Supply Chain Risk Management: Present and Future Scope

Purpose

This paper examines Supply Chain Risk Management (SCRM) from a holistic systems thinking perspective by considering different typologies that have evolved as a result of earlier research. The aim of the research reported in this paper is the identification of important strategic changes in the field and to outline future requirements and research opportunities in SCRM.

Design/methodology/approach

The Systematic Literature Review (SLR) methodology employed by our research was used to evaluate and categorise a literature survey of quality articles published over a period of 10 years (2000-2010). Additionally, the findings from the SLR have been strengthened through cross validation against results obtained from an associated text mining activity.

Findings

The SLR methodology has provided a rich, unbiased and holistic picture of the advances in the field of SCRM. Consequently, important new research areas have been identified based on a multi-perspective descriptive and thematic data analysis. In addition, our analysis based on evolved typologies indicates a growth of SCRM from a nascent to a fairly established activity over the past decade.

Practical implications

The systematic approach undertaken for the literature review will provide future researchers and managers with an insightful understanding of the scope of the SCRM field. Also, the literature review provides important clues on new research directions for SCRM through identification of gaps in current knowledge.

Originality/value

The holistic approach to SCRM was found to be an important missing link in earlier literature surveys. The outcome of the Systematic Literature Review reported in this paper has provided critical insights into the present and future scope of the SCRM field. The identified research insights, gaps and future directions will encourage new research techniques with a view to managing the risks in the globalized supply chain environment.

Keywords

Supply Chain Risk Management, Systematic Literature Review, Text Mining.

Paper type

Literature review

INTRODUCTION

Today's e-world has led to an information explosion from the countless data sources that appear on a daily basis. Supply Chain Risk Management (SCRM) is an area that has recently been receiving a great deal of interest from academics and practitioners. SCRM is believed to be in an emerging and promising new field by researchers (Sodhi et al., 2012) but has a number of open-ended boundaries in its scope. Various authors have carried out a literature review on SCRM at various stages over the last 10 years (e.g. Juttner et al., 2003; Vanany et al., 2009; Rao and Goldsby, 2009) who provide a good platform for researchers and practitioners trying to make sense of the on-going research and identify the current state-of-art. However, narrative literature reviews are believed to lack thoroughness and rigour (Tranfield et al., 2003). On the contrary, evidence based reviews are considered to be more thorough and transparent as they provide insights into the field by literature being analysed through a number of perspectives. The systematic review approach provides an evidence base for literature survey (Tranfield et al., 2003; Rousseau et al., 2008; Denyer and Tranfield, 2009). In this paper, a Systematic Literature Review (SLR) of the SCRM field is carried out by means of a structured process. SLR was first used in medical science and has expanded into the management field. The SLR

process followed in our research has been adopted from the work done by Tranfield et al. (2003) for developing evidence-informed knowledge management. Knowledge management is defined as the systemic and managerial approach to gathering, management, analysis, discovery and sharing of knowledge in order to maximize performance (Chen, et. al., 2001). Data mining and text mining tools are extensively used for knowledge management, knowledge retrieval and scientific discovery as well as business analysis. The more advanced tools employ artificial intelligence techniques to analyse sets of numerical or textual data and discover new patterns to help inform our knowledge base. Consequently, text mining is rapidly becoming an important tool for comprehending the data through intelligent and automated data analysis. More recently, text mining has been found to be useful for supporting systematic reviews for quick and evidence based data discovery (Ananiadou et al., 2009).

The following sections provide an overview of the research field in terms of the background and current advances in SCRM. A more detailed research methodology for conducting a systematic literature review will be described later. The research behind the SLR approach has identified critical insights into SCRM research and is presented in the analysis and findings section of the paper. In addition, gaps in existing work for defining future scope of SCRM and opportunities for future research is presented in future research agenda section.

SUPPLY CHAIN RISK MANAGEMENT

Managing risks in the modern environment is becoming increasingly challenging (Christopher and Lee 2004), primarily because of uncertainties in supply and demand, global outsourcing and short product life cycles. Risk in this context can be defined as the potential for unwanted negative consequences that arise from an event or activity (Rowe, 1980). Today, the global business environment is influenced by financial instability, just-in-time outsourcing, company mergers, new technologies, e-business, shorter time-to-market, etc. thus forcing organizations to adopt new ways of doing business (Stefanovic et al., 2009). However, today's leaner, just-in-time globalized supply chains are more vulnerable than ever before due to operational and external (natural and man-made) disruptions. Vulnerability is defined as an exposure to serious disturbance arising from risks within the supply chain as well as risks external to the supply chain (Christopher and Peck, 2004).

Supply Chain (SC) risk can be broadly defined as an exposure to an event which causes disruption, thus affecting the efficient management of the supply chain network. Risk management is becoming an integral part of a holistic SCM design (Christopher and Lee, 2004). There is diverse classification of supply chain risks found in the literature. Risk itself can be termed as disruption, vulnerability, uncertainty, disaster, peril and hazard. Academic literature within the domain of supply chains has sought to differentiate between the various forms by focussing on the availability of information and the intensity of these events. Hence, this can range from the completely unknown to the completely known serious and immediate danger.

Vorst and Beulens (2002) define uncertainty as a situation for the supply chain where the decision maker lacks information about the supply chain network and the environment; and hence is unable to predict the impact of the event on supply chain behaviour. Although risk and uncertainty are interchangeably used in SC literature, according to Knight (1921) uncertainty is immeasurable as it lacks complete certainty and has more than one possibility. On the other hand, risk is measurable as it is an outcome of uncertainty with some of possibilities involving loss or other undesirable outcomes (Hubbard 2007, 2009). According to Williams et al. (2008) supply chain security is a subcomponent of overall risk management strategy within the organization.

RESEARCH METHODOLOGY

Our research follows the systematic literature review methodology which differs from traditional narrative reviews by adopting a '*replicable, scientific and transparent process*' (Tranfield et al., 2003). We adopt the SLR process suggested and followed by Tranfield et al. (2003) for developing evidence-informed knowledge management process. The adapted SLR process for identifying the scope of SCRM research is addressed in four distinctive phases as shown in Figure 1. Although the SLR methodology is not widely used within the management field, it has been found to have reasonable acceptance as a desired methodology in literature review by the researchers (Badger et al., 2000). Systematic review is normally done manually and is quite laborious. But, with the help of new knowledge management tools, the SLR process could be made simple, quick as well as evidence based. Text mining is used in this research for supporting a quick and evidence based data discovery process in conjunction with the manual process. Although the SLR method has been used sporadically within the supply chain domain, a recent special issue of the 'Supply Chain Management: An international journal' has been focussed on using SLR to build supply chain theory. In the same

issue Colicchia and Strozzi (2012) have introduced a new methodology for SCRM using SLR and network analysis.

Systematic identification of data sources
The quality of SLR is driven by the data sources that are used for analysis. The preliminary stage of the SLR process is mainly an iterative process of definition, clarification and refinement of concepts (Clarke and Oxman, 2001). In this, databases are searched with manually constructed keywords commonly called '*search strings*'. While managing SLR, it is necessary to assess the relevance of the literature and to delimit it by considering cross-disciplinary perspectives (Tranfield et al., 2003). Hence, inclusion and exclusion criterion are predefined for identification of the data sources.
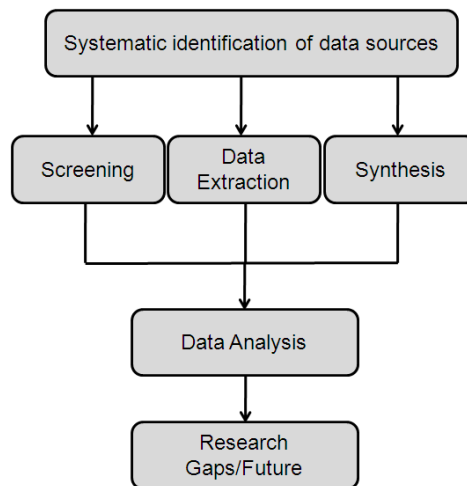
Figure 1: Systematic literature review process (adopted from Tranfield et. al., 2003)

Screening, Data Extraction and Synthesis
Comprehensive and unbiased search is one of the fundamental differences between a traditional narrative review and a systematic review (Lemmer et al., 1999; Tranfield et al., 2003). SLR screening is identification of quality data sources and is conducted using constructed search strings on available data sources. In order to develop a confidence on the data identified, it is preferred to rely on implicit quality rating of the academic journals rather than formally defining and applying any quality assessment criteria to different data sources (Tranfield et al., 2003). Text mining can be used to extract the important words and phrases automatically within set of documents identified during screening process. During text mining of documents, further cleaning of texts may be required to exclude the terms not useful for SLR. Research synthesis is term referred for a '*family of methods*' used in review for analysing and summarising the findings (Davies, 2000).

Data Analysis
Data analysis is considered to be most rigorous process of all other processes in SLR. Selected data is analysed through several qualitative and quantitative tools like statistical analysis and citation/co-citation analysis. Text mining can be further used at this stage to support data analysis by calculating the word and phrase frequency. It is identified that, there is a strong relationship between word frequency and vital description in a document (Cruzes et al., 2007).

Dissemination and Reporting
Management research output can be presented in two stages. The first stage is a descriptive analysis providing a set of classification on various attributes used in data analysis. Later, findings of thematic analysis can be reported through aggregative and interpretative approaches. Dissemination of results can be represented in the form of research findings, gaps and future scope.

DATA IDENTIFICATION
Following the SLR process discussed in the previous section, a panel of expert's (mainly academic researchers) in field of SCRM were sought to provide directions for the literature survey. To identify research articles for conducting quality analysis it was decided to use quality rating of journals in Operations Management (OM), Operations Research (OR) and Management Science (MS) instead of

developing our own quality assessment criteria. The Association of Business Schools (ABS), UK publishes quality rating of academic journals. These ABS ranked Journals were found to be vastly referred and accepted in the academic world. We strictly followed the journal quality rating provided in 'Journal Quality Guide' published by ABS and referred to only journals in the above mentioned areas with an average of 3* quality rating in last two years (2009, 2010). Three 2* quality rated journals were also included due to the large number of publications in the SCRM domain within the sample decade. Interestingly, these three Journals were also found to be heavily referred to in other 3* and 4* quality rated journals from the OM and OR/MS field. The methodology did not intend to create any bias by considering only the journals within the OM area however the SCRM area has been represented the most within this domain. It can be argued that to consider a holistic approach, it would have been pertinent to consider interdisciplinary journal sources, however since the unit of assessment is the 'supply chain' it was decided to focus holistically on factors that are considered within this domain. Figure 2 shows 15 identified data sources with their ABS ranking in OM and OR/MS areas.

SR. No.	Subject field/area	List of Journals	ABS Ranking*
1		Journal of Operations Management (JOM)	4
2		Production and Operations Management (POM)	3
3		International Journal of Production Economics (IJPE)	3
4	**Operations Management (OM)**	International Journal of Operations and Production Management (IJOPM)	3
5		Supply Chain Management: An International Journal (SCMIJ)	3
6		International Journal of Production Research (IJPR)	3
7		Production Planning and Control (PPC)	3
8		International Journal of Logistics: Research and Applications (IJLRA)	2
9		International Journal of Logistics Management (IJLM)	2
10		International Journal of Physical Distribution and Logistics Management (IJPDLM)	2
11		Management Science (MS)	4
12	**Operations Research and Management Science (OR/MS)**	European Journal of Operational Research (EJOR)	3
13		Naval Research Logistics (NRL)	3
14		Omega: The International Journal of Management Science (OMEGA)	3
15		Decision Sciences (DS)	3

Table 1: Identified data sources (*ABS ranking as on 17 Nov. 2010)

The keywords or search strings used for filtering the raw data from these data sources were constructed as "risk", "disruption", "vulnerability" and "uncertainty". These search strings were identified based on the authors previous understanding of the SCRM field and was also supported with several discussions with experts consisting of academicians and practitioners within the field of supply chain risks both in the UK and across the globe. Some of the academicians are members of the 'International Supply Chain Risk Management Network'.

Risk management within organisations is not a new phenomenon and it is also a prevalent theme within the Finance and IT industry. However, we believe that risk management within supply chains gathered more focus and momentum only after the 9/11 attacks in the US. It was observed during a preliminary search that, significant number of researchers started researching on SCRM in early 2000. In order to restrict the scope of the literature survey, we decided to analyse articles published only in the one decade (from 2000 to 2010). It was also observed that the research focus was initially profound for US and UK academics, hence the significance of the journals in which these papers were published in. Global recession affecting supply chains in 2001-02 (Hilmola et al., 2005) and challenges in outsourcing seem to have given a sound platform for research on supply chain risks in the early part of the decade. The preliminary search using search strings within 15 identified international journals found a significant number of articles. Filtering this data further and considering only publication dates between 2000 to 2010 yielded 140 quality articles.
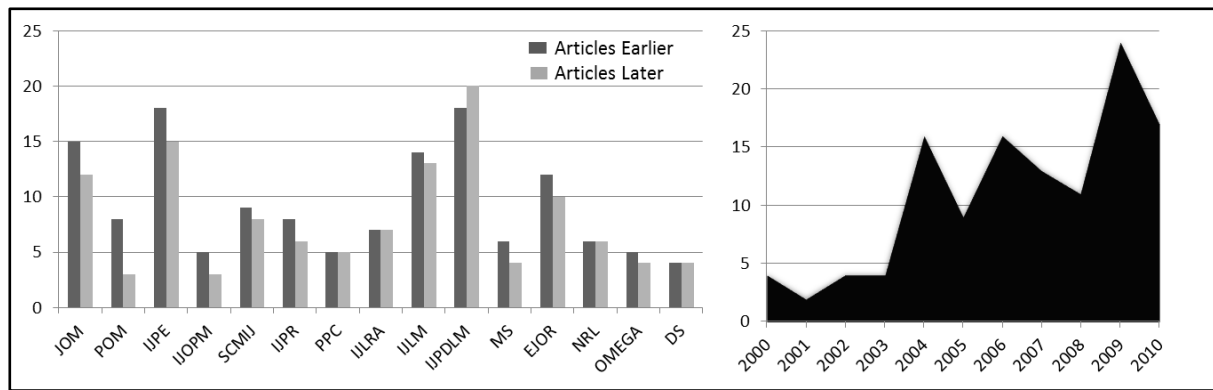
Figure 2: Journal-wise and year-wise distribution of articles

We further refined this search by setting exclusion criteria for the articles discussing risk management in other interdisciplinary fields like Finance, Enterprise, Information Technology, etc. In order to improve the quality of research we finally selected 120 quality articles by manual selection. Knowledge management techniques were used to document these individually and independently selected articles for SLR. This database of 120 articles was critically analysed by manual and statistical techniques. Knowledge discovery through text mining was used to validate these manual and statistical findings.

DATA SCREENING, EXTRACTION AND SYNTHESIS
During the first stage of the manual screening of the database, it was found that there was a radical increase in number of articles published in the field of SCRM from year 2004 (Figure 2). Preliminary studies showed that, the traditional focus of supply chains looking at operational risks shifted towards more tactical and strategic risks due to an increase in global outsourcing activities. The 9/11 terrorist attack (2001) disrupted major supply chains in the early part of the decade and also triggered interest in the SCRM field (Chopra and Sodhi, 2004; Sheffi, 2005). Although 2001 was the year of the 9/11 strikes we believe that the increase in the number of articles on SCRM during 2003 and 2004 were the result of the publishing timelines since active research started in the late 2001. The year 2009 represented a promising year in SCRM research contributing the most in the volume of papers published. Descriptive analysis of keywords and countries contributing to SCRM showed that the US academics contributed the most SCRM articles. This is followed by UK as a single country contributor. This is believed to be driven by the fact that countries like USA, UK along with other European countries outsource the most and are more vulnerable to risks or disruptions. This is assumed to drive the interest of researchers from these countries. Although the specific research area was favoured by researchers from these countries in the initial years of the decade, SCRM as a research area grew rapidly within researchers in the China and South East Asia. Although the journals from these countries do not feature in this analysis on account of the filtering criteria and the focus on ABS listed journals, the academics from these countries feature in the papers that were selected for this analysis. Some of the cases considered in the papers have affiliation to companies within China and South East Asia.

QDA Miner[©], a qualitative data analysis software developed by Provalis Research was used as a text mining platform to facilitate the systematic literature review process. The term 'Risk' was found to be mainly referred to the organizational and network related disturbances whereas disruption is commonly referred to exposure to environmental (man-made and natural) disturbances. Figure 3 depicts the frequency of keywords which signifies the importance of a word or phrase in a research area. Identifying these keywords and phrases through text mining provided the confidence in using the initially identified search strings. Using TF-IDF (*Term Frequency-Inverse Document Frequency*) weight search criteria in text mining, the frequently used keywords and phrases were identified. TF-IDF weight measures the relevance of a specific word as a statistical measure. This is commonly used to weight information retrieval in data mining techniques. The similarity in used search strings and keywords identified by text mining provided the required confidence in the data screening process. Risk, disruption, uncertainty, vulnerability and security were found to be most commonly used keywords in most number of cases (articles). Similarly, keywords like outsourcing, resilience, contract and simulation represents a strong association with the SCRM field. The phrases identified as seen in

Figure 3 reflects important links between information sharing, internal integration and risk behaviours in SCRM.

	FREQUENCY	% SHOWN	% PROCESSED	% TOTAL	NO. CASES	% CASES	TF · IDF
SUPPLY	11581	4.7%	2.4%	1.2%	101	84.2%	867.0
RISK	8435	3.4%	1.8%	0.9%	105	87.5%	489.2
CHAIN	8134	3.3%	1.7%	0.8%	102	85.0%	574.1
MANAGEMENT	6157	2.5%	1.3%	0.6%	108	90.0%	281.7
SUPPLIER	2417	1.0%	0.5%	0.2%	93	77.5%	267.6
RISKS	2245	0.9%	0.5%	0.2%	85	70.8%	336.2
SUPPLIERS	1754	0.7%	0.4%	0.2%	83	69.2%	280.8
MODEL	1719	0.7%	0.4%	0.2%	95	79.2%	174.4
INFORMATION	1715	0.7%	0.4%	0.2%	94	78.3%	181.9
BUSINESS	1621	0.7%	0.3%	0.2%	101	84.2%	121.3
PROCESS	1616	0.7%	0.3%	0.2%	94	78.3%	171.4
PRODUCT	1554	0.6%	0.3%	0.2%	94	78.3%	164.8
DEMAND	1528	0.6%	0.3%	0.2%	93	77.5%	169.1
PRODUCTION	1485	0.6%	0.3%	0.1%	100	83.3%	117.6
LOGISTICS	1446	0.6%	0.3%	0.1%	85	70.8%	216.6

	FREQUENCY	% SHOWN	% PROCESSED	% TOTAL	NO. CASES	% CASES	TF · IDF
OPERATIONS_MANAGEMENT	409	6.8%	0.1%	0.0%	54	45.0%	141.8
SUPPLY_RISK	462	7.7%	0.1%	0.1%	61	50.8%	135.8
RISK_AVERSE	139	2.3%	0.0%	0.0%	15	12.5%	125.5
RISK_NEUTRAL	119	2.0%	0.0%	0.0%	13	10.8%	114.9
STRATEGIC_VULNERABILITY	62	1.0%	0.0%	0.0%	2	1.7%	110.2
LOGISTICS_MANAGEMENT	333	5.6%	0.1%	0.0%	57	47.5%	107.7
SUPPLY_RISK_MANAGEMENT	269	4.5%	0.1%	0.0%	48	40.0%	107.0
SUPPLY_CHAINS	638	10.6%	0.2%	0.1%	82	68.3%	105.5
RISK_MANAGEMENT	417	7.0%	0.1%	0.0%	69	57.5%	100.2
RELATIONAL_RISK	56	0.9%	0.0%	0.0%	2	1.7%	99.6
INFORMATION_SHARING	141	2.4%	0.0%	0.0%	24	20.0%	98.6
SUPPLY_DISRUPTION_RISK	75	1.3%	0.0%	0.0%	6	5.0%	97.6
SUPPLY_BASE	117	2.0%	0.0%	0.0%	18	15.0%	96.4
SUPPLY_MANAGEMENT	584	9.7%	0.2%	0.1%	83	69.2%	93.5
WHOLESALE_PRICE	85	1.4%	0.0%	0.0%	10	8.3%	91.7
INTERNAL_INTEGRATION	49	0.8%	0.0%	0.0%	2	1.7%	87.1
SUPPLY_RISKS	189	3.2%	0.1%	0.0%	42	35.0%	86.2

Figure 3: Keywords and phrases identified through Text Mining

Data synthesis was done using various predetermined criteria for developing the family of classifications. Predetermined criteria were identified from various SCRM aspects. Clustering is a useful technique in text mining for discovering interesting data distribution and patterns from unorganized data (Ponsporrata et al., 2007). Initial concept mapping for classification was verified through Dendrogram, a text mining technique for concept mapping. Hierarchical clustering algorithms built within the software produce a nested sequence of partitions. These associations and partitions forming the groups are represented in a tree like structure called as 'Dendrogram'. The Dendrogram provides a visual representation of data correlation. Each Dendrogram node is formed by an association of two or more keywords forming branches and each branch length represents functional diversity in clusters. Figure 4 and, 5 shows an example of cluster diagramming and concept mapping for SCRM. The cluster diagram in figure 5 shows that the holistic approach to SCRM is evidently lacking as the link between the core cluster and outer elements is missing from the literature. We define 'holistic' as the process which considers the whole system and also the interdependence between its individual components. Elements like behavioural dimension of risks, risk sensitivity and real options shown associated in the cluster are clearly missing the links within the broad domain of SCRM. The strength of clustering is specified by the level as well as length at which elements joins a cluster (Anderberg, 1973). Each cluster expands into a larger concept map providing further detailed insights. The identified keywords, phrases, frequencies, classifications, clusters using text mining provide the necessary support for data extraction and synthesis stage in SLR.
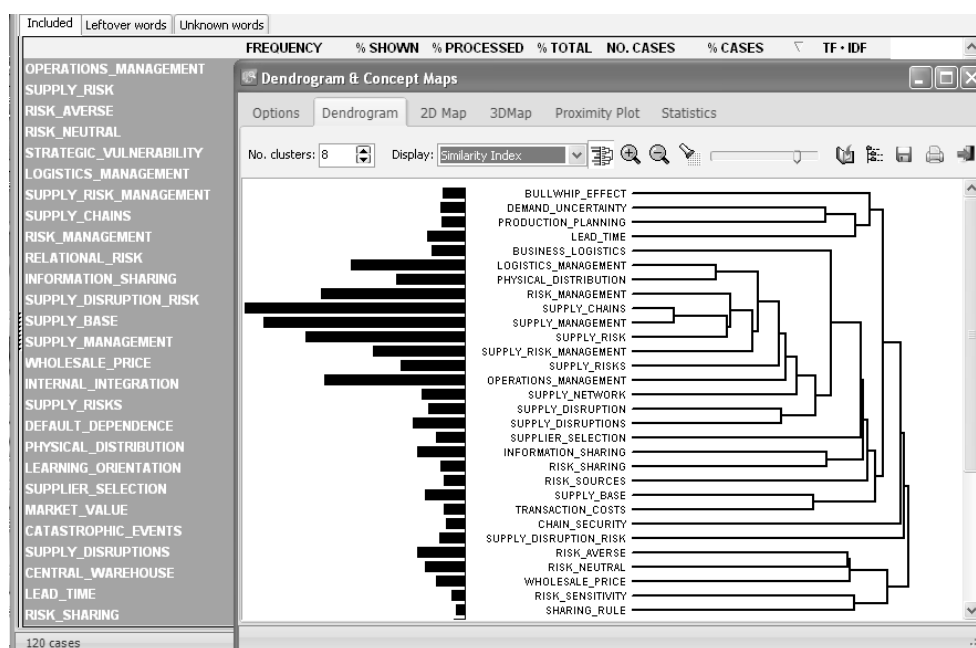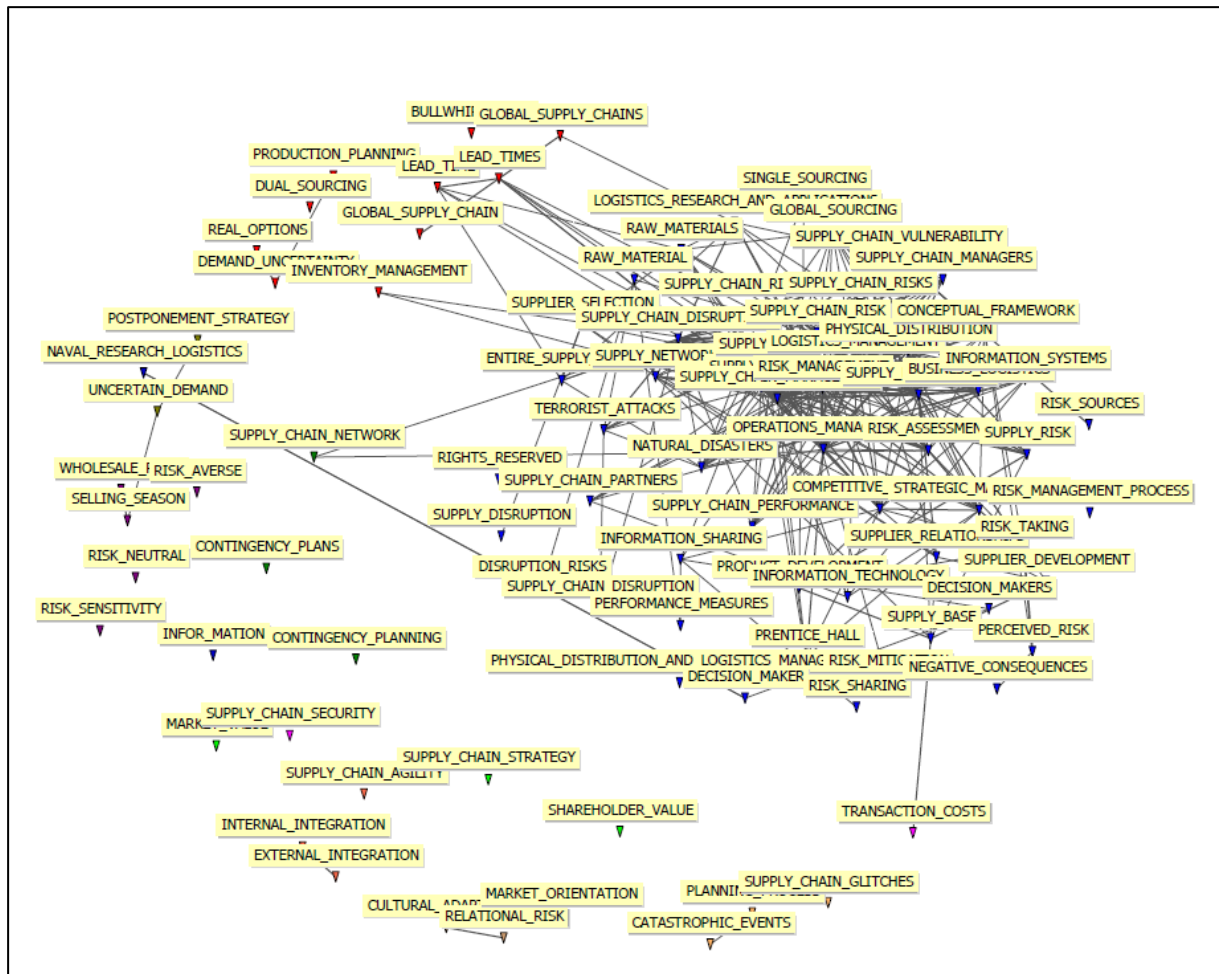

Figure 4: Concept mapping using Dendrogram for classification

Figure 5: SCRM Cluster Diagram

The developed typologies were identified based on clustering patterns, researcher's understanding and SCRM expert's perception of the field. Following typologies were identified for the data screening:

1. Based on type of risk: There is diversity in classifying risks in SCRM (Dani and Deep, 2010; Ghadge et al., 2010), this demanded clear and distinct classification for the data analysis. We followed the classification provided by Juttner et al. (2003) based on sources of risk as Organizational risk, Network Risk and Other risks comprising of environmental (man-made and natural disasters), political/Social and exchange rate risks.

2. Based on Management level: Mitigation strategies are decided based on expected level of management. It could be Operational, Tactical or Strategic depending on the nature of problem and requirement.

3. Based on research methodology: Qualitative and Quantitative research methodologies are classified to understand tools and techniques used in SCRM.

4. Based on risk management process: Based on the perception of researchers in SCRM, the risk management process is generally classified as risk identification, assessment and mitigation and/or control.

5. Based on approach to SCRM: The risk mitigation approach could be either proactive or reactive. This is done to identify mitigation strategies commonly used in the field of SCRM.

Two other classifications based on publication period and research contributing country were not considered as significantly important for this research due to its independent nature, the academic publication process and non-association with the actual SCRM research.

DATA ANALYSIS

Descriptive analysis

Although 'publication period' and 'contributing country' is not considered under the thematic analysis, it is useful to have an overview using descriptive analysis. With reference to table 2, the statistical analysis of the data depicts that nearly half (46.66%) of the contributions were from the USA. 'International' is used to indicate collaborative research among co-authors representing more than two countries (Altay and Green, 2006) and is considered separately in the table. Other leading countries researching SCRM and showing keen interest in supply chain disruptions are UK, Sweden, China, Canada and Italy. It is observed that research contributions from UK researchers are published mostly in the OM area and qualitative in nature. The methodological aspects of SCRM research are considered under thematic analysis. Dividing the decade into two halves showed a distinctive progress of SCRM research. Publications on SCRM in the later part of decade have almost doubled as shown in Table 2. This clearly shows the potential of SCRM research in current dynamic world.

Typology type	All Journals	OM Journals	OR/MS Journals	Typology type	All Journals	OM Journals	OR/MS Journals
Contributing country	%	%	%	**Research approach**	%	%	%
USA	46.66	43.47	57.14	Qualitative	54.16	67.39	10.71
UK	15.83	20.65	0.00	Quantitative	36.66	23.91	78.57
International	16.66	11.95	32.14	Mixed	9.16	8.69	10.71
Other countries	21.66	25.00	10.71				
				Risk management process			
				Identification	35.00	32.39	5.89
Publication period				Assessment	14.33	16.64	78.14
2000-2005	32.50	35.86	78.57	Mitigation/Control	5.83	4.72	13.84
2006-2010	67.50	64.13	21.42	Holistic	44.16	46.47	2.85
Type of Risk				**Risk mitigation approach**			
Organizational	4.85	5.87	0.00	Proactive	56.33	41.60	60.71
Network	48.78	52.69	11.65	Reactive	23.33	13.91	18.42
Other	14.63	12.38	50.61	Holistic	20.83	44.92	21.07
Holistic	31.66	28.58	38.42				

Table 2: Analysis of SCRM

Thematic analysis

Table 2 also depicts a detailed analysis of other important typologies that provide an interpretative analysis of the SCRM field. The classification schematic for the systematic analysis of SCRM literature was based on the typology as identified in the previous section. Risk classification, research methodology and risk management process typologies are further systematically analysed following the thematic analysis approach.

Risk classification: Supply chain risks were broadly identified as organizational, network and other risks comprising of natural and man-made disasters. We grouped these risks based on similarity and the interdependent nature of risks.

   Organizational Risks: Organizational risks commonly comprise of inventory risk, process/operational risk, quality risk and management risk. Inventory risk is a risk arising from buffer or stock out inventories leading to unnecessary handling cost or lost opportunity cost (Cachon, 2004; Juttner et al., 2003; Childerhouse et al., 2003; Zsidisin, 2003a; Chopra and Sodhi, 2004). Inventory risk could be mitigated by reducing cash-to-cash cycle and improved forecasting techniques (Papadakis 2006). Process or operational risk can be defined as risks initiated with operational events disrupting material or information flow within supply chain (Lockamy et al., 2010, Christopher and Peck, 2004; Jiang et al., 2007; Lewis, 2003; Cavinato, 2004; Colicchia et al., 2010; Cigolini and Rossi, 2010). Quality risk may result from problems at plant or due to supplier failure. Researchers identify outsourcing activity as being responsible for product quality risk (e.g. Zsidisin et al., 2000; Zsidisin et al., 2004; Chopra and Sodhi, 2004; Kaya, 2008) but this may be associated closely with a network risk than an organizational risk. Management risk is type of risk that arises from poor management ability

to anticipate and react to the market demands. The SCRM literature is lacking in identifying management risk as a critical risk for any business success.

Network Risks: Network related risks arise from interactions between organisations within the supply chain network (Juttner et al., 2003). Supply risk, supplier default and demand risk are some of the prominent network related risks being most researched in SCRM field (48.78%) for its apparent reasons of being "extrinsic" in nature. Supply risk, according to Zsidisin et al. (2004) is the potential occurrence of an incident associated with the inbound supply leading to inability of the purchasing organization to meet customer demand. Supply risk was one of the risks most discussed and researched in the literature. Wu et al. (2007) provides an integrated approach to classify, manage and assess supply risks. Supply chain disruption due to supplier default risk has been widely neglected (Wagner et al., 2009) and this is also confirmed from observations made through SLR. Demand risks are the risks associated with demand uncertainty (Tang and Tomlin, 2008) or risk associated with the outbound logistics flow (Svensson, 2002).

Environmental Risks: Environmental risks are defined as events driven by external forces such as weather, earthquakes, political, regulatory and market forces (Wagner and Bode, 2006). Recent research has shown an increased attention towards environmental (man-made and natural) disruptions due to several global events in past disrupting supply chains. Environmental risk sources comprise any uncertainties arising from the supply chain environment interactions (Juttner et al., 2003). Environmental risk can arise due to physical, social, political, legal or economic environment (Bogataj and Bogataj, 2007).

PROACTIVE RISK MITIGATION STRATEGY	REACTIVE RISK MITIGATION STRATEGY
• **Supplier development/management:** Risk sharing through contract manufacturing, contractual governance, Dual/multi sourcing.	• **Contingency planning:** strategic event management plan, enhanced flexibility in options.
• **Supply chain Contracts:** Developing incentive contracts, Mix and volume flexibility contracts for risk mutual benefits, VMI/buffer stock.	• **Disaster management:** Robust recovery, Rebuilding of Supply chain, resource utilization/management, Scenario analysis for future disruptions.
• **Product/process Management:** Product variety, postponement, product design and delivery management.	• **Demand management:** Operational Rerouting, shifting customer demand, dynamic pricing.
• **Supplier relationship:** Supplier collaboration through improved confidence, cultural adaptation, Continuous coordination.	

Table 3: Risk mitigation strategies in SCRM

Risk management process: By analysing the data based on different risk management processes, most of the articles were found to be focused on risk identification activity (35%). This depicts the embryonic stage of researchers in SCRM. Less attention is found to be given for holistic risk management processes. Only half of the articles analysed in the SLR discussed about either implementing proactive or reactive risk mitigation strategies (61 out of 120). The general approach of researchers to risk mitigation is preferred to be proactive (58.33%) as compared to being reactive (23.33%). But from practitioner's perspective, it is difficult to justify the investment in proactive risk mitigating strategies (Dani, 2008).

Risk mitigation and control strategies discussed by researchers were classified into two approaches as proactive and reactive. For holistic risk mitigation; agility, flexibility and preparedness are preferred generic strategies (Ponomarov and Holcomb, 2009). Key proactive and reactive risk mitigating strategies discussed in the literature are compiled in Table 3. It is found that at a strategic level, contingency planning and risk sharing outsourcing contracts are prominently used as risk mitigation strategies. Use of multi-strategy approach such as combining supplier alliance network with lead time reduction and/or recovery planning system (Tang, 2006a) can be effective for mitigating situational disruptions.

Research Methodology: Data synthesis of research methodologies used for decision-making in SCRM field was broadly classified as qualitative and quantitative methods. From table 2, it is evident that the preferred methodology has been qualitative.

Qualitative research methods were further divided based on research approaches as empirical study, conceptual theory and Literature survey. Similarly, Quantitative research methods were divided

into mathematical modelling, statistics and probabilistic theory and Simulation for detailed thematic analysis.

Empirical study: Empirical research employs case study, industrial survey, structured/ informal interview and focus group methodologies for analysing information gained by means of observation or secondary data study.
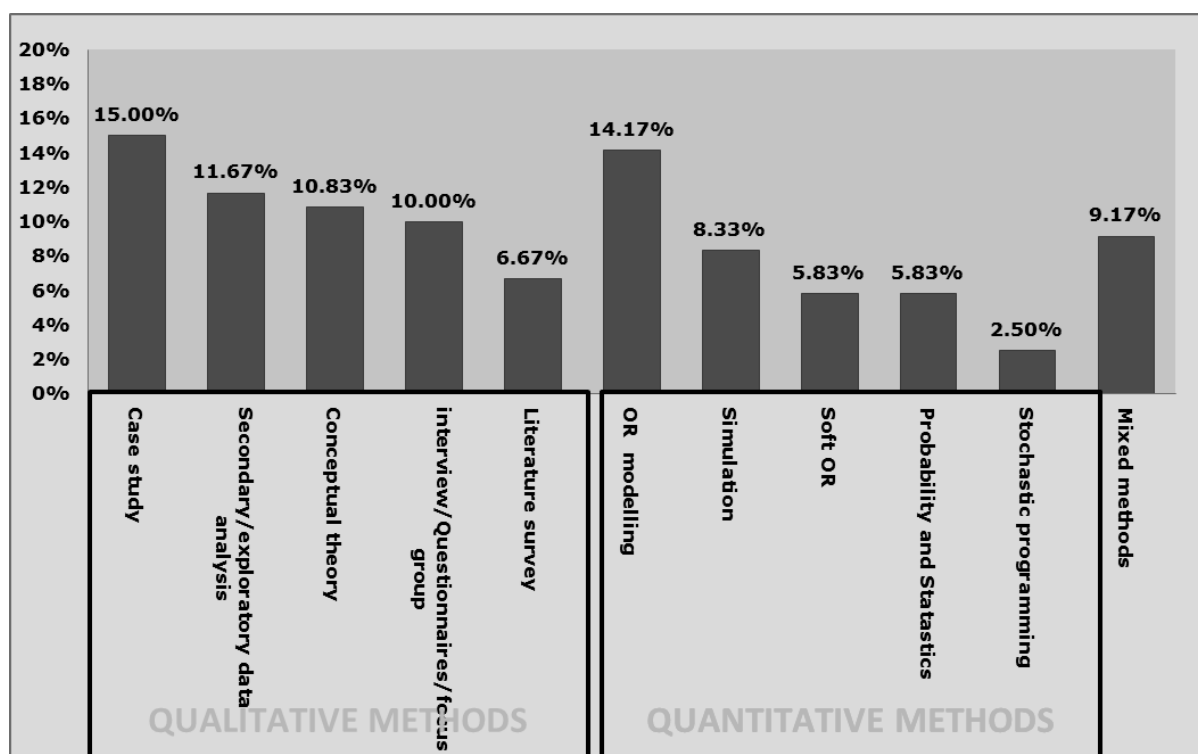
Figure 6: Preferred research methodologies in SCRM

Detailed analysis of data classified as Qualitative, Quantitative and mixed methods showed case study approach as being the most adopted by researchers for dealing with problems mainly at a strategic management level as seen in Figure 6. Apart from the preferred research methodologies categorised in Figure 6, the data analysis also shows the percentage use of each methodology within the context of SCRM research. A number of researchers have used the case study approach to study supply chain risks. These studies have looked at various topics and sectors; sources of uncertainty in the food sector (Vorst et al., 1998), strategies for global supply chain environments (Christopher and Peck, 2006; Khan et al., 2008), risks and mitigation best practices (Finch, 2004), knowledge management to manage risks (Hallikas et al., 2004), holistic nature of supply chain risks within the automotive and electronic industries (Mauricio et al., 2004). The analysis showed that 80% of case studies were focussed on network related risks. In qualitative research methods; other prominently used tools were exploratory analysis of secondary data using industrial surveys, Conceptual theory building for developing frameworks and use of Interviews/Questionnaires/Focus group study. Jonsson (2000) utilised surveys to study disruption whereas Blackhurst et al. (2005) using a multi-methodology empirical study identifies a critical need for quantitative assessment tools that could identify high probability nodes for disruptions within supply chain. Craighead et al. (2007) employed a three-phase empirical study of case study, interviews and focus group to study the severity of supply chain disruptions. Questionnaires and interviews are usually combined in qualitative research. Such combined qualitative approach was found to be effectively used for SCRM research in the past (e.g. Lewis, 2003; Jiang et al., 2009; Mantel et al., 2006; Brun et al., 2006; Autry and Bobbitt, 2008; Perry, 2007).

Conceptual model/theory: 'Conceptual' is meant to represent a research methodology describing fundamental concepts on SCRM (Vanany et al., 2009). Due to the developing stage of the SCRM field, conceptual theory or framework development are frequently attempted by many SCRM researchers. Svensson (2000, 2002) conceptualizes the inbound and outbound vulnerability in supply chain based on sources and categories of disturbances. Similarly, other conceptual frameworks like

supply chain security orientation framework (Autry and Bobbit, 2008), supplier risk management framework (Matook et al., 2009), model for SC network risk (Trkman and McCormack, 2009), risk and performance framework for SCRM (Ritchie and Brindley, 2007), disaster recovery pyramid (Richey Jr., 2009), SC: interactive adaptive system (Peck, 2005; Peck, 2006), SC disruption risk management (Kleindorfer and Saad, 2005), reactionary risk mitigation model (Dani and Deep, 2010) were found to be used for further research developments in SCRM.

Literature survey: Literature review is fundamental for any research field. Literature survey in SCRM has been conducted by few researchers with help of academic peer-reviewed journals to draw interesting insights. List of all past literature surveys with their adopted research methodologies and key findings/contributions is presented in Table 4. Most of the literature surveys are found to be narrative in nature.

AUTHOR(S)	RESEARCH METHODOLOGY	KEY FINDINGS/CONTRIBUTIONS
Juttner et al. (2003)	Literature survey findings are compared with results from exploratory semi-structured interviews, focus groups are undertaken to discover practitioners' perceptions.	Used four basic constructs to develop the concept: 1) Sources of risk, 2) Adverse consequences of risk, 3) Drivers of risk and 4) Mitigation strategies. Identified normative issues for future research in SCRM focusing need of empirically grounded research.
Khan and Burnes (2007)	Literature review of broad literature on risk and precise literature on supply chain risk.	Emphasize on the need to devise a robust and well-grounded models. In-depth empirical research is needed to identify adaptable tools in managing supply chain risk by incorporate risk management tools and techniques from other disciplines of research.
Williams et al. (2008)	Through review of the literature on supply chain security (SCS) from academic publications, white papers, and practitioner periodicals.	Provides good empirical findings and theory building through categorization of literature on SCS. Quantitative assessments are needed to better understand of SCRM. SCS can lead to improved organizational performance.
Vanany et al. (2009)	Through review of journal publications from 2000-2007 with help of classifications into several typologies.	RFID and ERP will become important part of SCRM. Use of IT for visibility, collaborative risk management strategies for making supply chains robust is lacking.
Natarajarathinam et al. (2009)	Review of academic peer-reviewed journals and case publications in supply chain management literature.	Much of the research is focused on external sources and proactive approaches to crisis in supply chains. Recovery planning and scales for crisis management needs attention.
Rao and Goldsby (2009)	Review of the literature on supply chain risk and synthesis of the broader domain of risk management.	Provides a typology of risks classified broadly as Environmental, Industry and Organizational risks based on identified variables from systematic key research findings in SCRM. SCRM is an area in need of further substantive investigation.
Tang and Nurmaya Musa (2010)	Literature survey and citation/co citation analysis using academic database to disclose SCRM development.	Need of an integrated view of SCRM is growing strongly. Requirement of analysis tools for proactively managing risks. Use of quantitative modeling in risk management is lacking and their lies a huge potential in developing quantitative models to make hard decisions SCRM.

Table 4: Past literature reviews in SCRM: Research method and finding

Quantitative research methods are broadly classified into mathematical modelling, simulation and statistical testing for detailed thematic analysis.

Mathematical Modelling: OR modelling can be broadly classified into hard OR and soft OR techniques. Hard OR techniques roughly consists of linear programming, game theory, queuing theory, Markov process (Carter and Price, 2001). And soft OR comprises of SWOT/PEST analysis, viable systems model, Scenario planning, systems thinking, etc. Linear programming was used to manage demand/supply uncertainty related problems (e.g. Sodhi, 2005; Lai et al., 2009). Parametric linear programming approach for risk measurement (Bogataj and Bogataj 2007), Stochastic modelling for risk and profit optimization (Goh et al., 2007), mixed-integer modeling for the disaster recovery ((Noel) Bryson et al., 2002; Barbarosoglu et al., 2002), Dynamic programming for disruption

management in production planning (Yang et al., 2005) are few noticeable OR modeling related articles identified from SLR as most influential in SCRM research. Soft OR decision support tool like Analytical Hierarchy/Network Process is capable of selecting most appropriate solution from set of solutions (Satty, 1990) and found to be a useful tool by researchers in SCRM. (e.g. Leopoulos and Kirytopoulos, 2004; Levary, 2007; Gaudenzi and Borghesi, 2006). Scenario planning (Dani and Deep, 2010) also has found potential for the strategic decision making in SCRM. Other soft OR approaches like viable systems model, systems thinking are finding its application in SCRM research.

Statistics and Probability theory: Statistics and Probability theory is another commonly used quantitative research tool efficiently used mainly for hypothesis testing. With the help of linear regression model, Hung and Ryu (2008) test the hypothesis for changing risk preferences in supply chain inventory decisions.

Simulation: Simulation modelling provides a systematic approach for understanding the relative and interactive impact of factors/parameters for different scenario settings. Simulation methods are not uncommon for assessing and modelling supply chain risks (Zsidisin et al., 2004). Several types of simulation modelling namely, Agent based simulation (e.g. Datta et al. 2007); Monte Carlo simulation (e.g. Ermoliev et al., 2000; Wagner et al., 2010) and Discrete-event simulation (e.g. Manuj et al., 2009) are few of the visible simulation related articles identified in SLR. Most of the simulation platforms are used for solving operational management level problems. Manuj et al. (2009) provides an exceptional eight-step development process for the design, evaluation and implementation of supply chain simulation models. In spite of few observed cases, supply chain literature lacks analytical research using simulation to investigate supply risk (Kull and Closs, 2008).

Mixed methods combining two research methodologies were also found in the review (9.17%). Undoubtedly, there is huge potential in developing quantitative models to make hard decisions in SCRM (Tang and Musa, 2010). Research methods suitable for capturing holistic as well as dynamic behaviour of risks within supply chain networks were found to be clearly lacking in the study.

FUTURE RESEARCH AGENDA

SLR is needed to propose a future research agenda (Torgerson, 2003). The extensive analysis of the selected papers identified new directions in the SCRM field. Some of the identified research areas are mentioned below as future research agenda for research in SCRM:

1. Behavioural perceptions in risk management:

The decision to choose the right risk strategy is crucial and is found to be commonly dominated by the behavioural aspect of managers. Research on developing practices for unbiased or rational decision making is unexplored area in SCRM approach demands research. The managerial perceptions of risks (Zsidisin, 2003b; Sodhi et al, 2012) are critical for SCRM has been studied by few researchers. Figures 5 and 6 depict the distance of this topic from the core research area. Choosing the appropriate risk management strategy in terms of risk averse, risk neutral, risk sharing or risk taking (Vanany et al., 2009) behaviour will have a direct impact on the mitigation.

2. Sustainability factors:

It is inferred from this research that sustainability factors (economic, environmental and social) will have a larger influence on how supply chains are designed in the future. This also leads to an inference that noncompliance with sustainability factors could provide supply chains risks and disruptions. Risks derived from enhanced reverse logistics activities for remanufacturing and recycling of materials and new government legislations on supply chains will be an important area for future research. Hence, although companies are increasingly focused on remaining profitable, there is greater need to mitigate risks and implement sustainability practices.

3. Risk mitigation through collaboration contracts:

It was evident during the analysis that, supplier default risk, quality risk and management risk within SC network are underexplored. Collaboration and outsourcing by introducing risk sharing and/or contracts amongst supply chain partners can help to improve the network efficiency (Urciuoli, 2010). Development of supplier partnerships and strategic alliances is becoming a key element for long term profitability as well as a robust risk mitigation strategy. Contingency/recovery planning strategies needs to be industry or supply chain specific (Juttner et al, 2003). Most of the previous research has focussed on different SC contracts in the context of price and demand fluctuations (Wakolbinger and Cruz, 2011) but, long term contracts for disruption management are lacking in the literature. Risk

sharing contracts have potential for handling risks in supply chains for network coordination in the future.

4. Visibility and Traceability:

Risk mitigation (proactive management or reactive risk response) can be greatly improved if information is readily available, is timely and accurate. Future Information and Communications Technologies (ICT) are expected to make a big impact in terms of visibility of the supply chain. Current technologies such as RFID, ERP and GPRS will become important information tools for management of supply chain risks (Tang, 2006b; Wilson, 2007; Rao and Goldsby, 2009; Vanany et al., 2009). The analysis depicts that visibility and traceability do not feature within the core of the research on SCRM. Hence, this will have an impact on the future work.

5. Risk propagation and recovery planning:

Research in disruption propagation, examining effects and recovery of the supply chain risks is lacking in the literature (Wu et al., 2007; Khan and Burnes, 2007; Natarajarathinam et al., 2009). Risk profile modelling and modelling of risk propagation in terms risk drivers like cost, duration, service will provide greater visibility for effective risk management. Understanding the risk potential beyond the dyad through the chain and then the network provides an insight into how risk can propagate. This has been evident in the recent past in the automotive industry as an effect of the Japanese Tsunami. Understanding risk propagation can also lead to better proactive risk management models.

There is a critical global need for recovery planning to mitigate against the effect of disasters ((Noel) Bryson, 2002). Uncertainties in the supply chain environment and also some instances of known risks provide instances when the only strategy available is to recover quickly after the risk has occurred. Creating the appropriate risk recovery models also needs proactive planning and a combination of the appropriate information and human intervention.

6. Industry Impact:

Although, this study is related to academic work on SCRM, it is vital to put it in the context of the impact that the work creates within industry. Although there may be a debate on which methodology is the most appropriate and whether quantitative models provide a better understanding and theory than qualitative work, it is the opinion of the authors that the research should have a direct influence on industry practices. Various authors have suggested the requirement for better risk management. Some of the proponents have suggested the following for better research in SCRM; empirically grounded research (Juttner et al., 2003), Quantitative tools like mathematical programming models, simulation models (Rao and Goldsby, 2009), Analytical/Network Hierarchy Process (Vanany et al., 2009), complexity and graph theory (Colicchia and Strozzi, 2012), development of well-grounded models by considering other interdisciplinary research approaches (Khan and Burnes, 2007).

7. Holistic approach to supply chain risk management:

Holistic supply chain risk management is found to be lacking in current literature and systems approach has the potential to guide in that direction. Mingers and White (2010) suggest that a system of systems approach is expected to bring fresh thinking for existing problems and to further uncertain world. An integrated approach to SCRM needs to incorporate the risk issues from industry practice (Tang and Musa, 2010). Research on redesigning SC strategies is a fertile area in current global, uncertain and dynamic environment. To the best of our knowledge no paper exists which relates product life cycle to SCRM. Quality risks like vehicle recalls, poor customer service are regular and primarily associated with the design and development aspects in the product lifecycle management. The multidimensional perspective focussing on management processes, risk dimensions, impact flows and mitigation alternatives needs to be studied in whole. It is our opinion that perceiving the supply chain as a system with multiple stakeholders and multiple interactions and then using systems thinking to understand the risk challenges is a largely unexplored area and has future scope.

Figure 7, presents an overview of the future scope. The linkages between the various factors depict the relationships and the flow of the work. The figure presents a map for future academic challenges. This is a macro representation and we hope that other researchers will be able to take this schematic to consider the detailed challenges within each factor. However, it is our opinion that the macro linkages will still hold ground.
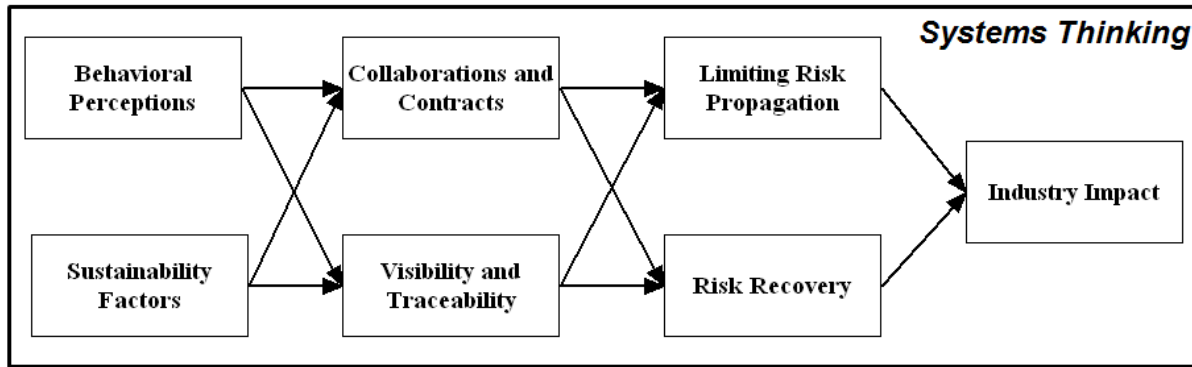
Figure 7: Overview of the future research scope for SCRM

Figure 7 depicts two major research strands representing the causal linkages between the future factors. The two strands start at 'Behavioural Perceptions' and 'Sustainability Factors'. Although a causal link between these two factors is also possible, it is not considered within this research as it can form an independent scope for future research. In the first strand, it is proposed that the perceptions of those involved in managing supply chain risks will have an impact on how collaboration agreements between supply chain partners are formed and the types of contracts which will be formulated. 'Risk taking' or 'being risk averse' will affect the systems being employed for creating visibility and traceability in the chain. There is a hidden implication (although not shown) that the choice of systems for visibility and traceability will also have an effect on the collaboration and contractual agreement and vice versa. The figure then proposes that both the 'collaboration and contractual agreements' and 'the visibility and traceability' systems will have an impact on how supply chain risk propagation is contained and what processes are employed for supply chain recovery. It is important that academics should consider the appropriate methodologies when researching supply chain risk to bring into context the industrial challenges and hence the research expects a direct influence on industry practices. The selection of research design (whether qualitative or quantitative) should not restrict the ability of the research to create the necessary industry impact. The second strand, starts at 'Sustainability Factors' and it is proposed that non-compliance of supply chain sustainability factors may become a source for risks. Hence, sustainability factors will influence collaboration agreements and supply chain contracts. The requirement to meet environmental and social (ethical) criteria will also affect the types of systems chosen for visibility and traceability. Both 'collaboration and contractual agreements' and the systems for 'visibility and traceability' will influence how supply chain risk propagation will be contained and recovery will be initiated in case the sustainability factors are not met. The strand culminates into a proposition for academics to consider the industrial context when designing their research. These two strands are contained within the Systems Thinking approach (holistic approach) which helps to have a better understanding of interplay of the various factors affecting supply chains within the industrial context.

CONCLUSION

The SLR of 120 quality articles was conducted following a systematic research methodology. The SLR methodology was found to be driven by a methodical process and provides a strong evidence base. SLR supported with modern knowledge management tools allows a multi-dimensional analysis of the field to reveal patterns that are less clear in conventional literature study. An evident weakness of the methodology is that it puts greater stress on efficient data analysis may be weak in deciphering future challenges. The process is not just systematic but open and unbiased in drawing the definitive inferences.

The identified seven distinctive research factors are presented in a framework which is expected to provide researchers with hypothesis for future work. The factors in themselves can provide individual research areas within the area of SCRM. The culmination of the flow as shown in figure 7 is with regards to industry impact and it is the opinion of the authors that this is essential for future academic research. To provide industry with proactive and reactive management models to manage SCRM is essential and this will be possible by taking a holistic approach to understanding the challenges that supply chains face. The data analysis reported in the paper was based on evolved typologies and suggests a major growth of SCRM from a nascent to a fairly established stage over the past decade. The authors hope that the paper has established firm insights and clearly identified gaps and future directions into SCRM field.

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