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Supply chain risk management: review, classification and future research directions

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Abstract

In order to be more efficient, firms have adopted strategies such as outsourcing, global partnerships and lean practices. Although such strategies have tremendous abilities to improve the efficiencies but simultaneously they make the firms vulnerable to market uncertainties, dependencies and disruptions. Moreover, natural calamities and manmade crises have also put negative impact on strategic, operational and tactical performance of supply chains. These factors have triggered the interest of academia and industry to consider the risk issues as prime concerns. To capture the more fine-grained elements of diversified risk issues related to the supply chain we employ a multi-layered top town taxonomy to classify and codify the literature and put forward the probable dimensions for future research. We further study the pool of SCRM literature focusing on coordination, decision making and sector-wise SCRM implementation issues and derive relevant propositions.

Keywords: supply chain risk management, risk, uncertainty, literature review

1 INTRODUCTION

Supply Chain Management (SCM) as a discipline has witnessed a tremendous growth during the last two decades. This growth has been noticed in terms of modelling and analysing various issues arising due to the development of complex networks amongst different organizations not only within countries but also across the globe. These issues are mainly related to designing, planning and coordinating the material, information, and money flows across the supply chains. But owing to increasing dynamism and uncertainty in the business environment risk issues are becoming key concerns to the organizations. The risks in supply chains arise mainly due to (i) operational fluctuations such as variability in supply, demand uncertainties, and price variability (Juttner, 2005; Christopher and Lee, 2004) (ii) natural events such as earthquakes, cyclones, epidemics and (iii) manmade crises such as terrorist attacks, unethical business practices and economic recessions (Kleindorfer and Saad, 2005). Further cultural, infrastructural and political differences and the trend towards strategies such as outsourcing, single-sourcing and lean practices have also made the supply chain vulnerable to risks (Juttner et al., 2003; Varma et al., 2007; Meixell and Gargeya, 2005).

Effective management of risks is becoming the focal concern of the firms to survive and thrive in a competitive business environment. Thus the supply chain risk management (SCRM) has emerged as a natural extension of supply chain management with the prime objective of identifying the potential sources of risks and suggesting suitable action plans to mitigate them. But developing an effective SCRM program is always a critical task and requires skills and expertise in multiple areas. Considerable work has been reported in the SCRM literature dealing with issues with qualitative and quantitative approaches. Several earlier attempts, however, have also been made by researchers to review the dimensions of risks and their impact on supply chain functioning. Tang (2006a) reviewed the literature dealing with quantitative models having strategies to manage the risks at the operational and strategic level by addressing the risk issues of such functional aspects of the supply chain as demand management, supply management and product management. Vanany et al. (2009) studied the SCRM literature based on unit of analysis and risk management processes. Rao and Goldsy (2009) elaborated the taxonomy of risk sources and a categorization scheme. Further to identify the key enablers and inhibiters of risk management practices Tang and Musa (2010) employed the bibliometric method of citation and co-citation and also assessed the potential sources of risk to enhance the understanding of the SCRM literature. Dailun (2004) provided the basic framework of risk management but was more influenced by financial risk management approaches. Industrial trends and practices that cause risks and business turbulence are also considered without reviewing their empirical linkages (Narasimhan and Talliri, 2009; Trkman and McCormak, 2009).

It is observed that the literature on SCRM is growing exponentially with diversified issues, approaches and purposes but most of the work is still found to be isolated and appears to be fragmented. Most of the earlier reviews found the missing elements and suggested guidelines to overcome them. However, our review differs in purpose, as we seek to assess how well the risk spectrum is explored considering the perceptive elements of risk definitions, categorizations, structural elements of the supply chain and implementation phases of SCRM. To provide deeper insights we suggest a multi-layered top-down taxonomy including risk factors, elements and attributes. We further unify the domain of the SCRM literature that consolidates and refines the available knowledge and practices. We also develop the codification scheme (Appendix), which could help practitioners not only to use classifications but also for retrieval of information for various quantitative and qualitative analyses.

The remainder of the paper is organized as follows: Section2 provides a review methodology, outcomes of preliminary investigations and a description of the taxonomy used in the study. Section3 outlines the qualitative and quantitative analysis of the literature, employing the proposed taxonomy. Section4 represents the managerial implications and challenges, focusing on coordination and decision making issues under business risks and also considering SCRM implementation issues for specific sectors. Section5 includes the closing remarks, identifies gaps in the research and proposes future research directions.

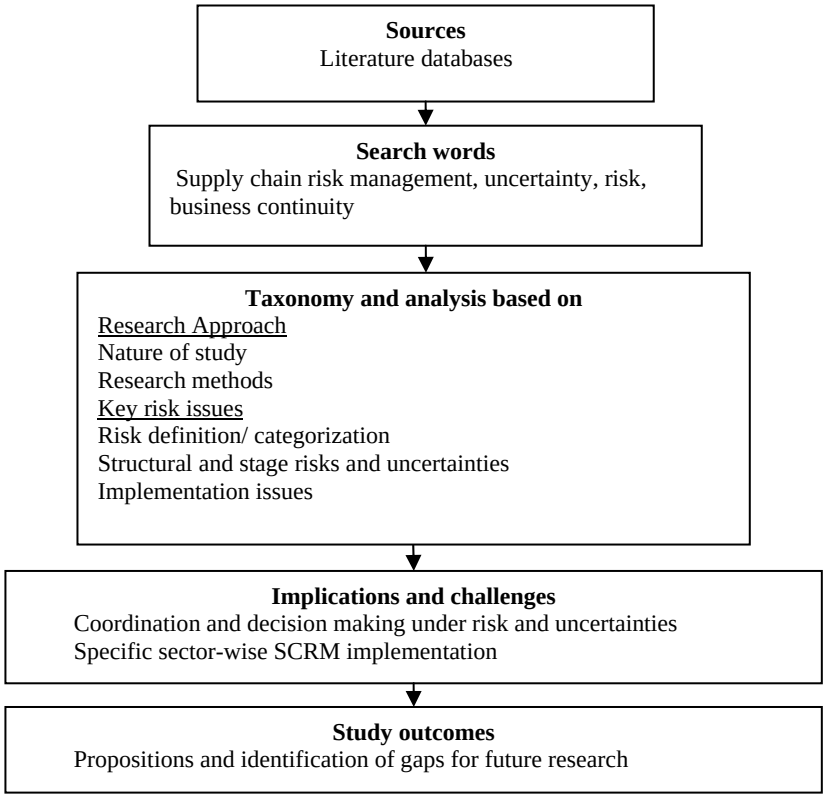
2 REVIEW METHODOLOGY AND PRELIMINARY FINDINGS

In this review, we focus on the SCRM literature and search the on-line library databases with the key words: supply chain risk management, uncertainty, risk and business continuity (Figure 1). The search was further narrowed down by a key focus on the papers addressing the following issues:

- Spectrum of supply chain risks with their significance
- Contribution of various research methodologies to managing the supply chain risks
- Issues primarily related to description and implementation of SCRM

This review includes 114 research papers taken from refereed journals published during the last fifteen years, from 1996 to 2010. The journals included in the review: *Computers and Chemical Engineering; Computers in Industry; European Journal of Operational Research; Expert Systems With Applications; International Journal of Agile Systems and Management; International Journal of Logistics Research and Applications; International Journal of Risk Assessment and Management; International Journal of Physical Distribution and Logistics Management; International Journal of Production Economics; Journal of Operations Management; Omega (The International Journal of Management Science); Supply Chain Management: An International Journal; The International Journal of Logistics Management; The Journal of Supply Chain Management.*

Figure1: Review methodology



2.1 Temporal trends in SCRM

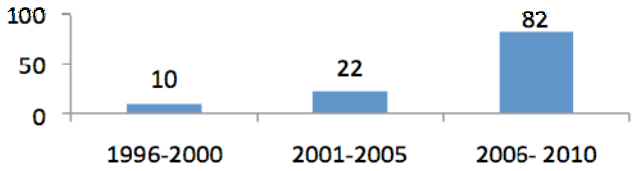
In order to view the periodic growth in the area of SCRM, the papers are divided into three time blocks each of five years duration. Figure 2 shows the number of papers in each period. Some key insights observed are presented below in Table 1:

- The papers dealing with supply chain risk issues appear in a variety of journals of different tracks such as management sciences/operational research, business management and systems engineering, indicating the multidimensionality of risk issues.
- More than 70% of papers included in the review were published during the last five years, indicating the growing importance of SCRM.

Table 1: Temporal trends of SCRM study

Period	**1996-2000**	**2001-2005**	**2006 onwards**
Trends in SCRM study	Risk definitions and investigation for focal firm perspectives usually influenced by financial risk analysis	Consideration of global risk issues, Investigation of operational parameters such as inventory policies, demand and supply, Capacity planning	Cross country relationship issues, Issues related to information sharing and security, Focus on brand image and comprehensive supply chain risk management program, Agility and resilience issues

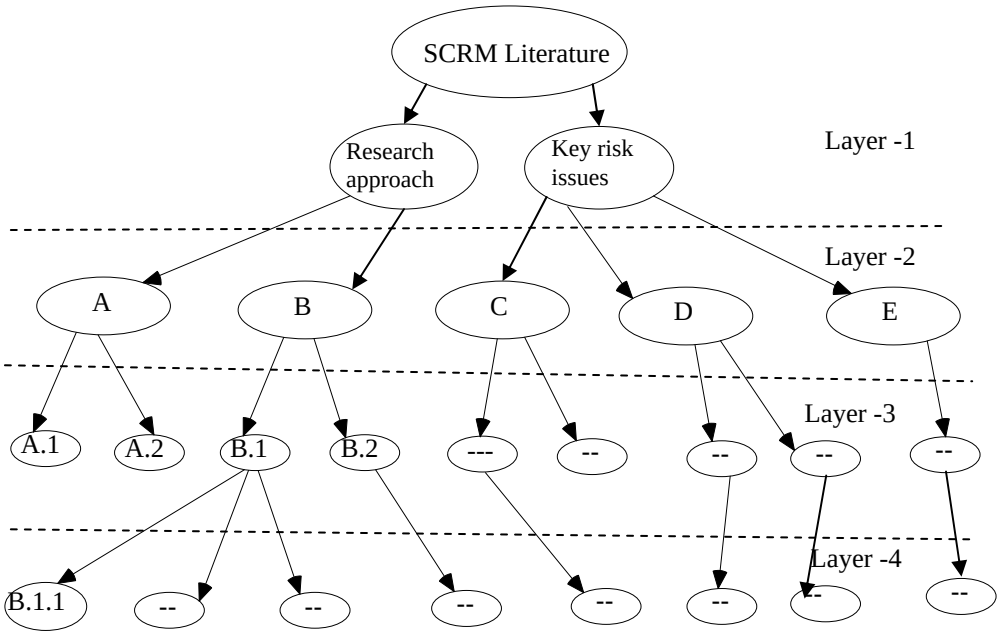
Figure 2: Publications in groups of five years



2.2 Details of Taxonomy and its relevance to SCRM

The proposed taxonomy and its classification factors have great relevance to describing and understanding the multi perspectives and complex risk issues. A multi-layered top-down structure is proposed to classify the SCRM literature and to encapsulate various research perspectives (Figure 3). To analyse the research efforts in the field of SCRM two criteria are considered: (i) research approach, (ii) exploration of key risk issues. Further to the research approach point of view, we consider the literature based on the nature of the study (A) and research methods (B) adopted to address the issues. Under exploration of risk issues we put specific emphasis on the exploration of supply chain risk elements in terms of risk definition/ classification criteria (C), risk related to structural elements of the supply chain (D) and issues related to the level of SCRM implementation (E). Each factor is further classified on the basis of the most discriminating elements followed by identification of the attributes of each subclass. Referring to the taxonomy, a logical identification code is also assigned to each factor, element and attribute, which can indicate the logical linkage among them (Appendix). In the next subsection we will discuss the classification criteria, their finer elements and their relevance to SCRM.

Figure 3: Top-town classification approach to SCRM literature



Research approach

A. Nature of study
A.1 Positive approach
A.2 Normative approach
B. Research Methods
B.1 Conceptual
B.1.1 Basic Theory
B.1.2 Theory Enhancement/Applied theory
B.1.3 Literature review/ Taxonomy developments
B.2 Empirical methods
B.2.1 Case Studies
B.2.2 Survey based statistical designs
B.2.3 Combined approach
B.3 Analytical
B.3.1 Risk Modelling
B.3.1.1 Modelling Type
B.3.1.1.1 Mathematical
B.3.1.1.2 Simulation
B.3.1.1.3 Multi agent
B.3.1.2 Model settings
B.3.1.2.1 Linear problem settings
B.3.1.2.2 Integer problem settings
B.3.1.2.3 Dynamic problem settings
B.3.1.2.4 Stochastic problem settings

Exploration of risk issues

C. Approach to defining/classifying Supply chain risk
C.1 Related to operational characteristics
C.2 Related to market characteristics
C.3 Related to business characteristics
C.4 Related to product characteristics
C.5 Miscellaneous
D. Risk issues related to structural elements of supply chain
D.1 Supplier(s) to manufacturer(s) relationship issues (Upstream issues)
D.1.1 Coordination and information issues
D.1.2 Supply system design issues
D.1.3 General issues
D.2 Manufacturer to buyer(s) relationship issues (Downstream issues)
D.2.1 Market volatility and demand fluctuations issues
D.2.2 Coordination under demand disruptions
E. Level of implementation of risk management approach
E.1 Risk identification approaches
E.1.1 Common listings
E.1.2 Taxonomy based risk identification
E.1.3 Scenario based
E.1.4 Objective based process mapping
E.2 Risk assessment and quantification approaches
E.2.1 Assessing the risk sources and exposure
E.2.2 Risk characterization
E.3 Risk mitigation approaches
E.3.1 Shaper
E.3.2 Acceptor
E.3.3 Recovery

2.2.1 Research approach

Nature of study (A)

In the proposed taxonomy the nature of the study (A) is considered to depict the motives of the study. As we know SCRM is an exponentially growing area of research, the exploration of literature with the nature of study perspective identifies the way by which the study contributes to the literature. It indicates whether the study is conducted to describe risk issues and propose solutions with due analysis or, as in some cases, if researchers prescribe solutions based on their experience and expertise. As the risk perceptions are multi-dimensional and elusive it will be interesting to explore the nature of the study adopted in the extant literature.

The nature of the study of the papers is analysed using the Malhotra and Grover (1998) scheme by categorizing them as having a positive research approach (A.1) or a normative research approach (A.2). Papers that attempt to describe, explain, investigate and predict the current supply chain risk issues and practices with various perspectives are considered as positive research. On the other hand, approaches that deal with the issues in a prescriptive manner where the author suggest(s) what an individual should do in a particular risk situation are termed normative. In normative research the author usually recommends the guiding framework and suggestions based on their experience and expertise in a particular field.

Research methods (B)

The next important element in the research approach is the research method, which represents the researcher's choice to follow the route to address the research objectives. Initially we follow the Wacker (1998) scheme and categorize the studies as conceptual, analytical and empirical. But owing to the fact that risk management has largely been adopted by practitioners and researchers from the last decade onwards, we require more detailed classification schemes to explore the underpinnings of risk management. Moreover, numerous emerging techniques, methodologies and approaches are involved to address the complex and entwined risk issues, which require a systematic framework to unify them under a relevant and logical classification scheme.

Focusing on this crucial need for comprehensive classification, we have fine-grained the classification by categorizing the conceptual study as basic theory (B.1.1), theory enhancement (B.1.2) and literature reviews/ taxonomy developments (B.1.3). Empirical studies are categorized based on the method of data collection and analysis such as case studies (B.2.1), survey based statistical design (B.2.2) and combination of both (B.2.3).

It is recognized that analytical approaches have been widely developed during the last decade and it is becoming difficult to discriminate and classify them as they have a number of derived and common elements. However, attempts are made in this study to classify the efforts of researchers adopting analytical methods. We found that researchers adopt various approaches to develop the analytical models to assess the risks and their impacts. We first consider the factor of risk modelling (B.3.1) and further classify this with two elements: model type (B.3.1.1) and model settings (B.3.1.2). Various model mechanisms are available in the literature: in the risk management perspective we consider them as mathematical (B.3.1.1.1), simulation based (B.3.1.1.2) and multi-agent based (B.3.1.1.3). The second critical element of the analytical approach is the problem setting, which depends upon the nature of the study and scope and domain of the research problem. We consider these as linear problems setting (B.3.1.2.1), integer problem setting (B.3.1.2.2), dynamic problem setting (B.3.1.2.3) and stochastic problem setting (B.3.1.2.4).

2.2.2 Exploration of risk issues

Approach to defining/classifying Supply chain risk (C)

The terms 'risk' 'uncertainty' 'disruption' and 'disaster' are frequently and interchangeably used in supply chains to describe the perceptions and interpretations of individuals and organizations. A general interpretation of risk is influenced by the negative consequences of variation in expected outcomes, their impact and likelihoods (March and Shapira, 1987). Risk events are also studied with core supply chain activities and investigated with common business practices. Christopher and Peck (2004) relate the risks with the vulnerability and likelihood of being lost or damaged. Interruptions to the flow of information, material and finance from the original supplier to the end user which cause a mismatch between demand and supply are also considered as risks (Juttner et al., 2003).

In line with the definitions discussed above and to relate the risks with supply chain functional aspects we categorize the orientation of risk definitions related to operational characteristics (C.1), market characteristics (C.2), business/strategic characteristics (C.3), product characteristics (C.4) and others (C.5). Table 2 shows the risk characteristics and features in each of the categories.

Table 2: Risk definition criterion and description

Classification code	Risk definition criterion	Definition description/Characteristics	Risk issues
C.1	Related to operational characteristics	Operational features of supply chain which mismatch demand and supply or even disrupt the functioning of supply chain and interrupt the flow of material, product and information	Supply disruptions, demand uncertainties, machine/system failures, improper planning and execution, information and security risks
C.2	Related to market characteristics	Market fluctuations which cannot be predicted precisely and change their nature, impact and occurrence over time.	Price variability, customer behavior and expectations, competitor moves, exchange rates, environmental risks and disasters
C.3	Related to business/strategic characteristics	Specific characteristics of business, sector, their strategies and environment which cause an undesired event to happen and negatively affect the supply chain performance	adverse effects of strategies such as outsourcing, single sourcing, lean manufacturing, improper supply network design, forecasting errors, lack of coordination and information sharing
C.4	Related to product characteristics	Features related to the specific nature of products which make the supply chain vulnerable to risk and uncertainties	Short product life cycles, complexity in product design and manufacturing, desire for variety of products, need for multifunctional products
C.5	Miscellaneous	Various other characteristics can also be considered which may fit in the above mentioned category or can be studied separately	political risks, credibility risks brand image risk, social risks, ecological risks etc

Risk issues related to structural elements of the supply chain (D)

Supply chain structures are complex networks of different players (including lower tier suppliers to the end customer) established with core objectives to minimize the costs, maximize the value and explore new markets through effectively managed relationships among members (Hallikas et al., 2002; Blackhurst et al., 2007; Trkman and McCormack, 2009; Tuncel and Alpan, 2010).Though networking is a way to take advantage of collaboration and partnership amongst various supply chain players, it becomes a source as well as a medium through which risks are generated and propagated to the entire network.

To capture the structural dimension of the supply chain risks we classify the literature for the perspectives of upstream (D.1) and downstream (D.2). We also study the literature with a single focal firm point of view but observe that most of the risk issues related to a single firm are more relevant in a dyadic frame. Therefore we prefer to analyse the risk issues from a relational point of view in the form of dyads. To provide deeper insights into the upstream risks we further classify them considering the elements of supply system design: number of suppliers (single/multiple sourcing), location of suppliers (local/global sourcing) and coordination and information sharing and thus divide the literature into supply system design (D.1.1) and coordination and information sharing (D.1.2). Other issues such as supplier behaviour, traits etc. are considered under the general issues category (D.1.3).

Downstream risks usually relate to the fluctuations in demand, volatile market conditions, customer behaviour, technological changes and shorter product life cycles. At one end these risks are associated with the physical distribution and product flow towards the downstream side and on the other hand they are related to forecasting issues (Szwejczewski, et al., 2008). These risks are usually the outcome of a mismatch between actual demand and projected demand resulting in a demand and supply mismatch throughout the supply chain. We focus on two discriminating elements and classify the demand issues as market volatility and demand fluctuation (D.2.1) and coordination and information sharing (D.2.2).

Level of implementation of risk management approach (E)

Implementation of supply chain risk management is an extremely critical task requiring a sound knowledge of business functions, market trends and financial and infrastructural status of the organization as well as the entire supply chain. Implementation of SCRM generally requires three steps given as: identifying the potential risks to the organization (E.1), assessing the risks and aftermaths (E.2) and adopting suitable risk managing

strategies (E.3). A hierarchy exists between these phases and the higher phase subsumes the lower phase (Dailun, 2004).

Risk identification is an important first step in any risk management effort. Numerous approaches have been proposed to identify the risks in supply chains, classified as: the common listing approach (E.1.1), where analysis of historical events is utilized to gain insight into future risks; taxonomy based approaches (E1.2),which provide a consistent framework to elicit and organize risk identification activities related to various business functions; scenario analysis (E.1.3), in which key risk factors and their effects on supply chain performance are analysed to develop a risk profile, making it easy to develop contingency plans at the operational level; risk mapping (E.1.4), with the capability of exposing the vulnerability of supply chains to potential risk before their occurrence.

Assessing the risks qualitatively or quantitatively is an essential task after the risk identification. When sufficient past data and expertise is available quantification of risks is meaningful, otherwise qualitative methods are more appropriate. We categorize the methods as assessing the risk sources (E.2.1) and risk characterization (E.2.2), with the latter being more rigorous. Assessing the sources and exposure (E.2.1) is effective when limited past data is available. The sources of risks and exposure are evaluated and subjectively indexed/ranked based on the assessor's perspective and experience. Risk characterization (E.2.2) provides a broader framework for risk assessment, grouping and prioritizing employing analytical models.

Various strategic and operational risk management stances are reported in the literature. We classify them as the shaper (E3.1), accepter (E3.2) and recovery approach (E3.3). In the shaper approach attempts are made to shape (reduce the impact and frequency) the uncertainty factors without changing the existing settings of the supply chain, while in the accepter approach risks are accepted and supply chains are reinvestigated and redesigned. Recovery strategies mainly support quick recovery mechanisms after severe damage in the supply chains.

3 ANALYSIS OF RESULTS AND DISCUSSION WITH PROPOSED TAXONOMY

We explore the literature and review the selected papers using the above discussed taxonomy. To develop a holistic view of SCRM efforts we included studies in practically all key demographical regions including Europe, Asia and the US. A combination of qualitative and quantitative approaches is adopted to describe the SCRM issues in the literature. The qualitative contents of the papers are provided in tables showing the issues discussed in the paper and also the approach adopted to address them. The quantitative exploration is presented in a table 3 and 2333 showing relative contributions of various classes and sub-classes under particular themes.

Table 3: Contribution of papers as per research approach

Classification Factor	Sub Classification	%Contribution	Sub Classification	%Contribution
Nature of study (A)	Positive (A.1)	91	……..	
	Normative (A.2)	9		
Research Method (B)	Conceptual (B.1	39	Basic Theory (B.1.1)	32
			Theory Enhancement (B.1.2)	54
			Literature reviews/ taxonomy development (B.1.3)	14
	Empirical (B.2)	26	Case Studies (B.2.1)	28
			Survey based statistical designs (B.2.2)	52
			Combined approach (B.2.3)	20
	Analytical (B.3)	35	……..	

3.1 Observations on research approach

3.1.1 Nature of study (A)

We first review the papers focusing on the nature of the study and approach adopted. We found that an ample amount of work has been done but still it seems to be in a nascent state due to the paucity of normative studies. It is noted that more research initiatives have been taken with a positive approach (91%) than normative research (Table-3). The low proportion of normative research (9%) exhibits the under-preparedness of research attempts to proffer precise and specific prescriptions to industries and academia.

3.1.2 Research methods (B)

Interestingly we found that even after the decade long period the contribution of conceptual research is highest, about 39%, followed by empirical (26%) and analytical, 35% (Table-3). This finding suggests that the field of SCRM is still emerging and requires theoretical support to develop practical frameworks. Analytical approaches have also made a major contribution to assessing and characterizing the risk issues. But the feeble acceptance of these models in actual practices point out the need for more empirical studies to explore the critical underpinning elements and relationships of the risk appetite of firms, their propensity and financial status.

Conceptual Study (B.1)

To provide the finer details, conceptual papers are further classified and it is observed that during 1996 to 2001 most of the papers focused on theoretical aspects related to risk issues, usually inspired by financial risk theories. But later on, catastrophic incidents such as the earthquake in Taiwan (2000), which severely damaged the supply base of the semiconductor industry, the Tsunami in Asia in 2005 that caused losses of more than $17 billion, Hurricane Katrina, which destroyed ports, railways, highways and communication networks and led to a significant drop in the US economy in 2006;terrorist attacks in the US and many Asian and European countries and many more motivated the researchers to redefine the risk issues for business continuity and devise mechanisms for quick recovery after disruptions. Thus agility, resilience and flexibility in supply chains have become the core agenda for research. This has increased the contribution to the applied theory of SCRM, dealing with contemporary and upcoming issues (Table-3).

Table-3 shows that theory is enhancing rapidly in the field of SCRM. Researchers are forming deeper insights and delving into critical SCRM aspects. Analysis also indicates that the field of SCRM is expanding but the attempts are still very small to review the prevalent literature. Thus more reviews are required to unify the various research efforts and explore the latent dimensions of risk management to support the global SCRM efforts significantly. The qualitative description of the issues addressed in papers, their approach and classification code is provided in Table 4.

Table 4: Description of conceptual research methods with risk issues discussed and classification code

Classification code	Theoretical Approach	Moves to manage uncertainties	Description of issues and papers
B.1.1	Fundamental supply chain and risk issues	Discuss the basic risk issues	Metrics and performance measurement for risks (Lawrence et al., 1996; Smeltzer and Sifered, 1998; Steven and Ronald, 1999; Sislian and Satir, 2000; Ritchie and Brindley, 2007), Risk management for practitioner perspectives (Hallikas et al., 2002; Finch, 2004; Yang et al., 2004; Juttner et al., 2003; Ojala and Hallikas, 2006), Risk definitions and classifications, risk constructs (Tang, 2006b; Kersten et al.,2007;Berg et al., 2008; Bailey and Francis, 2008; Trkman and McCormack, 2009)
B.1.2	Risk management theory enhancement	Propose theoretical models and frameworks to manage risk issues	Collaboration for responsiveness and customer satisfaction level (Christopher and Lee, 2004;Christopher and Peck, 2004; Jeng, 2004; Forme et al., 2007), Intangible issues of supply chain risks, behavioral aspects of risk (Ketzenberg et al., 2007; Kim and Park, 2008; Brun et al., 2006), Strategic and structural alignment issues (Giunipero and Eltantawy, 2004; Cigolini and Rossi, 2006; Peck, 2006; Khan and Burnes, 2007; Tapiero and Grando, 2008; Ritchie et al., 2008; Dani and Ranganathan, 2008), Value and risk identification and assessment in an advanced planning and scheduling system (Hung and Sungmin, 2008; Kenett and Raphaeli, 2008; Neiger et al., 2009, Szwejczewski, et al., 2008), Disruption risk management (Norrman and Jansson, 2004; Kleindorfer and Saad, 2005; Narasimhan and Talleri, 2009; Michael and Nallan, 2009), Robust strategies for risk mitigation (Tang, 2006b)

B.1.3	Literature review and taxonomies	Classify the risks, uncertainties and associated issues to unify the disjointed supply chain management literature	Classification of quantitative models dealing with risks and uncertainties(Tang, 2006), Classifications of risks (Dailun, 2004; Rao and Goldsby, 2009), Classification of literature considering unit of analysis, research methods etc as a classification factor (Vanany et al., 2009),Consideration of intangible and behavioral aspects of risk issues (Ponomarov and Holcomb, 2009), Focus on flow risks and developments (Tang and Musa, 2010)

Empirical study (B.2)

We include the papers that used empirical approaches with surveys followed by statistical designs and structured case studies. Many papers are also noted that have a combination of both methods for quantitative and qualitative analysis. The empirical approaches have been used to establish the relationships amongst latent supply chain issues such as short supplies, supplier characteristics, demand variability, erratic behavior of customers, risk propensity (Blackhurst et al., 2005; Shockley and Ellis, 2006; Bailey and Francis, 2008).These methods refine the level of understanding of risks, which further helps in taking strategic and operational decisions (Devraj et al., 2007; Sanders, 2008). It is recognized that survey based statistical designs are the most adopted approach in empirical studies (52%) to develop the relationship models. But in the SCRM literature case-studies also have increasing acceptability to develop more specific qualitative and quantitative models. Table 5 presents a description of the issues and moves to manage the risk in certain empirical papers.

Table 5: Description of empirical research methods with risk issues discussed and classification code

Classification code	Empirical Approach	Moves to manage uncertainties	Description of issues and papers
B.2.1	Case Studies	Investigation of specific cases	Value and risk assessment (Brun et al., 2006; Ojala and Hallikas, 2006), Perception of risks (Finch, 2004; Zhao et al., 2008),Managing information flow (Khan and Greaves, 2008 ; Bailey and Francis, 2008 ; Oke and Gopalakrishnan, 2009)
B.2.2	Survey based statistical design	Establish correlations for supply chain performance and risks	Investigation of outsourcing decisions (Lambros and Socrates, 1999), Investigation of the supply risk construct and integration (Shockley and Ellis, 2006 ;Wagner and Bode, 2006; Harland et al., 2007), Issues related to practitioner point of view(Juttner, 2005), Agency theory in risk management (Zsidisin and Ellaram, 2003), Effect of disruption on stock price performance (Hendricks and Singhal, 2005), Devaraj et al., 2007; Lee et al., 2007; Haan et al., 2007), Agility and flexibility in supply chain (Khan andGreaves, 2008;Braunscheidel and Suresh, 2008; Sodhi andTang, 2009)
B.2.3	Combined approach	Establishing the signifiacnt relationships for specific cases	Disruptions in supply chains (Blackhurst et al., 2005; Jiang et al., 2007), Risk and information sharing issues (Zhou & Benton Jr., 2007 ;Kocabasoglu et al., 2007; buyer perception of supply risks(Ellis et al.,2010)

Analytical study (B.3)

In order to plan and coordinate in a risk environment, quantification of risk and analytical modelling is required. Based on the modelling approach we categorize the literature into mathematical (B.3.1.1.1), simulation (B.3.1.1.2) and agent based methods (B.3.1.1.3) for a variety of settings such as linear (B.3.1.2.1), integer (B.3.1.2.2), dynamic (B.3.1.2.3) and stochastic (B.3.1.2.4). Table 5 lists the details of the papers and issues explored using analytical approaches.

The simple analytical approach to quantify and rank the risks is the Analytical Hierarchy Process (AHP) with linear problem settings in a multi attribute decision model. It reduces the complex decision problem into a series of one to one comparisons followed by synthesis of results based on a hierarchical structure (Korpela et al., 2002; Gaudenzi and Borghesi, 2006; Levary, 2008). However, the subjectivity involved in AHP has always been a matter of concern.

Owing to the very nature of the risk, the stochastic models are more accepted in supply chains to model risk issues, varying from strategic to operational levels (Beamon, 1998). The uncertainty associated with variables is tackled mainly with three approaches. First, standard distributions are used in which continuous probability distributions are assigned for decision variables. Second, when continuous distribution is not feasible, discrete finite scenarios are established considering various combinations of uncertain parameters. Third, there are fuzzy approaches, where uncertainties in decision parameters are considered as fuzzy numbers and membership functions (Chen and Lee, 2004; Mele et al., 2007). Underlying complexities and impractical assumptions limit the utility of mathematical modelling. Moreover, in some cases the explicit relationships between decision variables are difficult to model. In such situations, simulation techniques provide an alternative approach to analysing the supply chains by constructing an artificial environment within which the dynamic behavior of the risks can be assessed. Various risk mitigation strategies and tradeoffs are tested in a simulated environment with seasonality, level of information sharing, service level, net profit etc as simulation parameters (Labeau et al., 2000; Jammernegg and Reiner, 2007; Sohn and Lim, 2008; Thomas and David, 2008).

The simulation models also have certain limitations, such as the models can only be run with previously defined conditions and there are limited capabilities to design the system parameter itself (Swaminathan et al., 1998; Ohbyung et al., 2007). To overcome these shortcomings, multi-agent approaches, supported by advanced computational methods, have been introduced. In these approaches the problem is modeled as agent elements (supplier, manufacturer, distributor etc), control elements (inventory control, scheduling, logistics and transportation etc) and their interaction protocols (Swaminathan et al., 1998; Mele et al., 2007). These approaches are better than individual programs as they combine the various autonomous agents/programs in one platform. Various strategic and operational issues such as collaboration under demand and supply uncertainties, the role of information sharing, inventory levels, robust and optimal designs are investigated and managerial inferences are drawn by researchers (Chatzidimitriou et al., 2007; Mele et al., 2007; Ohbyung et al., 2007).

Table 6: Description of analytical research methods with risk issues discussed and classification code

Classification code	Analytical Approach	Moves to manage uncertainties	Description of issues and papers
B.3.1.1.1/ B.3.1.2.1	Mathematical (linear settings)AHP	Evaluating the risk ranks	Risk quantification using multi decision criteria (Korpela et al., 2002; Levary,2008;Teresa et al., 2006)
B.3.1.1.1/ B.3.1.2.2	Mathematical Stochastic Models (probability distributions and Scenario settings)	Quantification of risk using mean variance analysis	Quantifying the risk and performance attitude (Choi et al.,2008), Supplier failure risks (Lee, 2008)
B.3.1.1.1/ B.3.1.2.4		Uncertainty quantification with fuzzy sets	Evaluating the performance of the supply chain using fuzzy sets for uncertain parameters(Chen and Lee, 2004; Wang and Shu, 2007); Moghadam et al., 2008; Li and Kuo, 2008)
B.3.1.1.1/ B.3.1.2.4		Planning under uncertainties	Mid-term planning models (Gupta and Maranas,2003), Managing inventory levels and profit margins, strategies mix to minimize the effect of order variations, decomposing the problem to profit maximization and risk minimization objectives (Escudero et al., 1999; Kut and Zheng, 2003), Integrating risk management and B2B tools (Aggarwal and Ganeshan, 2007, Risk assessment in global chains, sourcing decisions under disruptions (Goh et al., 2007; Stephen et al., 2007; Boute et al., 2007; Ouyang, 2007; Hong and Sung, 2008;Haisheng et al., 2009, Bogataj and Bagataj, 2006)
B.3.1.1.1/ B.3.1.2.4		Coordination under uncertainties	Investigating the coordination strategies under production cost deviation and demand disruptions (Thomas and Griffin, 1996; Mantrala and Raman, 1999; Xiao et al., 2007), Quantifying coordinated decisions (Hsiesh and Cheng, 2008; Demirkan and Cheng, 2008)
B.3.1.1.2/ B.3.1.2.4	Simulation	Planning under uncertainties	Planning and controlling the inventory and supplier selection (Moghadam et al., 2008; Jammernegg and Reiner, 2007), inventory and capacity coordination (Liston et al., 2007), planning outsourcing, assessing risks and relations to inventory levels(Thomas and David, 2008)

B.3.1.1.2/ B.3.1.2.4		Coordination under uncertainties	forecasting of demand distortion in case of lack of information sharing(Meilin and Jingxian,2007; Carbonneau et al.,2008)
B.3.1.1.2/ B.3.1.2.4		Structuring of network under uncertainties	Design and restructuring of production/distribution networks (Mele et al.,2007)
B.3.1.1.2/ B.3.1.2.2		Information policies and forecasting methods for risk mitigation	Performance of supply chain with various information sharing levels (Lau et al.,2004), coordination between inventory and ordering (Sohn and Lim, 2008)
B.3.1.1.3/ B.3.1.2.4	Multi-agent systems	Robust mechanism	trading in dynamic and uncertain environments (Chatzidimitriou et al., 2008)
B.3.1.1.3/ B.3.1.2.2		Collaborations under uncertainties	Investigation of collaborations for maximum efficiency under demand and supply uncertainties (Ohbyung et al., 2008), Decision and implementation of risk management (Giannaikis and Louis, 2010)

3.2 Observations on exploration on risk issues

Literature is further reviewed to explore the risk issues addressed and contribution to various classification factors and presented in table 7.

Table 7: Contribution of papers as per risk issues explored

Classification Factor	**Sub classification**	**% contribution**	**Sub classification**	**%contribution**
Approach to defining/ classifying Supply chain risk (C)	Related to operational characteristic(C.1)	31	**……..**	
	Related to market characteristic(C.2)	25		
	Related to business characteristic (C.3)	19		
	Related to product characteristic (C.4)	13		
	Miscellaneous issues (C.5)	12		
Risk issues related to structural elements of supply chain (D)	Supplier(s) to manufacturer(s) relationship issues (Upstream issues) (D.1)	56	Coordination and information issues (D.1.1)	44
			Supply system design issues (D.1.2)	36
			General issues (D.1.3)	20
	Manufacturer to buyer(s) relationship issues (Downstream issues) (D.2)	44	Market volatility and demand fluctuations issues (D.2.1)	63.5
			Coordination under demand disruptions (D.2.2)	36.5
Level of implementation of risk management approach (E)	Risk identification approaches (E.1)	**…….**	Common listings (E.1.1)	27
			Taxonomy based risk identification (E.1.2)	20
			Scenario based (E.1.3)	30
			Objective based process mapping (E1.4)	23
	Risk assessment and quantification approaches (E.2)	**…….**	Assessing the risk sources and exposure (E.2.1)	45
			Risk characterization (E.2.2)	55
	Risk mitigation approaches (E.3)	**…….**	Shaper (E.3.1)	15
			Acceptor (E.3.2)	45
			Recovery (E.3.3)	40

3.2.1 Approach to defining/classifying Supply chain risk (C)

Employing the classification of risk definition criteria, table 7 shows that the operational characteristics (C.1) (e.g. demand-supply mismatch) are used to a greater extent (31%), followed by the market characteristic (C.2) (25%). The specific business features, strategies and their effects on the supply chain (C.3) have also been used in defining the risks (19%). In a business world where customers' expectations regarding products and services are changing, product centric orientation is a paramount consideration. Various definitions of risks, focusing on product characteristics (C.4) such as the product life cycle, functional features, variety, and the technical complexities involved are also gaining acceptance gradually (13%). Apart from this many more influencing features such as political, legal and financial issues (C.5) have also been used by some authors (13%). Table 8 provides the qualitative details of issues considered for risk classification in various papers.

Table 8: Details of papers on risk definition criteria with classification code

Classification Code	Risk issues/sources	Papers
C.1	Infrastructural, transport, communication, design, quality, cost, availability, manufacturability, health and safety, natural hazards, terrorism and political instability	Mason-Jones et al. (1998), Zsidisin et al. (2000), Kersten et al. (2007) Klerndorfer and Saad (2005), Faisal et al. (2006), Faisal et al. (2007), Boin et al. (2010)
C.2	Changing market conditions, customer expectations, product yields, quality, process time	Ritchie and Brindley (2007), Wong and Arlbjorn (2008), Serbanescu (2007), Mele et al. (2007)
C.3	Focus on efficiency rather than effectiveness, globalization of supply chains, trends of outsourcing, reduction of supplier base, Lack of trust, Inaccurate information sharing and asymmetry in power and dependency	Juttner et al. (2003), Finch (2004), Ojala and Hallikas (2006)
C.4	Product complexity and serviceability	Levary (2008), Knemeyer et al.(2009), Szwejczewski, et al. (2008)
C.5	Operational contingencies, Legal risks, political risk	Jiang et al. (2009), Manuj and Mentzer (2008)

3.2.2 Issues related to structural elements of the supply chain (D)

It is observed that researchers have focused on the risk issues on both sides of the supply chains but upstream issues get more attention, as shown in table 7, with a 56% contribution. This suggests that supply chains are more vulnerable to supply side risks. The downstream issues also make a significant contribution (44%), which shows that market uncertainties, demand fluctuations and associated risk issues are also well addressed by researchers. Table 9 shows the details and codes of papers representing upstream and downstream risk issues.

Upstream issues (D.1)

Upstream risks are associated with procurement and are considered to be threats to supply assurance, the possibility of improper supplier selection, increased company liabilities and uncertainty in supply lead time (Smeltzer and Sifered, 1998; Sislian and Satir, 2000; Meixell and Gargeya, 2005). It is observed that about 56% of the related papers focus on upstream risks. The key issues of supply risks are found to be related to supply system design (number of suppliers (single/multiple sourcing)), location of suppliers (local/global sourcing) and supplier's agility, flexibility, delivery reliability and infrastructural strength and coordination and information sharing, which we covered in our classification. Analysis of the literature focusing on supply risks shows that information sharing and coordination issues (D.1.1) have been paid the highest attention (44%) followed by the supply system design issues (D.1.2) (36%) (Table7).

Downstream issues (D.2)

We focus on two discriminating elements and classify the demand issues as market volatility and demand fluctuation (D.2.1) and coordination and information sharing (D.2.2). Coordination and information sharing amongst wholesalers, dealers, and retailers and shorter planning horizons are some of the measures suggested in the literature to manage demand side risks (Gupta and Maranas, 2003; Chen and Lee, 2004; Boute et al., 2007; Stephan et al., 2007). There have also been proposals to investigate the level of information sharing from a security point of view and adopt trust based mechanisms under volatile market conditions (Xiao et al., 2007). As mention in table 7 issues related to demand and order variability have been considered more (63.5%) in the literature than coordination and information sharing issues (36.5%) to manage downstream risks.

Table 9: Details of papers dealing with the structural element of risks with classification code

Classification code	Structural position of supply chain	Description of issues and papers
D.1.1	Up-stream issues	Number of suppliers, and location related issues (Teresa et al., 2006; Abbas et al., 2006; Moghadam et al., 2007; Lee, 2008; Aggarwal and Ganeshan, 2007; Li-ping Liu et al., 2007; Goankar and Viswanadham, 2004; Haisheng et al., 2009)
D1.2		Relationship and coordination issues on supply side (Hallikas and Virolainen, 2002; Levary, 2008; Sarkar and Mohapatra, 2009; Ojala and Hallikas, 2006; Trkman and McCormack, 2009)
D.1.3		Responsibilities and reliability of suppliers (Giunipero, and Eltantawy, 2004; Jeng , 2004; Thomas and David, 2008)
D.2.1	Down- stream issues	Demand variability and market uncertainties (Mantrala and Raman, 1999; Gupta and Maranas, 2003; Kut and Zheng, 2003; Chen and Lee, 2004; Donk and Vaart, 2005; Boute et al, 2007; Neureuther and Kenyon, 2008)
D.2.2		Coordination under demand disruptions, Profits and service levels (Xiao et al., 2007; Meilin and Jingxian, 2007; Chatzidimitriou et al., 2008; Ohbyung et al., 2007; Sohn and Lim, 2008; Hsieh and Cheng, 2008)

3.2.3 Issues related to implementation of Supply chain risk management (E)

Various levels of SCRM implementation are analysed: identifying and classifying potential risks to the organization (E.1), assessing the risks and aftermaths (E.2) and adopting suitable risk managing strategies (E.3).

Risk identification (E.1)

The literature reflects various approaches to identifying the risks which we have categorized, as noted earlier in our taxonomy. Table 7 indicates that scenario based approaches (E.1.3) are most accepted (30%) in the literature because of their ability to predict the impact of risks. Their accuracy, however, depends on the ability and vision of the person setting the scenarios. Listing methods (E.1.1) are also common (27%) due to their simplicity. Objective based mapping (E.1.4) has also been used. It is difficult to prepare an exhaustive mapping but once completed it provides a very effective and accurate tool to understand the sources and drivers of risk. This method is gaining acceptance for specific supply chains (23%). Taxonomy based approaches (E.1.2) are usually influenced by the existing literature and practices to establish detailed and systematic risk classification schemes. As the risk management practices and related literature is growing and becoming more refined, the acceptability of this approach is expected to grow.

Risk assessment and quantification approaches (E.2)

As indicated in table 7 risk characterization (E.2.2) is more common (55%) followed by assessing the sources and risk exposure (E.2.1) (45%). The analytical approaches are not widely accepted firstly, due to their complexity and the requirement of expertise to implement them and secondly, existing methods are yet not capable of quantifying the elusive and dynamic nature of risk.

Risk mitigation approaches

Various strategic and operational risk management schemes are classified: the shaper (E3.1), accepter (E3.2) and recovery approach (E3.3). When past knowledge and experience related to market uncertainties are available, shaper strategies are found to be better. With this stance efforts are made to avoid the risks by dropping the risk prone market, customer or supplier. Contractual agreements are also in practice to minimize the risk intensity. To control the severity of risk, stocking an excess buffer and safety stocks are also a common phenomenon.

If the risk events are unavoidable, accepter strategies are adopted, in which supply chain visibility and coordination is improved and supply networks are redesigned, considering risks as a prime concern (Berge et. al., 2008). A variety of strategies such as supplier selection, number of suppliers, coordination architecture and level of information sharing, accepting the risks and uncertainties (Moghadam et al.,2007; Mantrala and Raman, 1999; Gupta and Maranas,2003; Boute et al., 2007; Neureuther and Kenyon, 2008) have been suggested in the literature. After 9/11 (the terrorist attack in the US) and a series of natural disasters, recovery strategies are increasingly considered by researchers. Continuity management and development of quick recovery plans are becoming a focal research area. Flexibility, agility, knowledge management, information sharing and horizontal/vertical integration are the key issues that are investigated form the point of view of recovery (Norrman and Jansson, 2004; Peck, 2006; Dani and Rangnathan, 2008; Braunscheidel and Suresh, 2008). Table 7 shows that accepter approach is the mostly widely considered one in the literature to design risk management

strategies (45%) followed by the recovery approach (40%). Shaper approaches are not as commonly discussed as the other approaches (15%).

4 MANAGERIAL IMPLICATIONS AND CHALLENGES

The detailed classification scheme is further explored with two very significant factors representing the challenges to the adoption of SCRM: first, the coordination and decision making in uncertain business environments and second the implementation issues of SCRM for various sectors.

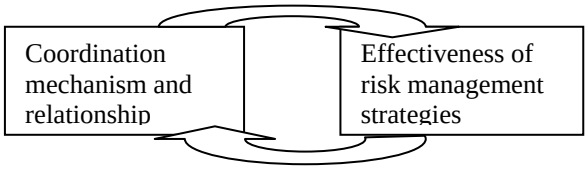


Figure 3: Linkage of coordination mechanism and effectiveness of risk management strategies

4.1 Coordination and decision making in an uncertain business environment

The literature reflects the fact that coordination strategies are established in supply chains at operational and strategic levels for synchronization of the inventory, logistics and production, employing information sharing as a tool for timely, relevant and accurate decision making (Sahin and Robinson, 2002). But in a changing business environment the paradigm has shifted and organizations are more inclined to integrate and review coordination strategies to reduce unexpected and undesired events throughout the network for better management of dependencies (Mele et al., 2007). Thus it will be interesting to study the decision making and coordination strategies with supply chain risk perspectives. In a competitive business environment coordination and collaboration is becoming the prime concern but criticality arises to make tradeoffs between the level and type of coordination and associated risks. A fundamental framework suggesting business integration is discussed by Kleindorfer and Saad (2005), including the strategies to reduce the impact and frequencies of disrupting elements. But theoretical treatment limits its application to the initial levels. Forme et al. (2007) have proposed an improved framework for business collaboration with two models, namely the collaboration characterization model (CCM) and the collaboration oriented performance model (COP). As far as the COP model is concerned they consider flexibility, reactivity, quality and lead times as a measure of performance index with various collaboration levels. They found that at the design and development level collaboration is high but at the operational level more efforts are required to compete in a demand driven market. Inclusion of supply, internal and financial risks can make these models more effective and acceptable.

Market volatility, shorter product life, uncertain demand is also considered by researchers while studying the coordination strategies at the operational and strategic level (Brun et al., 2006). They further assess the level of information sharing considering the value and risk in the supply chain. Donk and Vaart (2005) also studied the integration and collaboration issues with their empirical investigation with one supplier and their five buyers of a different nature. They found that shared resources in supply chains limit the possibility of integration. Their framework helps to set a level of integration in a particular risk and resource sharing situations. On a similar line of action Ojala and Hallikas (2006) touched on the investment risks in networking with the help of the case of two industrial original equipment manufacturers and nine of their suppliers, including from the electronics and metal sectors. Considering the network structure related risks and focusing on the investment decisions in networking in a buyer dominated environment they suggest four themes of investment decisions: investment specificity, investment pace, investment size and the possibility of wrong decisions. They found that the reliability of information plays a significant role in investment decisions. It is realized that more fine-grained models are now required to find the hidden complexities of the decision making process and coordination in the context of business risks and uncertainties.

As suggested in the literature, coordination strategies can be reviewed under the influence of two managerial decision making environments: centralized and decentralized. In a centralized decision making environment the focal concern of the managers is to align the marketing and operational management objectives to improve the relationship between supply chain members (Demirken and Cheng, 2008; Donk and Vaart, 2005; Hallikas and Virolainen, 2005). Managers are always assertive in order to develop strategic protocols for coordination among various members for sustainable relationships. The critical challenge faced by the managers in a centralized decision making environment is that the firm which leads the supply chain and has the power to take strategic decisions defines the risks with their own perspective and characterizes the risk impacts with their

own appetite. It is further argued that they have the tendency to bear minimum risk and transfer it to other players, resulting in imbalances in the whole supply chain, which strain the entire supply networks.

Decentralized supply chains can be viewed in a different way and considered as an aggregate body of various discrete entities, where coordination exists, not more than inter-firm or dyadic level. It is observed that most of the decentralized supply chains suffer from uneven power distribution and conflicting risk perceptions and attitudes that limit the performance of the individual risk management strategies of various members. Managers can handle this challenge by addressing three prime issues in centralized as well as decentralized decision making environments: First, as we discussed above, the risk is multidimensional and multi-perspective in nature it could be better to identify and define the risk and its elements not only at the firm level but jointly at the supply chain level, including lower tier suppliers to the end customer. Many times it becomes impractical to consider long chain analysis in strategic decision making, in this case, at least, dyadic relationships should be considered for initial listing of risks and their quantification schemes. Second, in cases where the members have their own risk perceptions and strategic stances and plan to mitigate them, sincere managerial efforts are essential for strategic alignment of multiple perceptions and incorporation of a common minimum program. Third, managers should encourage the tendency to share the appropriate risk by linking it with profit sharing and investment of funds in supply chains. Thus suitable coordination mechanisms, including resource as well as risk sharing structures and level of control can resolve the issues of centralized and decentralized supply chains under risk and uncertainties to a large extent.

On reviewing the risk management literature, it has been found that most of the studies dealing with risk and uncertainties sufficiently cover issues like demand and supply disruptions, network design and multilevel inventory studies but the role of coordination mechanisms under diversified risk situations have not been thoroughly addressed. Supply chain coordination provides the means to understand and analyse the supply chain as a set of dependencies in the form of physical flow and information flow. Appropriate coordination in the supply chain can also reduce uncertainty in networks and strengthen the networks to perform better in existing risks and uncertainties. It is also argued that coping with uncertain situations should be the prime motive of coordination mechanisms. From the above discussion we conclude that integration and coordination among supply chain partners is a prerequisite for an effective risk management program and, furthermore, existing coordination mechanisms should be revisited considering the perceived risks and uncertainties (Figure 15). This discussion has helped us to synthesize two coupled propositions. These propositions can be examined and investigated empirically in various business environments.

P-1 Strong relationships and appropriate coordination mechanisms among partners improve the effectiveness of risk management strategies.

P-2 Existing coordination strategies can be more effective if revisited and revised, considering perceived risks and uncertainties.

4.2 SCRM for various sectors

We further explore the literature with the theme of implementing SRCM in diversified sectors and the practical implications. Disparity among supply chain partners, limited visibility and conflicting risk perspectives are key barriers to the implementation of SCRM at the supply chain level. Further it is argued that common SCRM strategies cannot be effective for diversified industrial sectors as the notion of risks, challenges, barriers and facilitators may vary with the nature, size and type of industry (Finch, 2004; Juttner, 2005). To explore this fact we study the diversified risk issues and preferences of certain industrial sectors.

Managing the supply chains of high-tech industries such as semiconductors, computer hardware and other electronic components is becoming challenging due to current business trends towards shorter product lifecycles, ever-changing customer demand, expanding product variety, and globalization. In high-tech industries, technology is changing rapidly, resulting in higher costs of obsolescence compared to other industries (Kut and Zheng, 2003; Jeng, 2004). Accurate forecasting, information sharing and integration among the supply chain players are urgently needed for this sector to manage the market volatility and price variability. Thus a specific SCRM program including dynamic risk factors will be more effective for such conditions.

Chemical and process industries have different situations. This sector is more vulnerable to safety and hazard issues; the efforts in this area are primarily focused on reduction of operational risks in the form of accidents, machine failures and supply disturbance which can propagate throughout the supply chain (Kleindorfer and Saad, 2005; Donk and Vaart, 2005). An SCRM program focusing on operational features and safety issues will be more relevant for this sector.

The automobile and machine components sector has been found to be plagued with high costs, reducing profit margins and accelerating competition. The focus of SCRM strategies is to redesign supply networks considering specific business risk issues and to investigate trade-offs between efficiency and responsiveness in the known/anticipated business risks environment (Moghadam et al., 2008; Carbonneau et al., 2008).

Diversified product requirements, changing customer tastes, stiff competition and distribution problems are the marked features of the textile industry (Forme et al., 2007; Brun et al., 2006). For the textile sector SCRM should strive to develop strategies to optimally manage the production capacity, workforce level and storage space, considering customer preferences, flexibility, reactivity, quality and lead times as the performance measure.

Food companies are continuously reviewing their business models in a changing business environment. Sustainability is becoming a key concern for this sector. Safety hazards such as contamination, biological risks, genetic risks and natural disasters, distribution and packaging losses, inappropriate contingency plans are the key challenges of this sector (Hong and Sung, 2008). In this sector SCRM primarily focusing to minimizing the wastage through proper distribution, storage and packaging in a collaborative environment, but food supply chain elements are still loosely linked and require more transparent and integrative models.

The above discussion reveals that different industrial sectors have diversified risk issues, priorities and needs. It could be interesting to explore this proposition empirically and identify the commonalities and differences among different sectors regarding risk issues to form clusters and develop specific risk mitigation strategies for clusters.

P-3 A common SRCM program may not be effective for different supply chains and specific SCRM strategies for specific sectors and industries are required.

Table 10: Risk issues and risk management for specific industries/supply chains

Industry / Sector type	Risk issues & sources	Risk mitigation approach	Papers
Electronics components/systems			
Semi-conductor	Supply and demand uncertainties	Correlating external demand to the supply lead time variability	Kut and Zheng (2003), Jeng (2004)
Electronic devices	Network risks in a buyer dominated environment	Assessing information risk & reliability	Ojala and Hallikas (2006)
PC manufacturing	Inbound risk identification &classification	Prototype model based on lit. reviews	Wu . et al. (2006)
Telecommunication	Internal and network risks	Trade-off between capacity and inventory management	Jammernegg and Reiner (2007)
Electronics	Outsourcing risks with contract costing	outsourcing with control costing	Liston et al. (2007)
DDR/RAM manufacturer	Demand variability with seasonality multi-generation products	Combination of forecasting method and level of information sharing	Sohn and Lim(2008)
Process			
Chemical	Accidents and disruptions	Integration to reduce impact and frequency of risks	Kleindorfer and Saad (2005)
Chemical	Supply, demand and internal uncertainties	Risk calculation	Li Ping Liu et al. (2007)
Pigments as raw materials	Variation in product specifications and volumes	Suggesting different integration with various uncertainty levels	Donk and Vaart (2005)
Textile/Fashion			
Fashion products	Demand variability with product variety	Assessment of value and risks	Brun et al. (2006)
Textile	Collaboration Risks under high demand variability	Developing collaboration performance indexes such as key success factors & key performance factors	Forme et al. (2007)
Textile	Demand uncertainties	Production loading plans using uncertainty data	Stephan et al. (2007)
Miscellaneous			
Machine tools	Supply risks	Risk control with optimal inventories	Moghadam et al. (2005)
Foundries	Demand disruptions	soft computing methods for forecasting	Carbonneau et al. (2008)
Agriculture	Supply risks, product decomposition	Improved auction model	Hong and Sung (2008)
Automobile spare parts	Demand variability	Suggesting better forecasting methods and inventory management	Li and Kuo (2008)
Food, beverage and meat	Demand amplification due to information mismatch	Collaborative partnership to manage demand and information flow	Cigolili and Rossi (2006), Baily and Francis (2008)

5 REVIEW FINDINGS, EXPLORATION OF GAPS AND AVENUES FOR FUTURE RESEARCH

SCRM is an exponentially growing area of research encompassing multidisciplinary and multidimensional aspects of risks. As the body of SCRM literature involves complex and entwined issues, a systematic taxonomy could make a great contribution. To delve into the supply chain risk issues we presented a multi-layered top-down classification scheme. In the first layer we considered the research approach and exploration of risk issues; in the second layer we examined the nature of the study, research methods, orientation of risk definitions, structural elements and the level of implementation; in the third layer the key discriminating elements of each factor were considered and were further categorized into detailed attributes. Apart from this, we have used a logical codification scheme employing an alphanumeric code which can assist in quantitative and qualitative analysis. We have further explored the literature with two very important and practical dimensions of the study, namely coordination and decision making in an uncertain business environment and implementation of SCRM for various sectors. The outcomes of these analyses have been presented in the form of propositions. In addition to describing the contributions of the researchers, this study also provided new insights for practical aspects of SCRM.

The conclusions of this study have illustrated the importance of adopting a broader view and scope of coordination strategies in the context of effective implementation of SCRM. It has been argued that understanding the emerging techniques, including conceptual, analytical and empirical approaches with all the proposed elements, enable us to tackle better the managerial challenges involved in addressing the risk issues. This kind of broader view is specifically needed in relation to the kind of managerial challenges faced by a company operating as a focal firm and having more power in supply chains. As this study has illustrated, it is not enough to concentrate on developing and sharpening the risk mitigation strategies focusing on one side of the supply chain and practices. Rather, the company needs to understand and try to influence the entire supply chain, or more importantly, the nature and progression of the flows across the various interfaces. The broadening of the scope of SCRM from a company's internal processes towards the inclusion of external issues is thus an important managerial challenge.

The review reveals various insights and gaps in the SCRM literature. On comparison of the nature of the study it is observed that even though the literature has a plethora of work the contribution of prescriptive studies is significantly lower, which justifies the need for more focused and specific studies, acceptable to industry. We noticed that the contribution of conceptual studies to SCRM has been higher than that of empirical and analytical studies. This finding highlights the fact that, as risk management studies are still in a nascent state, conceptual and theoretical up-grading is still essential to improve the level of understanding of complex risk issues to provide the strands of effective empirical and analytical studies. It has also been noted that SCRM is accepted in multiple research fields and the literature reflects a huge variety of works with diversified themes, issues and approach. The literature reports very few reviews covering the width and depth of the field. Moreover, as we found that the area is still emerging, more reviews are needed encompassing the changing trends in methodology, approach and finer elements of risk issues with various perspectives. Thus attempts have been made in this study to cover the prevalent literature dealing with current research methods to address the risk issues.

The analysis of orientation of risk definitions suggests that operational aspects related to the demand supply mismatch and interruption of information, funds or material flow are the most utilized factors to define and classify risks. Market orientation factors such as customer expectations, market fluctuations, price variability, competitor moves etc. are also found to be significant to characterize the risk issues. Strategic decision elements such as outsourcing, single sourcing, degree of leanness in manufacturing, level and type of coordination and information sharing etc. are also issues of concern but are still not addressed as much as the operational elements. Moreover, product features such as life cycle, functionality and complexity in design have not been adequately explored to define the risk characteristics. Thus, including product and strategic perspectives to define the risks could improve the effectiveness of risk management mechanisms.

On exploration of the structural dimensions of the supply chain it was observed that researchers emphasize supply side risks more than the demand side. The optimal number of suppliers, delivery reliability, optimal size of deliveries, relationships and coordination are the key elements that influence the risk management strategies, but in a changing scenario customer related elements such as demand fluctuations and customer behaviour should also be included to improve the agility and responsiveness of the supply chain. The implementation of a risk management program shows that scenario based methods are more common due to their comprehensiveness to identify the risks, followed by listing methods due to their simplicity. Risk characterization techniques were found to be more accepted but are still not effective to quantify the elusive and dynamic nature of risks. Further, on investigation of risk management strategic stances we found that the acceptor stance with redesign of supply networks is more common than hitting the cause of risk and reshaping the uncertainty sources. After a series of natural and manmade disruptive events recovery strategies are also being developed with the prime notion of robustness and resilience.

It has been noted that empirical studies primarily analyse the supply chain, investigating the impact of various risk factors on performance determinants, information sharing, collaboration, and e-business practices. The implications of strategic moves such as outsourcing and lean practices have also been investigated with specific case studies and survey based statistical analysis. However, as we know the risk issues have strong perceptive elements and human and organizational behaviour plays a decisive role in managing the risk situations, behavioural elements such as human/organization risk propensity can be integrated with the conventional risks models to get more realistic solutions. Moreover, the role of various personality traits, context and experience can also be incorporated in risk management models. Thus empirical studies investigating behavioural, technical as well as commercial aspects and their role in decision making will be more relevant to develop better risk management models.

The literature reflects the dramatic growth in mathematical modelling to analyse the risk issues. Initially the problems were addressed with linear models but later on stochastic modelling, and multi-agent approaches have been employed more to analyse the risk issues under simulated environments using artificial intelligence tools. To deal with supply chain risk issues these models require further improvements. The literature reports various mathematical models developed to assist planning under uncertainties with number of impractical assumptions such as known probability distributions and linearization in relationships, which reduce the acceptability of the model for real life situations. Thus inclusion of deeper risk issues can improve the effectiveness of mathematical models to a large extent.

It is also necessary to develop coordination strategies considering the actual conditions such as non-ideal members and heterogeneous risk sharing attitudes. Many times managers have to analyse trade-offs considering the factors which contradict each other such as redundancy and efficiency. Methods and mechanisms are still required to analyse these trade-offs in a dynamic business environment with a risk perspective.

We have unified the study and analysed it for coordination strategies under different decision making environments and implementation issues of SCRM for various sectors. The coordination strategies have been studied with two decision making scenarios namely centralized and decentralized systems. In a centralized decision making environment the level of coordination and information sharing among various players is found to be better but it is also observed that the firms leading the supply chain have the tendency to transfer the risks to smaller players. However, in a decentralized decision making environment, coordination is found only at the inter-firm level, which causes conflicting risk perceptions and practices to manage them. Based on the discussion it can be said that coordination among various partners and appropriate level of information sharing is essential to improve the overall effectiveness of risk management strategies. Study further reflects the fact that different industries and sectors have different business environments, opportunities and limitations thus a common risk management framework may not be effective, that causes the need for specific SCRMs for diversified industries and sectors.

Thus by employing a detailed taxonomy we have investigated the prevalent SCRM literature focusing on the research methods adopted and exploration of the risk issues from definition to implementation phases and specific industry needs and we believe that the trend of growing interest in the field of SCRM will continue and new avenues will open from the strategic to the operation level with inclusion of new developments in technology, computing techniques and managerial concerns to effectively manage the risk issues.

APPENDIX: A LIST OF PAPERS WITH CLASSIFICATION CODE

Papers/articles	Classification Code	Papers/articles	Classification Code
Lawrence et al.,1996	A(1)B(1.1)C(5)E(3.1)	Li-ping Liu et al., 2007	A(2)B(1.2)D(1.1)
Thomas and Griffin, 1996	A(1)B(.3.1.1.1/B.3.1.2.4)D(1.2)	Liston et al., 2007	A(1)B(.3.1.1.2/B.3.1.2.4) D(2.2)
Mason-Jones et al., 1998	A(1)B(1.1)C(1)	Mele et al., 2007	A(1)B(.3.1.1.2/B.3.1.2.4) C(2)D(2.2)
Smeltzer and Sifered, 1998	A(1)B(1.1)C91)D(1.2)E(1.1)	Meilin and Jingxian, 2007	A(1)B(.3.1.1.2/B.3.1.2.4) D(2.2)
Escudero et al., 1999	A(1)B(.3.1.1.1/B.3.1.2.2)E(1.1)	Ouyang, 2007	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.2)E(3.3)
Lambros and Socrates,1999	A(1)B(2.2)C(3)D(1.2)	Ritchie and Brindley, 2007	A(1)B(1.1)C(2)E(3.2)
Mantrala and Raman, 1999	A(1)B(.3.1.1.1/B.3.1.2.4)D(2.1)E(2.1)	Serbanescu, 2007	A(1)B(2.2)C(2)E(1.2)
Steven and Ronald, 1999	A(1)B(1.1)C(1)E(2.1)	Stephen et al., 2007	A(1)B(.3.1.1.1/B.3.1.2.2) C(1)E(1.1)
Sislian and Satir,2000	A(1)B(1.1)C(5)	Wang and Shu, 2007	A(1)B(.3.1.1.1/B.3.1.2.2) E(3.1)
Zsidisin et al., 2000	A(1)B(1.1)C(1)	Xiao et al., 2007	A(1)B(.3.1.1.1/B.3.1.2.4) D(2.2)E(2.1)
Hallikas et al., 2002	A(1)B(1.1)C(2)D(1.1)E(3.2)	Zhou and Benton Jr, 2007	A(1)B(2.3)C(5)D(1.2)
Korpela et al., 2002	A(1)B(.3.1.1.1/B.3.1.2.1)	Bailey and Francis, 2008	A(1)B(1.1)D(2.1)
Gupta and Maranas, 2003	A(1)B(.3.1.1.1/B.3.1.2.2) D(2.1)E(1.3)	Berg et al., 2008	A(1)B(1.1)E(3.2)
Juttner et al., 2003	A(1)B(1.1)C(3)E(3.2)	Braunscheidel and Suresh,2008	A(1)B(2.2)C(1)E(3.3)
Kut and Zheng, 2003	A(1)B(.3.1.1.1/B.3.1.2.2) D(2.1)E(1.1)	Carbonneau et al.,2008	A(1)B(.3.1.1.2/B.3.1.2.4) D(2.2)
Zsidisin and Ellaram,2003	A(1)B(2.2)E(3.2)	Chatzidimitriou et al., 2008	A(1)B(.3.1.1.3/B.3.1.2.4) D(2.2
Chen and Lee, 2004	A(1)B(.3.1.1.1/B.3.1.2.2) D(2.1)E(3.2)	Choi et al., 2008	A(1)B(.3.1.1.1/B.3.1.2.2) E(2.1)
Christopher and Lee,2004	A(1)B(1.2)D(1.3)E(3.2)	Dani and Ranganathan,2008	A(1)B(1.2)E(1.3)
Christopher and Peck,2004	A(1)B(1.2)D(1.3)	Demirkan and Cheng, 2008	A(1)B(.3.1.1.1/B.3.1.2.4) D(1.2)
Dailun, 2004	A(1)B(2.3)	Hong and Sung, 2008	A(1)B(.3.1.1.1/B.3.1.2.2) C(1)D(1.1)E(1.3)
Finch,2004	A(1)B(1.1)C(3)	Hsiesh and Cheng, 2008	A(1)B(.3.1.1.1/B.3.1.2.4) D(2.2)E(2.1)
Giuniperoand Eltantawy, 2004	A(2)B(1.2)C(2)D(1.2)E(2.1)	Hung and Sungmin,2008	A(2)B(1.2)C(3)E(3.2)
Goankar andViswanadham, 2004	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(2.2)	Kenett and Raphaeli,2008	A(1)B(1.2)C(5)E(3.1)
Jeng,2004	A(1)B(1.2)D(1.3)	Khan and Greaves, 2008	A(2)B(2.1)C(3)E(3.2)
Lau et al.,2004	A(1)B(.3.1.1.2/B.3.1.2.2) D(1.1)	Kim and Park,2008	A(1)B(1.2)C(5)
Norrman and Jansson,2004	A(1)B(1.2)E(3.3)	Lee, 2008	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(2.2)
Yang et al., 2004	A(1)B(1.1)D(2.1)	Levary, 2008	A(1)B(.3.1.1.1/B.3.1.2.1) C(4)D(1.2)
Blackhurst et al.,2005	A(1)B(2.2)C(1)E(3.3)	Li and Kuo, 2008	A(1)B(.3.1.1.1/B.3.1.2.2) C(2)E(3.2)
Donk and Vaart, 2005	A(1)B(2.3)D(2.1)	Manuj and Mentzer, 2008	A(1)B(1.2)C(5)E(3.2)
Hendricks and Singhal, 2005	A(1)B(2.2)C(5)	Moghadam et al., 2008	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(2.2)
Juttner, 2005	A(1)B(2.2)C(1)E(3.2)	Neureuther and Kenyon, 2008	A(1)B(2.2)C(2)D(2.1)
Kleindorfer and Saad, 2005	A(1)B(1.2)C(1)	Ohbyung et al., 2008	A(1)B(.3.1.1.3/B.3.1.2.2) D(2.2)
Abbas et al., 2006	A(1)B(1.1)D(1.1)	Ritchie and Brindley,2008	A(1)B(1.2)C(3)E(3.2)
Bogataj and Bagataj, 2006	A(1)B(.3.1.1.1/B.3.1.2.2) C(5)E(2.1)	Sohn and Lim, 2008	A(1)B(.3.1.1.2/B.3.1.2.2) C(4)D(2.2)

Brun et al., 2006	A(1)B(1.2)C(1)E(1.1)	Szwejczewski et al., 2008	A(1)B(1.2)C(4)E(2.1)
Cigolini and Rossi, 2006	A(1)B(1.2)D(1.1)	Tapiero and Grando,2008	A(1)B(1.2)C(5)
Faisal et al., 2006	A(1)B(2.1)C(1)	Thomas and David, 2008	A(1)B(.3.1.1.2/B.3.1.2.4) D(1.3)
Gaudenzi and Borghesi, 2006	A(1)B(.3.1.1.1/3.1.2.1)C(3) E(2.2)	Wong and Arlbjorn, 2008	A(1)B(2.2)C(2)E(3.3)
Ojala and Hallikas, 2006	A(1)B(1.1)C(3)D(1.2)	Zhao et al., 2008	A(2)B(2.1)C(1)
Peck, 2006	A(1)B(1.2)E(3.3)	Zsidisin et al., 2008	A(2)B(2.2)C(3)E(3.2)
Shockley and Ellis,2006	A(1)B(2.2)C(1)D(1.1)	Haisheng et al., 2009	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)
Tang, 2006	A(1)B(1.3)	Jiang et al., 2009	A(1)B(1.2)C(5)
Tang, 2006b	A(1)B(1.1)E(3.3)	Knemeyer et al.,2009	A(1)B(1.2)C(4)E(3.3)
Wu. et al., 2006	A(1)B(.3.1.1.1/B.3.1.2.1) C(1)D(1.1)	Michael and Nallan,2009	A(1)B(1.2)C(1)E(3.3)
WagnerandBode,2006	A(1)B(2.2)C(3)D(1.1)	Narasimhan and Talleri,2009	A(1)B(1.2)C(5)E(3.1)
Aggarwal and Ganeshan, 2007	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(2.2)	Neiger et al. ,2009	A(1)B(1.2)E(1.1)
Blackhurst et al.,2007	A(1)B(2.3)C(1)D(1.2) E(3.1)	Oke and Gopalakrishnan, 2009	A(2)B(2.1)C(3)
Boute et al., 2007	A(1)B(.3.1.1.1/B.3.1.2.2) D(2.1)E(2.1)	Ponomarov and Holcomb, 2009	A(1)B(1.3)
Devaraj et al.,2007	A(2)B(2.2)C(3)	Rao and Goldsby , 2009	A(1)B(1.3)
Faisal et al., 2007	A(1)B(2.1)C(5)E(3.2)	Sarkar and Mohapatra, 2009	A(1)B(.3.1.1.2/B.3.1.2.2) D(1.2)
Forme et al., 2007	A(2)B(1.2)	Sodhi and Tang, 2009	A(1)B(2.2)C(2)D(2.1)
Goh et al., 2007	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(3.2)	Trkman and McCormack,2009	A(1)B(1.1)D(1.2)E(3.3)
Haan et al.,2007	A(1)B(2.2)C(2)	Vanany et al.,2009	A(1)B(1.3)
Harland et al.,2007	A(1)B(2.2)C(5)E(3.1)	Boin et al., 2010	A(1)B(1.2)C(3)E(3.2)
Jammernegg and Reiner,2007	A(1)B(.3.1.1.2/B.3.1.2.4) C(1)D(2.2)	Giannaikis and Louis, 2010	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(2.2)
Kersten et al.,2007	A(1)B(1.1)C(1)	Ellis et al., 2010	A(1)B(2.2)C(1)E(3.3)
		Tuncel and Alpan, 2010	A(1)B(.3.1.1.2/B.3.1.2.4) C(1)D(2.2
Ketzenberg et al.,2007	A(1)B(1.2)C(5)	Tang and Musa, 2010	A(1)B(1.3)C(1)
Khan and Burnes,2007	A(1)B(1.2)E(3.2)	Wanger and Neshat, 2010	A(1)B(.3.1.1.1/B.3.1.2.2) D(1.1)E(3.2)
Kocabasoglu et al., 2007	A(1)B(2.2)C(1)E(3.2)	Wuand Olson, 2010	A(1)B(1.2)C(5)
Lee et al., 2007	A(2)B(2.2)D(1.1)		

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