regular meetings and finalized the scope of study. Almost 200 peer-reviewed articles were collected through search strings of 'supply chain risk management', 'supply network risk', 'supply risk', 'supply chain disruption', and 'supply chain vulnerability'.

B. *Selection of Studies and Quality Assessment*

Studies that meet the inclusion criteria and strictly violate the exclusion criteria are selected for review process. The criteria are based on an important aspect of selecting high quality studies. However, this stage is quite subjective and therefore, more than one reviewer must be involved in conducting this stage of the review process. Disagreements need to be resolved through discussion and following a systematic approach. A preliminary review of all relevant citations is conducted followed by further selection for a more detailed evaluation. The number of sources selected at each stage needs to be recorded and the reasons for exclusion annotated. A quality assessment should include following criteria [21]:

- Does the research explore subjective meanings that relate to the experiences of other people?
- Is the study sample selected in a systematic manner governed by theory?
- Does the researcher explicitly mention the process of transformation from data to interpretation?

- Do the claims made to generalizability follow a logical/theoretical process from the data?

The inclusion criterion concerning the year of publication spanned across 15 years (from 2000 to June, 2014). The starting year of 2000 was selected on the basis of preliminary review that revealed growing interest of researchers in the field after the 9/11 attacks in USA. It was decided to gauge quality of selected articles through the lens of the Association of Business Schools (ABS) that publishes quality ratings of academic journals. Besides the quality criterion being the leading factor for selection, we manually scrutinized the articles for their relevancy and finally, 55 articles were dropped because of their strict relevance to the conventional field of supply chain management. Finally, 145 peer-reviewed articles were selected for conducting the systematic literature review. Maximum number of articles were published in 'International Journal of Physical Distribution and Logistics Management' and 'Supply Chain Management : An International Journal'. The distribution of articles with respect to the ABS ranking is depicted in Fig. 2. Almost 49 percent of the selected articles were published in high ranking journals (3 and 4 stars).

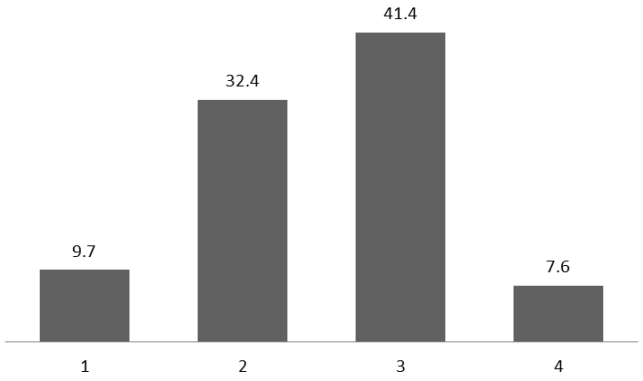

Fig. 2. Percentage distribution of articles with respect to ABS ranking (2010) of Journals.

C. Data Extraction

Selection and quality assessment stages are followed by the data extraction process that requires documentation of all steps taken. Data extraction can either be paper based or computer assisted. Data extraction forms can be used to record details of information source (title, authors, and publication details) and other pertinent details including context of the study and a qualitative evaluation of methodological underpinning. In order to utilize the computational power of text mining methods, all the selected articles were imported in NVivo 10 that is a useful software developed by QSR International for conducting qualitative data analysis.

D. Data Synthesis

Research synthesis is a process of consolidating the findings of different studies on a research topic. Narrative review is the simplest and well-known form of research synthesis but this type of review fails to seek generalization from the reviewed literature [22]. This shortcoming can be overcome by conducting meta-analysis that enables pooling of data through statistical techniques.

'Word frequency' query was run in NVivo 10 to determine the extent of research in various themes. The main inclusion criterion was aimed at focusing on studies pertaining to risk management in supply chains and text mining result validates our selection as per the inclusion criterion. The results are presented in the form of word cluster as shown in Fig. 3. Most of the studies relate to supplier risks as suppliers are considered to be the main source of disruptions. The cluster also reveals an important fact that certain themes are underexplored and need further research including but not limited to global supply chains, customer risks, quality risks, disruptions and risks related to new design. The size of each word represents its relative frequency.

Fig. 3. Word cluster diagram.

E. Data Analysis

The main purpose of a systematic review is to make it easier for a practitioner to understand the research that demands an effective reporting style. The report may comprise two stages focusing on the descriptive and thematic analyses. The first stage provides a descriptive analysis of the field that is extracted from the earlier recorded forms. This part of the report may include classification of articles with respect to the origin of authors, yearly volume of publications, epochs of research field and so forth. The researcher must also present a thematic analysis to report on the extent to which consensus is shared across various research themes within the field. Furthermore, research gaps need to be explored for identifying future research venues. An important part of the reporting process is to link various themes across core contributions.

1) Descriptive Analysis

a) Year of Publication: The articles were analyzed with respect to year of publication as shown in Fig. 4 that clearly reveals that the field of SCRM started gaining the attention of researchers in 2000 and since 2004, there has been an accelerated progress in the research field. Maximum articles were published in 2009 and if the timeline is segregated into two halves, the number of articles published in the second half is almost twice that of the first half. It manifests the growing interest of researchers and practitioners in the field and its potential for further growth and research.

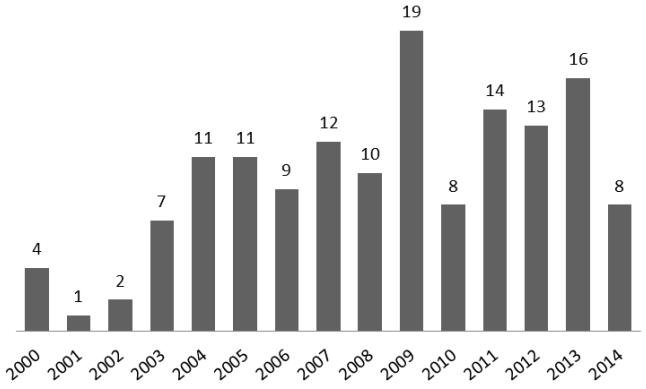

Fig. 4. Distribution of articles with respect to year of publication.

b) Industry: The classification of articles with respect to industrial application is shown in Fig. 5. Most of the studies have been conducted in automotive industry. Almost 38 percent of the articles did not have an application of the research in any industry that clearly necessitates conducting more industry focused research in future. 'Multiple' indicates a mix of different industries and the researchers either conducted multiple case studies or interviewed/surveyed practitioners in various industries. Only 3 percent of the studies were focused on small and medium enterprises whereas 59 percent of articles were aimed at companies with global footprint. The analysis indicates lack of research in the realm of small companies and keeping in view the major impact of disrupted bottleneck small firms on the entire supply network, there is a need for conducting extensive research in order to explore risk management techniques followed by the small companies and the impact of these practices on global companies.

c) Type of Supply Chain: We also categorized articles on the basis of their application in development project of a new product as shown in Fig. 6. Studies linked to conventional supply chains indicate that the aspects of design change or new product development were not considered in the research. Therefore, there is a need for conducting extensive research to explore risks associated with new product development and investigate how design changes affect supply chain risks.

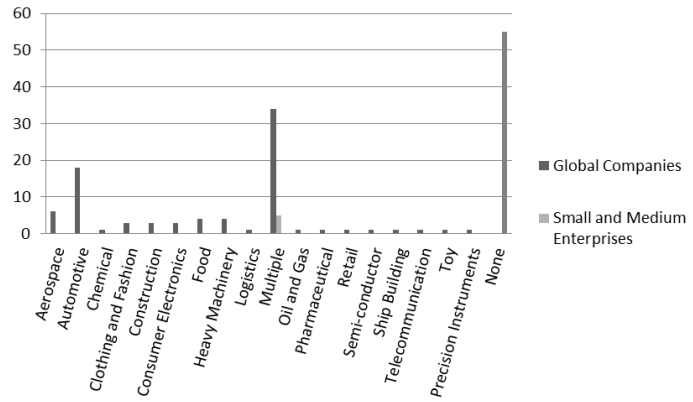

Fig. 5. Distribution of articles with respect to industrial application.

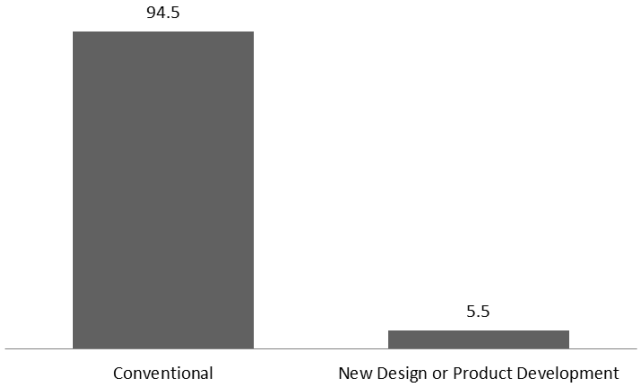

Fig. 6. Percentage distribution of articles with respect to type of supply chain.

*2) Thematic Analysis:*The articles have been analyzed on the basis of following significant themes:

- Research Method: Qualitative, quantitative or a combination of these methods are used to study the field of SCRM
- Type of Risk: There are a number of risk classifications; however, we classified the articles on the basis of organizational, network (supply or demand) and external risks
- Risk Management Process: The risk management process can be segregated into three stages of identification, assessment and mitigation/control

a) *Research Method:* The distribution of articles with respect to the type of research method is shown in Fig. 7. Most of the articles are based on qualitative methodology while a very limited research is focused on the quantitative methods. A few studies have employed mixed techniques. Hence, there is a need for conducting more research using quantitative techniques.

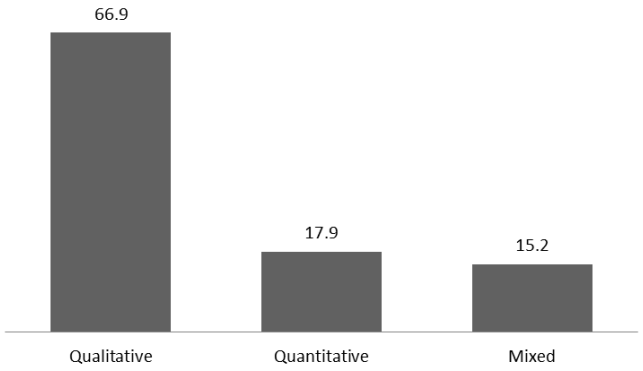

Fig. 7. Percentage distribution of articles with respect to research methodology.

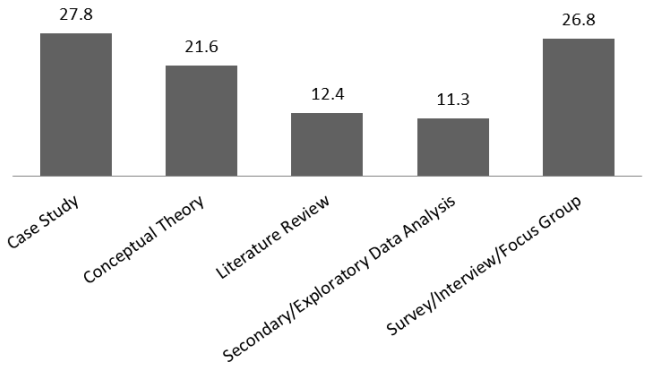

Fig. 8. Percentage distribution of qualitative methodology based articles with respect to sub-methods.

Qualitative methods were classified on the basis of research approaches as conceptual theory, literature review and empirical study as shown in Fig. 8. Empirical studies can be further classified as case studies, surveys, interviews, focused group methods and secondary data analysis. Most of the researchers have preferred conducting case studies. Blackhurst , et al. [23] used a multi-methodology empirical study combining case study, semi-structured phone interviews and focus group methods to study supply chain disruptions. Capó-Vicedo, et al. [24] presented a social network perspective of a supply chain and conducted an exploratory case study in construction industry. Christopher, et al. [25] conducted a multiple case study to explore the methods used by practitioners in assessing and mitigating global sourcing risks.

Khan, et al. [26] conducted an in-depth longitudinal case study of a major UK clothing and fashion retailer to investigate the impact of product design on supply chain risk management. Leat and Revoredo-Giha [27] conducted a case study in one of Scotland's major pork supply chains for identifying key risks and challenges involved in developing a resilient agri-food supply system. Researchers have also used surveys, semi-structured interviews and focus groups for collecting data to validate propositions and hypotheses [2, 16, 28-42]. Since the field of SCRM is still developing [1, 2, 8], there are a number of studies being conducted to develop conceptual theories and frameworks. Literature reviews are fundamental to conducting research in any field. Many researchers have conducted literature reviews mainly focusing on narrative reviews.

Few articles are focused on quantitative modeling of supply chain risks. Many researchers have used simulation technique for analyzing supply chain risks as shown in Fig. 9. Lutz, et al. [43] used game theory to demonstrate the practical impact of a multi-tier supply chain agreement. Interpretive structural modeling has been used to analyze supply chain risks in food industry [44] and model mutual relationship among the enablers of supply chain risk mitigation [45]. Lo Nigro and Abbate [46] used the concept of Shapley's value to devise a mechanism of profit sharing among supply chain partners.

Wieland [47] developed mathematical models for determining optimal solution and break-even points in the realm of four strategies-agility, robustness, resilience and rigidity. Multi-criteria decision making [48, 49] and stochastic programming [50-53] have also been utilized for assessing supply chain risks. Simulation has been extensively used by researchers in modeling supply chain risks. It provides a systematic approach for understanding the interactive impact of factors for different scenarios [8]. Simulation techniques used in the realm of supply chain risk management include agent-based modeling [54], Monte Carlo simulation [55, 56], discrete event simulation [57], system dynamics modeling [58] and Petri-Net simulation [59]

Researchers have also used mixed methods in their research. Analytical hierarchy process modeling [60-64] and interpretive structural modeling [65, 66] have been used to develop models and the validation and further development are conducted through case studies. Bayesian belief networks (BBNs) have started gaining the interest of researchers in modeling supply chain risks [67]. BBNs offer a unique feature of modeling risks combining both the statistical data and subjective judgment in case of non-availability of data [68-70]. Researchers have used the BBNs to model specific domains of supply chain risks and validated these models through case studies [71-76].

b) Risk Classification: The articles were classified on the basis of organizational, network and external risks as shown in Fig. 10. Organizational risks relate to the risks directly associated with the main focal firm and comprise inventory, operational, quality and management risks. The figure clearly reveals that a very limited research has been focused on the organizational risks. Inventory risk arises from stock-out inventories or buffer resulting into corresponding loss of opportunity or handling costs [7, 77]. Operational or process risks can be initiated with events disrupting processing and manufacturing activities within the organization [15, 78, 79].

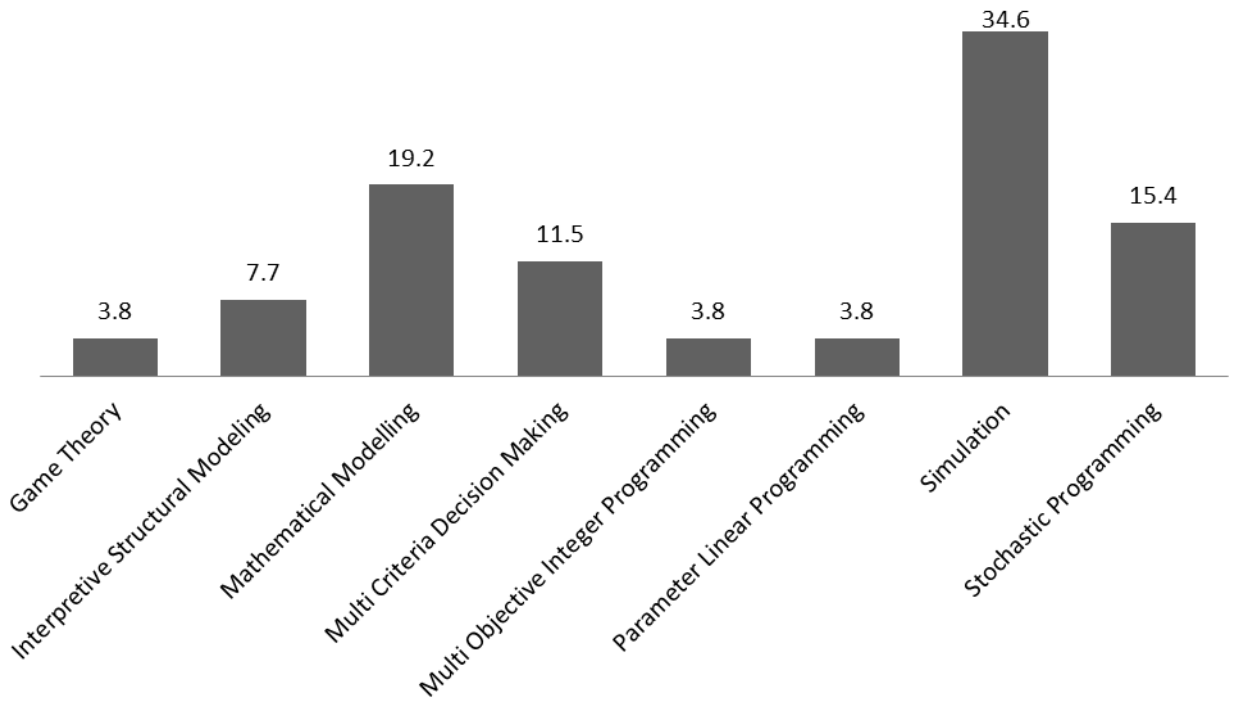

Fig. 9. Percentage distribution of quantitative methodology based articles with respect to sub-methods.

Quality risks arise from the problems associated with the manufacturing plant or suppliers. Global outsourcing is considered as an important driver of quality risk [77, 80, 81]. Management risk is related with the lack of management expertise in dealing with supply chain risks. Management risks have been classified as the main factor in failure of major development projects [82, 83]. The literature is lacking in identifying the organizational based characteristics of a mature firm in dealing with supply chain risks and disruptions [84].

Network risks arise from the interaction between the focal firm and its suppliers and customers. Network risks are found to be the most researched category of risks in the field of supply chain risk management. However, most of the articles deal with the supplier risks and customer related risks are not much discussed in literature [85]. Various studies have been conducted to assess supplier risks and evaluate their performance [64, 74, 75, 86, 87].

External risks are driven by external events like weather, earthquakes, political and market forces [88]. There has been an increase in the articles focusing on disruption risks [23, 30, 57-59, 89-91].

c) Stage of Risk Management Process: Articles were also classified on the basis of risk management process as shown in Fig. 11. Few studies have focused on risk identification exclusively while there is equal distribution of articles corresponding to risk assessment and mitigation stages. Almost 28 percent of the articles have analyzed the risk management process in its totality. Many researchers have proposed proactive mitigation strategies while a few studies focused on reactive strategies [39, 92-94].

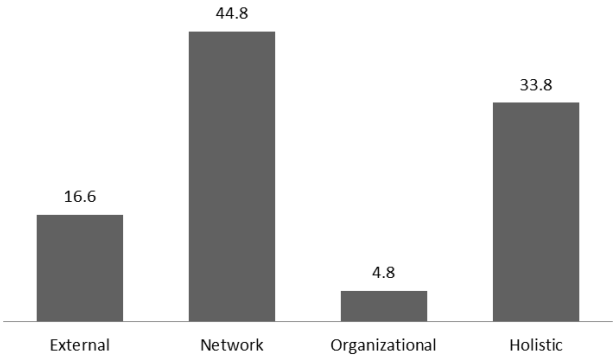

Fig. 10. Percentage distribution of articles with respect to classification of risks.

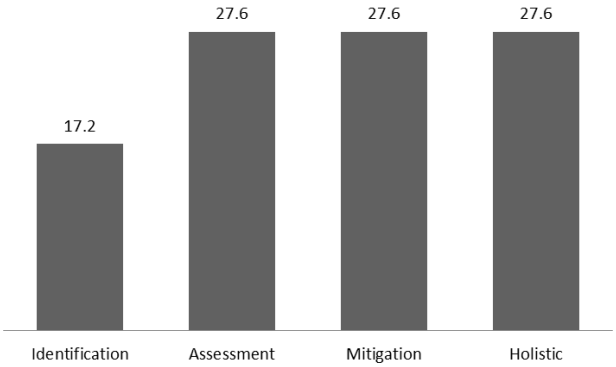

Fig. 11. Percentage distribution of articles with respect to risk management process.

F. Identifications of Research Gaps/ Future Research Agenda

Systematic literature review is a useful method to identify research gaps for exploring future research [8]. Our detailed and comprehensive analysis has revealed following important research areas:

1) Holistic Methods for capturing interdependencies between Risk Factors across entire Supply Network: Majority of the reviewed studies have focused on specific domains in supply chains. Furthermore, qualitative techniques are not able to capture the interaction of risks exclusively and existing quantification methods treat risks as independent [67, 72]. There is a need for considering the holistic nature of supply chain risks and modeling supply network as an open system [3, 95]. Based on the efficacy of Bayesian belief networks in handling interdependencies between risks, we propose modeling of an entire network as a Bayesian belief network. Such a modeling technique can help managers visualize supply chain risks and plan effective mitigation strategies [70]. The Bayesian network application in SCRM has been confined to the evaluation of suppliers so far whereas the technique has the potential to deal with complexity of risks across the entire network.

2) Organizational level studies for gauging Maturity Level: Based on the classification of articles with respect to risk categorization, the results necessitate conducting more research in exploring organizational risks. Specifically, there is a need for assessing management related risks as management expertise can help improve planning and mitigate supply chain risks [82]. Furthermore, some organizations are able to sustain disruptions while others succumb to the devastating impact. A very limited research has been conducted in this area [84, 96]. We propose Bayesian network as a useful tool in developing a model that can predict probability of sustaining a disruption based on the organizational characteristics.

3) Disruption Propagation and Reliability of an entire Network: Disruptions are unpredictable and in order to safeguard supply chain from the adverse effects of these disruptions, managers need to have complete visibility across entire network [3, 8]. Recently, researchers have started studying impact of disruptions on supply chains [17, 57, 92, 97, 98]. We propose treating a supply network as an engineering system and applying the techniques of system reliability in assessing reliability of supply networks. Though research has been conducted in assessing reliability of a supply network yet more research is needed to capture complexity of entire supply network through application of such techniques [99-101].

4) Synergy of Supply Chain Risk Management and Project Risk Management in New Product Development: Development of a new product demands integration of capabilities in managing supply chain risks and project risks. Few studies have focused on investigating supply chain risks associated with new design or development project of a new product. There is a need for conducting case studies in various industries for exploring means and methods of managing such risks [26].

5) Mechanism Design for mitigating Strategic Risks: Strategic risks can result between supply chain stakeholders based on conflicting incentives of the individuals [43, 83, 102-104]. Game theory is an effective technique in managing such risks [105]. Risk-sharing based contracts can be designed for aligning conflicting incentives that will not only help managers maintain the high reliability of a supply network but also materialize maximum profitability.

6) Supply Chain Risk Management practices in Small and Medium Enterprises: Supply chains are served raw material by a number of suppliers that are directly linked with multiple suppliers at higher echelon. Majority of the studies have been conducted in companies having global footprint whereas small and medium enterprises can have significant impact on the entire network. There is a need for conducting research in small and medium enterprises to explore their practices in managing supply chain risks [29]. The manufacturer must have visibility to assess the impact of such firms on the working of entire supply network in case of any disruption occurring at the site of a small firm [92].

We have linked the mentioned research gaps as shown in Fig. 12. All the actors in a supply chain are interconnected through a common base. Either an internal or external factor may cause disruption resulting in propagation across entire network. There is a need for assessing network reliability of the supply chain for investigating propagation pattern of such disruptions. Furthermore, the extent of disruption is not only determined by the nature of disruption but also influenced by the organizational maturity level in dealing with such disruptions. Therefore, there is a need for conducting research in this area. In order to mitigate risks arising due to conflicting incentives among stakeholders, game theory can be a useful tool in designing incentive schemes. Future research may be directed towards applying Bayesian belief networks in modeling interdependent risks across the entire supply network.

IV. Conceptual Framework

Keeping in view the need for presenting a holistic approach of modeling interdependent supply chain risks and promising results achieved through application of Bayesian belief networks in the realm of SCRM, we present a conceptual framework based on the well-established risk management standard AS/NZS ISO 31000:2009 [106] that incorporates BBNs for quantification (assessment) of risks as shown in Fig. 13. Separate BBNs are modeled for each classification of risks and linked corresponding to common triggers, risk events and consequences. For understanding the mechanics of BBNs, interested researchers can refer to these articles and books [68, 107-110].

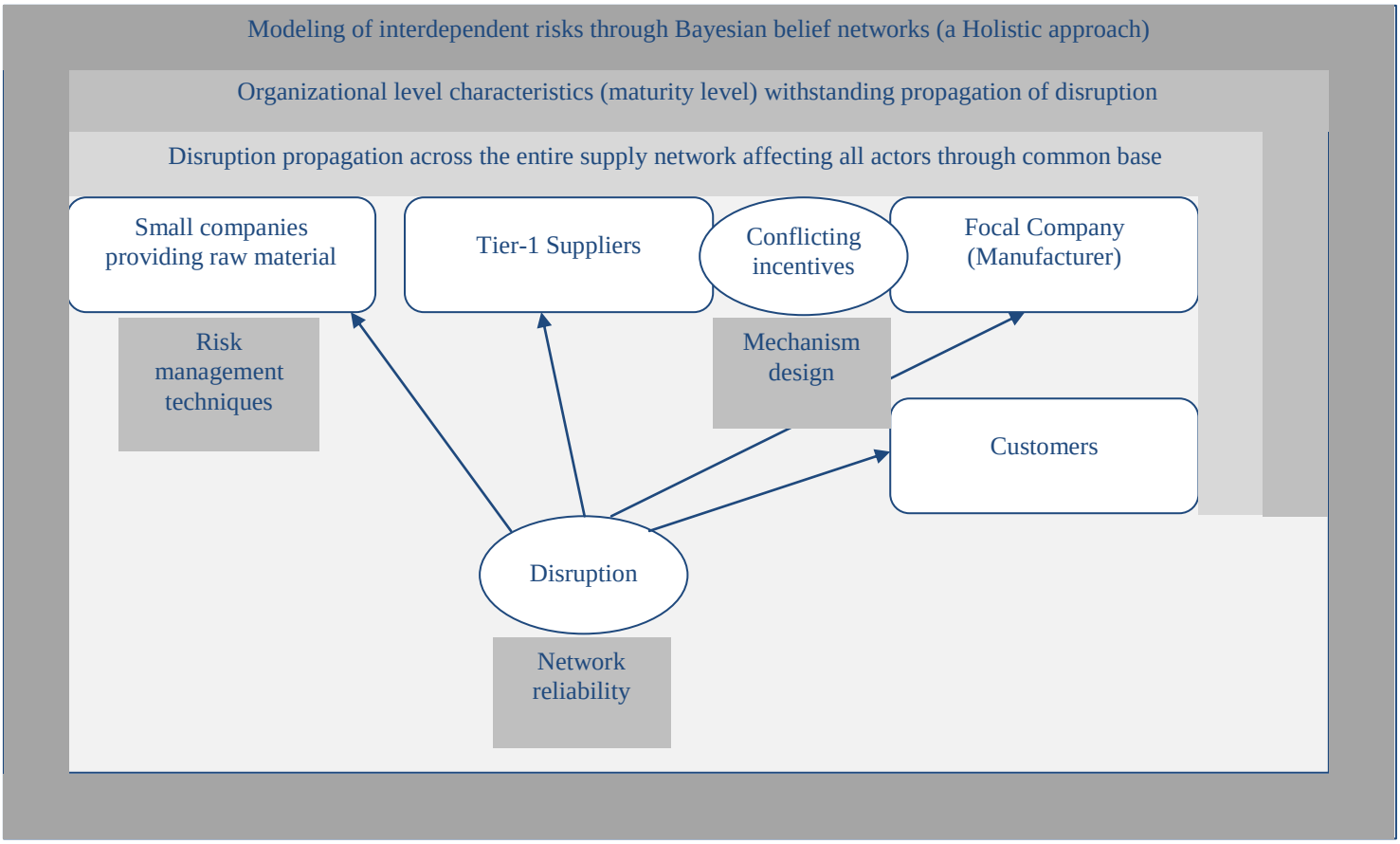

Fig. 12. Future research gaps linked through a holistic approach.

Risk management is an iterative process including different stages of establishing the context, risk assessment and risk treatment. We propose the use of BBNs as an effective tool for the risk assessment stage. Separate BBNs can be modelled for different classifications of risks from the perspective of a focal company and subsequently, these resulting BBNs can be linked together corresponding to common triggers and consequences. The characteristic of BBNs in capturing the interdependencies between risk factors makes it much effective in comparison with other methods treating risks as independent events.

V. Conclusion

Systematic literature review of 145 quality articles was conducted that were published between years 2000 and June, 2014. The methodology provided a systematic approach to gain an insight into the development of the field through different stages. Findings of the review were validated through the results of text mining technique. Such integration of systematic literature review and knowledge management technique allows identification of distinct patterns that may not be observed through conventional narrative reviewing methods.

The analysis revealed major research gaps that were modeled and linked together in order to present a holistic approach for undertaking future research. Based on the identified research gaps, a conceptual framework was also developed that can be used by the researchers to model interdependencies between dynamic risks. Bayesian belief networks have recently gained interest of researchers in modeling supplier risks; however, keeping in view the efficacy of technique, it can be further explored for modeling complex structure of the entire supply network. We hope that the recommended future agenda might help researchers in further developing the field of SCRM incorporating robust and effective risk quantification techniques.

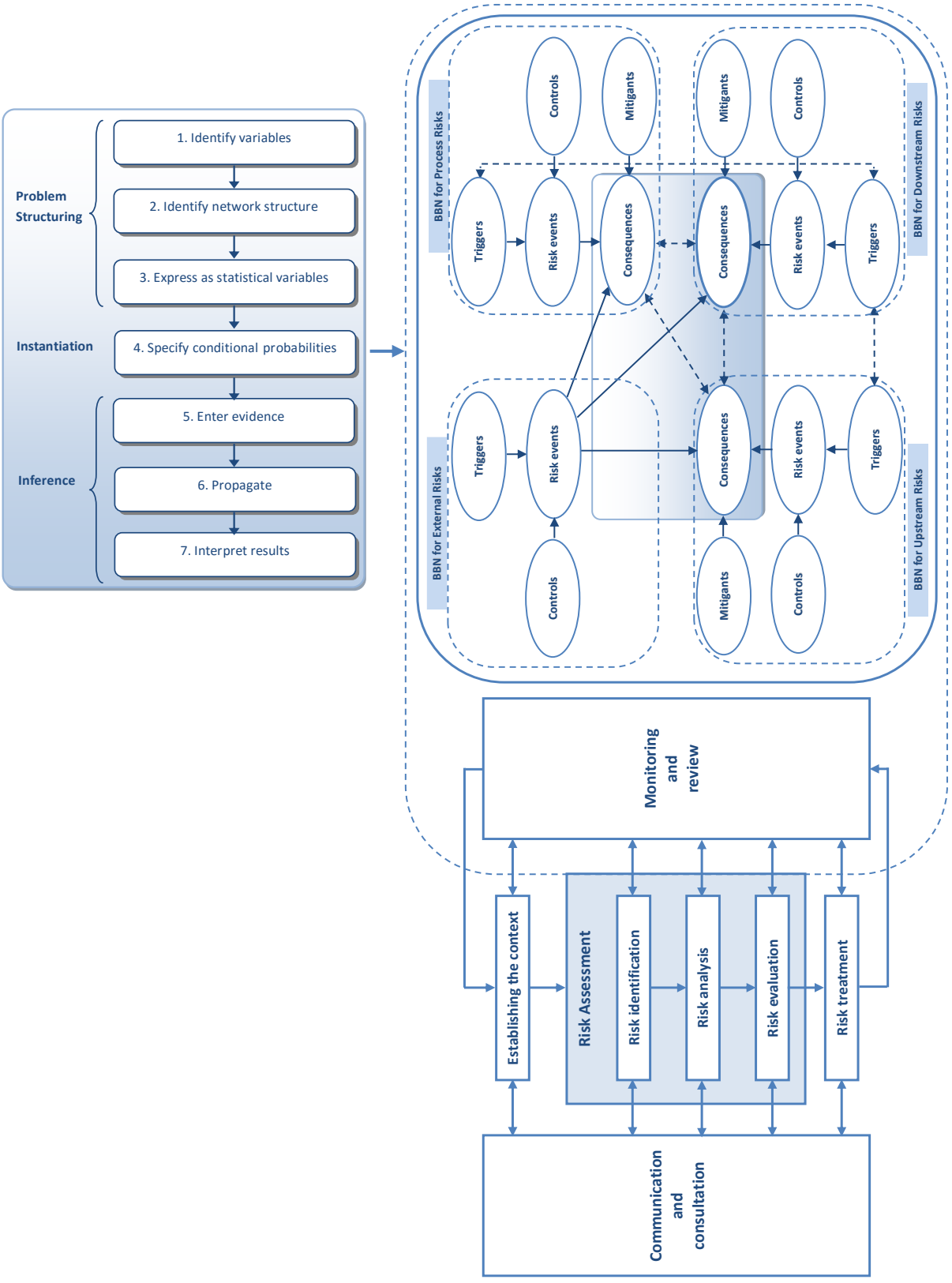

Fig. 13. A conceptual framework for capturing interdependencies between risks.

REFERENCES

[1] O. Khan and B. Burnes, "Risk and supply chain management: creating a research agenda," International Journal of Logistics Management, vol. 18, pp. 197-216, 2007.

[2] M. S. Sodhi, B.-G. Son, and C. S. Tang, "Researchers' Perspectives on Supply Chain Risk Management," Production and Operations Management, vol. 21, pp. 1-13, 2012.

[3] C. Colicchia and F. Strozzi, "Supply chain risk management: a new methodology for a systematic literature review," Supply Chain Management: An International Journal, vol. 17, pp. 403-418, 2012.

[4] I. Vanany, S. Zailani, and N. Pujawan, "Supply Chain Risk Management: Literature Review and Future Research," International Journal of Information Systems and Supply Chain Management (IJISSCM), vol. 2, pp. 16-33, 2009.

[5] M. A. Bellamy and R. C. Basole, "Network analysis of supply chain systems: A systematic review and future research," Systems Engineering, vol. 16, pp. 235-249, 2013.

[6] S. Rao and T. J. Goldsby, "Supply chain risks: a review and typology," International Journal of Logistics Management, vol. 20, pp. 97-123, 2009.

[7] U. Jüttner, H. Peck, and M. Christopher, "Supply chain risk management: outlining an agenda for future research," International Journal of Logistics Research and Applications, vol. 6, pp. 197-210, 2003/12/01 2003.

[8] A. Ghadge, S. Dani, and R. Kalawsky, "Supply chain risk management: present and future scope," International Journal of Logistics Management, The, vol. 23, pp. 313-339, 2012.

[9] D. Tranfield, D. Denyer, and P. Smart, "Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review," British Journal of Management, vol. 14, pp. 207-222, 2003.

[10] C. Harland, R. Brenchley, and H. Walker, "Risk in supply networks," Journal of Purchasing and Supply Management, vol. 9, pp. 51-62, 2003.

[11] F. H. Knight, Risk, Uncertainty and Profit: Houghton Mifflin, Boston, MA, 1921.

[12] I. Manuj and J. T. Mentzer, "Global supply chain risk management," Journal of Business Logistics, vol. 29, pp. 133-155, 2008.

[13] R. Handfield, J. Blackhurst, C. W. Craighead, and D. Elkins. (2011, 14 April, 2014). Introduction: a managerial framework for reducing the impact of disruptions to the supply chain. Available: http://scm.ncsu.edu/scm-articles/article/introduction-a-managerial-framework-for-reducing-the-impact-of-disruptions

[14] C. S. Tang, "Perspectives in supply chain risk management," International Journal of Production Economics, vol. 103, pp. 451-488, 10// 2006.

[15] M. Christopher and H. Peck, "Building the Resilient Supply Chain," International Journal of Logistics Management, The, vol. 15, pp. 1-14, 2004.

[16] I. Manuj and J. T. Mentzer, "Global supply chain risk management strategies," International Journal of Physical Distribution & Logistics Management, vol. 38, pp. 192-223, 2008.

[17] J. Y. Son and R. K. Orchard, "Effectiveness of policies for mitigating supply disruptions," International Journal of Physical Distribution & Logistics Management, vol. 43, pp. 684-706, 2013.

[18] D. White, "Application of systems thinking to risk management:: a review of the literature," Management Decision, vol. 33, pp. 35-45, 1995.

[19] D. J. Cook, C. D. Mulrow, and R. B. Haynes, "Systematic Reviews: Synthesis of Best Evidence for Clinical Decisions," Annals of Internal Medicine, vol. 126, pp. 376-380, 1997.

[20] C. D. Mulrow, "Systematic Reviews–Rationale for Systematic Reviews," British Medical Journal, vol. 309, pp. 597-599, 1994.

[21] J. Popay, A. Rogers, and G. Williams, "Rationale and Standards for the Systematic Review of Qualitative Literature in Health Services Research," Qualitative Health Research, vol. 8, pp. 341-351, 1998.

[22] T. Greenhalgh, "Papers that Summarise Other Papers (Systematic Reviews and Meta-analyses)," British Medical Journal, vol. 315, pp. 672-675, 1997.

[23] J. Blackhurst , C. W. Craighead, D. Elkins, and R. B. Handfield, "An empirically derived agenda of critical research issues for managing supply-chain disruptions," International Journal of Production Research, vol. 43, pp. 4067-4081, 2005/10/01 2005.

[24] J. Capó-Vicedo, J. Mula, and J. Capó, "A social network-based organizational model for improving knowledge management in supply chains," Supply Chain Management: An International Journal, vol. 16, pp. 379-388, 2011.

[25] M. Christopher, C. Mena, O. Khan, and O. Yurt, "Approaches to managing global sourcing risk," Supply Chain Management: An International Journal, vol. 16, pp. 67-81, 2011.

[26] O. Khan, M. Christopher, and B. Burnes, "The impact of product design on supply chain risk: a case study," International Journal of Physical Distribution & Logistics Management, vol. 38, pp. 412-432, 2008.

[27] P. Leat and C. Revoredo-Giha, "Risk and resilience in agri-food supply chains: the case of the ASDA PorkLink supply chain in Scotland," Supply Chain Management: An International Journal, vol. 18, pp. 219-231, 2013.

[28] C. W. Autry and L. M. Bobbitt, "Supply chain security orientation: conceptual development and a proposed framework," International Journal of Logistics Management, The, vol. 19, pp. 42-64, 2008.

[29] C. Ellegaard, "Supply risk management in a small company perspective," Supply Chain Management: An International Journal, vol. 13, pp. 425-434, 2008.

[30] S. C. Ellis, R. M. Henry, and J. Shockley, "Buyer perceptions of supply disruption risk: A behavioral view and empirical assessment," Journal of Operations Management, vol. 28, pp. 34-46, 2010.

[31] J. Hallikas, K. Puumalainen, T. Vesterinen, and V.-M. Virolainen, "Risk-based classification of supplier relationships," Journal of Purchasing and Supply Management, vol. 11, pp. 72-82, 3// 2005.

[32] B. Jiang, R. C. Baker, and G. V. Frazier, "An analysis of job dissatisfaction and turnover to reduce global supply chain risk: Evidence from China," Journal of Operations Management, vol. 27, pp. 169-184, 2009.

[33] P. Jonsson, "Towards an holistic understanding of disruptions in Operations Management," Journal of Operations Management, vol. 18, pp. 701-718, 11// 2000.

[34] A. Świerczek, "The impact of supply chain integration on the "snowball effect" in the transmission of disruptions: An empirical evaluation of the model," International Journal of Production Economics.

[35] U. Jüttner, "Supply chain risk management: Understanding the business requirements from a practitioner perspective," International Journal of Logistics Management, The, vol. 16, pp. 120-141, 2005.

[36] D. Kern, R. Moser, E. Hartmann, and M. Moder, "Supply risk management: model development and empirical analysis," International Journal of Physical Distribution & Logistics Management, vol. 42, pp. 60-82, 2012.

[37] O. Lavastre, A. Gunasekaran, and A. Spalanzani, "Supply chain risk management in French companies," Decision Support Systems, vol. 52, pp. 828-838, 2012.

[38] R. P. Lee and J. L. Johnson, "Managing Multiple Facets of Risk in New Product Alliances*," Decision Sciences, vol. 41, pp. 271-300, 2010.

[39] M. Perry, "Natural disaster management planning: A study of logistics managers responding to the tsunami," International Journal of Physical Distribution & Logistics Management, vol. 37, pp. 409-433, 2007.

[40] K. Selviaridis and A. Norrman, "Performance-based contracting in service supply chains: a service provider risk perspective," Supply

Chain Management: An International Journal, vol. 19, pp. 153-172, 2014.

[41] J. B. Skipper and J. B. Hanna, "Minimizing supply chain disruption risk through enhanced flexibility," International Journal of Physical Distribution & Logistics Management, vol. 39, pp. 404-427, 2009.

[42] J.-H. Thun and D. Hoenig, "An empirical analysis of supply chain risk management in the German automotive industry," International Journal of Production Economics, vol. 131, pp. 242-249, 2011.

[43] H. Lutz, D. O. Vang, and W. D. Raffield, "Using game theory to predict supply chain cooperation," Performance Improvement, vol. 51, pp. 19-23, 2012.

[44] A. Diabat, K. Govindan, and V. V. Panicker, "Supply chain risk management and its mitigation in a food industry," International Journal of Production Research, vol. 50, pp. 3039-3050, 2012/06/01 2011.

[45] M. N. Faisal, D. K. Banwet, and R. Shankar, "Supply chain risk mitigation: modeling the enablers," Business Process Management Journal, vol. 12, pp. 535-552, 2006.

[46] G. Lo Nigro and L. Abbate, "Risk assessment and profit sharing in business networks," International Journal of Production Economics, vol. 131, pp. 234-241, 5// 2011.

[47] A. Wieland, "Selecting the right supply chain based on risks," Journal of Manufacturing Technology Management, vol. 24, pp. 652-668, 2013.

[48] G. Soni and R. Kodali, "A decision framework for assessment of risk associated with global supply chain," Journal of Modelling in Management, vol. 8, pp. 25-53, 2013.

[49] A. R. Ravindran, R. Ufuk Bilsel, V. Wadhwa, and T. Yang, "Risk adjusted multicriteria supplier selection models with applications," International Journal of Production Research, vol. 48, pp. 405-424, 2010/01/15 2009.

[50] M. Goh, J. Y. S. Lim, and F. Meng, "A stochastic model for risk management in global supply chain networks," European Journal of Operational Research, vol. 182, pp. 164-173, 2007.

[51] G. Guillén, F. D. Mele, M. J. Bagajewicz, A. Espuña, and L. Puigjaner, "Multiobjective supply chain design under uncertainty," Chemical Engineering Science, vol. 60, pp. 1535-1553, 2005.

[52] M. S. Sodhi, "Managing Demand Risk in Tactical Supply Chain Planning for a Global Consumer Electronics Company," Production and Operations Management, vol. 14, pp. 69-79, 2005.

[53] C. Tang and B. Tomlin, "The power of flexibility for mitigating supply chain risks," International Journal of Production Economics, vol. 116, pp. 12-27, 2008.

[54] C. Breuer, G. Siestrup, H.-D. Haasis, and H. Wildebrand, "Collaborative risk management in sensitive logistics nodes," Team Performance Management, vol. 19, pp. 331-351, 2013.

[55] Y. M. Ermoliev, T. Y. Ermolieva, G. J. MacDonald, V. I. Norkin, and A. Amendola, "A system approach to management of catastrophic risks," European Journal of Operational Research, vol. 122, pp. 452-460, 4/16/ 2000.

[56] C. K. M. Lee, Y. C. Yeung, and Z. Hong, "An integrated framework for outsourcing risk management," Industrial Management & Data Systems, vol. 112, pp. 541-558, 2012.

[57] O. A. Durowoju, H. K. Chan, and X. Wang, "Entropy assessment of supply chain disruption," Journal of Manufacturing Technology Management, vol. 23, pp. 998-1014, 2012.

[58] M. C. Wilson, "The impact of transportation disruptions on supply chain performance," Transportation Research Part E: Logistics and Transportation Review, vol. 43, pp. 295-320, 7// 2007.

[59] T. Wu, J. Blackhurst, and P. O'grady, "Methodology for supply chain disruption analysis," International Journal of Production Research, vol. 45, pp. 1665-1682, 2007/04/01 2007.

[60] T. Wu, J. Blackhurst, and V. Chidambaram, "A model for inbound supply risk analysis," Computers in Industry, vol. 57, pp. 350-365, 2006.

[61] R. R. Levary, "Ranking foreign suppliers based on supply risk," Supply Chain Management: An International Journal, vol. 12, pp. 392-394, 2007.

[62] B. Gaudenzi and A. Borghesi, "Managing risks in the supply chain using the AHP method," International Journal of Logistics Management, The, vol. 17, pp. 114-136, 2006.

[63] K. Ganguly, "Integration of analytic hierarchy process and Dempster-Shafer theory for supplier performance measurement considering risk," International Journal of Productivity and Performance Management, vol. 63, pp. 85-102, 2014.

[64] P.-S. Chen and M.-T. Wu, "A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment: A case study," Computers & Industrial Engineering, vol. 66, pp. 634-642, 12// 2013.

[65] H.-C. Pfohl, P. Gallus, and D. Thomas, "Interpretive structural modeling of supply chain risks," International Journal of Physical Distribution & Logistics Management, vol. 41, pp. 839-859, 2011.

[66] M. N. Faisal, D. K. Banwet, and R. Shankar, "Information risks management in supply chains: an assessment and mitigation framework," Journal of Enterprise Information Management, vol. 20, pp. 677-699, 2007.

[67] F. Badurdeen, M. Shuaib, K. Wijekoon, A. Brown, W. Faulkner, J. Amundson, et al., "Quantitative modeling and analysis of supply chain risks using Bayesian theory," Journal of Manufacturing Technology Management, vol. 25, pp. 631-654, 2014.

[68] J. H. Sigurdsson, L. A. Walls, and J. L. Quigley, "Bayesian belief nets for managing expert judgement and modelling reliability," Quality and Reliability Engineering International, vol. 17, pp. 181-190, 2001.

[69] S. Kelangath, P. K. Das, J. Quigley, and S. E. Hirdaris, "Risk analysis of damaged ships – a data-driven Bayesian approach," Ships and Offshore Structures, vol. 7, pp. 333-347, 2012/09/01 2011.

[70] A. Qazi, J. Quigley, and A. Dickson, "A novel framework for quantification of supply chain risks," in 4th Student Conference on Operational Research, University of Nottingham, UK, 2014.

[71] I. Dogan, "Analysis of facility location model using Bayesian Networks," Expert Systems with Applications, vol. 39, pp. 1092-1104, 1// 2012.

[72] I. Dogan and N. Aydin, "Combining Bayesian Networks and Total Cost of Ownership method for supplier selection analysis," Computers & Industrial Engineering, vol. 61, pp. 1072-1085, 2011.

[73] E. Lee, Y. Park, and J. G. Shin, "Large engineering project risk management using a Bayesian belief network," Expert Systems with Applications, vol. 36, pp. 5880-5887, 4// 2009.

[74] A. Lockamy, "Benchmarking supplier risks using Bayesian networks," Benchmarking: An International Journal, vol. 18, pp. 409-427, 2011.

[75] A. Lockamy and K. McCormack, "Modeling supplier risks using Bayesian networks," Industrial Management & Data Systems, vol. 112, pp. 313-333, 2012.

[76] A. Lockamy and K. McCormack, "Analysing risks in supply networks to facilitate outsourcing decisions," International Journal of Production Research, vol. 48, pp. 593-611, 2010/01/15 2009.

[77] S. Chopra and M. S. Sodhi, "Managing risk to avoid supply-chain breakdown," MIT Sloan Management Review, vol. 46, pp. 53-61, 2004.

[78] J. L. Cavinato, "Supply chain logistics risks: From the back room to the board room," International Journal of Physical Distribution & Logistics Management, vol. 34, pp. 383-387, 2004.

[79] M. A. Lewis, "Cause, consequence and control: towards a theoretical and practical model of operational risk," Journal of Operations Management, vol. 21, pp. 205-224, 3// 2003.

[80] G. A. Zsidisin, L. M. Ellram, J. R. Carter, and J. L. Cavinato, "An analysis of supply risk assessment techniques," International Journal of Physical Distribution & Logistics Management, vol. 34, pp. 397-413, 2004.

[81] G. A. Zsidisin and M. E. Smith, "Managing Supply Risk with Early Supplier Involvement: A Case Study and Research Propositions," Journal of Supply Chain Management, vol. 41, pp. 44-57, 2005.

[82] C. S. Tang, J. D. Zimmerman, and J. I. Nelson, "Managing New Product Development and Supply Chain Risks: The Boeing 787

Case," Supply Chain Forum: an International Journal, vol. 10, pp. 74-86, // 2009.

[83] Y. Zhao, "Why 787 Slips were Inevitable?," ed: Rutgers University, New York, 2013.

[84] D. Simchi-Levi, I. M. Kyratzoglou, and C. G. Vassiliadis, "Supply Chain and Risk Management," 2013.

[85] M. N. Faisal, D. K. Banwet, and R. Shankar, "Mapping supply chains on risk and customer sensitivity dimensions," Industrial Management & Data Systems, vol. 106, pp. 878-895, 2006.

[86] J. V. Blackhurst, K. P. Scheibe, and D. J. Johnson, "Supplier risk assessment and monitoring for the automotive industry," International Journal of Physical Distribution & Logistics Management, vol. 38, pp. 143-165, 2008.

[87] S. Matook, R. Lasch, and R. Tamaschke, "Supplier development with benchmarking as part of a comprehensive supplier risk management framework," International Journal of Operations & Production Management, vol. 29, pp. 241-267, 2009.

[88] S. M. Wagner and C. Bode, "An empirical investigation into supply chain vulnerability," Journal of Purchasing and Supply Management, vol. 12, pp. 301-312, 11// 2006.

[89] C. W. Craighead, J. Blackhurst, M. J. Rungtusanatham, and R. B. Handfield, "The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities," Decision Sciences, vol. 38, pp. 131-156, 2007.

[90] T. Hale and C. R. Moberg, "Improving supply chain disaster preparedness: A decision process for secure site location," International Journal of Physical Distribution & Logistics Management, vol. 35, pp. 195-207, 2005.

[91] P. R. Kleindorfer and G. H. Saad, "Managing Disruption Risks in Supply Chains," Production and Operations Management, vol. 14, pp. 53-68, 2005.

[92] W. Hopp, S. R. Iravani, and Z. Liu, "Mitigating the Impact of Disruptions in Supply Chains," in Supply Chain Disruptions, H. Gurnani, A. Mehrotra, and S. Ray, Eds., ed: Springer London, 2012, pp. 21-49.

[93] J. R. G. Richey, "The supply chain crisis and disaster pyramid: A theoretical framework for understanding preparedness and recovery," International Journal of Physical Distribution & Logistics Management, vol. 39, pp. 619-628, 2009.

[94] S. Kumar and T. Havey, "Before and after disaster strikes: A relief supply chain decision support framework," International Journal of Production Economics, vol. 145, pp. 613-629, 10// 2013.

[95] A. Ghadge, S. Dani, M. Chester, and R. Kalawsky, "A systems approach for modelling supply chain risks," Supply Chain Management: An International Journal, vol. 18, pp. 523-538, 2013.

[96] B. Hittle and K. M. Leonard, "Decision making in advance of a supply chain crisis," Management Decision, vol. 49, pp. 1182-1193, 2011.

[97] M. Tsiakkouri, "Risk Management Processes for Managing Disruptions in Supply Chains," PhD Thesis, School of Management, University of Southampton, 2010.

[98] K. A. Marley, P. T. Ward, and J. A. Hill, "Mitigating supply chain disruptions – a normal accident perspective," Supply Chain Management: An International Journal, vol. 19, pp. 142-152, 2014.

[99] S. Ohmori and K. Yoshimoto, "A framework of managing supply chain disruption risks using network reliability," Industrial engineering and management systems, vol. 12, pp. 103-111, 2013.

[100] S. Ohmori and K. Yoshimoto, "A framework of managing supply chain disruption risks using network reliability," in Asia Pacific Industrial Engineering & Management Systems Conference, 2012, pp. 1837-1846.

[101] H. Taghizadeh and E. Hafezi, "The investigation of supply chain's reliability measure: a case study," International Journal of Industrial Engineering vol. 8, pp. 1-10, 2012/10/02 2012.

[102] R. Zhao, G. Neighbour, J. Han, M. McGuire, and P. Deutz, "Using game theory to describe strategy selection for environmental risk and carbon emissions reduction in the green supply chain," Journal of Loss Prevention in the Process Industries, vol. 25, pp. 927-936, 2012.

[103] Y. Z. Xu Xin, "Incentives and Coordination in Project Driven Supply Chains.," ed: Rutgers Business School– Newark and New Brunswick, NJ., 2013.

[104] T. Wakolbinger and J. M. Cruz, "Supply chain disruption risk management through strategic information acquisition and sharing and risk-sharing contracts," International Journal of Production Research, vol. 49, pp. 4063-4084, 2011/07/01 2010.

[105] M. J. Osborne, An Introduction to Game Theory: Oxford University Press, Incorporated, 2003.

[106] A. N. Z. Standard, "AS/NZS ISO 31000 : 2009 Risk management-Principles and guidelines," ed.

[107] E. Charniak, "Bayesian networks without tears: making Bayesian networks more accessible to the probabilistically unsophisticated," AI Mag., vol. 12, pp. 50-63, November// 1991.

[108] F. V. Jensen, Bayesian networks and decision graphs [internet resource]: New York : Springer, 2007.

[109] U. B. Kjaerulff, Bayesian networks and influence diagrams [internet resource] : a guide to construction and analysis: New York ; London : Springer, 2008.

[110] S. Nadkarni and P. P. Shenoy, "A causal mapping approach to constructing Bayesian networks," Decision Support Systems, vol. 38, pp. 259-281, 11// 2004.

BIOGRAPHY

Abroon Qazi received the BE degree in Aerospace Engineering from the National University of Sciences and Technology, Pakistan and the MSc. degree in Mechanical Engineering from the University of Engineering and Technology, Peshawar, Pakistan. At present, he is a research student and tutor in Management Science at the University of Strathclyde, UK. He is interested in modeling supply chain risks associated with new product development. In particular, his research project deals with the investigation of interdependency between supply chain risks using Bayesian Belief Networks and formulation of a fair-sharing strategy to align the conflicting incentives of stakeholders within a supply network using Game Theory. Abroon has won sponsored awards to present at conferences organized by the Chartered Institute of Logistics and Transport (CILT) and International Purchasing and Supply Education and Research Association (IPSERA). He has also qualified all the preliminary exams from the Society of Actuaries, USA.

John Quigley received the B.Math. degree in Actuarial Science from the University of Waterloo, Canada, and the Ph.D. degree in Management Science from the University of Strathclyde, UK. At present, he is a Professor and Director of Research in Management Science at the University of Strathclyde, UK. John's main research interests are in elicitation of prior distributions, statistical inference and applied probability modeling with application areas in risk and reliability. In particular, he is interested in decision support methodologies with few data. He has extensive experience with military, aerospace and railway industries. John is a member of the UK. Safety and Reliability Society, a Chartered Statistician, and an Associate of the Society of Actuaries. He has been involved in consultancy with

companies such as MoD, DSTL, Railway Safety Standards Board, BAE SYSTEMS, Goodrich and Siemens.

Alex Dickson received the BA degree in Economics and Finance from Keele University, UK and the MSc. degree in Economics from the University of Manchester, UK. He gained the Ph.D. degree in Economics from the Keele University, UK. At present, Alex is a Senior Lecturer in Economics at the University of Strathclyde, UK. Prior to this, he held a lectureship in Economics at Keele University preceded by a postdoctoral research fellowship at the University of Manchester. His primary research interests are in Microeconomics, in particular in: game theoretic approaches to general and partial models of competitive behavior; aggregative games with applications to contests and strategic market games; endogenous timing in games and commitment; and behavioral economics and game theory. Alex has further broad interests in industrial organization, international trade and applied game theory in general.