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Emerald Article: Supply chain risk management: a new methodology for a systematic literature review

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Abstract
Purpose – Supply chain risk management (SCRM) has recently gained increasing attention in the supply chain context, both from the practitioners' perspective and as a research area. Given the relevance of the topic, the aim of the present paper is to present a focused literature review, investigating the process of knowledge creation, transfer and development from a dynamic perspective within the context of SCRM.
Design/methodology/approach – A review of the literature on SCRM was undertaken. The new proposed methodology combines the systematic literature review approach to identify the most relevant articles to be included in the study with the citation network analysis in order to unfold the dynamics of the field under study. The authors define this new methodology as systematic literature network analysis.
Findings – The paper demonstrates that there are a number of key themes in the field of SCRM. The contributions that influenced the field were identified and, by analysing the evolution over time of key concepts, a number of research directions were identified and discussed.
Research limitations/implications – The dynamic nature of current literature review allows the identification of the directions in which research is moving and thus the recognition of streams of research that appear most promising. However, the application of the research methodology, and in particular of the citation network analysis, requires the support of specific computer programs. Moreover, the underlying assumption of the citation network analysis is that, by analysing the network of citations made to and from articles, it is possible to explain the flows of knowledge used to generate new results. This is only partially true since the spread of measures based on impact assessment led many researchers to an excessive use of citations, even if their content is not always decisive for the outcome of their work.
Practical implications – The present paper outlines a research agenda that may facilitate the development of models for managing supply chain risk. Furthermore from the evidence of the performed literature review some managerial insights can be derived on how to manage supply chain risk: by considering uncertainty in the design of supply chains, by understanding the impact of risks arising from network collaboration and interactions between supply chain partners, by developing proactive mitigation capabilities to hedge the increasing level of risk.
Originality/value – The novelty of this research lies in the combination of two existing methodologies for reviewing the literature and in the adoption of a dynamic perspective in order to analyse theory development.

Keywords Supply chain risk management, Systematic literature review, Citation network analysis, Supply chain management, Risk management

Paper type Literature review

1. Introduction

Few areas of management interest have risen to prominence in recent years as rapidly as supply chain risk management (SCRM), both from the practitioners' perspective and as a research area. The unpredictability of the business environment, variable consumer demands, actions by competitors, along with market dynamics and continuous improvement initiatives within organisations imply that the supply chain never actually reaches a stable steady state (Braithwaite and Wilding, 2005; Christopher, 1998; Haywood and Peck, 2004). These parameters of uncertainty can propagate through a supply chain network (Christopher, 1998; Van der Vorst and Beulens, 2002).

There is wide consensus, both in the literature and in practice, that managing risk in the supply chain is a critical capability in order to compete in the current, increasingly turbulent and unpredictable, business environment. Even though it is recognised that significant contributions can be made by an effective review of the extant literature, only few reviews of the field have been presented. To the best of the authors' knowledge only Manuj and Mentzer (2008), Khan and Burnes (2007) and Tang (2006) attempt to review the contributions pertaining to SCRM. The emphasis of their studies is on the identification of research gaps and development of a research agenda; but, whereas they provide useful insights based on an extensive literature review, the adopted perspective is static.

Hence, this paper seeks to advance our understanding of SCRM by conducting a focused literature review aiming to investigate the process of knowledge creation, transfer and

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development from a dynamic perspective. To reach this goal we combine the Systematic Literature Review (SLR) and the Citation Network Analysis (CNA) in a new methodology. We define this new methodology Systematic Literature Network Analysis (SLNA). The SLR provides a useful approach to identifying themes and selecting keywords to perform a first choice of the most relevant contributions in the field, while the CNA recognises a backbone in a citation network that helps us to understand how the body of knowledge has evolved over time. This paper will then discuss the main themes and the emerging topics, identify which streams of the SCRM appear as most promising and outline an agenda that may facilitate theory-building.

The remainder of the paper is organised as follows. The research methodology is described in Section 2 while the application of the methodology to the context under study is provided in Section 3. The dynamics of SCRM is presented in Section 4. The changing and evolving paradigm in SCRM will be outlined and the promising research directions identified and discussed (Section 5). Some conclusions close the paper.

1.1 Basic terminology

In preparation for the subsequent literature review, we define some key terms to provide the reader with the basic concepts regarding SCRM.

Different definitions of risk in a supply chain context are provided in a vast body of literature (Jüttner *et al.*, 2003; Zsidisin *et al.*, 2004). Supply chain risk is defined as "the variation in the distribution of possible supply chain outcomes, their likelihoods, and their subjective values" (Jüttner *et al.*, 2003). This definition highlights the two dimensions characterising risk: impact and likelihood of occurrence (Faisal *et al.* 2006).

The terms risk and uncertainty are often used interchangeably even if they are not the same. Knight (1921) made a distinction between risk and uncertainty, asserting that risk is something measurable while uncertainty is not quantifiable and the probabilities of the possible outcomes are not known. It relates to the situation in which there is a total absence of information or awareness of a potential event occurrence, irrespective of whether the outcome is positive or negative (Ritchie and Brindley, 2007).

Closely interconnected to the concept of risk is the notion of supply chain vulnerability, defined as the "existence of random disturbances that lead to deviations in the supply chain from normal, expected or planned activities, all of which cause negative effects or consequences" (Svensson, 2000). The strong correlation between the two concepts is confirmed by Christopher and Peck (2004).

Robustness and resilience taken together can be treated as a complement to vulnerability. Robustness represents the ability of the system to maintain its function unchanged, or nearly unchanged, when exposed to perturbations. Within supply chain management, robustness can be defined as the extent to which the supply chain is able to carry its functions for a variety of possible future scenarios. Resilience implies that the system can adapt to regain a new stable position (recover, or return close to, its original state) after perturbations. Ponomarov and Holcomb (2009) borrowed several key elements from other disciplines and – using multidisciplinary perspectives – developed the following definition of supply chain resilience: "The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function". In this sense, resilience must be intended not just as the ability to recover from mishaps, but should be considered a proactive, structured and integrated exploration of capabilities within the supply chain to cope with unforeseen events.

Just as there is an abundance of supply chain risk definitions, numerous techniques have been put forth to supply chain risk management. Supply chain risk management is defined as, "the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain members, to reduce supply chain vulnerability" (Christopher *et al.*, 2003). The main aim of supply chain risk management is to protect the business from adverse events.

2. Research methodology

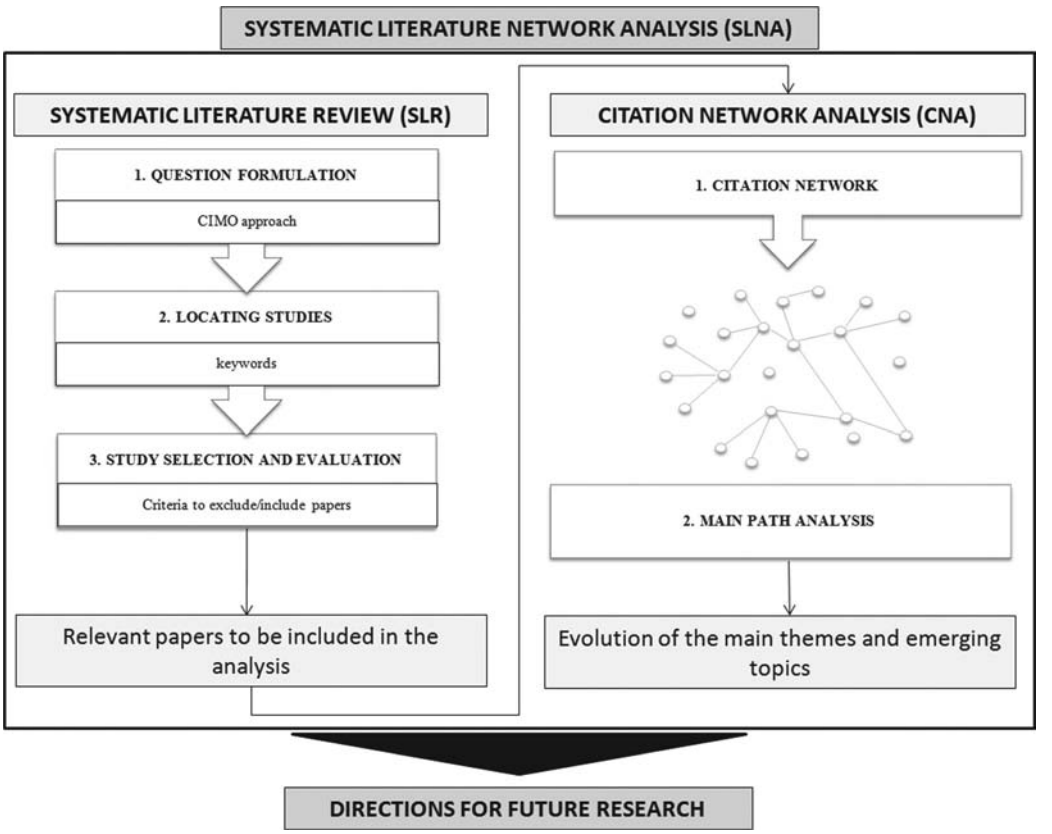
Literature review is a major contribution to research progress, and it is intended "to provide a historical perspective of the respective research area and an in-depth account of independent research endeavours" (Mentzer and Kahn, 1995).

A two-pronged methodology was undertaken: the SLR approach (Rousseau *et al.*, 2008; Tranfield *et al.*, 2003) to perform a first selection of the most relevant articles to be included in the analysis, and CNA (Hummon and Doreian, 1989) in order to perform a second selection based on citations to investigate the process of knowledge creation, transfer and development. From the combination of these two methodologies a new one is derived, called SLNA.

The SLR approach allows for an evidence-based approach to identifying, selecting and analysing secondary data. SLR differs from other review methods because of its principles, i.e. transparency, inclusivity, explanatory and heuristic nature, that allow for a more objective overview on the search results as well as to eliminate any bias and error issues (Denyer and Tranfield, 2009). The underpinning assumption of the CNA is that fields of research are not just formless sets of articles in terms of citations. It considers a citation network as a system of channels which transform scientific knowledge or information, assuming that researchers in the same field tend to cite each other in order to position their work in the field based on previous knowledge (Hummon and Doreian, 1989). An article that uses information from many other articles and really adds new knowledge, will cause an increase of the citations of the previous articles and will receive many citations itself. Consequently it will be an important junction between channels of knowledge (De Nooy *et al.*, 2005). The most important citations constitute the backbones of a research tradition and can be organized in different paths. The method proposed by Hummon and Doreian (1989) for studying the connectivity of the citation network, i.e. Main Path Analysis, explicitly focus on the identification of specialties, the evolution of research traditions, and changing paradigms.

These two methodologies, i.e. SLR and CNA, are integrated in a research process as represented in Figure 1. The adoption of these two existing methodologies combined together is aimed at maximizing the advantages related to each of them: SLR offers a solid and reliable technique that

Figure 1 Research methodology



can be easily applied to broad fields of research to select the most relevant contributions; CNA allows for a dynamic analysis in order to identify the papers that most contributed to theory-building in the field. Even if quantitative and qualitative aspects are mixed to assess existing theory, such a robust research methodology offers the potential to ensure high-quality results, trying to maximise the objectivity of the analysis and the repeatability of the results.

3. Applying the SLNA to the context under study

In this section the application of the research methodology to the context under study is described. The steps represented in Figure 1 are performed and an in-depth description of the process of source selection and analysis is provided.

3.1 Systematic literature review

3.1.1 Question formulation

The first phase is represented by the definition of the scope of the study in compliance with the objectives and the underlying research hypotheses. Denyer and Tranfield (2009) proposed to use the acronym CIMO (Context, Intervention, Mechanisms, and Outcome) to specify the four critical parts to be investigated in order to conduct the following phases of a well-built systematic literature review. According to the CIMO-logic, a well-built literature review is framed with the following elements:

1 *Context:*
   - Which individuals, relationships, institutional settings or wider systems are being studied?

2 *Intervention:*
   - The effects of what event, action or activity are being studied?

3 *Mechanisms:*
   - What are the mechanisms that explain the relationship between interventions and outcomes?
   - Under what circumstances are these mechanisms activated or not activated?

4 *Outcomes:*
   - What are the effects of the intervention?
   - How will the outcomes be measured?
   - What are the intended and unintended effects?

Applying this logic to the context under study, i.e. answering the above-mentioned questions, it emerges that risk and risk management have gained increasing attention in the supply chain context, both from the practitioners' perspective and as a research area due to the degree of uncertainty and complexity that characterises modern supply chains. In this context, characterised by an increased level of uncertainty and complexity, the interventions of interest are represented by effective practices and tools for SCRM, developed according to a defined strategy aligned with the corporate one. This means that the mechanism of interest is the organization of the risk management process and the expected outcomes are an enhanced robustness and resilience of the supply chain. Hence the main themes of interest are complexity and uncertainty (C), practices and tools for SCRM (I),

organization of SCRM process (M) and increased SC robustness and resilience (O).

3.1.2 Locating studies

The identification of the keywords connected to the subjects and the objectives of the study are as follows. A total of 20 keywords were identified by the authors by means of a brainstorming process (supply chain management, supply chain configurations, supply chain strategy, supply chain structure, supply chain design, global supply chain, alignment, flexibility, complexity, agility, risk, vulnerability, resilience, robustness, risk management process, sources of risk, uncertainty, risk analysis, risk assessment, disruptions). To refine the keywords, a team composed of three academics and two supply chain managers was constituted in order to give the search a sound validity. The keywords were combined in order to constitute a series of strings, to be applied in the search on the databases. Since the focus of our research is SCRM, the strings were specifically designed in order to select relevant papers for the overlap between risk management and supply chain management in general. By combining keywords through simple operators and Boolean logic, complex searches can be constructed in order to avoid too generic and wide results (e.g. the string "supply chain risk" AND (vulnerability OR complex*) searches for documents which contain the exact phrase "supply chain risk" and the word "vulnerability" or the terms "complex" or complexity). These search strings were brainstormed and refined until a reasonable list of terms was deemed sufficient (resulting in approximately 30 relevant research strings).

3.1.3 Study selection and evaluation

We collected citation data from the Science Citation Index (SCI) compiled by the Institute for Scientific Information (ISI) at the beginning of 2010. We used the Web of Science, which is a web-based user interface of the ISI's citation databases. The rationale for this choice is that the ISI Citation Databases "collectively index more than 8,000 high quality, peer-reviewed journals cover-to-cover, providing users with complete bibliographic data, full-length author abstracts, and cited references from the world's most influential research" (http://resources.library.yale.edu/online/dbsbysubjecthfxml_info.asp?searchfor = science&lookfor = YUL03923), assuring high quality and comprehensive search results. As argued by other authors (Newbert, 2007), it was deemed that by restricting the search to peer-reviewed journals, the quality control of search results can be enhanced due to the rigorous process to which articles published in such journals are subject prior to publication. Furthermore, the results retrieved from the ISI Databases can be easily organized and analysed through specific software packages, such as HistCite.

In order to obtain and include relevant and important documents to concentrate on, a series of inclusion and exclusion criteria should be defined. The following criteria, based on the ones proposed by Newbert (2007), have been considered to include/exclude papers:

- Search for papers published in peer-reviewed scientific journals in English.
- Search for papers published in the last 15 years.
- Ensure substantive relevance by requiring that selected articles contain at least one keyword in their title or abstract.
- Eliminate substantively irrelevant articles by excluding papers related to very narrow aspects or contexts.
- Ensure substantive and empirical relevance by reading all remaining abstracts.
- Further ensure substantive and empirical relevance by reading all remaining articles in their entirety.

The rationale for considering articles published in the last 15 years is that SCRM as a field of study has only relatively recently been addressed and the interest in this topic is growing increasingly in the last years, as mentioned in the introduction. Thus, a 15-year literature review allows for a sufficiently exhaustive analysis of the scientific research on this area.

The collected citation data were organized through the HistCite software package. From the review of the reference and the bibliography list of the selected articles, a series of "milestone" papers were added in order to improve the degree of comprehensiveness of the literature review. This further search allows us to identify interesting and relevant papers, i.e. cited several times from the already selected articles, "missed" by the keyword search but worthy to be included in the results.

By performing the above-described steps, 55 papers were selected. The 55 selected papers represent the nodes of the citation network, whereas citation data represents the links between nodes.

3.2 Citation Network Analysis

A network consisting of 55 nodes was then constructed (Figure 2). It comprises one large connected component and some isolated nodes.

The primary software used in conducting the analysis of the network was Pajek (http://vlado.fmf.uni-lj.si/pub/networks/pajek/), which is one of the best-known and most frequently used package developed to conduct comprehensive analysis on network data (De Nooy *et al.*, 2005). The citation network enabled us to study the data from two different perspectives: a static one through the analysis of the citation network and a dynamic one by means of the Main Path Analysis.

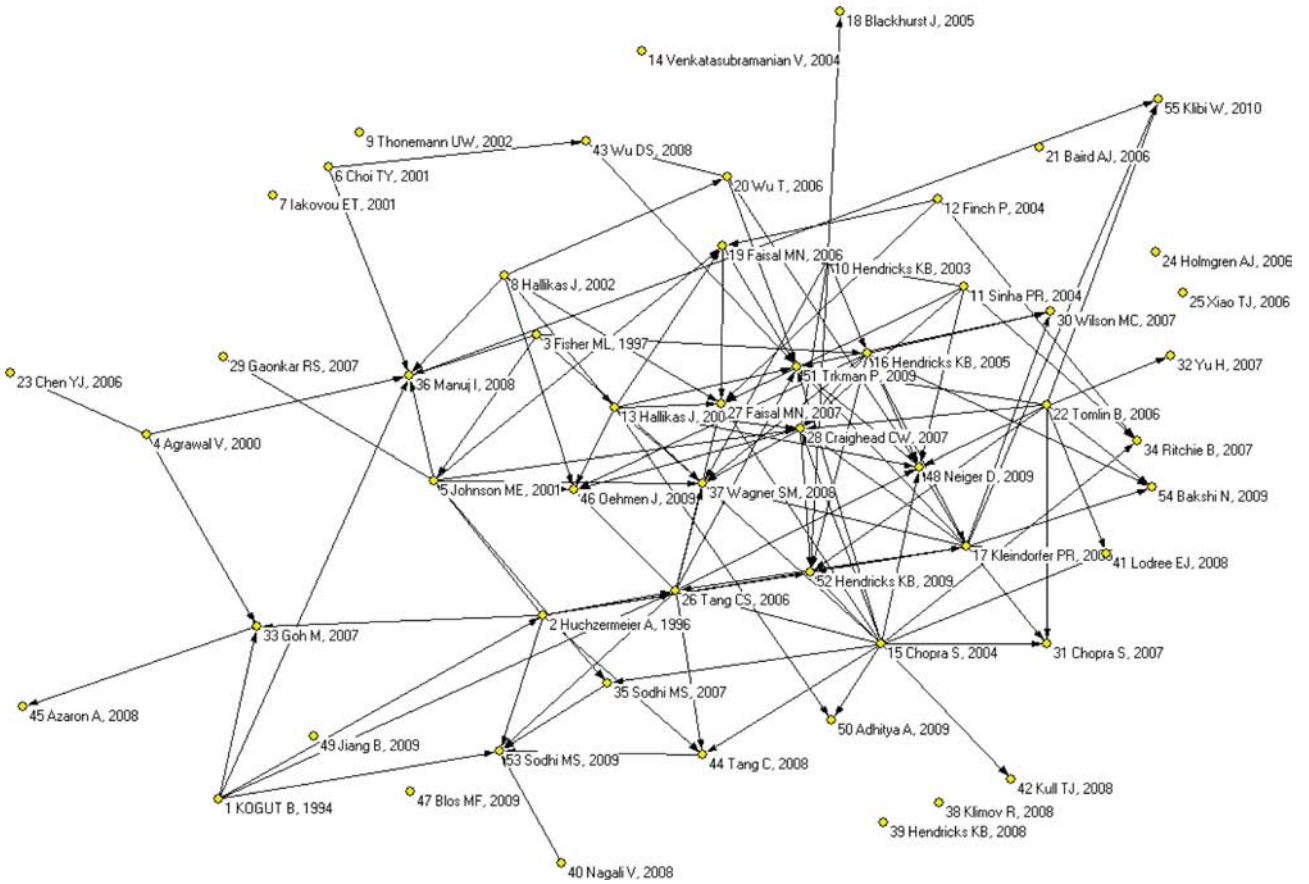
3.2.1 Citation Network

From a static perspective – considering the printing year – it is interesting to note that the number of articles is clearly increasing during the period (1994-2010), so the area is under expansion (Figure 3).

The CNA of the selected papers allows us to compute a ranking of articles. The ranking can be estimated in terms of the frequency of articles being cited (locally and globally) or in terms of the closeness centrality (Sabidussi, 1966) within the network.

The former measure, i.e. the frequency of articles being cited, ranks the articles by number of received citations, identifying the most cited papers. The software package HistCite allows us to create a list of experts in the field taking into account also citations received by articles included in the ISI Citation Databases but not selected by the keyword search. Through the second measure, i.e. the closeness centrality, it is possible to identify papers that are cited by very cited papers and thus that contributed to the theory-building. Indeed this index seeks to quantify a contribution's relevance within the citation network by summarizing the structural relations among all nodes. Closeness centrality, in fact, reflects how central a node is in the network, i.e. the extent to

Figure 2 Citation network

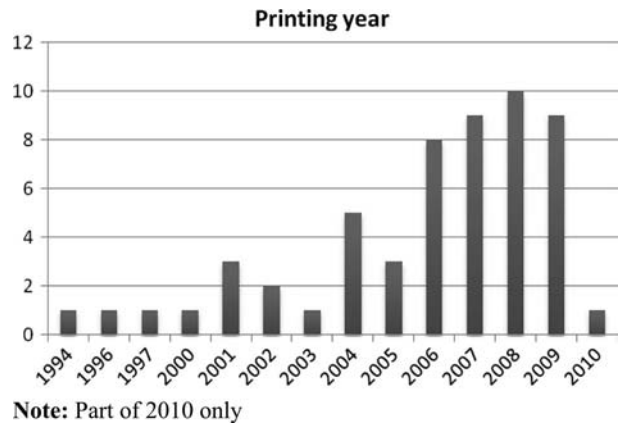


which an article can be connected with others or through minimal intermediaries (Knoke and Yang, 2008). In this sense it identifies the articles that represent the basis of the field and that were used by many authors for the development of their contributions.

Tables I-II show the rankings of articles in terms of frequency of articles being cited (Table I) and of the closeness centrality for all articles within the network (Table II). A positive relationship between these two parameters is suggested by the fact that five articles are ranked on the top ten in both charts simultaneously. The difference in rankings can be due to the fact that the closeness centrality assesses the impact that an article has on the development of theory considering all the citation links within the network, whereas the citation score counts only the direct citations that an article receives.

Finally in Table III the number of citation network articles published in each journal is presented.

Figure 3 Distribution of scientific articles within SCRM published during the years 1994-2010



Note: Part of 2010 only

3.2.2 Main Path Analysis

The Main Path Analysis was performed in order to gain a dynamic perspective. Techniques of network analysis, like Main Path Analysis, are specifically designed for identifying the most relevant papers at different moments that constitute the backbone of a research tradition. By analysing the chronological network of citations among the selected papers it is possible to show the dynamic behaviour of the field under study, making its development over time visible (De Nooy *et al.*, 2005; Lucio-Arias and Leydesdorff, 2008). In fact the Main Path highlights the articles that build on prior articles but continue to act as an authority in reference to later works (Lucio-Arias and Leydesdorff, 2008). The steps to perform Main Path Analysis are the following:

1 Quantifying the traversal weight of the citation, i.e. the extent to which a particular citation is necessary to link articles. Three methods included in Pajek can be distinguished: Search Path Count – Which considers all paths from each source (i.e. an article that is not citing any

Table I Most frequently cited ten articles

Rank	Title	Author	Journal/Year	LCS	GCS
1	Managing risk to avoid supply-chain breakdown	Chopra, S. and Sodhi, M.S.	*MIT Sloan Management Review* (2004)	14	45
2	Managing disruption risks in supply chains	Kleindorfer, P.R. and Saad, G.H.	*Production and Operations Management* (2005)	12	54
3	On the value of mitigation and contingency strategies for managing supply chain disruption risks	Tomlin, B.	*Management Science* (2006)	9	42
4	Risk management processes in suppliers networks	Hallikas, J., Kervonen, I., Pulkkinen, U., Virolainen, V.M., Tuominen, M.	*International Journal of Production Economics* (2004)	8	33
5	An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm	Hendricks, K.B. and Singhal, V.R.	*Production and Operations Management* (2005)	8	38
6	Valuing operational flexibility under exchange rate risk	Huchzermeier, A. and Cohen, M.A.	*Operations Research* (1996)	7	85
7	Learning from toys: lessons in managing supply chain risk from the toy industry	Johnson, M.E.	*California Management Review*	7	34
8	Perspectives in supply chain risk management	Tang, C.S.	*International Journal of Production Economics* (2006)	7	53
9	Operating flexibility, global manufacturing, and the option value of a multinational network	Kogut, B. and Kulatilaka, N.	*Management Science* (1994)	5	195
10	Risk analysis and assessment in networks environments: a dyadic case study	Hallikas, J., Virolainen, V.M., Tuominen, M.	*International Journal of Production Economics* (2002)	5	11

Notes: LCS = local citation score shows the count of citations to a paper within the collection; GCS = global citation score shows the total number of citations to a paper in the Web of Science

others) to each sink (i.e. an article that is not cited by others), the weight of the citation is given by the ratio between the number of paths including the citation and the total number of paths between the sources and sinks; Search Path Link Count – Which traces all paths from all vertices to the sink. Using this method the citation of an early article receives a lower weight; Search Path Node Pair – Where each vertex is considered as a source and a sink and thus vertices and edges in the middle of the paths will have higher weights.

2 Extracting main paths. Using the traversal weights of citations and articles it is possible to extract the main paths that will identify the main streams of the considered literature.

3 Extracting the main path component. A cut-off value between 0 and 1 is used to remove all arcs in the original citation network with a lower value, in order to extract the most important connected component. We used the default value, i.e. 0.5.

Main Path Analysis was performed using the Pajek graph analysis software package. We refer the interested reader to De Nooy *et al.* (2005) for a thorough description of the commands to be used.

Figure 4 shows the Main Path component deriving from the application of the described process to the citation network under investigation through the Pajek software. It identifies the most relevant articles in the field of SCRM at different moments of time, i.e. the ones facilitating the flow of information and the progress of knowledge.

4. The evolution of supply chain risk management literature starting from the Main Path Analysis

The main path depicted in Figure 4 shows some important milestones in the development of the SCRM theory in the last 15 years. The first two articles (Kogut and Kulatilaka, 1994; Huchzermeier and Cohen, 1996) have explored the field of risk in supply chain context from the perspective of flexibility. The issue addressed is how operational flexibility embedded in supply chain network design can be used in reducing supply chain risk (considered especially in terms of exchange rate risk due to the increasing level of globalisation of supply chains). Within a global manufacturing strategy, both articles propose a model to evaluate the potential benefits arising from alternative production options. Risk or, more specifically, uncertainty is determined by an exogenous stochastic process that affects production decision of a company.

In these contributions future uncertain events represent a necessary condition to increase the value of operating flexibility – utilised as a hedge against the firm's exchange risk exposure. At this stage of SCRM theory, uncertainty is considered as an opportunity available to a company in order to gain significant benefits. "Despite the popular notion of riskiness of international markets, it is this uncertainty that drives the opportunity available to the firm that is

Table II Ten highest closeness centrality articles

Rank	Title	Author	Journal/Year	Centrality
1	Managing disruption risks in supply chains	Kleindorfer, P.R. and Saad, G.H.	*Production and Operations Management* (2005)	0.2969
2	An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm	Hendricks, K.B. and Singhal, V.R.	*Production and Operations Management* (2005)	0.2917
3	Operating flexibility, global manufacturing, and the option value of a multinational network	Kogut, B. and Kulatilaka, N.	*Management Science* (1994)	0.2604
4	Perspectives in supply chain risk management	Tang, C.S.	*International Journal of Production Economics* (2006)	0.2187
5	Supply chain risk in turbulent environments – a conceptual model for managing supply chain network risk	Trkman, P. and McCormack, K.	*International Journal of Production Economics* (2009)	0.2135
6	What is the right supply chain for your product?	Fisher, M.L.	*Harvard Business Review*	0.2083
7	Valuing operational flexibility under exchange rate risk	Huchzermeier, A. and Cohen, M.A.	*Operations Research* (1996)	0.2083
8	The severity of supply chain disruptions: design characteristics and mitigation capabilities	Craighead, C.W., Blackhurst, J., Rungtusanatham, M.J., Handfield, R.B.	*Decision Sciences* (2007)	0.1875
9	The effect of supply chain glitches on shareholders wealth	Hendricks, K.B. and Singhal, V.R.	*Journal of Operations Management* (2003)	0.1771
10	An empirical examination of supply chain performance along several dimensions of risk	Wagner, S.M. and Bode, C.	*Journal of Business Logistics*	0.1510

Table III Journals with the highest number of citation network articles

Journal	Number of articles
International Journal of Production Economics	8
Journal of Operations Management	5
European Journal of Operational Research	4
Supply Chain Management: An International Journal	3
Production and Operations Management	3
Journal of the Operational Research Society	3
Management Science	2

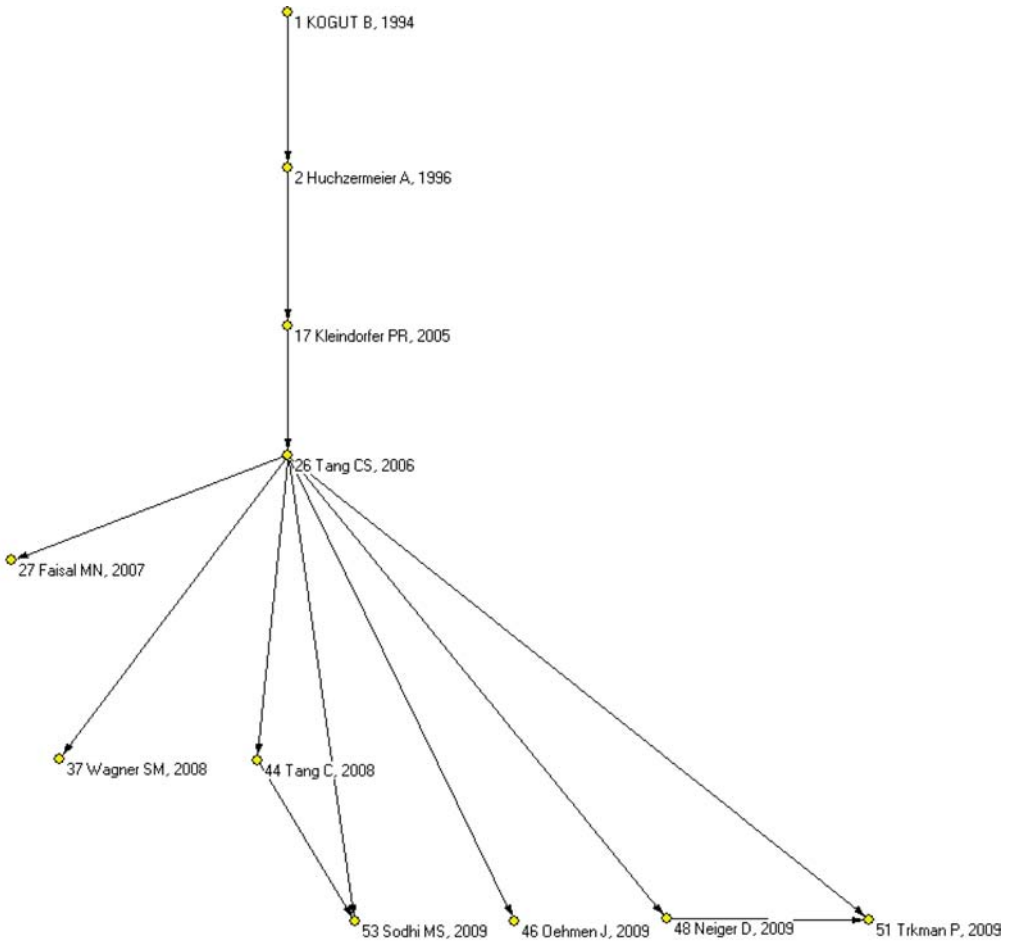
multinational in terms of its investments and operations" (Kogut and Kulatilaka, 1994).

Operational flexibility is tied up with the concept of efficiency: it is necessary to value it in terms of expected gains arising from the possibility to switch to alternative manufacturing strategy options (Huchzermeier and Cohen, 1996).

These early articles on the main path reflect a reactive approach to risk management: the investments are put in place in order to enhance the capability to respond to uncertain future events after they have occurred. Furthermore the focus is on the single company: the supply chain network design is addressed from the perspective of the single company.

The development of theory-building in SCRM has been influenced by the evolution characterizing the business environment. The trend towards globalisation has become in the later years only one of the drivers of supply chain vulnerability and the flexibility the only way to improve supply chain resilience. Shorter lead times and recent series of crises and catastrophes (e.g. the Taiwan earthquake of September 1999, the terrorist attack on the World Trade Center on September 11, 2001, the August 14, 2003 blackout in the Northeastern US) are but a few recent reminders that the business environment is unpredictable and increasingly unstable. Disruption risks, lying in different processes of the supply chain as well as in the external environment, began to receive increased attention. In fact, the work of Kleindorfer and Saad (2005) shows how traditional operational risks are joined with disruption risks arising from natural hazard, terrorism, and political instability. The authors formulated a set of ten principles for managing disruption risks in supply chains, considering both internal processes and the interconnections between supply chain partners. The provided principles reflect the effective integration of the joint activities of risk assessment and risk mitigation, while

Figure 4 SPC, SPLC, SPNP Main Path Component in the SCRM field



Note: Vertical dimension represents the publication year

offering strategic directions, actions, and necessary conditions that help advance cost-effective mitigation practices for supply chain disruptions. The approach of risk management process becomes proactive: "Risk avoidance should precede risk reduction" (Kleindorfer and Saad, 2005). Furthermore, the focus goes beyond the boundaries of the single company, as it involves collaborative sharing of information and best practices among supply chain partners. Also in this contribution, the importance of valuing the efficiency of risk management is emphasised.

In so far as SCRM has, lately, gained more and more attention by the scientific literature, in 2006 Tang proposed an extensive literature review. The author developed a unified framework for classifying SCRM articles and, by highlighting the gap between theory and practice, identified directions for future research. The author proposes four basic approaches (supply management, demand management, product management, and information management) that a firm could deploy for managing supply chain risks, in a context where traditional initiatives are no longer effective. According to these approaches the extant literature is analysed. The insights arising from this contribution are the following:

- an approach intended to improve supply chain operations via coordination or collaboration with both upstream and downstream partners is needed;
- companies tend to underestimate the relevance of a proactive approach to RM and only few of them take actions to mitigate risks in a proactive manner; and
- a lack of effective tools that explicitly consider the economic dimension of risk strategies precludes companies to widely adopt them.

Following Tang (2006), a series of research articles contributing to theory-building in SCRM have emerged on the main path. Later articles, which characterised the evolution of SCRM have commonly explored the dimension of complexity in the supply chain from different perspectives. Faisal *et al.* (2007) and Wagner and Bode (2008) explored practices and tools for risk identification, assessment, and mitigation. Tang and Tomlin (2008) and Sodhi and Tang (2009) developed quantitative models to manage the risks of modern supply chains. Finally, with the contributions by Neiger *et al.* (2009), Trkman and McCormack (2009) and Oehmen *et al.* (2009), the consideration of supply chains as complex systems starts to emerge and consequently the need to reduce the increased level of supply chain vulnerability

becomes more relevant. The focus is not on the focal company anymore, rather, a system-wide perspective involving networks of supply chains is adopted in order to increase value to all supply chain members and effectively handle the complexity of supply networks.

In the next section the insights arising from the main path analysis are combined with the evidence gathered from the 55 papers that represent the basis of the present literature review for each of the main themes of SCRM literature defined through the application of the CIMO logic, as described in Section 3 (i.e. Complexity and uncertainty, practices and tools for SCRM, organization of SCRM process, and increased SC resilience and robustness). Then, the evolution of key concepts is presented, highlighting the adopted perspectives, the directions in which research is moving and the shortcomings of the existing contributions. The Main Path Analysis, by highlighting the 11 papers constituting the main path, gave us an additional valuable support in interpreting the evolution, the gaps and the research directions of the field under study.

4.1 Complexity and uncertainty

As an initial step, the evolution of the context in which supply chains nowadays operate is outlined. Two dimensions characterising the context have been put forward through the CIMO-logic: uncertainty and complexity. Even if these two concepts have always been related to SCRM their nature has evolved over time.

As mentioned above, in the early articles of the main path (Kogut and Kulatilaka, 1994; Huchzermeier and Cohen, 1996) uncertainty is considered as an opportunity that a firm that is multinational in terms of its investments and operations needs to exploit. In more recent papers not included in the main path, the downside potential of uncertainty is stressed (Chopra and Sodhi, 2004; Chopra *et al.*, 2007; Ritchie and Brindley, 2007). As far as complexity is concerned, the main path suggests that the concept has evolved from an abstract construct to a challenge that can be effectively understood and managed by means of specific theories. Indeed, this evolution can be better identified and explained considering the other contributions present in the citations network. Though complexity has always been related to supply chains, and SCRM in particular, the study of this concept through a formalized approach has only relatively recently been addressed and researchers have suggested new definitions of complexity. In fact, in the early contributions complexity is often related to the topology of the supply chain. The static dimension of complexity is addressed and the complex nature of supply chains is considered related to its complicated structure, arising both from the number of partners operating in the same supply chain and from the geographical dimension of the supply chain, i.e. the extended reach of globe-spanning supply chains (Agrawal and Seshadri, 2000; Kogut and Kulatilaka, 1994; Hallikas *et al.*, 2002; Huchzermeier and Cohen, 1996). In more recent papers complexity includes also the dynamics of supply chains: the interconnectivity between different supply chains and the dynamic behaviour of the system. Craighead *et al.* (2007) define complexity as the sum of the total number of nodes and the total number of forward, backward and within-tier material flows within a given supply chain. According to Manuj and Mentzer (2008) "supply chain complexity is an aggregate measure of the structure, type, and volume of interdependent activities, transactions, and processes in the supply chain". Also Adhitya *et al.* (2009) argue that supply chain complexity "arises from the interconnections among supply chain entities".

Building on these definitions, a number of writers have sought to develop appropriate approaches to appraise complexity's effect on the supply chains. Craighead *et al.* (2007) relate the design characteristics of the supply chain, including the complexity, to supply chain disruptions. By conducting an empirical research, the authors prove the hypothesis that supply chain disruption is a result of complexity. The results of their work aim at offering simple and useful directions to supply chain managers in evaluating specific supply chain decisions. The authors recommend future research should seek to quantitatively assess the investigated relationships. As a matter of fact, the main path suggests that a research stream within the area of SCRM is advocated for quantifying relationship between risk and complexity. Oehmen *et al.* (2009) propose a system-oriented approach in order to deeply investigate the behaviour of the supply chain and thus identify concrete decisions that are more likely to be effective in reducing risk. Their approach comprises a SCR Structure Model enabling a static analysis of causal factors and the effects of risks, and a SCR Dynamics Model to represent the dynamic development of supply chain risks as its members interact with one another.

Indeed, some earlier contributions have tried to locate SCRM within the broader study of complexity. Choi *et al.* (2001) assert that even if managers have always acknowledged the complex nature of the supply chain, recognizing it as a complex system can more accurately reflect the complexity dimension and dynamism of a real-life supply chain. The complexity of the supply chain can be analysed through the complex adaptive system (CAS) theory. The term CAS refers to a system that spontaneously evolves over time. Modern theories of CAS are specifically designed to address the interrelationships between a system and its environment and the co-evolution of both of them. By thinking of a supply chain as a CAS, "managers must appropriately decide how much to control and how much to let emerge" (Choi *et al.*, 2001). Venkatasubramanian *et al.* (2004) study complex networks, investigating how their structure and organization affect other dimensions such as the performance of the system. Using a graph theoretic formalism, a number of critical measures of the network (i.e. efficiency, robustness and cost) are defined and a framework for integrating performance objectives and topological features of the network is provided. The authors suggest that complex networks theory can be effectively applied in supply chains context.

Even if these contributions provide novel approaches to model, design and analyse complex supply chains, research in complexity analysis and graph theory appears to be underdeveloped in the area of SCRM. Linking concepts and measures coming from these disciplines is certainly of great potential to advance our understanding in the field of SCRM.

4.2 Practices and tools for SCRM

To mitigate supply chain risk many researchers have developed different models or strategies. We refer the interested reader to Tang (2006) for a thorough review of quantitative models for SCRM.

However, the author highlights an overriding drawback to the many reviewed approaches: they primarily deal with supply chain operational risks, and not disruption risks. As suggested by the main path articles (Kleindorfer and Saad, 2005), the uncertainty of the business environment and the very complexity of supply chain networks appear to be increasing the probability of experiencing supply chain disruptions, as confirmed also by the other papers included in our review (Bakshi and Kleindorfer, 2009; Chopra *et al.*, 2007; Craighead *et al.*, 2007; Hendricks *et al.*, 2009). This implies that the traditional Operational Risk Management needs some re-thinking in the era of disruptions. Academics and practitioners have begun to address "disruption management", with the aim to reduce the risk of disruptions, mitigate their negative impact on performance and restore the supply chain to normal operation as soon as possible (Adhitya *et al.*, 2009; Hendricks *et al.*, 2009; Lodree and Taskin, 2008).

From our literature review it emerges that the key challenges for an effective disruption management are: developing supply chain design models able to take into account the uncertainty and complexity in which supply chains operate; and developing structured and systematic tools for risk identification and assessment that explicitly consider the dynamic interactions among supply chain partners and among risk sources. In fact, these interactions are considered, among others, as a source of disruptions (Adhitya *et al.*, 2009).

For many authors the starting point for an effective disruption management is the redesign of the supply chain. The underpinning assumption suggested by the literature is that many companies are not prepared for the challenges they have to confront nowadays. If this assumption is correct, an alignment of supply chain strategy and design to the new operating context is unavoidable (Wagner and Bode, 2008). Likewise Blackhurst *et al.* (2005) state that supply chain redesign is a critical area for managing disruptions. As mentioned above Craighead *et al.* (2007) investigate the relationship between the severity of supply chain disruptions and the design characteristics of the supply chain, i.e. density, complexity and node criticality. Venkatasubramanian *et al.* (2004) propose a general framework to design an efficient and robust supply chain.

However, literature on how supply chain structure and design affect supply chain risk exposure is quite limited (Tang and Tomlin, 2008; Trkman and McCormack, 2009). Despite an extensive literature on supply chain design, most published models have the following disadvantages: they produce static optimal solutions that may not be robust in dynamic environments as key parameters evolve (Blackhurst *et al.*, 2005; Klibi *et al.*, 2010); they deal with deterministic parameters without considering the uncertainty that affects input data (Azaron *et al.*, 2008; Klibi *et al.*, 2010); they do not take resilience and robustness into consideration in their objective function (Klibi *et al.*, 2010) and they focus on minimising cost or maximising profit as a single objective (Azaron *et al.*, 2008).

In order to cope with the uncertainty of future events the use of stochastic optimization approach for supply chain design is showing increasing promise (Sodhi and Tang, 2009). Goh *et al.* (2007) presented a stochastic model of a global supply chain problem operating under a scenario of a variety of risks. Azaron *et al.* (2008) developed a multi-objective stochastic programming approach for supply chain design under uncertainty. Sodhi and Tang (2009) presented a stochastic programming formulation for a supply chain problem that takes into account demand uncertainty and cash flows.

Stochastic optimization, modelling for robustness and resilience, value-based supply chain design models, multi-period future scenario development and modelling multi-hazard arrival processes are the main research directions proposed in literature in order to develop a comprehensive methodology for supply chain design in a complex and uncertain environment (Gaonkar and Viswanadharn, 2007; Klibi *et al.*, 2010).

Following the supply chain redesign, disruption management deals with disruption discovery, i.e. risk identification and assessment (Blackhurst *et al.*, 2005). As mentioned above, over the years a number of well-used tools for identifying, quantifying and managing risks have been developed (Tang, 2006). There is some work also on defining frameworks for SCRM. Ritchie and Brindley (2007) identified five main components of SCRM:

1 risk drivers;
2 risk management influencers;
3 decision maker characteristics;
4 risk management responses; and
5 performance outcomes.

Faisal *et al.* (2006) proposed to consider two dimensions, i.e. customer sensitivity and risk alleviation competency, to select suitable supply chain strategy.

Though numerous risk classifications have been put forward (e.g. Chopra and Sodhi, 2004) and numerous tools for risk management have been proposed (Agrawal and Seshadri, 2000; Kull and Talluri, 2008; Sinha *et al.*, 2004; Wu *et al.*, 2006), the validity and usefulness of the practices and tools proposed is not strongly supported by empirical evidence and widely acknowledged in the current literature (Hendricks *et al.*, 2009). Adhitya *et al.* (2009) state that "the existing literature does not provide a way to systematically identify risks". In order to fill this void the authors propose the HAZard and Operability (HAZOP) analysis for risk identification and evaluation. The aim is to consider both deviations that can occur in a component of a system and new sources of risk related to the interaction between the components of the same system.

The need to consider risks arising from network collaboration and interactions between supply chain partners is stressed by several authors (Bakshi and Kleindorfer, 2009; Blos *et al.*, 2009; Finch, 2004; Hallikas *et al.*, 2002; Hallikas *et al.*, 2004; Kull and Talluri, 2008; Ritchie and Brindley, 2007). Research should investigate how the effects of a disruption experienced by one firm spread to its supply chain partners (Hendricks *et al.*, 2009). As mentioned above, nowadays companies are involved in a network of different supply chains. This entails the emergence of network-related sources of risks, i.e. supply chain dynamics and relationships as highlighted by the main path articles (Trkman and McCormack, 2009; Oehmen *et al.*, 2009); furthermore, new effective tools able to address the dynamic aspect of the network of events causing risks are needed (Klimov and Merkuryev, 2008; Oehmen *et al.*, 2009).

4.3 Organization of SCRM process

Effective practices and tools for SCRM need to be supported by an appropriate organization of the SCRM process, i.e. definition of the scope of the considered process and resource/capabilities allocated to the process under consideration. As highlighted by the foregoing examination of the literature on practices and tools for SCRM, there is a high level of awareness of the potential risk arising from interaction and relationships between supply chain partners. This implies that, in recent years, over time a number of writers have sought to broaden the scope of disruption risk management process from the level of the single company to the level of the entire supply chain (Bakshi and Kleindorfer, 2009; Faisal *et al.*, 2007). Even the study of dyadic relationships is not sufficient anymore, whereas a wide analysis on a larger network has to be conducted (Trkman and McCormack, 2009). The supply chain is as strong as its weakest node and a disruption at a company can cause a disruption in the entire supply chain (Bakshi and Kleindorfer, 2009). Hence, SCRM should go beyond the boundaries of the single company. This means that the process aims at discovering and quantifying hazards in the extended supply chain (Kleindorfer and Saad, 2005; Yu *et al.*, 2007) and, starting from a comprehensive picture of potential risk exposures, at mitigating the overall supply chain risk environment (Faisal *et al.*, 2007; Oehmen *et al.*, 2009).

The organization of the SCRM process includes also the definition of mitigation capabilities (Blackhurst *et al.*, 2005). According to the definition provided by Craighead *et al.* 2007, the mitigation capabilities can be considered as the organizational routines that "enhance the abilities of the supply chain to recover expediently from a manifested disruption and to create awareness of a pending or realized disruption". The severity of a disruption appears to be negatively related to the presence of mitigation capability, that can be proactive, reactive or both (Craighead *et al.*, 2007). Especially in the current business environment, from the analysis of the literature, it emerges that a proactive approach is to be preferred than a reactive one, which was efficient in a more stable competitive landscape as the one of the past years. Resilience (which is the ultimate goal of an effective risk management process) should be considered as a proactive exploration of capabilities to cope with unforeseen events. (Gaonkar and Viswanadharn, 2007; Kleindorfer and Saad, 2005). Indeed, a proactive approach to risk management is intended to understand and avoid risks, while enhancing the level of preparedness to respond to risks after they have occurred (Kleindorfer and Saad, 2005). A proactive approach, that enables a dynamic analysis of risks in supply chains, is also included in the methodology proposed by Neiger *et al.* (2009) for risk identification. Even if it is a critical first step of the process to determine the main vulnerabilities, as well as worst case scenarios arising from such vulnerabilities, companies tend to underestimate its relevance (Tang, 2006). The idea that "nobody gets credit for fixing problems that never happened" needs to be overcome to promote best mitigation practices for identifying and managing risk in advance.

In order to translate these recommendations in practice there is a need for empirical research into how companies manage supply chain risk (Hendricks *et al.*, 2009). In particular it is necessary to investigate what processes and techniques they use to assess their extended supply chain risk exposure and how they develop mitigation capabilities, both proactive and reactive, at a supply network level (Bakshi and Kleindorfer, 2009; Blackhurst *et al.*, 2005; Neiger *et al.*, 2009).

4.4 Increased SC resilience and robustness

The ultimate goal of an effective SCRM process is to create robust and resilient supply chains. However, a general or high-level view of SCRM process has guided the theory-building so far. Both internally and externally induced supply chain disruptions can significantly and negatively influence the financial bottom line of a firm, determining its profitability and survival (Hendricks and Singhal, 2005; Tang, 2006). Furthermore the failure of any one node in the supply chain could imply a failure of the complete supply network (Bakshi and Kleindorfer, 2009). A better understanding on the relationships between a set of strategies for managing risk and the impact on the performances would provide interesting insights in the field of SCRM (Hendricks *et al.*, 2009). In particular SCRM strategies are justified only if supply chain risks interfere with companies' performances (Wagner and Bode, 2008). To the best of the authors' knowledge only few contributions in the literature investigated the relationships between supply chain risk and performance (Hendricks and Singhal, 2003, 2005, 2008; Hendricks *et al.*, 2009; Tomlin, 2006; Wagner and Bode, 2008). Notwithstanding their relevance in defining and proving correlations between these two concepts, only general managerial implications can be derived. Indeed, these relationships have neither been supported by empirical evidence nor underpinned with theory (Kleindorfer and Saad, 2005; Wagner and Bode, 2008; Trkman and McCormack, 2009). The need to investigate the relationships between risks and performance at a company level and not only from a general perspective means that an assessment of the value of the increased robustness and resilience of the supply chain is required. As mentioned above, for SCRM to be implemented comes at a cost, and the risk mitigating strategies must be tied up with the obtained payoff, measuring the financial impact on the firm's bottom line (Sodhi and Lee, 2007; Tang and Tomlin, 2008; Tomlin, 2006). A lack of effective tools that explicitly consider the economic dimension of risk strategies precludes companies to widely adopt them (Tang, 2006). In particular the value of an increased supply chain robustness and resilience in terms of trade-off between the investment required for mitigation actions and the disruption loss, weighted by the probability of a disruption over a significant planning horizon, needs to be further explored (Kogut and Kulatilaka, 1994; Huchzermeier and Cohen, 1996; Kleindorfer and Saad, 2005). A thorough analysis based on empirical research or on the development of models for effectiveness and efficiency evaluation of risk reduction strategies would support supply chain managers in decision making (Kleindorfer and Saad, 2005).

5. Identifying research directions in the field of SCRM

The analysis of the dynamic evolving paradigm characterising the theory development in the field of SCRM allows us to better understand how the key concepts evolved over time and thus what are the directions for further research suggested by their evolution. In Table IV the evolution of key concepts

of SCRM is summarised. Despite a rich literature on SCRM, and on disruption management in particular, most published contributions consider only a subset of the foregoing issues.

The following research directions are identified:

- Locating research into SCRM within the more structured study of the SC complexity. It is clear from the above review of the literature that there is a lack of understanding of the nature of complexity among many supply chain researchers and this could affect the effectiveness of risk management. Future research should seek to investigate how other disciplines of research, i.e. complexity theory and graph theory, can advance our understanding of SCR. To this end, it is necessary to analyse how key concepts and performance measures from other disciplines can be incorporated into SCRM. Furthermore, the implications of a consideration of supply chains as complex system for SCRM need to be further examined.
- Modelling supply chains considering robustness and resilience. To confront the challenges of a complex and unstable competitive environment and to gain long-term benefits, it is necessary to include resilience and robustness considerations into supply chain design. Besides optimising the efficiency of the supply chain, it is important to maximise its capability to ensure continuity of supply thanks to its structure and design able to quickly adapt to changes or disruptions.
- Assessing and managing disruption risks. Considering the raised level of complexity and unpredictability of future events, as it would appear that traditional practices and tools are no longer effective. Dynamic supply chain models under uncertainty are needed, as well as tools able to consider the maze of interactions characterizing supply chains and risk sources, considered as a source of supply chain disruptions.
- Investigating mitigation practices, adopting a Supply network perspective, i.e. considering the SC as an open system interconnected with the environment. Empirical research into how risk is managed in supply chains is needed. The literature suggests that proactive approaches at supply chain level should be implemented in order to effectively manage disruptions. In order to translate this recommendation in practice there is a need to investigate – through empirically based research – how companies assess their supply chain risk exposure and how they develop mitigation capabilities in collaboration with their supply chain partners.
- Evaluating the value of an increased supply chain resilience and robustness. There is a need for research into the role of SCRM for mitigating the negative impact of disruptions on performance. The value of an increased supply chain robustness and resilience in terms of trade-off between the investment required for mitigation actions and the disruption loss, weighted by the probability of a disruption over a significant planning horizon, needs to be further explored in order to effectively support decision-making.

6. Pro and cons of the adopted methodology

In this section we will highlight the main advantages and disadvantages of SLNA. It combines the advantages of SLR and CNA. Using SLR the objectives and questions of the review are clearly stated, the definition of literature review process is structured and clear, the search of published and unpublished information is rigorous and comprehensive, the inclusion and exclusion criteria are pre-determined (Denyer and Tranfield, 2009). SLR identifies the issues and strings better suited for making a first selection of articles (55 articles in the case of SCRM considered in this article). CNA, based only on citations, is able to identify a smaller set of relevant articles (the Main Path of SCRM field is composed by 11 articles). Using this analysis it is possible to place the articles in a historical context and connect them by directed paths that identify how the flow of scientific discovery has changed over time. It is important to underline that the Main Path is automatically calculated according only to the citations and thus provides an objective result.

CNA is a blind methodology based only on citations and has the limitation that it is difficult to find relevant information if applied to a wide field without a pre-selection of the articles. SLR is not able to automatically identify the dynamics in the evolution of knowledge.

By combining these two methodologies in the new SLNA it is possible to overcome these limitations, but unfortunately, others are still present. The application of SLNA, and in particular of CNA, requires the support of specific computer programs (e.g. HistCite, Pajek) and information about the cited references, which has to be structured in a precise way. The first selection of articles made with the SLR is not completely objective: a different level of knowledge in a field may lead to different sets of items upon which the CNA will be applied. The cut-off values used in CNA to find the main path is a parameter that, depending on its value, will include and consider as relevant a different number of items. In this

Table IV Identifying research directions in SCRM

Main themes	From	To	Research directions
1. Complexity and uncertainty (C)	Uncertainty as an opportunity	Uncertainty as a threat	Locating research into SCRM within the more structured study of the supply chain complexity
	Complexity of the supply chain structure	Supply chain as a complex evolving system	Modelling supply chains considering robustness and resilience Assessing and managing disruption risks
2. Practices and tools for SCRM (I)	Operational risk management	Disruption risk management	Investigating mitigation capabilities, adopting a supply network perspective, i.e. considering the supply chain as an open system interconnected with the environment
3. Organization of SCRM process (M)	Reactive approach Focus on supply chain	Proactive approach Focus on supply network	
4. Increased SC resilience and robustness (O)	Theoretical point of view Focus on effectiveness	Practical point of view Focus on efficiency	Evaluating the value of an increased supply chain resilience and robustness

work we have considered the default value 0.5. The change of the default value becomes necessary when, for example, the resulting main path is composed by many disconnected components.

It should be noted that the contributions identified with the Main Path Analysis are not necessarily those that contain the best or most important results, but those which were more used/cited by the others. The main path highlights papers that can be considered as the most important in terms of dissemination rather than quality. Contributions that contain important results but not yet used by others will not be identified with this approach.

In addition, the underlying assumption of CNA is that the citation of a work implies that the results obtained are in some way based on the cited work. This assumption is only partially true because the spread of measures based on impact assessment has led many researchers to an excessive use of citations, even if the content is not always decisive for the outcome of their work. Furthermore, the interpretation of the main path is itself subjective. Its interpretation and identification of the evolution of concepts, albeit assisted by the small number of articles to read, always depends on the experience of the reader. Although we were able to compute indices and obtain the most relevant papers at different moments of time with the support of computer programs, interpreting the outputs is the researchers' responsibility. The quality of a citation is unknown without further contextual examination of the content. Finally SLNA, at least in the present form, does not allow for a classification of the existing research in terms of methodology being used or theoretical perspectives, but it supports a dynamic analysis of the process of knowledge development.

7. Conclusions

The present literature review has taken a close look at SCRM and the issues emerging in this field. Two existing methodologies, i.e. SLR and CNA, were combined in a new one, the Systematic Literature Network Analysis (SLNA). Through the SLR approach it was possible to select the most relevant papers that have contributed to theory-building in the field of SCRM. Then, with CNA, a dynamic analysis of the selected contributions has been performed. From the identification of evolutionary patterns and emerging trends in key concepts, important directions for new research paths have been identified and discussed and some managerial insights provided.

Different aspects underpinning the concepts of risk and uncertainty emerge as new distinctive features of supply chain management. Considering the raised level of complexity and unpredictability of future events (Christopher and Holweg, 2011), it would appear that the key elements for a robust and resilient supply chain are a strategy and a structure aligned with the actual business context, a dynamic and comprehensive approach to risk management, and, finally, collaboration among all companies operating within the same supply network. Indeed building robustness and resilience in the supply chain is a tough task since it involves a number of trade-offs: specific supply chain decisions can enhance the resilience of the supply chain, but at the same time they can result in a more complex network, thus entailing a higher exposure to disturbances and disruptions; furthermore, the cost-efficiency of risk-reduction strategies must be assessed, determining if greater network resilience and robustness are worth the extra cost. In examining tools and practices for managing supply chain risk, the literature review revealed that different approaches are presented. However, most of them address the topic from a general perspective, underestimating the relevance of a deep analysis on the relationships between SCRM strategies and performances. Although most researchers would agree that supply chains are inherently risky, one issue remains relatively unexplored; that is: a practical perspective to improve supply chain robustness and resilience in order to deal with unexpected events. From a practical point of view the "silver bullet" to managing supply chain risk that emerge from the evidence of the performed literature review is: considering uncertainty in the design of supply chains, understanding the impact of risks arising from network collaboration and interactions between supply chain partners, developing proactive mitigation capabilities to hedge the increasing level of risk.

The identified research directions can be the way to move towards the development of models for managing supply chain risk from both a research and practical perspective, intertwined to assist with supply chain complexity. Despite the meaningful achievements discussed above and in sections 4 and 5, the adopted methodology has some limitations, as described in detail in section 6. Notwithstanding these limitations, we believe that the present study takes a step towards theory-building and offers meaningful directions for a well-grounded and promising programme of research.

We think that this study, as well as helping to identify promising research directions in the specific field of SCRM, also stimulates the attention to the need of a more objective literature review so as to exploit the richness of existing software packages and databases.

References

Adhitya, A., Srinivasan, R. and Karimi, I.A. (2009), "Supply chain risk identification using a HAZOP-based approach", *Aiche Journal*, Vol. 55 No. 6, pp. 1447-63.

Agrawal, V. and Seshadri, S. (2000), "Risk intermediation in supply chains", *IIE Transactions*, Vol. 32 No. 9, pp. 819-31.

Azaron, A., Brown, K.N., Tarim, S.A. and Modarres, M. (2008), "A multi-objective stochastic programming approach for supply chain design considering risk", *International Journal of Production Economics*, Vol. 116 No. 1, pp. 129-38.

Bakshi, N. and Kleindorfer, P. (2009), "Co-opetition and investment for supply-chain resilience", *Production and Operations Management*, Vol. 18 No. 6, pp. 583-603.

Blackhurst, J., Craighead, C.W., Elkins, D. and Handfield, R.B. (2005), "An empirically derived agenda of critical research issues for managing supply-chain disruptions", *International Journal of Production Research*, Vol. 43 No. 19, pp. 4067-81.

Blos, M.F., Quaddus, M., Wee, H.M. and Watanabe, K. (2009), "Supply chain risk management (SCRM): a case study on the automotive and electronic industries in Brazil", *Supply Chain Management: An International Journal*, Vol. 14 No. 4, pp. 247-52.

Braithwaite, A. and Wilding, R. (2005), "The supply chain risks of global sourcing", working paper, Cranfield School of Management, Cranfield University, Cranfield.

Choi, T.Y., Dooley, K.J. and Rungtusanatham, M. (2001), "Supply networks and complex adaptive systems: control versus emergence", *Journal of Operations Management*, Vol. 19 No. 3, pp. 351-66.

Chopra, S. and Sodhi, M.S. (2004), "Managing risk to avoid supply-chain breakdown", *MIT Sloan Management Review*, Vol. 46 No. 1, p. 53.

Chopra, S., Reinhardt, G. and Mohan, U. (2007), "The importance of decoupling recurrent and disruption risks in a supply chain", *Naval Research Logistics*, Vol. 54 No. 5, pp. 544-55.

Christopher, M. (1998), *Logistics and Supply Chain Management*, 2nd ed., Financial Times, Burr Ridge, IL.

Christopher, M. and Holweg, M. (2011), "Supply chain 2.0: managing supply chains in the era of turbulence", *International Journal of Physical Distribution & Logistics Management*, Vol. 41 No. 1, pp. 63-82.

Christopher, M. and Peck, H. (2004), "Building the resilient supply chain", *The International Journal of Logistics Management*, Vol. 15 No. 2, pp. 1-13.

Christopher, M., Peck, H., Rutherford, C. and Jüttner, U. (2003), *Understanding Supply Chain risk: A Self-assessment Workbook*, Department for Transport, Cranfield University, Cranfield.

Craighead, C.W., Blackhurst, J., Rungtusanatham, M.J. and Handfield, R.B. (2007), "The severity of supply chain disruptions: design characteristics and mitigation capabilities", *Decision Sciences*, Vol. 38 No. 1, pp. 131-56.

De Nooy, W., Mrvar, A. and Batagelj, V. (2005), *Exploratory Social Network Analysis with Pajek*, Cambridge University Press, Cambridge.

Denyer, D. and Tranfield, D. (2009), "Producing a systematic review", in Buchanan, D. and Bryman, A. (Eds), *The Sage Handbook of Organizational Research Methods*, Sage Publications, London, pp. 671-89.

Faisal, M.N., Banwet, D.K. and Shankar, R. (2006), "Mapping supply chains on risk and customer sensitivity dimensions", *Industrial Management & Data Systems*, Vol. 106 Nos 5-6, pp. 878-95.

Faisal, M.N., Banwet, D.K. and Shankar, R. (2007), "Quantification of risk mitigation environment of supply chains using graph theory and matrix methods", *European Journal of Industrial Engineering*, Vol. 1 No. 1, pp. 22-39.

Finch, P. (2004), "Supply chain risk management", *Supply Chain Management: An International Journal*, Vol. 9 No. 2, pp. 183-96.

Fisher, M.L. (1997), "What is the right supply chain for your product?", *Harvard Business Review*, Vol. 75 No. 2, p. 105.

Gaonkar, R.S. and Viswanadharn, N. (2007), "Analytical framework for the management of risk in supply chains", *IEEE Transactions on Automation Science and Engineering*, Vol. 4 No. 2, pp. 265-73.

Goh, M., Lim, J.Y.S. and Meng, F.W. (2007), "A stochastic model for risk management in global supply chain networks", *European Journal of Operational Research*, Vol. 182 No. 1, pp. 164-73.

Hallikas, J., Virolainen, V.M. and Tuominen, M. (2002), "Risk analysis and assessment in network environments: a dyadic case study", *International Journal of Production Economics*, Vol. 78 No. 1, pp. 45-55.

Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V.M. and Tuominen, M. (2004), "Risk management processes in supplier networks", *International Journal of Production Economics*, Vol. 90 No. 1, pp. 47-58.

Haywood, M. and Peck, H. (2004), "Supply chain vulnerability within UK aerospace manufacturing: development of a vulnerability management toolkit", *Supply Chain Practice*, Vol. 6 No. 1, pp. 72-83.

Hendricks, K.B. and Singhal, V.R. (2003), "The effect of supply chain glitches on shareholder wealth", *Journal of Operations Management*, Vol. 21 No. 5, pp. 501-22.

Hendricks, K.B. and Singhal, V.R. (2005), "An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm", *Production and Operations Management*, Vol. 14 No. 1, pp. 35-52.

Hendricks, K.B. and Singhal, V.R. (2008), "The effect of supply chain disruptions on shareholder value", *Total Quality Management & Business Excellence*, Vol. 19 Nos 7-8, pp. 777-91.

Hendricks, K.B., Singhal, V.R. and Zhang, R.R. (2009), "The effect of operational slack, diversification, and vertical relatedness on the stock market reaction to supply chain disruptions", *Journal of Operations Management*, Vol. 27 No. 3, pp. 233-46.

Huchzermeier, A. and Cohen, M.A. (1996), "Valuing operational flexibility under exchange rate risk", *Operations Research*, Vol. 44 No. 1, pp. 100-13.

Hummon, N.P. and Doreian, P. (1989), "Connectivity in a citation network: the development of DNA theory", *Social Networks*, Vol. 11 No. 1, pp. 39-63.

Johnson, M.E. (2001), "Learning from toys: lessons in managing supply chain risk from the toy industry", *California Management Review*, Vol. 43 No. 3, p. 106.

Jüttner, U., Peck, H. and Christopher, M. (2003), "Supply chain risk management: outlining an agenda for future research", *International Journal of Logistics: Research and Applications*, Vol. 6 No. 4, pp. 197-210.

Khan, O. and Burnes, B. (2007), "Risk and supply chain management: creating a research agenda", *International Journal of Logistics Management*, Vol. 18 No. 2, pp. 197-216.

Kleindorfer, P.R. and Saad, G.H. (2005), "Managing disruption risks in supply chains", *Production and Operations Management*, Vol. 14 No. 1, pp. 53-68.

Klibi, W., Martel, A. and Guitouni, A. (2010), "The design of robust value-creating supply chain networks: a critical review", *European Journal of Operational Research*, Vol. 203 No. 2, pp. 283-93.

Klimov, R. and Merkuryev, Y. (2008), "Simulation model for supply chain reliability evaluation", *Technological and Economic Development of Economy*, Vol. 14 No. 3, pp. 300-11.

Knight, F.H. (1921), *Risk, Uncertainty and Profit*, Houghton Mifflin, Boston, MA.

Knoke, D. and Yang, S. (2008), *Social Network Analysis*, 2nd ed., Sage, Thousand Oaks, CA.

Kogut, B. and Kulatilaka, N. (1994), "Operating flexibility, global manufacturing, and the option value of a multinational network", *Management Science*, Vol. 40 No. 1, pp. 123-39.

Kull, T.J. and Talluri, S. (2008), "A supply risk reduction model using integrated multicriteria decision making", *IEEE Transactions on Engineering Management*, Vol. 55 No. 3, pp. 409-19.

Lodree, E.J. and Taskin, S. (2008), "An insurance risk management framework for disaster relief and supply chain

disruption inventory planning", *Journal of the Operational Research Society*, Vol. 59 No. 5, pp. 674-84.
Lucio-Arias, D. and Leydesdorff, L. (2008), "Main path analysis and path-dependent transitions in HistCite based histograms", *Journal of the American Society for Information Science and Technology*, Vol. 59 No. 12, pp. 1948-62.
Manuj, I. and Mentzer, J.T. (2008), "Global supply chain risk management", *Journal of Business Logistics*, Vol. 29 No. 1, p. 133.
Mentzer, T.J. and Kahn, K.B. (1995), "A framework of logistics research", *Journal of Business Logistics*, Vol. 16 No. 1, pp. 231-50.
Neiger, D., Rotaru, K. and Churilov, L. (2009), "Supply chain risk identification with value-focused process engineering", *Journal of Operations Management*, Vol. 27 No. 2, pp. 154-68.
Newbert, S.L. (2007), "Empirical research on the resource-based view of the firm: an assessment and suggestions for future research", *Strategic Management Journal*, Vol. 28 No. 2, pp. 121-46.
Oehmen, J., Ziegenbein, A., Alard, R. and Schonsleben, P. (2009), "System-oriented supply chain risk management", *Production Planning & Control*, Vol. 20 No. 4, pp. 343-61.
Ponomarov, S.Y. and Holcomb, M.C. (2009), "Understanding the concept of supply chain resilience", *The International Journal of Logistics Management*, Vol. 20 No. 1, pp. 124-43.
Ritchie, B. and Brindley, C. (2007), "An emergent framework for supply chain risk management and performance measurement", *Journal of the Operational Research Society*, Vol. 58 No. 11, pp. 1398-411.
Rousseau, D.M., Manning, J. and Denyer, D. (2008), "Evidence in management and organizational science: assembling the field's full weight of scientific knowledge through syntheses", *The Academy of Management Annals*, Vol. 2 No. 1, pp. 475-515.
Sabidussi, G. (1966), "The centrality index of a graph", *Psychometrika*, Vol. 31 No. 4, pp. 581-603.
Sinha, P.R., Whitman, L.E. and Malzahn, D. (2004), "Methodology to mitigate supplier risk in an aerospace supply chain", *Supply Chain Management: An International Journal*, Vol. 9 No. 2, pp. 154-68.
Sodhi, M.S. and Lee, S. (2007), "An analysis of sources of risk in the consumer electronics industry", *Journal of the Operational Research Society*, Vol. 58 No. 11, pp. 1430-9.
Sodhi, M.S. and Tang, C.S. (2009), "Modeling supply-chain planning under demand uncertainty using stochastic programming: a survey motivated by asset-liability management", *International Journal of Production Economics*, Vol. 121 No. 2, pp. 728-38.
Svensson, G. (2000), "A conceptual framework for the analysis of vulnerability in supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 30 No. 9, pp. 731-49.
Tang, C. and Tomlin, B. (2008), "The power of flexibility for mitigating supply chain risks", *International Journal of Production Economics*, Vol. 116 No. 1, pp. 12-27.
Tang, C.S. (2006), "Perspectives in supply chain risk management", *International Journal of Production Economics*, Vol. 103 No. 2, pp. 451-88.
Tomlin, B. (2006), "On the value of mitigation and contingency strategies for managing supply chain disruption risks", *Management Science*, Vol. 52 No. 5, pp. 639-57.
Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a methodology for developing evidence-informed management knowledge by means of systematic review", *British Journal of Management*, Vol. 14 No. 3, pp. 207-22.
Trkman, P. and McCormack, K. (2009), "Supply chain risk in turbulent environments – a conceptual model for managing supply chain network risk", *International Journal of Production Economics*, Vol. 119 No. 2, pp. 247-58.
Van der Vorst, J. and Beulens, A. (2002), "Identifying sources of uncertainty to generate supply chain redesign and strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 32 No. 6, pp. 409-30.
Venkatasubramanian, V., Katare, S., Patkar, P.R. and Mu, F.P. (2004), "Spontaneous emergence of complex optimal networks through evolutionary adaptation", *Computers & Chemical Engineering*, Vol. 28 No. 9, pp. 1789-98.
Wagner, S. and Bode, C. (2008), "An empirical examination of supply chain performance along several dimensions of risk", *Journal of Business Logistics*, Vol. 29 No. 1, p. 307.
Wu, T., Backhurst, J. and Chidambaram, V. (2006), "A model for inbound supply risk analysis", *Computers in Industry*, Vol. 57 No. 4, pp. 350-65.
Yu, H., Sun, C.H. and Chen, J. (2007), "Simulating the supply disruption for the coordinated supply chain", *Journal of Systems Science and Systems Engineering*, Vol. 16 No. 3, pp. 323-35.
Zsidisin, G.A., Ellram, L.M., Carter, J.R. and Cavinato, J.L. (2004), "An analysis of supply risk assessment techniques", *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 5, pp. 397-413.

Further reading

Baird, A.J. (2006), "Optimising the container transhipment hub location in northern Europe", *Journal of Transport Geography*, Vol. 14 No. 3, pp. 195-214.
Chen, Y.J. and Seshadri, S. (2006), "Supply chain structure and demand risk", *Automatica*, Vol. 42 No. 8, pp. 1291-9.
Holmgren, A.J. (2006), "Using graph models to analyze the vulnerability of electric power networks", *Risk Analysis*, Vol. 26 No. 4, pp. 955-69.
Iakovou, E.T. (2001), "An interactive multi-objective model for the strategic maritime transportation of petroleum products: risk analysis and routing", *Safety Science*, Vol. 39 Nos 1-2, pp. 19-29.
Jiang, B., Baker, R.C. and Frazier, G.V. (2009), "An analysis of job dissatisfaction and turnover to reduce global supply chain risk: evidence from China", *Journal of Operations Management*, Vol. 27 No. 2, pp. 169-84.
Nagali, V., Hwang, J., Sanghera, D., Gaskins, M., Pridgen, M., Thurston, T., Mackenroth, P., Branvold, D., Scholler, P. and Shoemaker, G. (2008), "Procurement risk management (PRM) at Hewlett-Packard company", *Interfaces*, Vol. 38 No. 1, pp. 51-60.
Thonemann, U.W. and Bradley, J.R. (2002), "The effect of product variety on supply-chain performance", *European Journal of Operational Research*, Vol. 143 No. 3, pp. 548-69.
Wilson, M.C. (2007), "The impact of transportation disruptions on supply chain performance", *Transportation Research Part E – Logistics and Transportation Review*, Vol. 43 No. 4, pp. 295-320.

Wu, D.S. and Olson, D.L. (2008), "Supply chain risk, simulation, and vendor selection", *International Journal of Production Economics*, Vol. 114 No. 2, pp. 646-55.

Xiao, T.J. and Yu, G. (2006), "Supply chain disruption management and evolutionarily stable strategies of retailers in the quantity-setting duopoly situation with homogeneous goods", *European Journal of Operational Research*, Vol. 173 No. 2, pp. 648-68.

Appendix. Glossary

- CIMO: acronym for Context, Intervention, Mechanisms, Outcome. According to the CIMO-logic developed by Denyer and Tranfield (2009) a well-formulated review question is framed with the knowledge on combinations of problematic contexts, possible interventions, possible intended outcomes and generative mechanisms producing the outcomes.
- CNA: acronym for Citation Network Analysis. The citation network is one form of social network in which authors and papers can be represented as nodes, and their mutual interactions (i.e. citations) can be modelled as edges. By analysing the citation network, it is possible to identify research traditions and changing paradigms, so that a historical account of development of scientific thought can be constructed.
- SCRM: acronym for Supply Chain Risk Management. According to Christopher *et al.*, 2003, SCRM is defined as "The identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain members, to reduce supply chain vulnerability".
- SLNA: acronym for Systematic Literature Network Analysis. It is the proposed methodology for a dynamic literature review, which combines two existing approaches, the SLR and the CNA.
- SLR: acronym for Systematic Literature Review. Denyer and Tranfield (2009) state that SLR is "a review of the evidence on a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant primary research, and to extract and analyse data from the studies that are included in the rear-view".

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