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Supply chain risk management research agenda – from a literature review to a call for future research direction

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Supply chain risk management research agenda – from a literature review to a call for future research directions

Abstract

Purpose- Supply chain risk has increasingly attracted academic and corporate interest, however the supply chain risk debate in academic literature are rather limited to case and location specific studies. Hence, this paper utilised a systematic literature review to explore the supply chain risk research trends and gaps within the management literature.

Design/methodology/approach- To achieve the research objective a systematic literature review (SLR), looking into 25 years since 1990, into supply chain risk management was conducted, which resulted in 114 papers.

Findings- While the supply chain risk management literature is growing, results from the systematic literature review identified limited organized understanding of what constitutes holistic supply chain risk process, and high reliance of particular categories for supply chain risk, such as the high reliance on specific country settings (the USA and the UK); limited presence of cross competitive supply chain risk process analysis and challenges in developing conceptual supply chain risk frameworks.

Originality/value- Current literature on supply chain risk have been assessed based on its definition and utilisation. The current paper bridges this gap by synthesizing the diverse academic journal papers into the categories based on design continuum, relationship continuum, process continuum and economic continuum. In addition it highlighted the gaps in industry context, theoretical contribution, geographic location, and research methods applied and addresses the scope for further research.

Research limitations – The supply chain risk embeds categories of location, scope of supply chain, risk management tools and industry sectors involved, The search for related publications was mainly used from a wide range of coverage from accountancy to design in supply chain risk, hence although there is indication to specific industries, and foci of risk, this could be further explored.

Practical implications – This review of supply chain risk management identifies various research gaps and directions for future research to develop theory and practical understanding of supply chain risk.

Introduction

Crisis and catastrophes such as volcano eruptions in Ireland, earthquake in Taiwan and Japan, and Hurricanes in US gulf coast has led the companies to asses “how vulnerable their global supply chains” actually were (Wieland and Wallenburg, 2012:890) with an increasing interest from supply chain practitioners as well as academics (Christopher and Holweg, 2010; Wieland and Wallenburg, 2012; Colicchia and Strozzi, 2012). In a study 400 senior supply chain executives classified supply chain risk (SCRM) as one of the biggest challenges, despite only 69 percent reporting that they had risk monitoring processes present (McKinsey, 2010, Butner, 2010). The supply chain risk (SCR) is not a new phenomenon as “doing business require[d] the acceptance of some level of risk within organisations” (Olson and Wu, 2011:401). Nevertheless, the supply chain risk management (SCRM) has gained in momentum as it became a supply chain capability, one that supported businesses (Colicchia and Strozzi, 2012) and had the potential to reduce cost (Nelson et al, 1998), considering that a cost of a crisis for a day can surmount to companies 72\$ million in profits (Pettit et al. 2013) . Barry (2004) noted that it is also imperative to keep a risk and the uncertainty lens as one of the firm’s capabilities and for its competitiveness and viability. Due to the fact that “a supply chain [...] can never be risk free, that is, one cannot eradicate the chance of an undesirable/desirable event occurring” (Tummola and Schoenherr, 2011:474), the importance of the concept supply chain risk is here to stay.

Equally, supply chain risk has been associated with vulnerability, disruption, and uncertainty and in also in some cases with supply chain security (Autry and Bobbitt, 2008; Ghadge et al. 2012). The SCR can be defined as the “variation in the distribution of possible supply chain outcomes and their likelihoods, and their subjective values” (Juttner et al. 2003)” as well as an “expected outcome of an uncertain event, i.e. uncertain events lead to existence of risk” (Manuj and Metzger, 2008:196). “[T]ypically risk contexts [involves] ... often somewhere in the middle of risk-uncertainty spectrum (i.e. neither pure risk taking nor complete uncertainty)” (Ritchie and Brindley, 2007:306; Colicchia and Strozzi, 2012). However, some authors highlighted the difference between supply chain risk and vulnerability (Ritchie and Brindley, 2007; Colicchia and Strozzi, 2012; Barry, 2004) which can be

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3 differentiated both terms based on probability and outcome (Sanches-Rodrigues et al.
4 2010). Sanches-Rodrigues et al. (2010:62) noted that “uncertainty occurs when
5 decision makers cannot estimate the outcome of an event or the probability of its
6 occurrence. By contrast, the risk is the function of outcome and probability and hence
7 its something that can be estimated”. The variations in definitions, terminology and its
8 scope reflects the “challenge to capture the multi-dimensional and interdependent
9 behavior of the risk” (Ghadge et al. 2013) “owing to the high interconnectedness of
10 today's supply chain” (Pfohl et al., 2011:840), which may be time-based on an event
11 (Heckman et al. 2015:127) as well as the dynamic nature of the supply chain risk,
12 which is inherently difficult to assess (Qazi et al., 2017). In this paper the discussion
13 of supply chain will include the terms vulnerability, disruption and security as it is
14 interlinked to supply chain risk.
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24 In the supply chain literature we can find different supply chain risk classifications
25 based on; variation in distribution in supply chain outcomes and subjective values
26 (Juttner et al. 2003), contextual factors (such as organizational risk, network risk, and
27 other risks, i.e. environmental, political, social and exchange rate risks) (Ghadge et al.
28 2012; Juttner et al. 2003; Ritchie and Brindley, 2007); content of risk and its
29 management (risk drivers, risk management influencers, decision maker
30 characteristics, risk management response and performance outcomes) (Ritchie and
31 Brindley, 2007); situational factors of risk between suppliers and buyers (i.e. Degree
32 of product technology, the need for security, importance of supplier and the
33 purchasers prior experience) (Giunipero and Eltantawy, 2003); assessing the risk the
34 probability factor and impact level (Wieland, 2013); and dependencies of
35 vulnerabilities which are (1) time dependence (i.e. time delays, lead times, and
36 delivery schedule); (2) functional dependence (i.e. Inventories, production, products,
37 transport) (Zepeda et al. 2016); (3) relational dependence (knowledge, social aspects,
38 communication, suppliers and customers). Considering that global supply chains are
39 complex, lengthy and distanced from their markets, supply chains are forced to find
40 ways to be responsive on how to manage the risks (Khan and Creazza, 2009; Wieland
41 and Wallenburg, 2012). Hence, not only the definition of supply chain risk, but also
42 the categorization of the supply chain risk becomes problematic (Pfohl et al., 2011).
43 Considering the potential impact of collaborative relationship characteristics the
44 impact on supply chain risk can vary (Fan et al. 2015). As seen from the terminology
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3 and its classification, risk assessment and measurement may be difficult to quantify
4 where the risk never materializes, making any investment in supply chain risk
5 prevention difficult to justify (Zsidi et al. 2000). However understanding the supply
6 chain risk may "...foster internal integration and training competencies in order to
7 strengthen warning and recovery capabilities, which enables firms to identify supply
8 chain risks earlier and/or shorten the duration of manifest consequences" (Riley et al.,
9 2016:971). Hence, a SLR was conducted aiming to collect and analyse all relevant
10 papers in the field of supply chain risk as well as understanding the need for
11 establishing supply chain risk processes. It is with this motive that this literature
12 review was undertaken,

- 13 • To develop an understanding of the supply chain risk areas that have created
14 an interest for academic research
- 15 • To discuss some of the major issues and relationship addressed in supply
16 chain risk.
- 17 • Moving beyond the systematic literature review (SLR) analysis, the gap in
18 supply chain risk literature is identified.

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32 The next part of the paper provides the process of the systematic review and the paper
33 selection criteria. Followed by an analysis of supply chain categories, highlight the
34 main trends in. Finally drawing upon the key trends and areas with potential for
35 further research.

36 37 38 39 40 **Research methodology**

41 Shapira (1995) noted that that not one definition of risk could encompass all
42 circumstances, as the risk has multiple facets. Hence, the use of systematic literature
43 review (SLR) provides "a key tool ...to manage the diversity of knowledge for a
44 specific academic inquiry" (Tranfield et al. 2003:208) with the benefit of an evidence
45 trail, whilst minimizing the level of possible bias and error (Tranfield et al. 2003).
46 Adopted from the NHS Center for Review and Dissemination (2001), Tranfield et al.
47 (2006) suggest a three stage approach; (1) planning the review, (2) conducting the
48 review, and (3) reporting and dissemination of the review, enabling the researchers to
49 assure internal validity, reduce potential possible bias in the analysis. However, in
50 order to reduce the human-error the so-called data extraction forms have been used to
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ascertain the information from sources such as title, author and year of publication; methods utilized, and emerging theories and concept synthesized (Tranfield et al. 2006).

Hence, as Ghadge et al. (2012) also noted supply chain risk profile, functionality and impact levels is underdeveloped in the literature. One way to overcome this challenge is to evaluate the risk areas, such an attempt, for categorisation was made by Ritchie and Brindley (2007) in which they categorized the definitions in three areas; (1) likelihood of occurrence of a particular event or outcome; (2) consequences of the particular event or outcome occurring; and the (3) causal pathway leading to the event. In the area of SCR we can find literature review papers based on; (1) systematic literature review on supply chain risk for last 10 years (2000-2010) including only last two years ABS with an average of 3* rated papers (Ghadge et al. 2012); as well as only few studies which contributed to SC risk interrelationships (Kayis and Karningsih, 2012); Colicchia and Strozzi based on 15 years SLR and citation network analysis (2012) to understand the process of knowledge creation and transfer and development; valuable efforts for advancement in this discipline has been made by Wieland and Wallenburg (2012), through evaluation of inherent supply chain risks and relevant strategies to overcome these.

Delimitations and the search for literature

In order to complete the systematic literature review each defined category in the literature was systematically analyzed based on the occurrences. For the SLR following boundaries were set which resulted in 114 academic journal articles encompassing;

1. Based on the academic and professional discussions on supply chain risk, several key themes have been used, including the interchangeable terminology (see discussions on supply chain risk definitions by Ghadge et al, 2012; Ritchie and Brindley, 2007:306; Colicchia and Strozzi, 2012) the search included five sets of “keyword search strings” in main text (1) “supply chain”, “risk” ; (2) “supply chain”, “disruption”; (3) “supply chain”, “vulnerability”, (4) “supply chain”, “uncertainty”; (5) “supply chain”, “security”.

2. Publications including supply chain risk in law aspects has not been considered as this may include a broader range of complexity which may not fall under the supply chain scope (Seuring and Mueller, 2008).
3. The search for related publications was mainly used from management literature with a wide range of coverage from accountancy to design in supply chain risk from looking into 25 years from 1990, excluding dissertations, conference papers and magazine articles. SLR coverage has been noted to be sufficient when carried out for 10-15 years, indicating the changes and developments in the literature (Colicchia and Strozzi, 2012).

Each of these has been examined independently with respect to the supply chain risk literature review areas. Major databases were used such as Elsevier, Springer, Emerald, Wiley and other library services such as Ebschost. Considering the delimitations of the current study the results yielded with 114 papers. The categories of the papers have been established using the following categories in Table 2.

Categories	Variables	Description of the categories coded
Author(s)	Author 1 -7	Refers to incl. of all co-authors
Years	Years	Year of publication
Authors Affiliation	Location	Location of authors
Type	Paper type	Classification of article type
Years	Timeframe	Timeframe for the articles if stated i.e. literature review, longitudinal studies
Keywords	Keywords	Keywords as utilized alongside the table 1 chosen key strings
Industry	Industry context	Industries involved in the research
Sampling	Sample size	This category highlights the sample size
Context	Contextual setting	This category identifies size of network, country and industry context
Research Method	Methodology	Research Methods utilized
Method	Specific methods used	Includes AHP, ANP and others
Findings	Supply chain risk impact area	Associated with the supply chain risk impact
Journal Title	Title	Journal article titles

Table 2: Coding categories for journal papers

Descriptive Analysis

Distribution of paper categories

Analyzing the distribution of the journal papers, we see that the supply chain risk has been evaluated based on research papers and through conceptual papers, practitioner driven papers and viewpoints remain rather limited (Figure 3). Considering the dates of the articles the peaks of supply chain risk papers in 2004, 2009, and consequently

in 2013 were partly due to “special issues” assigned particularly to supply chain risk, supply chain security (i.e. special issues of International Journal of Operations and Production Management, Supply Chain Management an International Journal and International Journal of Physical Distribution & Logistics Management).

Paper Type	Authors
Research Paper	Adenso-Diaz et al.(2012); Autry and Bobbitt (2008) Aylward and Clements (2008) Butner (2010) Cheng and Kam (2008) Childerhouse and Towill (2011) Chiu and Chen (2005) Cucchiella and Gastaldi (2006) Durowojuet al. (2012) Dynes et al. (2007) Ekwall (2009) Ekwall and Lantz (2013) Elangowan et al. (2010) Ellram and Cooper (1990) Faisal et al. (2007) Faisal et al. (2006) Faisal et al. (2006) Farooq and O'Brien (2010) Finch (2004) Ganguly (2014) Ganguly and Guin (2013) Gaudenzi and Borghesi (2006) Golgeci and Ponomarov (2013) Hoffmann (2011) Jiaand Rutherford (2010) Johnson et al. (2013) Juttner and Maklan (2012) Juttner (2005) Kavcic and Tavcar (2008) Kavcic and Bertoncelej (2010) Kayis and Karningsih (2012) Kern et al. (2012) Khan and Burnes (2007) Khan and Creaze (2009) Kolluru and Meredith (2001) Laeequddin et al. (2009) Leat and Revoreda-Gida (2013) Lemke and Petersen (2013) Li and Chandra (2007) Liu et al. (2010) Lin and Zhou (2011) Lockamy and McCormack (2012) Manuj and Mentzer (2008) Micheli et al. (2008) Nijhoff-Savvaki et al. (2012) Norrman and Jansson (2004) Olson and Wu (2010) Papadakis (2003, 2006) Peck (2005) Peres and Grenouilleau (2002) Pfohl et al. (2011) Ponomarov and Holcomb (2009) Pujavan and Geraldin (2009) Punniyamoorthy et al. (2013) Ritchie and Brindley (2000, 2002, 2007) Rose-Anderssen et al. (2010) Sanches-Rodrigues and Porter (2010) Sanches-Rodrigues et al. (2010) Sheffi (2001) Shih and Wen (2005) Shin et al. (2004, 2012) Sinha et al. (2004) Soni and Kodali (2003), Sodhi et al. (2012) Spekman and Davis(2004) Stonebaker et al. (2009) Svensson (2004) Towill (2005) Tummala and Schoenherr (2011) Wang et al. (2013) Wieland and Wallenburg (2012, 2013) Wieland (2013) Wiengarten et al. (2013) Wild and Zhou (2010) Zelbst et al. (2009) Zhao et al. (2013) Zsidi et al. (2000, 2004) Yeh (2005)
Conceptual Paper	Bell et al. (2013) Christopher and Peck (2004) Christopher and Lee (2004) Elahi (2013) Giunipero and Eltawy (2004) Hirschauer et al. (2012) Khan et al. (2008) Khan and Creaze (2009) Kolluru and Meredith (2001) Kumar et al. (2009) Lonsdale (1999) Manning and Baines (2004) Manuj and Mentzer (2008) Ritchie and Brindley (2002) Tse et al. (2011) Warren and Hutchinson (200)
Case Study	Bloset al. (2009), Khan et al. (2008), Khan et al. (2012), Khan and Creaze (2009), Kumar et al. (2009), Ritchie and Brindley (2002), Shih and Wen (2005), Wai and Wongasurat (2013)
Literature Review	Aloini et al. (2012) Colicchia and Strozzi (2012) Ghadge et al. (2012, 2013) Olson and Wu (2010) Rao and Goldsby (2009) Williams et al. (2008)
Practionar Paper	Butner (2010)
Viewpoint	Barry (2004) Cavinato (2004) Chakravarty (2013) Denning (2013) Grimsdell (1996) Hamdar (1999)

Table 2: Categories for journal papers

Global distribution of supply chain risk research

The geographical distribution of the authors provided another interesting category with three countries USA, UK and India leading the supply chain risk research. When looked into the country selection researchers have linked country context profile to the nature of supply chain risk, for example, Lin and Zhou (2011) note in their paper on supply chain risk based on the product design can be observed in developing countries, such as Brazil, China and India, which has also drawn interest from

academics and practitioners (Lin and Zhou, 2011) as the SCRM is relatively new in developing country context. Blos et al. (2009). However the global distribution also may stem from a common language setting authors carrying work out in three German-speaking countries Germany, Austria and Switzerland (Wieland and Wallenburg, 2012). It is interesting to observe, that some of the locations generating more research on the supply chain risk area, whereas others, such as Africa, Near East, South America and limited research (Figure 1). Only a few studies included a wider geographical context, one such example is the study from Zhao et al. (2013) which has built upon a sub data set of a global investigation in 2005 included ten locations including Australia, China, Finland, Germany, Italy, Japan, South Korea, Spain, Sweden, USA.

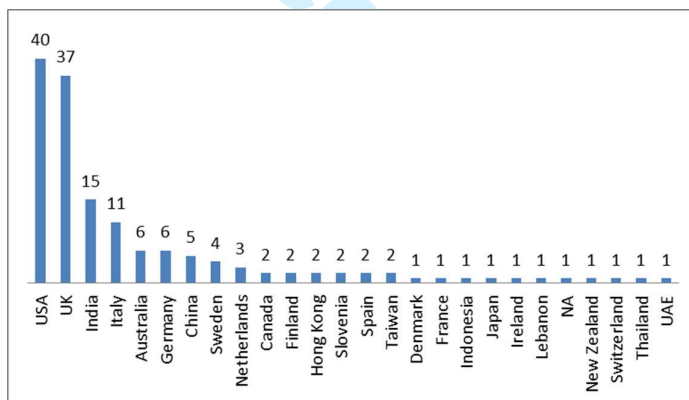


Figure 1: Geographical location of authors

It is nevertheless interesting that the research interest seems to outweigh particularly in the USA and in the UK, this may be also due to the globalisation and the impact on the particular country profiles (Kern et al., 2012). The majority of supply chain risk studies conducted did not entail an indication to country specific details, with a 56 per cent. In some of the studies the region has been mentioned, but no specific country context; Europe five times, consequently Asia, Asia Pacific, Europe, Middle East, North America. The SLR indicated a research profile that has been carried on geographically weighted in the UK and the USA. This may be also due to fact that cross comparisons across locations and geographically dispersed areas are difficult to conduct as Juttner (2005) stated it is not easy for an organization to assess and identify the likelihood of risks and their possible impact upon its operations, as it is rather complex and difficult task to carry out.

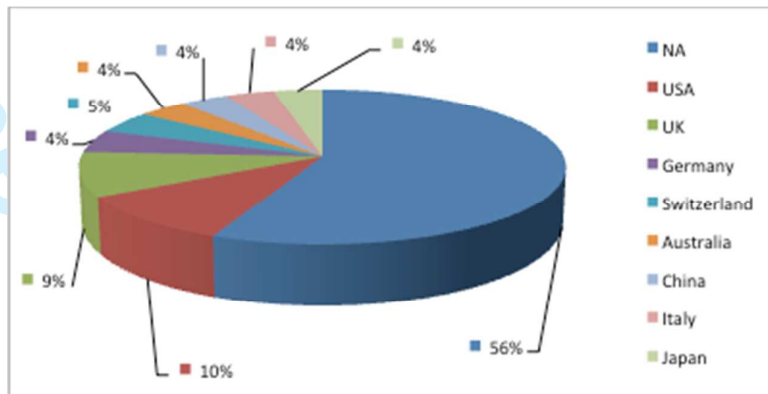


Figure 2: Location of studies undertaken

Some studies tried to overcome this challenge with a comparative risk profile, while providing a risk focal area, i.e. specific region (Lin and Zhou, 2011). Lin and Zhou (2011) also note that the risk may also correlate to the increased number of global customers outsourcing their products to China. Khan and Creazza (2009) research was carried in the UK and in one global organization. They reported within the risk strategies of one company entailed for volatile items the shift to cost neutral countries such as in this case Turkey, Spain and Italy and sourcing the basic common and stable products from China. Another study which was conducted in China has looked into the Chinese remanufacturing products in the automotive industry and addressed the purchasing risk involved (Wang et al. 2013). Another study carried out again by the same authors in 2009 looked into risk in relation with design centric supply chains based on three UK companies. In some cases leading these companies were ill prepared when it comes to termination looked into Slovenian outsourcing companies (Kavcic and Tavcar 2008, 2010). Faisal et al. (2006) in their work investigated three Indian SME clusters on risk and customer sensitivity dimensions and noted the importance of the outsourcing scope.

Supply chain risk in industrial context

Today's supply chain risk profile involves a multitude of levels involving a myriad of inter-organisational relationships within dynamic and complex context of globalization (Kern et al., 2012). The SCRM moved from traditional risk of product and services to future capabilities to broader scope entailing; the security of internal information systems, relationships between supply chain partners, the corporate

sustainability and liability (Spekman and Davies, 2004), design decisions (Khan and Creazze, 2009), loss of innovation and image (Cavinato, 2004). Specimen and Davis (2004) note that risk definition differs based on the discipline being queried, such as in the medical field to risk of dying from a disease, or in accountancy it may be at risk of having irregularities in audit data. When looked into the industry context of the papers we note that 20% of the papers are assigned to manufacturing industry without highlighting the particular industry, this may be due to the fact that manufacturing can entail a variety of industries from mining industry to third party logistics. However the next stand alone industry category was aerospace with 8%, followed by automotive with 7%, transportation and logistics, electronics by 7% and remainder with 4-5% of chemical products, textile and fashion, food, wood and timber and construction industry.

Industry Context		
Aerospace Industry	Poultry & Meat	Agricultural equipment
Automotive	Small medium enterprises	Defense
Transportation & Logistics	Telecommunication	Heating ventilating and air conditioning
Electronics	Paper and printing	Wine industry
Chemical products	Retailer	Public sector
Textile & Fashion industry	Computer*	Non-Government organizations
Food Industry**	Mining & Metal Industry	Outsourcing
Wood & Timber	Personal Computer Manufacturers	Packaged Food Industry
Construction Industry	Semiconductor	Pharmaceutical Industry
Journal articles	Slovenian outsourcing companies	Public Organization
Others		Rail

Table 3: Industries mentioned based on their occurrence in the journal papers

* Includes hardware and software

** Including Packaged food

Considering that risk evaluation can be inherently subjective, as it relies on the analyst observations on what constitutes inherent risk and what's not (Gaudenzi and Orghesi, 2006) lead to a widening gap between supply chain risk definition and its scope (Anderson et al. 2001). Hence, defining the risk is also closely interlinked with how the risk could be mitigated, for example, looking into the natural resource scarcity as one of the areas for supply chain risk, which natural resources are “earths’ natural occurring tangible, physical entities that can be considered assets for companies because of their inherent value” (Bell et al. 2013: 352). In their conceptual paper they highlighted a closed-loop supply chain as a means of managing the natural

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3 resource scarcity in supply chains considering the impact of the European legislation
4 on manufacturers to recover products as a means to avoid the landfills. Hence the
5 supply chain design to mitigate the risk of resource scarcity needs to include the risks
6 associated with returns and recycling.
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11 When looked into industry specific developments in the poultry and meat supply
12 chains Manning and Baines (2004:831) note “complete elimination of risk and
13 reduced to an acceptable level is not always possible especially in a livestock supply
14 chain”. Nijhoff-Savvaki et al. (2012) has looked specifically in pork supply chains in
15 the UK, Spain and Greece. The pork supply chain has a number of barriers which may
16 also contribute to risk; which are, lack of visibility of customer demand; weak
17 collaborative relationship; lack of trust and shared information. Another research into
18 a pork supply chain was conducted by Leat and Reveardo-Giha (2013) based on seven
19 senior managers highlighting some similar issues such as importance of supply chain
20 partners collaboration, however, they also highlight the need to design a supply chain
21 which incorporates resilience as well as development of risk management focus
22 within the supply chain. The supply chain risk in food, however, can stem from
23 different scenarios such as falling prices, oversupply, and weather conditions, etc.
24 (Grimmsdell, 1996) as well as political subsidies (Hamdar, 1999). Similarly, a study
25 conducted on 100 Australian SME wine supply chains reported to be unable to meet
26 the demand, unit price increase and the risk for non-supply (Aylward and Clements,
27 2008) as “both the grower and vinery take the majority of risk and receive
28 disproportionately small returns” (Alyward and Clements, 2008: 83). Finch
29 (2004:190) noted that large companies have to “comply with certain legal
30 requirements relating to risk, however this is not the case for SMEs” this also related
31 to the fact to what extent SMEs is ready to include the assessment of risk within their
32 supply chain context. Faisal et al. (2006, pp.889) in their work investigated three
33 Indian SME clusters on risk and customer sensitivity dimensions indicating that
34 “managing risks in supply chain require a lot of information sharing, close
35 relationship and on the partners, alignment of incentives and knowledge about risk”.
36 However, Christopher and Peck argue (2004:11) that there is a “requirement to create
37 a risk management culture within the business”. Ritchie and Brindleys’ (2000)
38 conceptual paper noted SMEs need to manage a multitude of different and interrelated
39 relationships across the supply chain.
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Although one way of reducing the supply chain risk has been seen as redesigning and designing the supply chain with risk in mind in other industries such as fashion, textile and manufacturing (Khan et al., 2008, Khan et al., 2008). The inherent supply chain risk may involve capital cost during the product deployment, process and also in positioning products in the market (Tang and Musa, 2011), which may differ in terms of the industry bound by its product and process design (Khan et al., 2008) and design related dimensions, of internal (R&D, production, plan, information, and organisation), and external (supply, policy and delivery) processes (Lin and Zhou, 2011).

Research methodologies applied

When assessed, the analysis indicated that case study and conceptual framework development seemed to be most often used reflecting the inherent complexity of supply chain risk as well as the multitude of supply chain risk avenues (Table 3). Case studies provide a good insight to supply chain risk when assessed, as it supported the analysis of wide ranging issues and its interlinkages into risk profile and tools, for example Rose-Anderssen et al. (2010) through a case study on aerospace industry were able to explore across USA, Japan and Europe. Ritchie and Brindley (2007) in the two case studies used the principal agent theory to investigate the interaction between performance and risk within the companies' supply chains. Similarly Cheng and Kam (2008) explored the sharing of risk benefits in supplies network collaborations. Khan and Creazza (2009) cross case analysis based on three UK based companies investigated how product design can be a tool for mitigating supply chain risk. In 2012 a case study on product design (Khan et al. 2012) highlighted managing product design as a significant tool for mitigating supply chain risk.

	Authors
Agency theory	Cheng and Kam (2008), Brindley and Ritchie (2007)
Bayesian Network Model	Li and Chandra (2007) , Lockamy and McCormack (2007)
Case study	Bloset al. (2009), Khan et al. (2008), Khan et al. (2012), Khan and Creaze (2009), Kumar et al. (2009), Ritchie and Brindley (2002), Shih and Wen (2005), Wai and Wongasurat (2013) Farooq (2012),Khan et al. (2008), Khan and Creaze (2009), (Khan et al. 2012), Lonsdale (199), Wild and Zhou (2007) Ganguly (2014) Gaudenzi and Borghesi Johnson et al. (2013) Juttner and Maklan (2012)Kayis and Karningsih (2012) Khan and Burnes (2007) Leat and Revoreda-Gida (2013) Micheli et al. (2008) Norrman and Jansson (2004) Peres and Grenouilleau (2002) Rose-Anderssen et al. (2010) Zsidin et al. (2004)

Cladistic approach	Rose-Anderssen et al. (2011)
Cluster Analysis	Childerhouse and Towill (2011),
Conceptual	Bell et al. (2013) Christopher and Peck (2004) Christopher and Lee (2004) Elahi (2013) Giunipero and Eltawy (2004) Hirschauer et al. (2012) Khan et al. (2008) Khan and Creaze (2009) Kolluru and Meredith (2001) Kumar et al. (2009) Lonsdale (1999) Manning and Baines (2004) Manuj and Mentzer (2008) Ritchie and Brindley (2002) Tse et al. (2011) Warren and Hutchinson (200)
Event Study	Papadakis (2003, 2006)
Focus Group	Sanchez-Rodrigues et al. (2010), Sinha et al. (2004),
Grid Technology	Pilgermann et al (2006)
Interpretive Structural Modelling	Faisal et al. (2016)
Interview	Ganguly (2014), Khan et al. (2012), Leat and Revoreda-Gida (2013), Manuj (2008), Kavcic and Bortenjfel (2012), Nijhoff-Savvaki et al. (2005), Peck (2005), Sinha et al. (2004), Zsidin et al. (2000)
Literature Review	Liu et al. (2010), Manuj and Mentzer (2008), Olson and Wu (2010), Rao and Goldsby (2009), Williams et al. (2008)
Modelling and Simulation	Pfohl and Gallus (2011), Pujavan and Gerdaldin (2009), Shin et al. (2012), Soni and Kodali (2013), Wieland (2013)
Monte Carlo Simulation	Adenso-Diaz (2012)
NA	Bell et al. (2013) Christopher and Peck (2004) Christopher and Lee (2004) Elahi (2013) Giunipero and Eltawy (2004) Hirschauer et al. (2012) Khan et al. (2008) Khan and Creaze (2009) Kolluru and Meredith (2001) Kumar et al. (2009) Lonsdale (1999) Manning and Baines (2004) Manuj and Mentzer (2008) Ritchie and Brindley (2002) Tse et al. (2011) Warren and Hutchinson (200)
Qualitative	Lemke and Petersen (2013)
Questionnaire and Survey	Blos et al. (2009), Elangowan et al. (2010), Kavcic and Tavcar (2008), Zhao et al. (2013), Yeh (2005), Aylward and Clements (2008), Juttner (2005), Laeequddin et al. (2009), Lockamy and McCormack (2012), Svensson (2004), Wieland and Wallenburg (2013), Wiengarten et al. (2013), Zelbst et al. (2009)
Secondary Research	Ekwall and Lantz (2013), Aloini et al. (2012) Colicchia and Strozzi (2012) Ghadge et al. (2012, 2013) Olson and Wu (2010) Rao and Goldsby (2009) Williams et al. (2008)
Simulation	Ghadge et al. (2013), Olson and Wu (2011), Towill (2005)
Structural Equation Modelling	Wieland and Wallenburg (2012)

Table 3: Research methods mentioned in the journal papers

In order to provide a wider picture of supply chain risk and how it could be approached, the second most utilised method has been the development of conceptual models and frameworks. Tse et al. (2011) for example created a conceptual framework for mitigating quality risk, in assessing the inherent supply chain risk behind the recent product recall due to the global supply chain vulnerabilities. Their study highlighted the importance of supply chain visibility and strategic supply management in a multilayered supply chain. Nooraie and Parast (2015:192) noted that “many situations that could lead to disruptions in the supply chain can be identified and defused long before they reach a critical state”, hence highlighted the importance of modeling. Jia and Rutherford (2010) in their conceptual paper looked into the cultural inferences between China and West and evaluated the causal relationship

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3 between adaptation based on culture and partnership performance to define the supply
4 chain relational risk SCRR). Another conceptual paper by Elahi (2012) identified four
5 types of risk; rewarded risks, anti-disruptive risks, disruptive risks, unrewarded risks.
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7 However, Elahi (2012:120) noted that also, that “dealing with risk is not the
8 responsibility of a limited number of employees and managers, [rather] it should be
9 throughout the company”. Ponomorov and Holcomb (2009) introduced a conceptual
10 framework of the relationship between logistics capabilities in supply chain assessing
11 supply chain resilience, based on supply chain risk sharing. However Wieland and
12 Wallenburg (2013) findings indicated that supply chain integration has a rather
13 limited role in enhancing resilience. Looking at the studies all conceptual papers
14 iterated the absence of conceptual models developed within the supply chain arena.
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23 Another method to evaluate the potential supply chain risk and its impact, modeling
24 has been used throughout the studies. For example, in their work, Ganguly and Guin
25 (2013) highlighted the need for quantification of risk, and the use of mathematical
26 modeling as a tool for establishing the link between objectives and risk indicators, in
27 order to mitigate the potential risk. In their research to assess the inbound supply
28 chain risk they applied the Analytical Hierarchy Process (AHP) involving the
29 decomposition of supply chain risk areas including pairwise comparisons and use of
30 priority vector. Similarly, Gaudenzi and Borghesi (2006) found AHP to be useful
31 when prioritizing the risk within their model. This has also been an important part of
32 the evaluation, as risk evaluation can be subjective, as each party, an individual may
33 have different views on what constitutes risk or not (Gaudenzi and Borghesi, 2006).
34 Pujavan and Geraldin (2009) created a similar work to House of Quality and termed it
35 House of Risk wherein a first stage the risk are ranked and second stage the aggregate
36 risk prioritized for action. For illustration a public organization case study has been
37 included and the effectiveness of the framework has been discussed. Faisal et al.
38 (2006, 2007) in their study utilised interpretive (ISM) to understand the
39 interrelationships among the enablers of risk mitigation, they have utilised 12
40 variables for modelling the information risk. Pfohl et al. (2011) note that ISM proved
41 to be a useful methodology to structure supply chain risk. It seems from the findings
42 that supply chain risk modeling is used to explain the risk, however in most studies
43 they have been accompanied by other methods, partially to provide an
44 implementation context in some cases.
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5 Other methods that have been utilized and would benefit from mentioning are; DEA
6 simulation model and also a Monte Carlo Simulation, for example Olson and Wu
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8 (2011) analysed the outsourcing risk based on using a risk adjusted cost concept.
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10 According to the authors, the DEA method helps the buyer in supplier classifications
11 into two categories: the efficient suppliers and the inefficient suppliers. From the
12 consumer's viewpoint perceived risk in connection with remanufactured products has
13 been looked in an empirical study by Wang et al. (2013) in the Chinese automotive
14 spare parts industry which involved 288 respondents using structural equation
15 modelling. The findings iterated that perceive risk was jointly influenced by physical
16 risk, performance risk, financial risk, time risk, resource risk, social risk and product
17 knowledge. Another empirical testing based on structural equation modelling
18 completed by Yeh (2005) included 851 raw material and spare parts suppliers for the
19 Taiwanese motor industry. His research has indicated that there is a positive
20 relationship between resource dependence, trust and relationship commitment and
21 electronic supply chain relationship and a negative relationship to risk in the presence
22 of cooperative electronic relationship. Lockamy and McCormack (2012) presented
23 another modelling effort was done conducting the Bayesian networks on 15 casting
24 suppliers in the US. Their research indicated that Bayesian networks can be used to
25 develop supplier risk profiles to assess the suppliers potential risk exposure. Wieland
26 and Wallenburg (2013) through data collected from three countries, Germany, Austria
27 and Switzerland based on 270 returned responses run a structural equation modeling,
28 which resulted with positive effect of communication and cooperative relationship
29 upon resilience, and integration rather has a limited role in enhancing resilience.
30 Although not a study on supply chain, risk mitigation was introduced by eight step
31 simulation model development process by Manuj et al. (2009) in order to create a
32 more rigorous simulation modeling in the supply chain.
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49 *Developing Supply chain risk assessment tools*

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51 It was interesting to observe that several studies attempted conceptual frameworks to
52 evaluate the supply chain risk, to overcome the lack of supply chain wide risk
53 assessment tools. The frameworks and tools moved from a generic supply chain wide
54 frameworks to a specific industry and case based examples, which indicates the areas
55 for future developments. For example, Farooq and O'Brien (2010) created a
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3 technology selection framework investigating manufacturing environment, supply
4 chain environment and general environment. Whereas, the manufacturing
5 environment was interpreted in Svensson (2004) study into vulnerability and the
6 differences between upstream and downstream supply chains based on 215 executives
7 subcontractors in the Swedish automotive industry Another study by Johnson et al.
8 (2013) investigated in a specific setting, namely Network Rail, found that there is a
9 high level of trust within the contractual network, even in crisis, there was evidence of
10 willingness to work without formal contracts in place, showing that frameworks and
11 tools can be also created informally during a specific need or emergency.
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20 We see that supply chain risk identification system (SCRIS) have been used that is
21 based upon causal and hierarchical structure in which the “causal interrelationships
22 between risk sub-factors, risk factors and risk events which correspondents to IF-
23 THEN statements” (Kayis and Karningsih, 2012:841). Stonebaker et al. (2009)
24 created a fragility index including internal (such as product design, logistics,
25 information systems, people, supplier and market); external (such as Government,
26 Competition, Economic/Financial, Environment) and random factors (such as acts of
27 nature, culture/time/language, war/error/piracy, and corruption). As supply chains are
28 getting more complex with high level of interdependency. We see this also evidenced
29 in the application as similar integral supplier risk assessment has taken place in the
30 USA The Defense Contract Agency (DCMA) with a risk rating for suppliers in the
31 three key areas; performance, schedule and cost (Zsidin et al., 2004). Also
32 department for transport (DFT) in England indicated that traditional risk assessment
33 tools were used in supply chains with the exception of six sigma; which are
34 brainstorming, process mapping, risk likelihood /impact analysis and scenario
35 planning (Juttner, 2005). However, Ganguly (2014) noted that when categorizing
36 supply chain risk and creating a portfolio of risk assessment the inability to
37 incorporate all relevant risks into the model” may be problematic and potentially limit
38 its effectiveness (Gangully, 2014: 98).
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52 53 *An evaluation of the supply chain risk impact areas*

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55 Based on the SLR there seems to be a wide ranging supply chain risk impact starting
56 from initial raw material supplier to the end customer, including but not limited to,
57 intangible impact areas, such as trust, confidentiality. One of the research papers
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3 which looked into collaboration in the aerospace industry explored the risk impact
4 based on risk-sharing partnerships, they found that reliance in supply chains
5 contributed to risk mitigation (Rose-Anderssen et al. 2011). Earlier, in 2007, a risk
6 performance study found that one of the companies sought to manage risk through
7 good communication, close collaboration and building trust within the supply chain
8 (Ritchie and Brindley, 2007). Collaboration has been also assessed by Cheng and
9 Kam (2008) in the so called “risk footprint” as important to understand any SC risk
10 impact and its flow throughout the supply chain. However, Yeh (2012) noted that the
11 cooperation between the parties are affected if the risk perceptions acceptable by
12 either partner.
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21 Supply chain risk can be also seen as an output of product design, and internal and
22 external operations (Lin and Zhou 2011). As evidenced in the case of Western
23 Digitals 46 day recovery from the Thai flood disaster, the rapid comeback was
24 possible due to the strong cash position, stakeholders support and supply mitigation
25 (Wa and Wongsuwarat, 2013). An aerospace research conducted by Pérès and
26 Grenouilleau (2002) proposed a method based on minimisation of a maintenance
27 operation to reduce the residual risk. In order to overcome the SCRM challenges,
28 Khan and Creazza (2009) highlighted to evaluate most common risk issues, which
29 were capacity, planning and production; reaction to the changes in production
30 schedules; as well as quality of supplies. In their research one of the companies to
31 overcome the associated risk decided to procure one of the volatile items nearer to
32 cost neutral countries. This is an interesting work which incorporated the concept of
33 risk aversion in the supplier selection process and its implications upon the
34 manufacturing environment; supply chain environment and general environment.
35 Papadakis (2003, 2006) introduced the notion that after a short period of supply
36 disruption (the so-called event window) the normal stock behavior does not take place
37 as it is reasonable to assume that the disruption may impact the supply chain and
38 hence the company’s stock prices. However, their study calculated the supply chain
39 disruption impact might vary between the pull and push systems.
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54 One of the areas, which is often overlooked in the supply chain context is the
55 reputational risk management in supply chains (Lemke and Petersen, 2013). Juttner’s
56 (2005) research indicated at the philosophical level to underpinnings; one the need for
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openness to share risk related information and the other to accept the supply chain wide risk as a joint risk. The joint risk and interlinkage of the risks have been also highlighted in Manuj and Metzger's work (2008) wherein the global supply risk has been seen as different to domestic one, one that linked to each other in a complex pattern with an increasing unpredictability and impact. In managing the global supply chain risk, their model highlighted three elements; (1) supply risk; (2) demand risk; and (3) operational risk and in an environment which entails other risk. When looked into industry specific needs the authors Manning and Baines (2004) suggest that in order to deal with the risk is to accept the risk; to transfer it to a third party or subcontract via insurance or risk sharing provisions, and reduce manage by adopting an exit strategy. The studies on supply chain risk and how it is mitigated rather proposes the use of modularisation of a product as a risk aversion strategy.

Supply chain risk categories

The literature review indicates different sources of supply chain risk and suggest that supply chain risk transforms over time. Hence, the initial relations throughout the supply chain may differ based on the supply chain structure and supply chain complexity. The research themes indicates a focus upon four consistent supply chain research themes as shown below in Figure 3.

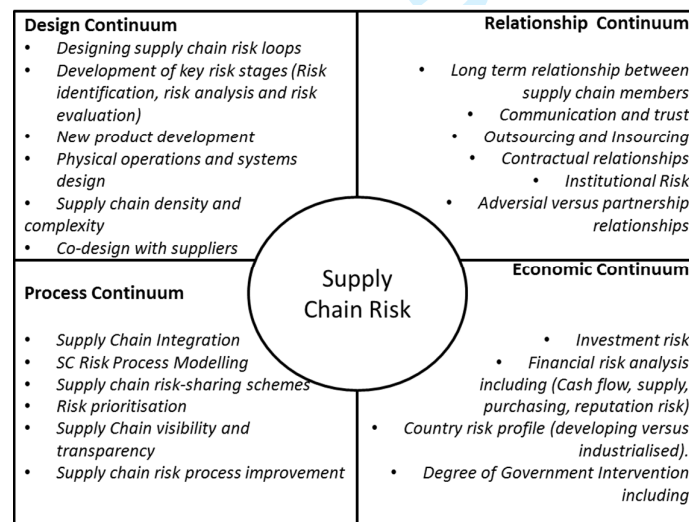


Figure 3: Supply Chain Risk categories based on continuous themes

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3 The themes in the SLR revolved around four supply chain risk continuum in the
4 management area, including the design, relationship, economic and process
5 continuum.
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10 *The design continuum*, refers to how supply chain risk can be included at the
11 initiation/design stage, such as the discussion of design led manufacturing (Khan et al,
12 2008; Manuj et al. 2014) including the physical design of supply chain (i.e. store
13 layout, plant planning, inventory management) (Christopher and Creazza, 2012). This
14 point echoed by Craighead et al. (2007) who indicated that the supply chain risk can
15 be designed with the understanding of supply chain density and level of supply chain
16 complexity, which may range between supply chain members and the extended
17 supply chain network. However, Micheli et al. (2008) addressed the importance of
18 focal points, such as the dyadic co-design with suppliers, which may be also a source
19 of competitive advantage as well as a strategy for supply chain risk mitigation.
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28 *The relationship continuum*, looking into the aspect of relationships between supply
29 chain members the implication of associated risk, studies revolved around either on a
30 particular dyad (i.e. supplier-buyer relationship) (Jia and Rutherford, 2010; Johnson et
31 al, 2013) or characteristics of supply chain relationship (i.e. Long term relationship
32 between supply chain members and its impact on supply chain risk) (Khan and
33 Burnes, 2007; Jia and Rutherford, 2010). Kavcar and Tavcic (2008) in their work
34 highlighted the high supply chain risk in the context of outsourcing and also
35 insourcing, and discussed how the setting of contractual relationships may present
36 itself as a supply chain risk mitigation strategy (Kavcar and Tavcic, 2008; Liu et al,
37 2010; Rose-Anderson et al, 2010. Svenson, 2004). However, in some cases the
38 institutional risk may be high (Laequiddin et al, 2009), and sometimes context
39 specific to companies residence and regulations that underpin the relationships
40 (Nijhoff-Savvaki et al. 2012). To overcome regulatory and context specific
41 challenges it is important to create the understanding of the relationship type, i.e.
42 adversarial versus partnership relationships (Ritchie and Brindley, 2007; Kavcar and
43 Tavcic, 2008; Kolluru and Meredith, 2001; Rose-Anderson et al, 2010). Hence, it is
44 important to understand the process continuum.
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3 *The process continuum*, involves the processes necessary to identify, assess and
4 mitigate the supply chain risk. The studies in this research agenda indicated a wide
5 array of issues in relevance to processes, for example the discussion of integration,
6 whether the supply chain risk process would involve a vertical or horizontal
7 integration (Leat and Revaedo-Gida, 2013). However, the extended supply chain
8 network included also a discussion of modular process applications (Pilgerman et al,
9 2006) as these may be able to pinpoint to the supply chain risk area more precisely.
10 One way to reduce the burden of the supply chain risk processes is to establish risk
11 sharing partnerships, to create risk mitigation processes together with the supply chain
12 members which is mutually inclusive (Rose-Anderson et al. 2011). To understand the
13 potential supply chain process risk, several studies included the use of modelling and
14 simulation (Pfohl and Gallus 2011; Pujavan and Geraldin, 2009; Shin et al. 2012;
15 Soni and Kodali, 2013; Wieland, 2013). However, although the supply chain risk
16 processes can be identified and measured, due to its complex nature the processes that
17 are involved needs to be prioritised in terms of the likelihood and if-when scenarios
18 (Punniyamoorthy et al. 2013). A step further would be creating system integration
19 which would enhance the risk visibility and transparency across the supply chain (Tse
20 et al. 2010; Butner, 2010, Christopher, 2004). However the supply chain risk process
21 identification and definition is an ongoing process which may change over time, i.e. a
22 potential risk may not be a risk in the future due to new product or process
23 development, hence supply chain risk process improvement is one of the areas
24 highlighted in the literature (Zsidin, 2004).
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41 *The economic continuum* includes the risk assessment and its relevance to the
42 economic area involving the discussion of investment risk, not only for the
43 manufacturing company and supply chain processes but also investment risk for supply
44 chain risk mitigation. As Zsidin noted (2010) risk assessment and measurement may
45 be difficult to quantify where the risk never materializes, making any investment in
46 supply chain risk prevention difficult to justify, whereby economic estimates becomes
47 important to note (Dynes et al, 2007). Hoffmann (2011) highlights that financial risk
48 analysis may indicate also the need for hedging for raw materials to overcome the
49 potential price fluctuations of currency and commodity prices. Also the
50 understanding of suppliers financial analysis may help to reduce the supplier risk
51 (Cavinato, 2004) . The degree of government intervention based on regulation and
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3 investments may shape the supply chain risk such as political subsidies (Hamdar,
4 1999), leading to falling prices, oversupply etc. (Grimmsdell, 1996). Whereby, Finch
5 (2004:190) noted that in some government regulations large companies to “comply
6 with certain legal requirements relating to risk”, whereas in some countries risk may
7 be seen as the country profile (Laequiddin et al. 2009)
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13 This research agenda has the potential to offer new insights into the points for supply
14 chain risk assessment, which are design continuum and relationship continuum,
15 process continuum, and economic continuum relevant to the supply chain risk
16 initiation and assessment. This is supported by recognition that, whilst the economic
17 and supply chain implication of supply chain risk is attracting growing policy,
18 academic, and media interest, comparatively little is known about the time level
19 processes upon which supply chain risk is handled. This problem has been
20 exacerbated by a lack of understanding concerning the relationships continuum and
21 the involvement of stakeholders in supply chain risk.
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29 **Discussion and Conclusion**

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31 The current study serves as the first step towards understanding the supply chain risk
32 categories, connotations and context. Thereby this research represents a first attempt
33 toward the mapping of supply chain risk management literature. The structured
34 literature review assisted in the identification and development of categories that
35 made up the current supply chain risk literature comprising of tools used, location
36 and research methods undertaken. Based on the structured literature review, we have
37 identified four undervalued themes in the literature.
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- 43 • As stated by Hofmann (2012:138) although concrete risk management
44 strategies are needed to evaluate the risk, it is nevertheless a “long-term plan
45 and cannot be made from one day to the next”. The lack of availability of
46 longitudinal studies in the supply chain risk area, makes it difficult for the
47 researchers to build up a coherent research risk profile and changing risk
48 management strategies over the years.
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- 50 • Secondly, although a number of authors looked into what constitutes supply
51 chain risk and its impact areas, such as Zsidin et al. (2000) defining inbound
52 supply chain risk six dimensions; business risks, supplier capacity constraints,
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3 quality, production technological changes, and product design change and
4 disaster in the context of nine manufacturing companies, and Tummola and
5 Schoenherr (2011) evaluating phases of risk identification, risk measurement
6 and assessment, risk evaluation, risk mitigation and contingency planning, and
7 risk control and monitoring, nevertheless there is lack of comparative case
8 studies evaluating the impact of business processes management based on
9 product types and supply chain structures upon the supply chain risk.

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15 • The four categories including economic continuum, relationship continuum,
16 design and process continuum highlighted the themes occurring in the supply
17 chain risk area, however the interlinkage of these themes have not been
18 developed at this stage, a further study is needed to develop it further.
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22 • Finally, although categories of the literature review indicated that most supply
23 chain risk studies were located in a specific location and region (in this case,
24 UK, US, America and Europe) there is further research needed evaluating the
25 different country settings and associated impact upon supply chain risk
26 profiles. However, bearing in mind that global supply chains are complex,
27 lengthy and distanced from their markets, supply chains are forced to find
28 ways to be responsive on how to manage the risks (Khan and Creazza, 2009;
29 Wieland and Wallenburg, 2012) which may be different to each other when
30 compared.

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38 Nevertheless the categories established in this study can bring a new perspective and
39 angle for further research in the supply chain area and how these can be mitigated
40 through business processes. Hence, comparative studies are needed to further evaluate
41 and analyse the nuances between the different supply chain context and scope.

42 43 44 45 46 **Implications and further research**

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48 This paper highlights the significant role that supply chain risk plays within the
49 management literature context. The literature review highlighted the importance of
50 understanding the supply chain risk management and the role supply chain members,
51 its processes and resources as the key aspects. Further research in this vein should
52 improve the understanding of the strategic supply chain risk, whilst identifying how
53 supply chain members interact and collaborate, which resources are required and to
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3 what extent the network of supply chain relationships are needed to mitigate the
4 supply chain risk in the long run.
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8 Acknowledging that the work in this stage is indicative and relates to management of
9 supply chain risk, further conceptual studies are could for to assist beyond the
10 development of four categories of supply chain risk, or how they relate to
11 organisations. The lack of longitudinal studies also addresses that it can aid
12 understanding the developmental aspect of supply chain risk management and the
13 shifting role in mitigating, assessing the risk, which will inform a richer
14 understanding of the supply chain risk management practices.
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