Managing Upstream Environmental Risk and Uncertainty in the Global Automotive Supply Chain

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Thesis Summary

Managing risk in supply chains has emerged as an important topic in contemporary supply chain management theory and practice. This is due to a number of trends, including increased globalisation of markets, creating more complex supply networks and a move towards 'leaner', more efficient supply chain operation generally. Whilst these trends have undoubtedly produced significant benefits in terms of productivity and profitability, for many organisations, they have also increased susceptibility to disruption. It is generally accepted that risk can be segmented into those which are internal to the organisation or its supply chain, operational risks (commonly referred to as supply, process and demand risks) and those which are external to the organisation and its supply chain, corporate-level disruption risks. The vulnerability of global supply chains to external risk of this nature has been catapulted in to the spotlight in recent years, following a number of high-profile events including, the financial crises in North America, Europe and Australia (2007-08), the Chao Phraya river floods in Thailand (2011) and the Tōhoku Earthquake/ Tsunami in Japan (2012), amongst many others. Whilst there is a broad and growing body of literature around supply chain risk management (SCRM) generally, focus on understanding and building supply chain resiliency to the impact of corporate-level disruption risk at a strategic level remains an area of the field in its relative infancy.

Following an extensive review of the SCRM literature, a demonstrable research gap was highlighted for more in-depth analysis of organisations that are taking steps to manage supply chain risk, especially corporate-level disruption risk. In addressing this gap, the current research adopts an applied case study methodology to assess how a leading automotive manufacturer strategically approaches supply chain risk management, gaining an understanding of how and why traditional processes are evolving to manage corporate-level disruption risk (Case Study 1). Organisational SCRM strategy, including mitigation and response processes, are critically discussed in relation to the literature. The study finds that, whilst proactive strategy is employed for operational risk within the organisation's control, a lack of upstream supply chain visibility inhibits initiatives to mitigate the impact of corporate-level disruption risk within the extended upstream supply chain. The study is set against a background of significant regulatory drivers forcing organisations to increase upstream supply chain visibility. These are critically reviewed, including how the focal organisation is responding to them through a collaborative supply chain mapping initiative.

Building upon findings from Case Study 1, the research presents a conceptual 'stakeholder salience' framework, exploring how increased visibility might be used to better assess susceptibility to corporate-level supply chain disruption risk (Case study 2). This framework is empirically explored using an example of a 'critical' automotive component supply chain – the Lithium-ion battery cell. It applies a combination of upstream geographic supply chain mapping data with weighted geo-political, economic and environmental indicators, in a GIS environment, to assess stakeholder salience amongst suppliers. The study highlights the significant susceptibility of supply chains to corporate-level risk beyond lower tiers and argues that through better understanding of where key hotspots lie, limited resources can be more appropriately targeted onto the mitigation and strategic management of risk within those areas.

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1   Chapter 1 – Introduction

1.1   Research Background

The field of Supply Chain Risk Management (SCRM) has developed significantly over recent years and is now an important contributor to most fields of management decision and control (Christopher et al., 2011). Supply chain risk can be segmented into those risks which are internal to the organisation or its supply chain, operational risks (commonly referred to as supply, process and demand risks) and those which are external to the organisation and its supply chain (corporate-level disruption risks). In other words, as Kleindorfer and Saad (2005, p. 53) assert, 'these two categories can be distinguished as risk that arises from problems in the co-ordination of supply and demand and risk arising from a disruption to normal activities'.

In the UK, businesses increasingly operate as part of the global economy and are heavily reliant on goods and services supplied by overseas markets. A recent report by the Committee on Climate Change Adaption Sub Group (2014), found that the value of UK imports has risen from £149 billion in 1990 to £527 billion in 2012. Supply chain globalisation has produced significant benefits in terms of productivity and profitability. However, combined with 'leaner' supply chain operation, increased supply chain complexity and the move away from a 'safety stock' culture, this also leaves businesses more susceptible to unanticipated corporate-level disruption (Thun and Hoenig, 2011, Tang and Tomlin, 2008, Haraguchi and Lall, 2012, Saenz and Revilla, 2014), often with significant fiscal and operational impacts (Hendricks and Singai 2005, CCC, 2014). External risks which are not within the immediate operational control of an organisation, but can have a significant direct impact on the supply chain, can be separated out in to three groups: 1) geo-political, 2) economic and 3) environmental. These groupings, which will be discussed in more detail later in this thesis and are in keeping with joint industry/ academically led work undertaken by the World Economic Forum (WEF) to identify new models for 'Addressing Supply Chain Risk' (2012) and also the WEF's wider 'Global Risk Report' (2013).

The vulnerability of global supply chains to external corporate-level disruption risks of this nature, has been catapulted in to the spotlight in recent years following a number of high

profile events, including: the financial crises in North America, Europe and Australia (2007-08), the Indian Ocean Tsunami (2004), the 9/11 terrorist attacks (2001), the SARS virus outbreak in China (2002-04), the Japanese Earthquake/ Tsunami (2012), the Gulf of Mexico oil spill (2010) and the Chao Phraya river floods in Thailand (2011).

As organisational executives become increasingly concerned about the increase in supply chain risk, practitioner interest in the area has increased significantly. This is evidenced by the number of SCRM reports that have been published by major consultancies in recent years, see for example Deloitte's 'The Ripple Effect' (2012), Price Waterhouse Cooper/ MIT Forum's joint report on 'Supply Chain Innovation and Risk' (2013) or Mckinsey and Company's 'Building the Supply Chain of the Future' report (2011). In parallel, the academic literature in the area of SCRM has expanded significantly in recent years with comprehensive texts on the subject including, Zsidisin and Ritchie (2008), Wu and Blackhurst (2009) and Sodhi and Tang (2012), as well as a number of special issues and literature reviews (Ritchie and Brindley, 2007, Narasimhan and Talluri, 2009 or Tang, 2006).

Whilst there is a broad and growing body of literature around SCRM generally, focus on building supply chain resiliency to the impact of corporate-level disruption risk at a strategic level remains an area of the field in its relative infancy (Pereira et al, 2014, Sodhi and Tang, 2012). Moreover, in an applied sense, it is clear that whilst most managers know that they should protect their supply chains from serious and costly disruptions, comparatively few take sufficient action (Chopra and Sodhi, 2014). In other words, while many managers appreciate the impact of supply chain disruptions, they have done very little to prevent such incidents or mitigate their impacts (Tang, 2006, Saenz and Revilla, 2014). There are two broad reasons for this highlighted in the literature. Firstly, developing and implementing strategies to address corporate-level disruption risks is often seen as financially and resource intensive for organisations, undermining efforts to improve supply chain cost efficiency (Chopra and Sodhi, 2014). Thereby necessitating the building of more targeted strategic SCRM processes, which don't sacrifice the hard-earned gains in financial performance achieved through existing 'lean' efficiency practices. Secondly, the literature suggests that supply chain disruptions are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of the chain. A lack of upstream supply chain visibility inhibits managerial ability

to understand, even at a basic level, how susceptible their upstream supply chain is to various corporate-level disruption risks (Colicchia and Strozzi, 2012). This issue is especially pertinent at present, given a number of recent social and environmental regulatory developments that are driving companies to increase transparency of their upstream supply chain, creating significant SCRM opportunities.

1.2   Research Gaps

Following a critical exploration of the current SCRM literature, this doctoral thesis explores how a leading automotive organisation strategically approaches corporate-level disruption SCRM and how this fits in to established SCRM practices. Using a real-world example of a 'critical' component supply chain (the Li-ion battery), the research then seeks to develop a conceptual framework for how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk.

The research contributes to the field in addressing a number of identified knowledge gaps in the academic literature, including:

- The demonstrable need for best practice case studies of companies that are taking steps to proactively manage supply chain risk, especially corporate-level disruption risk.
- Understanding why disruption risk often remains unaddressed by many organisations.
- That many organisations do not understand the complexities of their upstream supply chain where disruption risks are most likely to occur.
- That the value of proactive and holistic approaches to managing supply chain risk in this area remains largely unexplored, especially from an applied perspective.
- A need to understand the legislative and regulatory drivers are forcing organisations to increase upstream supply chain visibility which provides significant opportunities for SCRM.
- The call for development of understanding around more targeted approaches to the management of upstream corporate-level supply chain risk.

1.3 Importance of the Automotive Sector

As highlighted above, the focus of the current research is a multinational automotive manufacturer. For reasons of confidentiality, the manufacturer has chosen to remain anonymous. However, in order to provide context and enable potential future comparison with similarly sized organisations, there seems merit in providing a brief overview of the organisation's scale and capability. The focal organisation is a volume car manufacturer whose principle operation involves the design, development, manufacture and marketing of consumer vehicles. The organisation employs staff split between several sites and its primary markets are Europe, the US and more recently China.

It is acknowledged in the literature that SCRM varies across industries with some more prepared than others (CCC, 2014). In recent years, the automotive sector is generally accepted to have been impacted more significantly than others by many of the disruption events discussed above and as a result, SCRM has become an important debate within the industry, making this a particularly relevant sector to focus the current research on. Automotive manufacturing is a fundamental part of the economy, with an annual turnover of £60bn in the UK, accounting for two thirds of overall manufacturing turnover (SMMT, 2014). As the 4th largest automotive sector in Europe (OICA, 2013), the industry employs more than 700,000 people contributing to the production of 1.5 million vehicles and 2.5 million engines per annum. Current forecasts suggest manufacturers will break record volumes in the coming years (SMMT, 2014). One of the driving forces of increased competitive advantage for the UK industry stems from its expertise in the area of low carbon technologies. The next 20 years will see over £150bn of investment in low carbon vehicle technologies, with the UK government having committed more than £450m of initial funding in developing the UK's position to take advantage of this (BIS, 2014).

From a supply chain perspective, the UK alone has 2,350 companies who regard themselves as 'automotive' suppliers (SMMT, 2014). However, these companies are usually lower tier suppliers and volume manufacturers remain heavily reliant upon a complex global supply chain for the majority of their production needs. The susceptibility of the global automotive supply chain to disruption risk has been clearly evidenced in recent years through the events discussed above, bringing the management of automotive supply chain risk in to the spotlight.

1.4   Aims and Objectives of the Research

Through applied case study analysis, the aim of this doctoral thesis is to gain an in-depth understanding of strategic approaches to SCRM within a leading automotive manufacturer, gaining an understanding of how and why traditional processes are evolving to manage corporate-level disruption risks (Case Study 1). Building upon this and set against a background of significant regulatory drivers for increasing organisational transparency, the research then seeks to develop a conceptual framework for how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk (Case study 2). In order to do this a real-world 'critical' component supply chain is used, the Li-ion battery.

In order to ensure this aim is achieved, four research objectives are identified. These are to:

O_1) Review key drivers increasing the susceptibility to corporate-level disruption risk within UK organisation's supply chains and critically analyse the latest SCRM literature in this area.

O_2) Assess how a leading automotive manufacturer currently manages corporate level disruption risk within its immediate supply chain partners (T1) and attitudes toward increasing supply chain visibility beyond this.

O_3) Review legislative and policy drivers placing pressure on organisations to increase upstream supply chain visibility.

O_4) Propose a framework for how increased visibility might be used to better target mitigation strategies for corporate-level supply chain disruption risk and test this using the Li-ion battery supply chain (as an example of new technology exposing automotive manufacturers to new risks) in this area.

1.5   Thesis Structure

The current chapter, *Chapter 1*, is intended to provide a broad overview of this doctoral research. It presents the aims and objectives of the research, as well as the thesis structure (Figure 1-1) and broad context of the work.

The structure of the thesis for the remaining chapters will be as follows. *Chapter 2* presents an exploration of both the academic and wider literature relevant to the aforementioned aims and objectives of this research. It begins with a brief background to the field of SCRM generally, before moving on to critically assess some of the key drivers increasing organisational and academic focus upon the risks associated with external disruption to the upstream supply chain. Following this, an academic review is undertaken of the SCRM process literature, before finally considering stakeholder theory as an appropriate organisational lens with which to develop a conceptual framework for improved assessment and management techniques.

Chapter 3 provides an overview of the methodological paradigms and process that have helped to meet the aims of this research, the research design. The chapter provides justification of the selection of a hybridised research approach in the development of two applied case studies, including semi-structured interviews with the focal firm and its supply chain partners, analysis of internal organisational documentation, supply chain mapping, and quantitative analysis of weighted corporate-level disruption risk metrics using Geographic Information System Software.

Chapter 4 presents the findings and analysis of case study 1 of this research. It draws on semi-structured interviews with experts in the selected vehicle manufacturer, as well as collation and analysis of a range of internal organisational reports, presentations and other documents. The primary focus of this applied case study is to understand how a leading automotive manufacturer is currently engaging with SCRM, gaining a specific understanding of how and why traditional processes are evolving to better manage corporate-level disruption risks. These findings are then critically assessed in relation to the SCRM literature discussed in Chapter 2.

Chapter 5 presents the findings and analysis of Case study 2 of this research. Building upon the findings of Case Study 1, this utilises a number of research methods, as it seeks to explore some of the key questions around how increased supply chain visibility can be used to improve the identification and assessment of external, corporate-level disruption risks within the upstream supply chain, including semi-structured interviews with supply chain partners and analysis of organisational documents in order to map the supply chains of two Li-ion battery chemistries. The case study also adopts more quantitative methods, in the exploration of a conceptual framework, to proactively identify potential hotspots of risk and explore the potential of strengthened stakeholder resource targeting in strategic risk mitigation efforts beyond tier 1. This approach combines upstream geographic supply chain data with weighted governance, economic and environmental indicators for the two example supply chains.

Finally, ***Chapter 6*** provides an overview of the key conclusions of this research, contributions to both academic literature and management practice, limitations of the research and potential directions for future work in this area.

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Figure 1-1: Structural Overview of the Doctoral Thesis and Fit with Objectives

2   Chapter 2 - Literature Review

2.1   Introduction

This chapter presents an exploration of both the academic and wider literature relevant to the aforementioned aims and objectives of this research. It begins with a brief background to the field of Supply Chain Risk Management generally, before moving on to critically assess some of the key drivers increasing organisational and academic focus upon the risks associated with external disruption to the upstream supply chain, termed corporate-level disruption risks.

Following this, an academic review is undertaken of the Supply Chain Risk Management (SCRM) process literature, with emphasis being placed upon the strategic identification, assessment and mitigation of external corporate-level disruption risks. It is noted that there is a lack of 'real-world', in-depth case studies in the literature examining how organisations are starting to engage with this area (in the light of a number of drivers requiring increased supply chain visibility), how this fits with established SCRM practices and overall fit with more theoretical SCRM literature. *This underpins the development of Case Study 1.*

A clear need for improved strategic management of these risks throughout the upstream supply chain is also highlighted, as well as some of the misconceptions and organisational difficulties associated with implementing them, often associated with a lack of visibility. To this end, consideration is given to the use of Stakeholder Theory as an appropriate organisational lens with which to develop a conceptual framework for improved assessment and management techniques of these types of risk and the relevant literature is critically reviewed. *This underpins the development of Case Study 2.*

2.2   Supply Chain Risk and its Management

Whilst the concepts of risk and risk management have their research routes in the seventeenth century, it is only during the last half of the twentieth century that this research has been adapted to a business context (Christopher et al., 2011). Since then, the subject has been studied from an array of different perspectives including economics, finance, strategic management and international management (Christopher et al., 2011). The field of Supply

Chain Risk Management (SCRM) has developed over recent years, in parallel to a number of global catastrophes which had the effect of bringing the vulnerability of global supply chains into the spotlight. Strategic management of supply chain risk is now an important contributor to most fields of management decision and control (New & Westbrook, 2004, Christopher et al., 2011).

Supply chain risk can be segmented into those risks which are internal to the organisation or its supply chain, operational risks (commonly referred to as supply, process and demand risks) and those which are external to the organisation and its supply chain, corporate-level disruption risk. In other words, as Kleindorfer and Saad (2005, p. 53) assert, 'these two categories can be distinguished as risk that arises from problems in the co-ordination of supply and demand, and risk arising from a disruption to normal activities'. The definitional differences of these categories of risk are discussed in detail in section 2.7.1.

Whilst it is clear that most organisations are aware that corporate-level disruption risks could affect their organisation, through a systematic review of the literature, Adhitya et al (2009), highlight that existing SCRM strategies primarily deal with supply chain operational risks, and *not* corporate level disruption risks. This implies that whilst organisations are becoming more adept at managing operational supply chain risk, there is insufficient focus on understanding the dynamics of external disruptions and how they might affect the focal organisation. The underpinning and underexplored assumption suggested by the literature is that many organisations are not prepared for the external challenges they have to confront nowadays (Colicchia and Strozzi, 2012).

2.2.1 Background to the field of SCRM

Before discussing the foundations of SCRM, there is merit in briefly discussing the basics of supply chain management. To this end, a supply chain can be defined as 'a network of organisations including suppliers, manufacturers, logistics providers, wholesalers/ distributors and retailers that aims to produce and deliver products or services for the end customer' (Sodhi and Tang, 2012, p. 6). Supply Chain Management (SCM) is the process of planning, implementing, and controlling the operations of a supply chain as efficiently and effectively as possible, for example, from the extraction of raw materials (upstream) to the

eventual provision of goods or services (downstream). SCM involves forecasting, purchasing, inventory management, information management, quality assurance, scheduling, production, distribution, and customer service (Stevenson, 2007). It is a multi-disciplinary and multi-functional set of activities, which deals not only with the more physical and tangible attributes, such as logistics, but equally the more behavioral and intangible dimensions, such as relationship building and management (Richie and Brindley, 2007), as well as optimisation of strategic and operational performance. However, the disciplinary roots of SCRM go beyond simply the field of supply chain management. The following diagram illustrates the multidisciplinary nature of both SCRM practice and research, in that it has evolved from three distinct fields, which in turn draw on a broad number of areas of academic literature.

Figure 2-1: Depiction of the interdisciplinary roots of contemporary SCRM (Sodhi and Tang, 2012)

The diverse roots of this growing area of the literature and the diversity of the field in general, is driven primarily by the fact that its leading academics that come from a similarly diverse range of backgrounds, such as those depicted In figure 2-1.

In a survey conducted by Sodhi and Tang (2012) of academics' views regarding where SCRM sits in the current literature, the most predominant views amongst researchers were that 1) SCRM overlaps most with the more established fields of supply chain management and enterprise risk management or that 2) SCRM forms a subset of crisis management or business continuity literature (See figure 2-1). However, SCRM is now becoming a standalone field in its own right. Furthermore, whilst it cannot be denied that the fields of supply chain management, enterprise risk management and crisis management have significant overlaps with that of SCRM, each also has its own primary function which is different to that of SCRM.

For example, Sodhi and Tang (2012) note that enterprise risk management focuses primarily on risk disclosure in the financial reporting documents issued by a company so as to comply with various regulations. Similarly, crisis management tends to focus more on organisational survival following a significant event that is much wider in scope than the impact on supply chains. Finally, they argue that whilst supply chain management perhaps bears the most overlap with SCRM, as a field, it is primarily concerned with the improvement of operational performance of supply chains under 'normal circumstances'. Whilst, SCRM draws on all of these fields, as is demonstrated in the subjects varied literature, it would not be appropriate to describe it as wholly part of any of them and instead is starting to become recognised as a field in its own right.

As will be discussed in detail below, over the past two decades, many organisations have restructured their supply chains to gain advantages in terms of increased revenue, cost reduction or asset reduction. The increasing geographical spread of 'the modern supply chain' has left many organisations susceptible to an increased risk of disruption (Craighead et al., 2007, p. 155). There are many examples of corporate-level supply chain disruptions, some of which are highlighted below, that have had a significant effect on organisational performance. As organisational executives become increasingly concerned about the increase in supply chain risk, practitioner interest in the area has increased significantly, as evidenced by the number of SCRM reports that have been published by major consultants in recent years, see for example Deloitte's 'the ripple effect' (2012), Price Waterhouse Cooper/ MIT Forum's joint report on 'supply chain innovation and risk' (2013) or Mckinsey and Company's 'building the supply chain of the future' report (2011). In parallel and as a result of this, the academic literature in the area of SCRM has expanded significantly in recent years with comprehensive texts on the subject including, for example, Zsidisin and Ritchie (2008), Wu and Blackhurst (2009) and Sodhi and Tang (2012), as well as a number of special issues and literature reviews on SCRM (Ritchie and Brindley, 2007, Narasimhan and Talluri, 2009 or Tang, 2006).

2.2.2 Increased Susceptibility to Supply Chain Risk: The Hidden Risks Economic Globalisation and 'Leaner' Supply Chains

In recent decades, globalisation has significantly transformed the global business landscape. Liberalisation of trade & financial markets, technological innovations such as satellite communication and the internet, new organisational models based on networks rather than hierarchies and the emergence of important new markets are some of the contributing factors that have significantly decreased spatial barriers and encouraged businesses to decentralise, outsource or off-shore aspects of their operations to different locations worldwide (Castells et al., 2012). The move towards globalised operations is indicated by considering global capital flows or the volume of foreign direct investment (FDI). A recent report by commissioned by the United Nations (2013), notes that FDI peaked at US$2.35 trillion in 2008, of which US$1.13 trillion went to services and infrastructure, US$0.23 trillion in to primary services including mining and oil and gas extraction and US$0.98 trillion into manufacturing. The result of these capital flows has been a sustained increase in the value of produced capital globally. However, most significantly in those low-middle income nations that have been successful in attracting direct foreign investment. See for example the East Asia/ Pacific region, whose produced capital has more than doubled to US$10 trillion between 1995 and 2005. In the UK, businesses increasingly operate as part of the global economy and are heavily reliant on goods and services supplied by overseas markets. A recent report by the Committee on Climate Change Adaption Sub Group (2014), found that the value of UK imports has risen from £149 billion in 1990 to £527 billion in 2012. Moreover, the report highlighted that, as a proportion of GDP, overall UK international trade increased from 50% in 1990 to 65% in 2012, demonstrating the increasing reliance of UK businesses on overseas markets as part of their supply chains.

Today's globalised supply chains, have enabled organisations to increase both productivity and profitability by taking advantage of the comparative advantages of low-middle income geographical locations, including, attractive labour costs and skill base, affordable land and materials costs, tax breaks and easy access to export markets. For example, decentralisation of large parts of the Japanese automotive industry's supply chain in the 1990's, had the effect of increasing competitiveness and led to a doubling of total parts exports in the subsequent 10 years, from 1.3 million manufactured parts in 1999 to 3.2 million in 2010 (United Nations,

2013). This evolution towards increasingly globalised supply chains for many organisations is characterised by a number of trends according to Ye and Abe (2012). For example, they note that the production process is often split between separate geographical nodes and linked by multi-modal distribution facilities. Moreover, economies of scale are achieved through supplier consolidation and reduced transaction costs as well as locating production facilities in areas with low transport costs, increasing the dependence of globalised supply chains on international distribution centres.

Although supply chain globalisation has produced significant benefits in terms of productivity and profitability, the extended geographical spread of many modern supply chains has led to increased susceptibility to external corporate-level risks, many of which are dictated by geography. The modern supply chain is now often a complex network with multiple dependencies. This has the potential of increasing risk susceptibility throughout the supply chain. Organisations that operate a global supply chain are exposed to an increased amount of risk due to the complex and uncertain environment in which they are involved (Tang and Tomlin, 2008). As Peck (2005, p. 214) describes 'the more complex a network is, the more interfaces exist and the higher the vulnerability will be'. Moreover, when disruptions occur at a critical node of the supply chain, the resulting effects can ripple throughout the entire value chain; A phenomenon described by Forrester's Bullwhip Effect (1961).

In addition to the purely economic production savings that can be made from decentralising key supply chain functions, today, organisations are placing more emphasis than ever on streamlining and cost-efficiency in order to increase competitiveness. This can be done for example, by reducing inventories, reducing transportation times and streamlining production generally. As organisations are now managing more supply chains then they were in previous decades to produce multiple products (AMR Research, 2006), the creation of 'lean' supply chains is advantageous in the sense that it minimises surplus stock and fosters close relationships throughout supply chains. However, increased supply chain complexity through outsourcing and the move away from a 'safety stock' culture, also leaves businesses more susceptible to external corporate-level risk (Thun and Hoenig, 2011) and can undermine supply chain resilience generally (Haraguchi and Lall, 2012). For example, 'lean' supply chains utilising 'just in time' delivery principles require an increasing frequency of supply to minimise

on site inventory. This results in increased interdependence between supply chain nodes, where disruption at a critical point can have a systemic impact.

2.2.3 Increased Frequency of Corporate-level Disruptions and their Impact on the Globalised Supply Chain

Based on the above it can be concluded that supply chains today are more vulnerable to unanticipated disruption from seemingly self-contained events than they were in the past (Craighead et al., 2007). A study by Aon Risk Solutions (reported in Saenz and Revilla, 2014) found that, on average, the percentage of companies reporting a loss of income due to corporate-level supply chain disruptions of this nature increased from 28% in 2011 to 42% in 2013. Although, it can be said that any disruption in the flow of goods could impact companies along a supply chain, due to the increasing interconnections between companies and complexities in supply chain designs, corporate-level supply chain disruptions are becoming more prevalent (Pereira et al, 2014). In parallel to this, various studies modelling historical data, surmise that the frequency of natural and man-made disasters has risen significantly since the turn of the century. See for example the Annual Statistical Reviews conducted by the Centre for Research on the Epidemiology of Disasters (2012). Examples of such disasters include: the financial crises in North America, Europe and Australia (2007-08), the Indian Ocean Tsunami (2004), the 9/11 terrorist attacks (2011), the SARS virus outbreak in China (2002-04), the Japanese Earthquake/ Tsunami (2012), the Gulf of Mexico oil spill (2010) and the Chao Phraya river floods in Thailand (2011). These events, amongst many others, have the effect bringing the vulnerability of global supply chains into the spotlight.

In a recent World Economic Forum Report, 4 out of the top 5 most significant supply chain disruptions that occurred in 2012 were found to be Corporate-level disruption risks (Pereira et al, 2014). Events such as these can seriously undermine businesses competitiveness and longer-term economic sustainability (United Nations, 2013). A recent report by professional services firm Price Waterhouse Cooper (2012), surmised that losses from disruption events of this nature can be categorised in to four distinct groups: direct losses affecting the organisation itself, indirect losses affecting the organisation's supply chain partners, wider detrimental impact on relationships/ market positioning/ reputation and macroeconomic effect on the wider economy of a given country (see figure 2-2). This categorisation model is

useful in that it highlights the distinction between 'immediate impact cost' i.e. stemming from the loss of organisational assets and also 'reduced flow cost' i.e. stemming from disruptions within the wider supply chain. The combined organisational cost stemming from events such as those listed above are well documented. For example, following the 2011 Japanese earthquake and tsunami, Toyota lost $1.2 billion dollars in product revenue, due to parts shortages that caused 150,000 fewer of the company's vehicles to be manufactured in the USA, 70% reductions in India and 50% reductions in China (United Nations, 2013). Mobile phone maker Ericsson suffered a 400 million Euro loss after the factory of their key supplier of semi-conductors caught fire. Similarly, a two year delay in launching the Airbus A380, caused in large-part by the political issues amongst the four-nation consortium producing the plane, cost the company 4.8 billion Eur in opportunity lost. The fiscal implications of poor SCRM have been well noted in the literature. For example, in their study of 827 disruption announcements over a 10 year period, Hendricks and Singai (2005) found that those who suffer a significant supply chain disruption experienced 33-40% lower stock returns compared to industry benchmarks over a sustained 3 year period. A Recent Committee on Climate Change Adaption Sub-Group (2014) similarly found that share prices can fall between 7-30% on average following significant supply chain failures from external disruptions and do not necessarily recover after the event. Conversely, the financial rewards for enacting an effective SCRM strategy are also significant. A study by Boston based group AMR Research (2006) found that companies in their 'Supply Chain Top 25 List' had an 11.5% stronger return than the Dow Jones Industrial Average.

Direct Losses
Impact on the business's own as assets (including its own factories, equipment, final goods, goods in process and raw materials).

Indirect Losses
Impact as a result of business interruption to supply chain partners operations and/ or their ability provide goods or services.

Wider Impact
Wider detrimental impacts, including, loss of market share competitors taking clients, labour shortages, severed relationship with suppliers and negative effects on brand and reputation.

Macroeconomic Effects
Combined effect of the above impacts and losses across a number of organisations and the effect this can have on the economy of a country.

Figure 2-2: How businesses are affected by disasters/ corporate level risk (Adapted from PWC, 2013)

2.3   The Need for More Resilient Upstream Supply Chains

In the light of both the increased frequency and susceptibility of many organisations to external corporate-level risks over the last decade, it is clear that not all risks can be prevented (Juttner and Maklan, 2011). As such, there is a need for supply chains to become more resilient to these types of events. Understanding and building resilience capabilities in to the SCRM process, supports companies in proactively responding to disruption ahead of their competitors (Azevedo et al, 2013). This is important as, in present-day business environments there is a notion that Supply Chains compete instead of companies and therefore organisational performance is intrinsically linked to supply chain performance. (Christopher and Towill, 2001)

The SCRM literature contains many definitions of what is meant by supply chain resilience, however, the general idea is consistent. It is the ability of a system to return to its original state or move to a new, more desirable state after being disturbed (Pereira et al, 2014, Scholten et al, 2014, Carvalho et al., 2012, Juttner and Makan, 2011). In other words, the adaptive capability of the supply chain to '*prepare* for unexpected events, *respond* to disruption and *recover* from them by maintaining continuity of operations at the desired level of connectedness and control over structures and function' (Ponomarov and Holcomb, 2009, p. 131)

The resilience literature has grown significantly in recent years but is still considered by many scholars to be a research area in its infancy (Pereira et al, 2014). Whilst resilience is often thought to be a purely reactive construct, i.e. the ability for a supply chain to react to a given disruption, it would be incorrect to consider resilience purely as a form of response in the SCRM process. Instead resilience should be seen as a proactive and holistic approach to managing supply chain risks enhancing traditional risk management strategies (Scholten et al, 2014). In other words, in order to improve an organisation's ability to respond in a timely manner to a disruption, resilience needs to be considered throughout the SCRM process.

Pereira et al (2014) argue that achieving this resilience requires effort from internal actions within the business as well as the wider network (supply chain partners). Moreover, the authors note that little attention has been given in the literature, to studying the issues

associated with the enhancement of resilience capabilities in organisations, particularly from activities which are responsible for managing the flow of goods and information in the upstream supply chain. Yi et al (2011), also note the timely need for research exploring how companies are currently engaging building resilience in to their SCRM strategies.

In the context of the current research, there is merit in considering the key themes discussed in the literature regarding how organisations might build resilience in to their SCRM strategies. Building on work by Christopher and Peck (2004) on creating a resilient supply chain, Scholten et al (2014) identify a base of three primary processes which allow for re-engineering the supply chain to improve resilience, these are: Collaboration, risk awareness (culture) and knowledge management – See Table 2-3.

Resilience Theme	Literature Definition	Practical Meaning
Foundations which contribute toward resilient SCRM practices		
1) Collaboration	The level of joined decision making and working together at a tactical, operational or strategic level between two or more supply chain members. Scalable through magnitude of relationship, strength, quality and closeness (Juttner and Maklan, 2011)	Collaboration and knowledge sharing across the supply chain is essential in building supply chain resilience. Christopher and Peck (2004) define the fundamental principle of collaboration is that exchange of information or shared knowledge can reduce uncertainty. This can be vertical collaboration i.e. between supply chain partners at different tiers of the chain, or, horizontal collaboration i.e. between different departments within an organisation or even different organisations in a similar industry to share knowledge around SCRM (Scholten et al, 2014).
2) Risk Awareness (Culture)	Making supply chain risk assessment a formal part of the decision making process at every level (Chrispher and Peck, 2004)	Risk awareness is about installing a culture throughout the supply chain where the focal firm and its suppliers share the same strategic vision in terms of supply chain risk management. Kleindorfer and Saad (2005) note that organisations need to be continuously aware of risk by developing management policies and actions that assess risk continuously and coordinate the efforts of their supply network.
3) Knowledge Management	Knowledge and understanding of supply chain structures – both physical and informational and its ability to learn from changes (Ponomarov and Holcomb, 2009)	The capacity to learn from past disruptions to develop better preparedness for future events in a principal property of resilience (Ponomarov and Holcomb, 2009). Knowledge management involves building upon supply chain visibility gained through collaboration to gain a better understanding of how susceptible different nodes of the supply
Supply Chain Re-engineering		
Supply Chain (re)engineering	The conceptualisation, design, implementation, operation and re-engineering of the supply chain (Naim et al, 2000)	Resilience must be built in to the supply chain in advance of a disruption in order to incorporate readiness to enable an efficient and effective response (Scholten et al, 2014). Strategic resilience measures can include building buffers, identifying secondary suppliers. However, in order to identify where to add this flexibility within the supply chain a number of SCRM building blocks are needed, including better collaboration, risk awareness and knowledge management.
Increased Resilience		
Increased Supply Chain Resilience through Agility (Flexibility through Rapid Response)	The ability of the supply chain to rapidly respond to change by adapting its initial stable configuration (Wieland and Wallenburg, 2012)	Agility requires in built flexibility in to the supply chain such as buffers or dual suppliers. However, it is also about responding to a disruption event in a rapid manor. To do this supply chain visibility is of critical importance as it facilitates effective decision making and more specific intervention (Christopher and Peck, 2004, Juttner and Maklan, 2011)

Table 2-3: Key Foundations Enabling Supply Chain Re-engineering to Increase Resilience (Scholten et al, 2014, p.213)

2.4   Misconceptions around Organisational Ability to Manage Risk

Considering the above, it can be said that for supply chain executives, the early years of the 21st century have been notable for major supply chain disruptions that have highlighted vulnerabilities for individual companies and for entire industries globally (Chopra and Sodhi, 2014). However, it is clear that at many companies, the resiliency of the supply chain has not kept pace with continually rising level of logistical complexity and increased risk of disruption (Saenz and Revilla, 2014).

Research highlights that whilst most managers know that they should protect their supply chains from serious and costly disruptions, comparatively few take sufficient action (Chopra and Sodhi, 2014). In other words, while many managers appreciate the impact of supply chain disruptions, they have done very little to prevent such incidents or mitigate their impacts (Tang, 2006, Saenz and Revilla, 2014). These findings are highlighted in a practical scale network study conducted by MIT (reported by Saenz and Revilla, 2014) found that 60% of supply chain managers surveyed do not currently work on supply chain risk management or do not consider their company's supply chain risk management practices effective for disruption risks.

The literature suggests a number of reasons for a lack of organisational investment in the most obvious strategic solutions to protecting supply chains from serious and costly disruptions – such as increasing inventory, adding capacity at specific locations or dual sourcing. These can broadly be categorised in to two groups

1) *Financial/ Efficiency – I.e. Strategic Investment in SCRM undermining efforts to create leaner supply chains and improve supply chain cost efficiency.*

Developing and implementing strategies to address corporate-level disruption risks is often seen as financially and resource intensive for organisations, undermining efforts to improve supply chain cost efficiency (Chopra and Sodhi, 2014). For example, traditional recurrent risks (such as fluctuations in demand) can generally be addressed through 'good supply chain management practices' and contribute to 'lean' operation of the supply chain. However, corporate level disruption risks are rather more difficult to justify the management of, as

standard mitigation strategies (such as holding buffer stock or dual sourcing at certain nodes of the supply chain) can lead to a substantial cost and loss in efficiency (Chopra and Sodhi, 2014). In this sense, the difficulty of linking strategic management of this type of risk to supply chain efficiency is a key challenge of managers. There is evidence that the tendency of many companies to seek low-cost solutions, due to pressure on margins, may have led to leaner but also to more vulnerable supply chains (Azevedo et al, 2013, Wagner and Neshat, 2010)

Chopra and Sodhi (2014, p. 73) pose a fundamental question here: 'How should executives lower their supply chain's exposure to disruption risks without giving up hard earned gains in financial performance from improved supply chain cost efficiency?' This question has traditionally been viewed as an all or nothing proposition. For example, accept that some disruption events cannot be avoided and accept the consequences, or build flexibility in to the entire supply chain, accepting any negative implications on cost or efficiency.

Chopra and Sodhi (2014) argue that this is not the case and a more targeted approach should be explored. They go on to discuss that increasing visibility and organisational knowledge around which nodes of the supply chain for key products (i.e. product segmentation) are most susceptible to different forms of corporate-level disruption risk, should be viewed as the first critical first step in developing a balance between management of this type of risk without significantly reducing supply chain efficiency, in other words mitigating the impact of corporate-level disruption risk while also limiting the impact upon supply chain cost and efficiency.

Identification of which geographical nodes of the supply chain are most susceptible to corporate-level disruption risk, allows supply chain managers to employ more targeted strategies to mitigate the impact of a potential risk. For example, in the automotive industry, many key upstream electronics suppliers were located in relatively narrow region within areas of Japan affected by the 2011 Earthquake and Tsunami. In cases such as this, Chopra and Sodhi (2014) suggest that segmenting and de-regionalising supply chains in susceptible areas helps managers design and deploy solutions fairly quickly in the event of a disruption.

2) *Underestimation of the Susceptibility to Disruption or failing to understand the potential impact of disruption on the organisation due to a lack of supply chain visibility or poor estimations of potential impact.*

It seems clear that organisations often consider themselves to have robust immediate supply chains (Zsidisin and Ritchie, 2008). In a sample of major UK-based companies, mainly in the FTSE 250 list, Sodhi and Tang (2012) found that nearly 70% of respondents rated satisfaction of their organisations current state of supply chain risk management to be 7 or higher in a 10-point Likert scale with 1 being completely dissatisfied and 10 being completely satisfied. However, another study, conducted by AMR Research (2006) found that supply chain visibility remained relatively low in the companies it surveyed. In the context of corporate level disruption risks, these two studies observe a common organisational phenomenon, in that, traditionally organisations have perceived risk in their immediate supply chain and often take a proactive approach to managing risk at this level, leading them to believe they have a strong approach to SCRM. However, due to a lack of visibility beyond this lower tier level, it is inherently difficult for an organisation to understand the risks and interdependencies between upstream supply chain partners and as a result they are forced to take a more delayed, reactive approach to supply chain disruptions which affect higher tier supply chain partners.

A lack of supply chain visibility in this area also inhibits managerial ability to understand, even at a basic level, how susceptible their upstream supply chain is to various corporate-level disruption risks. In turn this leads to many organisations underestimating the potential impact of this type of risk on their supply chain. Research adopting analytical models and simulation found that underestimating the likelihood of corporate-level disruption risk is far more expensive in the long run than overestimating the likelihood and that the loss incurred, in the event of a disruption, generally overwhelms any savings from not investing in risk mitigation strategies (Chopra and Sodhi, 2014). Saenz and Revilla (2014) go further to suggest that there is a lack of a guiding framework in this area generally and that many managers understand extremely little about the potential impact of disruption risk upon their supply chain.

2.5   A lack of Upstream Supply chain visibility

It is clear that disruption events, such as those discussed above, can have a significant impact upon organisational supply chain performance. Whilst corporate-level disruption events may impact any node throughout the supply chain, the literature suggests that supply chain disruptions are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of the chain. For example, those higher tier stages of the supply chain, that involve the raw material extraction, refining and processing of materials before they are transformed in to a final product to be sold.

A recent study by Owen and Barrett (2014), focusing on climatic disruption risks to UK organisations, found that that the largest disruption risks to UK supply chains appear to be in the earlier stages of product manufacture (higher tiers in the upstream supply chain). Moreover, the authors suggest that this risk is amplified as these tiers of the supply chain are less likely to be understood and managed by UK businesses. This finding is in keeping with analysis undertaken by the Chartered Institute of Purchasing and Supply (CIPS, 2014) in the UK, which suggested that many organisations do not understand the complexity of their upstream supply chain and are thus more susceptible to the impact of disruption risk.

The previous section highlighted the underlying financial and operational reasons for a lack of engagement with proactive management of corporate-level disruption risk. Repenning & Sterman (2001, p. 81) aptly discuss these barriers in relation to the notion that 'nobody gets credit for fixing problems that never happened'. It can be said that issues of financial and human resource constraints have led many companies to adopt what could be described as a low visibility, 'outsourced' approach to SCRM, whereby the focal organisation may take steps to assess and manage supply chain risk within its immediate operating environment. However, lower tier suppliers are often responsible for reporting risk further upstream.

There are several inherent problems with adopting a supply chain risk management approach that relies heavily on supplier reporting of upstream risk. Perhaps the most significant of which is the added time delay between a disruption occurring and the focal organisation becoming aware of the issue (see section 2.7.6). There are also difficulties around how different suppliers might view the severity of a particular disruption, whether they can

mitigate the impact themselves and therefore the merit of reporting it to the focal organisation. After-all a supplier might consider that it is not in its future business interests to report all potential risks, meaning that the focal organisations upstream supply chain risk visibility, is very much dictated by the wishes of the supplier. Considering this and assuming the common position that the supply chain is only as strong as its weakest point, Colicchia and Strozzi (2012) assert that SCRM needs to go beyond simply the lower level boundaries of the focal organisation and its immediate suppliers, instead aiming to discover and quantify hazards in the extended supply chain.

With this in mind, there is merit in considering how visibility differs between different risk groups. Figure 2 builds on Sodhi and Tang's risk categorisation model (discussed in more detail below) and is underpinned by the assertion put forth in the literature (Colicchia and Strozzi, 2012, Adhitya et al, 2009), that many large organisations have a good visibility of operational risk in their immediate operating environment, but, due to the resource constraints rarely take a proactive approach to identifying and managing risk beyond this – especially beyond a first tier level.
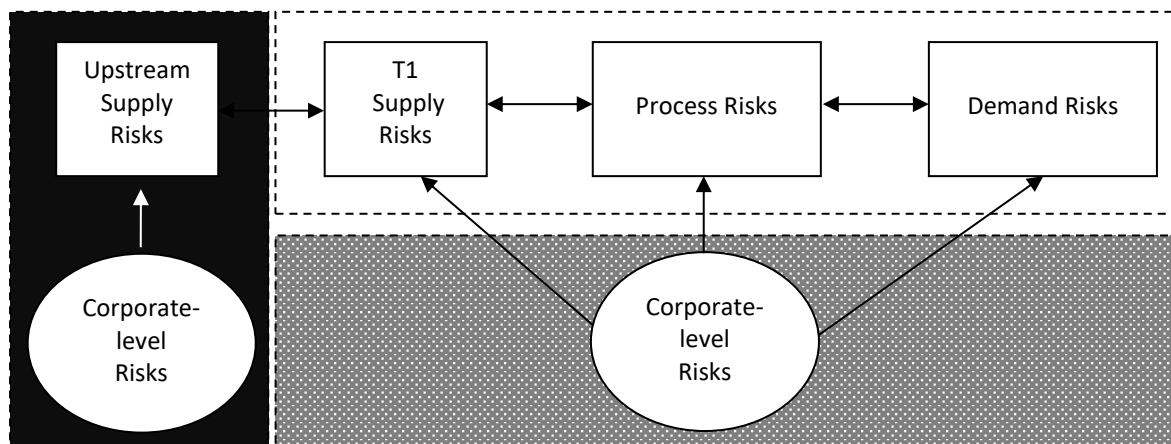
Figure 2-4: Traditional organisational visibility of supply chain risk: adapted from Sodhi and Tang's (2012) categorisation model

Based on the above, it is clear that visibility forms a key issue in the contemporary supply chain management literature, affecting performance of the whole supply chain (Choi and Sethi, 2010, Williams et al, 2013). The fundamental objective of increasing supply chain visibility is to improve company performance by supporting the decision-making process (Wang and Wei, 2007). In a practical sense, increased visibility can be seen as an enabler of

stronger supply chain relationships, offering the potential to make improvements in cost, quality, service level, flexibility and time (Caridi et al, 2014). Whilst much of the literature focuses upon the benefits of downstream relationship building, Mason et al (2007) advocate, from a logistics perspective, that vertical relations should be developed in both upstream and downstream directions along the supply chain.

Although referred to commonly in the supply chain literature, the meaning of 'supply chain visibility' often remains somewhat ambiguous. In its most basic sense, Supply Chain Visibility is defined in the literature as 'the ability of the focal company, i.e. the supply chain leader, to access/ share information related to the SC strategy and the operations of SC partners' (Caridi et al, 2014, p. 2). The authors elaborate on this definition, stating that it is 'the sharing of all relevant information between supply chain partners, even over echelons in the chain'.

In recent years, supply chain visibility has been considered from a number of perspectives in the literature, including forecasting, planning, scheduling/ co-ordination, inventory management and logistics efficiency (Caridi et al, 2014). However, Yo and Goh (2013) found that there is very little research in linking visibility and SCRM, acknowledging that the area is still nascent and warrants further in-depth study. Caridi et al (2014) also identify a clear gap in the literature, noting that to date there has been very little attention in the literature regarding the benefits of increased visibility of upstream supply chain partners. This point is especially poignant considering visibility is commonly cited as a major factor in the impact of disruptions on organisational supply chains.

From a SCRM perspective, as businesses operate in increasingly complex and dynamic environments, it is essential that the supply chains which underpin them are more responsive. To increase responsiveness, supply chain managers often seek information that provides greater visibility in to factors affecting supply and demand (Williams et al, 2013). Researchers have argued that the management of supply related information (through increased visibility) plays an important role in building capability to flexibly respond in a targeted way to changes in the upstream supply chain (Wang and Wei, 2007). In this respect, greater visibility into supply operations is thought to enable faster and better decision making (in terms of deciding where to add flexibility) for responsive production systems (Williams et al, 2013). The

literature suggests three key challenges which must be addressed in facilitating increased supply chain visibility.

What Visibility Data is Needed?	→	How can that Visibility Data be Obtained?	→	What can be done with that Visibility Data?
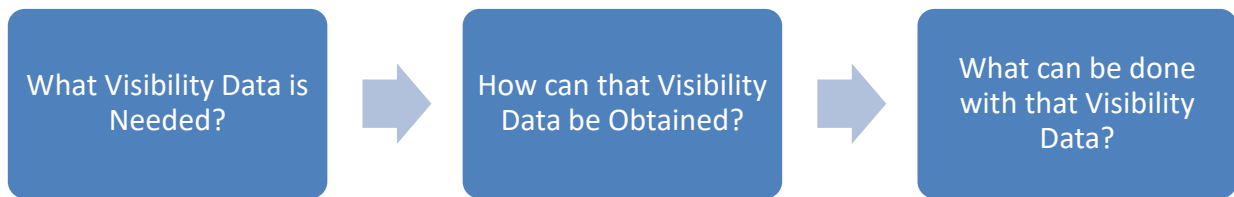
What Data is needed?

The literature makes clear that the type of data needed will differ dependent upon the perspective visibility is being considered from (Caridi et al, 2014). For example, data that is relevant in order to increase visibility for improved forecasting or scheduling, will be different to that which is needed to improve responsiveness for SCRM. Kembro et al (2014) notes that with regards to structure (what to share with whom), there is a need for different approaches for different industries and supply chain problems. All empirical papers in this area converge in to the conclusion that 'one size does not fit all'.

How can that Data be Obtained?

Despite significant interest in supply chain visibility, having access to accurate and relevant information is a challenging issue in global supply chains (Caridi et al, 2014). Although there are a wide range of information sharing means, such as face-to-face contact, telephone and fax, as well as email, EDI, web-enabled portals, enterprise resource planning and data warehouse management (Kembro et al, 2014), the increased complexities associated with upstream manufacturing supply chain dynamics (Caridi et al, 2014) often make it challenging to obtain data. For example, in the current context, automotive manufacturers are located comparatively close to end consumers in the supply chain, with the upstream supply network being much more complex than the downstream retail network. Other barriers to obtaining information include, for example, cost and complexity of implementing advanced systems, existing systems incompatibility, confidentiality of shared information and concern about becoming overly dependent on partners who receive the information or partners reaping all the benefits.

What can be done with the Data?

The literature suggests that a common complaint amongst supply chain managers is that they are often awash in data yet lacking in valuable information (Williams et al, 2013). Taken together Williams et al (2013) argue that these conditions suggest, whilst supply chain visibility is necessary, it is not enough alone to improve performance and must be combined with the right tools or knowledge, i.e. in terms of SCRM how to use the data to improve responsiveness. It is clear that there is often a lack of knowledge around how to interpret and act upon the visibility a given system provides, referred to in the literature as low internal integration (Williams et al, 2013).

These three challenge areas suggest that there is a significant gap in the literature to explore both how organisations are engaging in this area from a SCRM perspective, both in terms of the type of data that they need and how it is being obtained. There is also a clear need to understand how increased visibility could contribute to improved management of supply chain disruptions in terms of responsiveness and improved targeting of flexibility, without significant investment in additional financial and human resource. As, for example, in the vast majority of cases it is simply impractical to take measures to mitigate risk within every node of the supply chain. Whilst many organisations are being driven to gain a better understanding of their upstream supply chain from an array of legislatively prescribed product safety, environmental and social perspectives, increased supply chain visibility alone is not enough to manage supply chain risk. It does, however, make this a pertinent time to consider the issue.

2.6   The Need for Case Studies on SCRM

Whilst there have been some notable real-world, industry specific research in the field of SCRM (see Oke and Gopalakrishnan's 2009 study on the retail sector, Sodhi and Lee's 2007 study on the electronics industry or Saenz and Revilla 2014 study Cisco Systems), there is generally considered to be a lack of applied work in the area of SCRM, especially in terms of real world qualitative case studies. For example, in their review of key literature in the area of SCRM, Sodhi and Tang (2012), found over half of good quality publications were of a conceptual nature. Considering this, alongside the fast-moving nature of the SCRM field,

means that it is challenging to build an accurate picture of how managers actually feel about SCRM.

Research suggests that it is clearly possible to manage and reduce the risk of corporate-level supply chain disruptions (CCC, 2014). Indeed, a report prepared by the Committee on Climate Change Adaption Sub-Group, notes that some large companies are already doing this across various industries. The food and drink sector is highlighted as particularly advanced in this area due its increased upstream supply chain visibility and reliance on highly risk susceptible agricultural products, with Asda and Nestles' work with PWC and the Carbon Disclosure Project respectively cited as particularly relevant. However, the report also notes that other sectors are quickly catching up, with the UK automotive sector highlighted as a potential future best practice example.

Saenz and Revilla (2014) highlight the significant gap in the academic literature for best practice case studies of companies that are taking steps to proactively manage supply chain risk, especially disruption risk. In their article, 'Creating More Resilient Supply Chains' the authors consider the example of Cisco Systems and how, in 2005, the company experienced a *watershed moment* when Hurricane Katrina hit the gulf coast of the US and caused significant disruptions to the organisations supply chain. Their article charts the progress made by the organisation made in the subsequent years and how they have evolved to become industry leaders in their approach to SCRM.

Other authors have also highlighted the need and benefits of real-world supply chain case studies in this area. Scholten et al (2014) (as well as Azevedo et al, 2013) note that the academic literature in this area largely fails to move beyond theory and offer management insight on the implementation and operationalisation of SCRM practices. They argue that there are few real-world case studies on the topic to date, so the research picture is incomplete and lacks specific and important practitioner insight. Todo et al (2014) go on to note that, while it is sometimes possible to determine basic SCRM and recovery processes through company reports and releases, qualitative in-depth interviews would provide a much more complete picture of this area. For example, it is very difficult to build a complete picture

of actions being taken to address supply chain risk, based upon the publically available reports of large multinational companies (CCC, 2014)

Recent focus upon increasing upstream visibility and the impact of supply chain disruptions upon organisations, make this a pertinent time to consider real-world examples of engagement in SCRM practices. There is a clear need to understand both how organisations are implementing new strategic approaches to the management of corporate level disruption risks and how these approaches fit in to their traditional SCRM processes. There is also a need to understand how these real-world examples correlate with the theoretical SCRM literature.

2.7   The Supply Chain Risk Management Process

The following section presents an overview of recent academic debates and trends in the SCRM literature. Academic diversity in the field of SCRM has led to differences in how researchers view the scope of the field. However, for more structured discussion and comparison in future chapters, this research segments the SCRM process in to four stages, in keeping with key research in the field (Zsidisin and Ritchie, 2008, Sodhi and Tang, 2012, Waters, 2007).
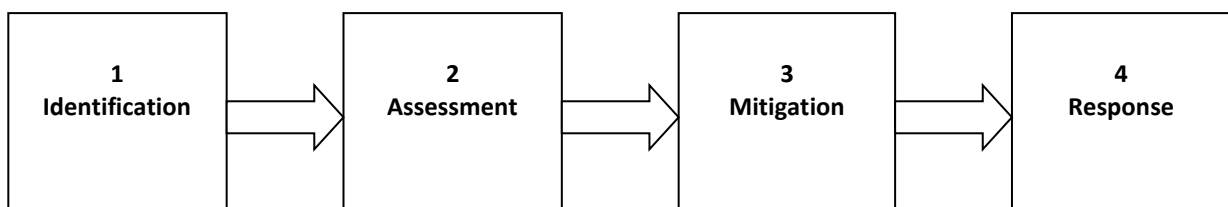
Figure 2-5: High level strategic risk management categorisation

The first element of the process involves identification and categorisation of potential risk and uncertainty and is considered by most researchers to be the initial step in managing supply chain risks (Chopra and Sodhi, 2004, Manuj and Mentzer, 2008). Next, those identified risks must be assessed to evaluate the likelihood of occurrence and their potential impact on a given organisation (Thun and Hoenig, 2011 and Knemeyer et al., 2009). Both *identification* and *assessment* stages of the SCRM process are covered broadly in the literature. However, as will be illustrated in the following sections, this is largely from a conceptual perspective,

where discussion forms part of a wider SCRM framework. Notable exceptions to this include, for example, Hendricks and Singhal (2005) who sought to empirically ascertain the impact of supply chain disruption on actual organisational performance, or Norrman and Jansson (2004) who outline Ericsson's supply chain risk assessment strategy for dealing with risk from specific site events, such as multi-site impact from natural disasters. Sodhi and Tang (2012) reflect the previous section's finding that there is a notable gap in the literature for more applied 'case based' research of this nature.

The third step in the SCRM process is mitigation. This is a proactive step by organisations, to reduce the likelihood of a given risk's occurrence and/ or impact. Again, it is covered widely in the literature, both as part of an overarching SCRM framework (Manuj and Mentzer, 2008, Zsidisin et al., 2004) and also in a more applied sense. See for example Braunscheidel and Suresh's (2009, p. 121) study which concluded that cultural drivers and organisational practices played a significant role in 'the capability of a firm, internally, and in conjunction with its key suppliers and customers, to adapt or respond in a speedy manner to a changing marketplace, contributing to agility of the extended supply chain'.

The final element in the SCRM process is 'response'. This is a reactive stage in the process and involves the organisation attempting to reduce impact and hasten recovery following an actual risk event has happened. With a few exceptions, such as Kleindorfer and Saad (2005) this is a relatively underdeveloped area of the SCRM literature; A point 'glaring in light' given the recent well-publicised supply chain disruptions reported in the press (Sodhi and Tang, 2012, p. 142). Whilst this could be due to a number of factors, the current research adopts the view of Knemeyer et al. (2009, p. 142) that an effective supply chain risk response mechanism stems from proactively addressing the first three proactive elements of the SCRM process. 'This process should help managers identify key locations in their supply chains, systematically measure the risk of suffering a disruption event at each key location and then select cost effective countermeasures to be adopted at selected key locations'.

To make sense of the field's diversity, Sodhi and Tang (2012) undertook a review of high quality SCRM publications in a broad range of journals, which specifically addressed the four different SCRM process elements (see table 2-6).

Article	Identification	Assessment	Mitigation	Responsiveness
Treleven and Schweikhart (1988)	X	X		
Johnson (2001)			X	
Hendricks and Singhal (2003)		X		
Chopra and Sodhi (2004)	X	X	X	
Christopher and Lee (2004)			X	
Guinipero and Eltantawy (2004)		X	X	
Norrman and Jansson (2004)	X	X	X	X
Spekman and Davis (2004)	X		X	
Zsidisin et al. (2004)	X	X	X	
Blackhurst et al. (2005)			X	X
Hendricks and Singhal (2005a)		X		
Hendricks and Singhal (2005b)		X		
Kleindorfer and Saad (2005)	X	X	X	X
Brun et al. (2006)		X		
Choi and Krause (2006)			X	
Cucchiella and Gastaldi (2006)			X	
Gaudenzi and Borghesi (2006)		X		
Bogataj and Bogataj (2007)		X		
Sodhi and Lee (2007)	X		X	
Cheng and Kam (2008)	X	X	X	
Manuj and Mentzer (2008)	X	X	X	
Tang and Tomlin (2008)			X	X
Wagner and Bode (2008)			X	
Braunscheidel and Suresh (2009)			X	X
Jiang et al. (2009)			X	
Knemeyer et al. (2009)	X	X	X	X
Neiger et al. (2009)	X			
Oke and Gopalakrishnan (2009)	X		X	
Rao and Goldsby (2009)	X			
Trkman and McCormack (2009)	X	X		
Ellis et al. (2010)		X		

Table 2-6: The elements of SCRM covered by key authors in the literature (Sodhi and Tang, 2012)

This table illustrates where much of the spread of current literature amongst the four elements. However, as has been described above, applied work (both quantitative and qualitative) is not extensive in the field of SCRM (Mangan et al, 2004). Using the sample above, Sodhi and Tang (2012) found that while 18 of the 31 studies (58%) took the form of a conceptual framework, there were only 10 (32%) quantitative and 8 (26%) qualitative empirical studies. Combined with the previous section's findings, this suggests that there is a significant gap in the literature in this area. To this end, Mangan et al (2004) argue that methodological triangulation, using quantitative and qualitative methodologies, can provide multidimensional insights into many management research problems.

2.7.1 Defining Risk - Identification and Categorisation

The following section critically assesses the relationship between different risk groups and the various categorisation models presented in the literature. It highlights the importance of corporate-level risk as a standalone risk group and presents a more structured definition of sub-risks within this group that will be utilised for the purposes of the current research. As has been discussed from the outset, supply chain risk has been defined in a number of ways in the literature. However, at its most fundamental level, supply chain risk can be viewed as 'an event that adversely affects supply chain operations and hence it's desired performance measures, such as chain-wide service levels and responsiveness, as well as cost' (Tummala & Schoenherr, 2011, p. 474). Whilst, variations of this definition are used throughout the literature, its usefulness in a practical sense is limited due to the numerous types of risk that can 'affect supply chain operations'. Therefore, in order to make sense of the multitude of diverse risks that can affect organisational performance, SCRM scholars have developed a number of categorisation models. Adopting a method to identify and categorise risk is the fundamental first step in creating an effective SCRM strategy and in a practical sense each organisation has their own understanding and way of undertaking this process. However, the end product of this exercise will usually take the form of a risk register of identified risk and their relative importance

A number of authors have sought to categorise supply chain risk in different ways, however, few move beyond the categorisation stage to suggest how identified risk should be addressed (Sodhi and Tang, 2012). Jurttner et al, (2003) for example, provide a classification approach based on where a particular risk derives from, including, environmental risk sources, network risk sources and organisational risk sources. Sodhi and Lee (2007) segment risk into supply, demand and contextual categories. Christopher et al (2011) (building on earlier work by Christopher and Peck, 2004), discuss supply, process, demand, control and environmental risks. Oke and Gopalakrishnan (2009) categorise low-impact high-frequency and high-impact low frequency risks in the retail sector in to three main categories: Supply, Demand and Miscellaneous risks. Manjuj and Mentzer (2008) categorise risk in to: supply, operations, demand and other risk (including security and currency) groups. Tang and Tomlin (2008) discuss: supply, process, demand, intellectual property, behavioural and political social risks. And, Bogataj and Bogataj (2007) categorise: supply, process, demand and control risks.

More recently, Sodhi & Tang (2012) presented a critique of many of the aforementioned identification and categorisation models, concluding that, for the most part, diversification of risk categorisation frameworks is largely down to definitional differences and the vocabulary adopted, rather than physical divides in the categories used. In an effort to better define the language used, the authors present a butterfly depiction of supply chain risk (Figure 2-7). This is not a categorisation model, but instead is seen as a way to delineate, along an x-axis representing time, the events before a 'risk event' (underlying causes and prevention efforts) and the events following a 'risk event' (impact and response effort). Separating cause and effect in this manor, is a useful, in that it adds clarity to defining what the risk or network of risks actually are and the appropriate timing of different stages of preparation and response. The addition of a feedback loop is also important as it signifies that organisations should learn from historical events to reduce the likelihood or at least impact of similar future events.
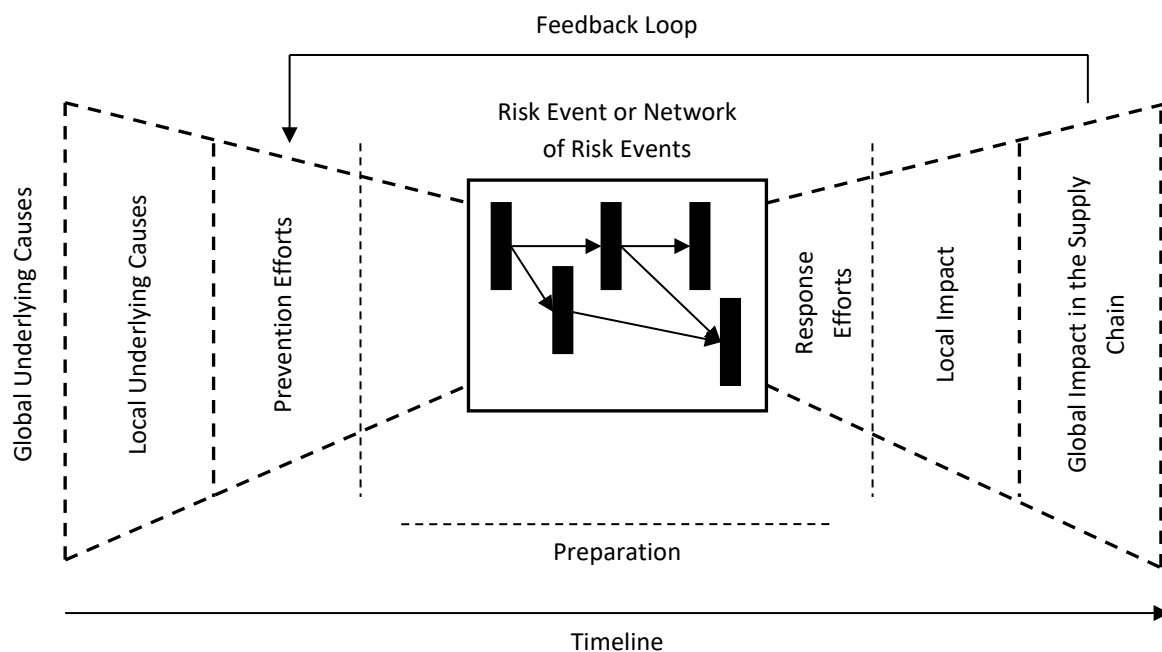
Figure 2-7: Butterfly depiction of supply chain risk (Sodhi and Tang, 2012)

Building on this clarified depiction of supply chain risk, Sodhi and Tang (2012) consider the need to align risk categorisation with standardised organisational supply chain management structure. For example, as organisations have invested significant money in establishing

supply chain structures, it seems logical for each categorisation to be split between the organisational entities which should be charged with its management. With this in mind, the authors propose a more comprehensive categorisation model which draws on and aims to clarify much of the definitional confusion in existing literature. Table 2-8, breaks down the four categories proposed by Sodhi and Tang (2012), where, for example, purchasing are perhaps best aligned to manage *supply risks*, those working on internal processes such as manufacturing and internal distribution to manage *process risks* and those departments facing downstream such as sales and distribution to manage *demand risks*. Finally, cutting across these specialist departmental functions, a more strategically focused entity would be best aligned to manage external corporate-level disruption risks.

Supply Risks	Process Risks	Demand Risks	Corporate-level Risks
• Supplier failure • Supply commitment • Supply cost	• Design • Yield • Inventory • Capacity	• Forecasting • Receivable • Change in technology or consumer preference	• Financial • Supply chain visibility • Political • Social • Exchange rate • Environmental

Table 2-8: Examples of risk in Sodhi and Tang's (2012) Supply Chain risk categorisation model, motivated by Supply Chain Organisation.

Sodhi and Tang's (2012), categorisation model is effective for both its simplicity and alignment with organisational structure. It also builds on existing well-regarded work in the field, for example, Christopher and Peck's (2004) highly cited framework, by better defining and justifying drivers for the vocabulary used in the categorisation process. As has been discussed, supply chain risk can generally be segmented into those risks which are internal to the organisation or its supply chain, operational risks (commonly referred to as supply, process and demand risks) and those which are external to the organisation and its supply chain, corporate-level disruption risk. In other words, as Kleindorfer and Saad (2005, p. 53)

assert, 'these two categories can be distinguished as risk that arises from problems in the co-ordination of supply and demand, and risk arising from a disruption to normal activities'.

Building upon Sodhi and Tang's (2012) categorisation model, Figure 2-9 considers where each category of risk sits in relation to the focal firm and the relationship between different risk types, depicting that each risk group is not self-contained and that one risk event can trigger another between groups. For examples, external, corporate-level disruption risk can have a ripple effect throughout the entire supply chain and trigger numerous operational risks.
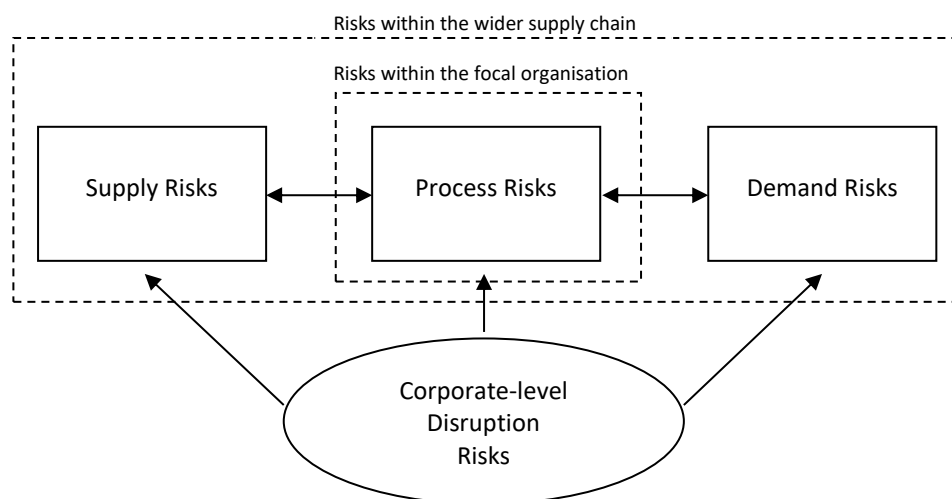
Figure 2-9: Sources of Risk in the supply chain: adapted from Sodhi and Tang's (2012) categorisation model

The above categorisation model presents a high-level view of both the operational and external risks that can impact on an organisation's supply chain. Where, localised 'operational' disruptions can occur on a daily basis and are to varying degrees controllable, certain external events, when combined with the aforementioned vulnerabilities faced by the modern organisations, have the potential to cause widespread, systemic supply chain disruption. Those external risks which are not within the immediate operational control of an organisation but can have a significant direct impact on the supply chain, can be separated out in to three groups: 1) geo-political, 2) economic and 3) environmental. These groupings are in keeping with joint industry/ academically led work undertaken by the World Economic Forum (WEF) to identify new models for 'Addressing Supply Chain and Transport Risk' (2012)

and also the WEF's wider 'Global Risk Report' (2013). In keeping with the research objectives, only upstream risks are included. Moreover, the WEF also include a fourth 'technology' group within this area. However, in keeping with the academic literature this is excluded as a corporate level disruption risk here, as technological risks (such as network issues and IT security) are thought to be within the controllable remit of most organisations and furthermore are not affected by geography in the same way other risk groups here are. Work by the WEF in this field is well regarded for its practically driven approach, developed through close consultation with leading industry and academic stakeholders.

The WEF supply chain categorisation and risk model is based on a multifaceted analysis of the risks to the supply chain industry. Data was obtained from a range of sources between April and December 2011, including, interviews with executives in 32 organisations, a survey involving 55 individuals from a range of organisations and a series of 6 workshops bringing together 100 diverse stakeholders across industry, academia and government. Each of the key groups of geographically driven, corporate level supply chain risk will now be discussed.

Environmental: This group incorporates various environmental risk factors, including a wide spectrum of natural disasters, extreme weather events and high impact disease outbreaks. Given a number of high-profile recent events, such as the Japanese earthquake/ tsunami or Thai floods in 2011, it is perhaps unsurprising that natural disasters were indicated by 60% of experts surveyed by the WEF, as the most likely environmental risk to cause systemic supply chain disruption. The related risk and impact of extreme weather events also ranked highly in this category with 27% of respondents placing it as a significant concern. Considering the uncontrollable nature of environmental risk, the WEF concluded that 'focus must be on making the right investments before the event to reduce supply chain and transport network system vulnerability and improve recovery capability'.
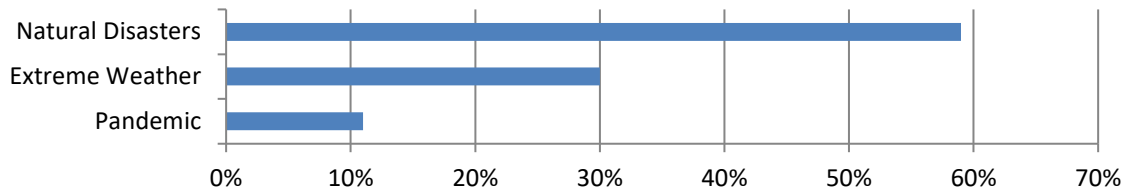
Figure 2-10: Major Environmental Triggers of Global Supply Chain Disruption (Adapted from WEF report on New Models for Addressing Supply Chain and Transportation Risk, 2012)

Geo-political: Geo-political disruptions include a range of potential disruptions encompassing corruption, crime, terrorism and political unrest/ conflict. Whilst events of this nature can have a direct effect on organisations, the resulting disruption and change can be equally damaging. For example, major supply chain disruptions in the wake of the 9/11 terrorist attacks in the US, were not caused wholly by the event itself, but instead the resulting grounding and delays of global air traffic. Moreover, the regulatory and legislative changes following a geo-political risk event can also have a significant impact on global supply chains. In the WEF study, 46% of respondents, identified conflict and political unrest as their key geo-political supply chain concern. Other keys areas respondents highlighted show a concern that areas where terrorism or limited law enforcement is prevalent, pose a significant risk to supply chain operations. Again, these risks are very difficult for organisations to manage in the short term which the WEF say necessitates a dual approach of both risk reduction and increased network resiliency.
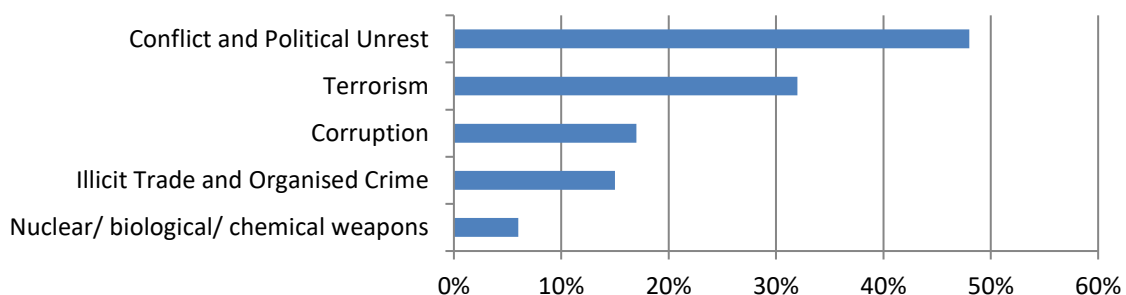
Figure 2-11: Major Geo-political Triggers of Global Supply Chain Disruption (Adapted from WEF report on New Models for Addressing Supply Chain and Transportation Risk, 2012)

Economic:

A number of economic risks have the potential to interrupt organisational supply chains and this group covers a range of issues, including, currency fluctuations, labour shortages, sudden

demand changes and volatility in commodity prices. Many of these risks have been highlighted following the 2008 global financial crisis. This has been significant in the automotive sector, where bankruptcy filings of suppliers doubled between 2007 and 2008 (United Nations, 2013). External events, such as those mentioned above can have knock-on effect in economic terms on sudden demand fluctuations, with 44% of respondents noting this as a key concern. Currency exchange fluctuations are also highlighted as a significant economic risk where organisations have a significant number of suppliers located in a single monetary zone. This was illustrated in 2010 when a number of exchange rate fluctuations had a significant impact on many companies supply chains.
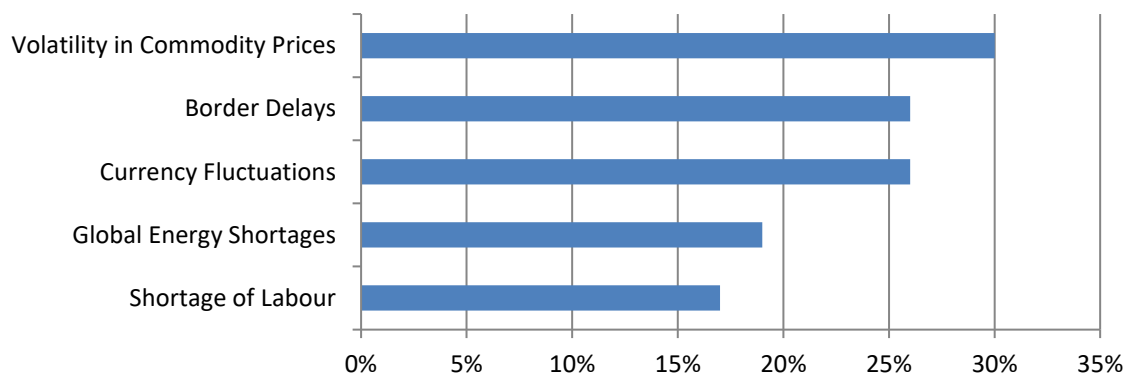
Figure 2-12: Major Economic Triggers of Global Supply Chain Disruption (Adapted from WEF report on New Models for Addressing Supply Chain and Transportation Risk, 2012)

2.7.2 Risk Assessment and Prioritisation of Corporate Level Disruption Risk

The literature suggests that if the purpose of risk identification and categorisation is to consider all risks that might conceivably impact upon the supply chain, then the next logical step is to assess those risks. This is a critical process, as the assessment stage will inform which areas of risk should be prioritised and resources allocated to managing them. In other words, inaccurate assessment therefore leads to poor allocation of resources. Again, there is a distinction between, assessing day-to-day risks in the immediate operational environment of an organisation (operational risks), and assessing risk outside of this environment (corporate-level disruption risk). In the previous section the importance of those geographically driven external risks which can impact an organisation, throughout the supply chain was discussed.

It can be said that most organisations have developed at least basic methods to help assess and prioritise risk (Rice and Caniato, 2003). Be these of a qualitative or quantitative nature, in general terms they will inform key decision makers of where risk management efforts/ budget should be directed and often the monetary value of a particular risk impact so that, for example, mitigation cost can be weighed up or exposure transferred to an insurance company. In their 2010 survey of UK FTSE 250 companies, Sodhi and Tang (2012) sought to understand how Chief Risk Officers viewed risk and risk management in their organisations. They found that the typical approach to assessment of supply chain risk was through *risk mapping* exercises, where the frequency or probability of an event occurring in a given time frame was weighed against the likely impact or consequences, usually in monitory terms, of the event on the organisation. By combining the likelihood and probable impact of an event (on a 10 point Likert scale), the overall importance rating, or risk intensity score, is calculated: (Risk Intensity = Frequency + Impact). Respondents to the survey were also asked to consider existing prevention controls and responsiveness (again, using a 10 point Likert scale) to assess the residual frequency and impact of a given risk on their organisation: Residual frequency = Frequency x (1 – Prevention Controls/ 10) + 1 and Residual impact = Impact x (1 – Responsiveness/ 10) + 1. Sodhi and Tang's (2012) findings are in keeping with existing literature in this area. Figure 2-13, which has been adapted from Thun and Hoenig's (2011) study on the German automotive industry, illustrates the process at its most basic level. For example, considering Figure 2-13, theoretical supply chain risk B warrants immediate attention as it is both high impact and high probability, supply chain risk C does not require attention as it is both low impact and low probability and supply chain risk A should be analysed further as it has a low probability of occurring but potentially a high impact on business operations.
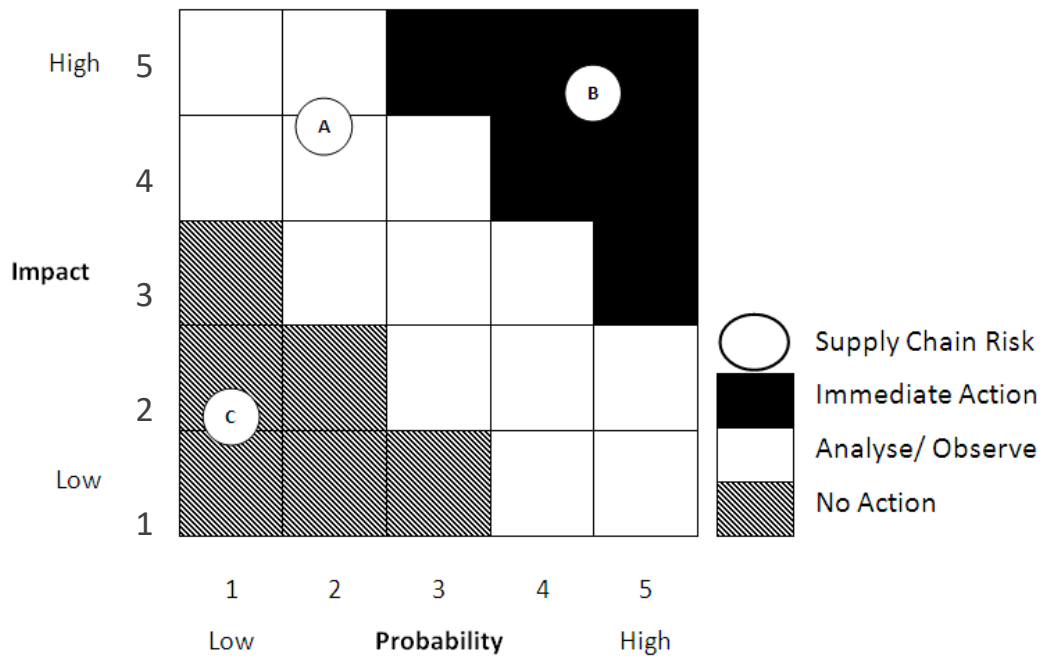
Figure 2-13: Theoretical Impact Probability Matrix: Thun and Hoenig (2011)

Exercises such as this are undoubtedly useful, in that that they help develop a shared awareness of the risks facing an organisation and that organisations ability to mitigate or respond to them, as well as allowing for separation of unmitigated risk from residual risk. However, the impact/ probability model is not without its challenges and the significant variation in perceived likelihood/ impact across the survey's respondents demonstrates limitations in terms of bias and subjectivity. There are also a number of interpretations with regards to how probability should be calculated, from more objective (historical frequency based) approaches, which this research seeks to develop, to more subjective ('belief' or 'gut-instinct') interpretation. The literature suggests that whilst the probability of 'normal' operational risks are usually assessed using a frequency view of likelihood, 'abnormal disruption' risks are usually subjected to a more 'gut instinct' assessment, which is fraught with subjective difficulties (Sodhi and Tang 2012). Judging impact is weighed down with similar difficulties, such as prescribing a single monetary value to what is often a multi-dimensional impact on both short and long term business operations. Figure 2-14 is taken from the WEF report on new models for addressing supply chain and transportation risk (2012) and represents the views of surveyed respondents on the likelihood/ tractability of the three key corporate level risk groups discussed above: environmental, geo-political and economic risk. The radar chat was compiled by asking supply chain professionals to rate the

likelihood (probability) and tractability (predictability) of a particular corporate-level risk causing a disruption to their supply chain over the next 5 years.
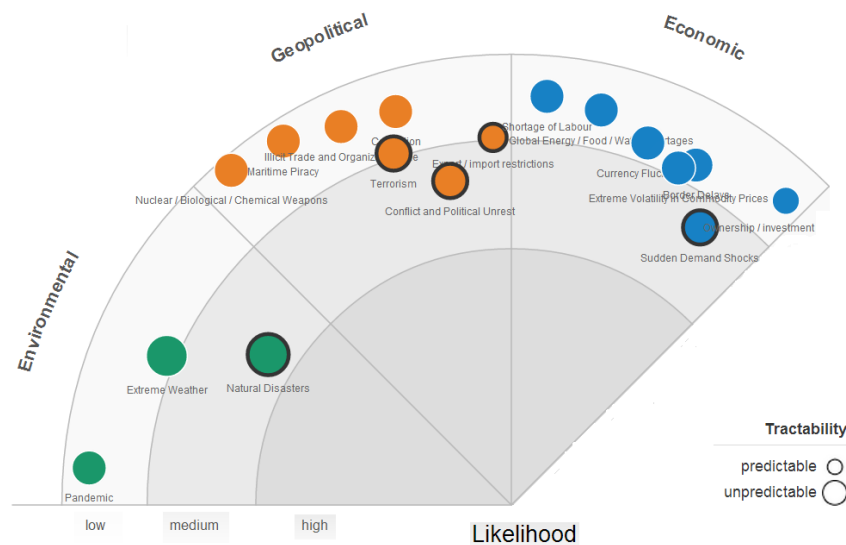
Figure 2-14: Corporate-level Risk Likelihood/ tractability radar chart (Adapted from WEF report on New Models for Addressing Supply Chain and Transportation Risk, 2012)

The process of undertaking traditional risk assessment, is beneficial in that it has the ability to focus staff and lead to a shared sense of urgency about approaches to managing a certain sub-set of risks. However, with regards to corporate-level disruption risks, it also highlights the subjectivity often employed in the assessment process. This is in line with Zsidisin et al's (2004) reasoning that, 'due to few good estimates of the occurrence of any particular disruption and accurate measure of potential impact, it is difficult for firms to perform cost/ benefit analysis to justify certain risk reduction programs or contingency plans'. This can often lead to a tendency to over focus mitigation resources on areas where a particular recent 'incident' had a significant impact on the organisation (Sodhi and Tang, 2012). An example of this is the widespread increase in spending on financial risk management in the light of the 2007/08 financial crisis, highlighting a notion noted earlier in the literature, the difference between assessment of risk and assessment of the 'perception' of risk (Slovik, 1987). Whilst this is sometimes justified, and indeed forces companies to commit resources to addressing issues which have previously not been considered, a significant bias to subjectively driven, reactive SCRM can lead to other significant external risks being ignored. As Sodhi and Tang (2012) assert, rather than focus on a horse that has already bolted the stable, effective risk

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assessment can help focus on the horses, the stable and the business processes of managing the stable. Moreover, whilst managers may have an understanding of the key risks and be able to use 'gut instinct' assessment within their immediate operating environment and supply chain, considering risk within the wider upstream supply chain will inevitably present areas where they have little or no expertise. Therefore, exploring methods to fully utilise historical and forecast geographical data, will allow for more objective assessment of organisational susceptibility throughout the entire upstream supply chain.

Whilst much emphasis has been placed on the tools and processes to mitigate supply chain risk (which will be discussed broadly in the next section), the literature suggests that that the assessment stage of SCRM is much less developed. Most significantly it highlights the difficulties in trying to apply traditional high-level operational risk assessment processes, to better understand and prioritise corporate-level disruption risk. It is argued that effective corporate-level SCRM will only be possible when organisations are able to develop more accurate risk assessment models and allocate resources accordingly. This is a particularly relevant topic to explore now because as organisations expand the visibility of their upstream supply chain (due to various legislative and regulatory drivers), new opportunities present themselves in terms of ability to identify, assess and prioritise susceptibility of suppliers to various economic, geo-political and environmental corporate level risks. However, whilst increased supply chain visibility has the potential to bring significant opportunities for organisations with regards to SCRM, there will also be major challenges as organisations face increasing pressure to prioritise which suppliers throughout multiple tiers should be focused on and identify new ways to effectively manage the large amounts of data that come with that increased visibility. The geographical nature of the subset of risk, identified as corporate-level disruption risk, also places importance on identifying appropriate methods and tools with which to utilise locational data from the upstream supply chain and combing this with historical and forecast risk metrics.

2.7.3   Strategic Risk Mitigation for Prioritised Risks

Once an organisation has identified, assessed and prioritised a particular risk, strategies to help mitigate or manage that risk must be considered. This 'risk management' stage of the wider SCRM model can be defined as 'the process whereby decisions are made to accept a

known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence' (Norrman and Jansson, 2004).

Prior to reviewing the literature in this area, it is useful to consider two well-known examples that highlight the value of risk mitigation and contingency strategies in SCRM. The first is highlighted in Norrman and Jansson's (2004) case study on mobile phone manufacturer Ericsson. The event in question concerned two Scandinavian mobile phone producers, Ericsson and Nokia, who were affected by a fire at their joint microchip supplier, Phillips. The fire at the company's Albuquerque production plant was started when lightning stuck a nearby power-line, causing a major electricity surge through the grid, damaging millions of radio frequency microchips destined for the two Scandinavian companies. In preparation for a serious disruption, Nokia had developed a multiple supplier SCRM strategy to mitigate against risk in this critical node of its supply chain and immediately switched its microchip orders to other companies, as a result they recorded relatively minor impact during the incident. On the other hand, Ericsson, having no such strategy in place and relying singularly on the Phillips plant, suffered a major loss of about $200 million due, in large part, to a gap in the supply of radio frequency chips caused by down-time at the Albuquerque plant.

A second example of the value of risk mitigation and contingency strategies is highlighted by Griffy-Brown's (2003) account of the damage Hurricane Mitch caused to Central American banana production in 1998. The aftermath of this natural disaster led to prolonged loss of supply for food companies Dole and Chiquita. Although Chiquita temporarily lost supply, it had the supply chain flexibility to increase production in some of its other (unaffected) suppliers in the region. Conversely, Dole had no other suppliers in the region and lost 70% of its regional supply, leading to a 4% quarterly decline in overall revenues (worth $100 million). The outcomes of these two examples highlight the importance of understanding risk throughout the whole upstream supply chain as well as adopting appropriate, proactive supply chain risk mitigation and management strategies to increase responsiveness following an unavoidable risk incidence.

The value of employing risk mitigation and contingency strategies, or the detriment of 'not having a Plan B', is explicitly highlighted in Tomin's (2006) highly cited paper published in

Management Science. In it, Tomlin (2006) quantitatively demonstrates the necessity and benefits of building an effective disruption management strategy in to a firms overall supply chain strategy. Using the example of a single product setting in which a firm can source from two suppliers with different profiles, Tomlin (2006) demonstrates that along with cost, supplier characteristics such as percentage uptime, disruption length, capacity, flexibility and overall risk tolerance, play a large role in determining the firm's optimal disruption management strategy.

An organisation is not limited choosing a single mitigation or contingency tactic, and in many circumstances a combination of tactics might be the appropriate strategy for managing disruption risk (Tomlin, 2006). Various authors have proposed groupings with which to categorise risk management techniques or actions (Norrman and Jansson, 2004, Paulsson and Nilsson, 2008). However, at a basic level there are only three approaches: accept, avoid or mitigate (Sodhi and Tang, 2012). For the most part, the nature of corporate-level supply chain disruption risk means that incidents themselves are beyond the complete control of an organisation and can therefore not be fully avoided. As a result, the focus of the literature in this area is placed firmly upon the development of appropriate mitigation strategies. Whilst most companies prepare for 'normal' operational risks that are recurrent and relatively low impact on the supply chain (such as a quality control issue with a low tier supplier), few develop mitigation strategies to handle, what are often perceived as unavoidable, corporate-level disruptions, such as the impact of multiple suppliers being based in an earthquake prone country (Sodhi and Tang, 2012). Supply chain risk mitigation involves efforts to reduce the impact of events which fall beyond the controllable remit of organisations. Sodhi and Tang (2012) discuss three broad strategic categories of risk mitigation strategy: 1) alignment of supply chain partners, 2) flexibility and 3) building buffers. However, as is demonstrated in the following discussion, there is exists substantial overlap between categories.

Alignment: Perhaps the most obvious form of alignment in this context is the establishment of long-term supply chain partnerships. There are substantial benefits to building long term partnerships throughout the supply chain in terms of corporate-level risk management. For example, Lee (2004) suggests that alignment such as this will help facilitate close communication, co-operation and collaboration between supply chain partners, this will help

increase the flow of information during and immediately after a supply chain disruption occurs reducing lead times. Narayanan and Raman (2004) discuss incentivisation as a powerful method to increase alignment. The authors consider supplier risk sharing and revenue sharing schemes as potential ways to align and incentivise suppliers throughout the supply chain to work towards shared goals of reducing risk. Supply alliance networks also constitute an example of significant benefit for the most critical areas of production. This sort of arrangement often promotes increased communication and co-ordination between firms and their suppliers to form a strategic alliance, where each member can rely on the support of others if a disruption were to occur.

Flexibility: In terms of corporate-level disruption risk, there are several forms of flexibility which might be employed by an organisation as an effective mitigation tool. One of the most commonly observed strategies in the literature involves the creation of a flexible supply base (see for example, Chopra and Sodhi, 2004). This can be done in a number of ways, such as building flexibility in to supply contracts to allow for shifting order quantities between suppliers. Moreover, it can be a powerful tool in hedging risk and as was exemplified in the above discussion, flexible multi-supplier contracts for critical components also allow for contingency suppliers in the case of a disruption to one supply chain node. Further flexibility can be built in to the supply base by, for example, encouraging flexible supply contracts or a diversified supply transportation system. In this context, flexible supply contracts allow for a percentile increase from remaining suppliers of a component, if another supplier is forced to close/ reduce output due to a disruption (Tsay and Lovejoy, 1999). Contracting suppliers to adopt more diversified transport routes for critical components can also increase flexibility significantly in case of disruption. This can take the form of diversified transport routes or more diversified transport modes. See for example, Lee's (2004) discussion of Japanese supermarket Seven-Eleven's diversified transport delivery network or Hick's (2002) study of Chrysler's transport flexibility compared with Ford following the 9/11 terrorist attacks in New York. As discussed above, economic supply incentives can also add flexibility, as well as increased alignment, in terms of risk mitigation, where there is limited number of suppliers in the market and spreading risk between multiple suppliers is more difficult. Finally, varying degrees of supply chain integration can offer powerful flexibility in reducing impact for critical products or components. The concept of 'make or buy' integration decisions are discussed

extensively in the literature and can offer increased control in case of a disruption occurring (see for example, Ghemawat, 2003 or Chopra and Sodhi, 2004). Ghemawat, 2003, uses clothing manufacturer Zara as an example, citing the company's vertically integrated strategy for producing complex items in house whilst outsourcing more basic items.

Building Buffers: Building buffers or 'reserves' in to some critical areas of the supply chain can be a powerful way to reduce the impact of certain unavoidable risk events (Chopra and Sodhi, 2004). In a sense, this is another form of flexibility for the organisation. For example, whilst the literature suggests that firms are often unwilling to build significant inventory buffers due to the cost involved and pressures to streamline operations (Sheffi, 2005), identifying back–up production facilities and back-up suppliers help absorb short term effects of disruption in the supply chain of critical components. However, there are tradeoffs between the potential cost of a risk on an organisation and the cost of building an appropriate reserve (be this of inventory, capacity or redundant suppliers). Chopra ad Miendl (2004) refer to this as *'the newsvendor problem'*, where the role of the supply chain manager is similar to that of a stock manager i.e. determining the optimum amount of reserve without exceeding a point where it becomes more financially damaging for the organisation than the mitigated risk itself. This point can be illustrated by a simple risk/ reward framework as in figure 2-15. For example, as an organisation decreases exposure to risk through better mitigation strategies (more flexibility and/ or reserve etc), managers will require more reward to cover the cost of implementing those strategies. An optimisation curve can be drawn at the point where risk mitigation expenditure meets reward necessary to cover mitigation cost. Beyond this optimised level, lowering risk further will trigger an un-proportionate increase in reward. Considering the upstream supply chain as a whole, this notion supports the idea that organisations will receive more reward by targeting mitigation efforts at those critical suppliers most susceptible to risk
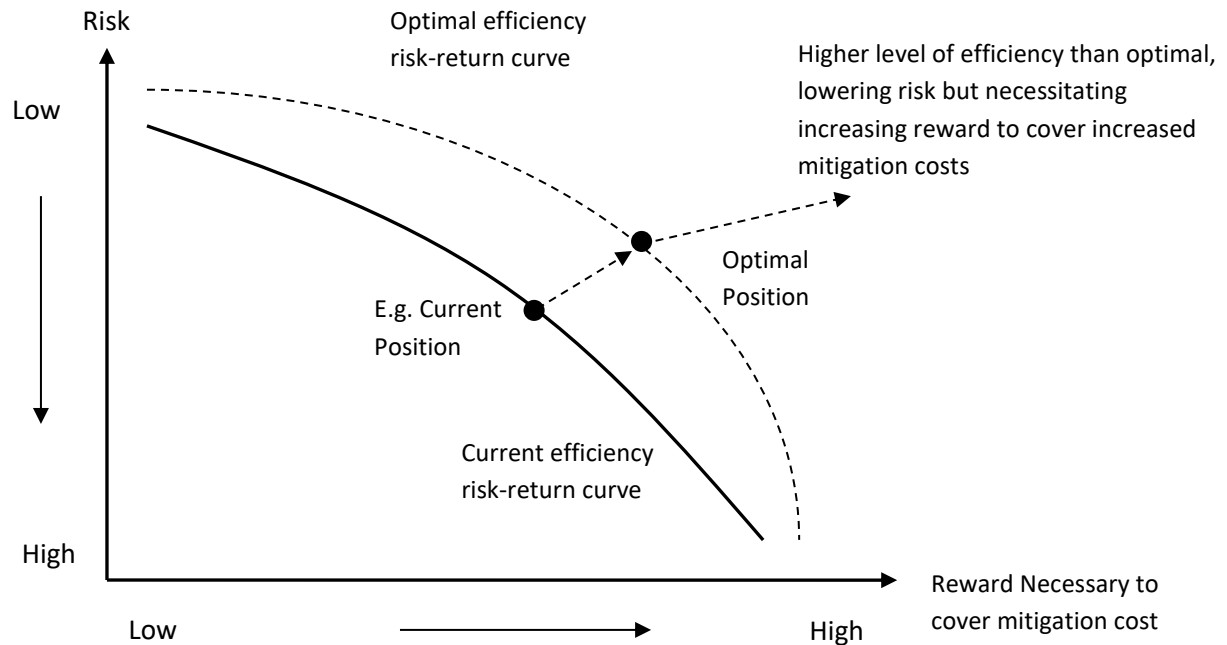
Figure 2-15: Choosing the trade-offs between risk and reward (Chopra and Sodhi, 2004)

2.7.4   The Role of Inter-firm Accounting in Supply Chain Management and Control

It is clear that many modern organisational supply chains have witnessed fluidity and blurring in respect of their organisational boundaries in recent years, largely as a result of outsourcing and corporate unbundling (Coad and Cullen, 2006). In parallel to this trend and perceived loss of supply chain control, contemporary industrial organisations often express a desire to foster intrinsically closer relationships with suppliers (Seal et al, 2004). In other words, although activities are being moved outside the firm, there is often an expectation that close links will still be maintained. This desire is echoed in the literature, with consensus that effective supply chain management entails the development of closer, long-term supplier relationships with mutual benefits and information sharing (Varoutsa and Scapens, 2015). However, there is often a lack of clarity about how such a relationship can be achieved. This section considers how inter-firm accounting practices can be used to foster additional openness that is beneficial to the management and maintenance of inter-organisational supply chain relationships.

Interest from accounting scholars in the field of supply chain management has increased significantly in recent years (Varoutsa and Scapens, 2015). Whilst accounting and management controls were primarily developed for internal use in organisations, as a result

of competitive pressures and the need to improve results, managers have started to pay more attention to the role of these controls in improving relationships with external links (Cullen and Meira, 2010).

There has been a long-standing call in the accounting literature to explore the lateral processing of information, transcending legal organisational boundaries. For example, Hopwood (1996) specifically noted the need for management accounting to be studied beyond the organisations own four walls. Since then there have been a number of contributions to the management accounting literature devoted to understanding the role of accounting practices in improving inter-firm relationships. See for example Seal et al (2004), whose review focuses on the possibilities for re-embedding supplier relations by synthesising institutionalist and managerialist approaches, finding that accounting information may be used to build collaborative networks as new information and information technologies enable closer ties between firms. Similarly, Meira et al (2010), conclude that accounting can be an actor in the development and maintenance of close supply networks. They note that accounting controls help to constitute the network's boundaries because they make clear how relationships do and should happen. Finally, Mouritsen and Thrane (2006), highlight that sharing accounting information is important to manage the conflict between the goals of each organisation and those of the network as a whole.

Management accounting researchers have largely focused upon the control of supply chains through various practices, often with inter-organisational cost management in mind. The majority of research has focused upon dyadic relationships, although a few studies have considered the management of whole networks or supply chains; see for example, Dekker (2003). The accounting techniques used in inter-organisational settings have been shown to change depending on the buyer-supplier relationship in question (Varoutsa and Scapens, 2015), as will be discussed below. However, one of the more prevalent practices discussed in the literature is that of open book accounting. Cullen and Meira (2010) discuss the logic of open book accounting as being where one or both companies in a supply relationship 'open their books' to their counterpart and disclose internal information. The most common form of open book accounting involves a supplier allowing the focal firm access to its cost and supplier information (Cullen and Meira, 2010). This type of practice obviously depends on the

development of close, reliable relationships. However, if successful, open book accounting can facilitate cooperation in relation to the identification of critical areas throughout the supply chain.

The management accounting literature clearly highlights the potential benefit, application of inter-firm accounting techniques can have for supply chain management and control. However, in addition to ensuring that structural, integrated systems are in place to facilitate sharing of accounting information, behavioural elements play an equally important role (Coad and Cullen, 2006). After all, alliances are routed in social relations; with trust, for example, implicated in how these relationships are built and managed. The issue of trust has featured prominently in a significant number of studies in this area and the extant literature has shown how difficult it is to build trust in supply chain relationships (Meira et al, 2010, Caglio and Ditillo, 2008).

It is important to differentiate here the difference between information sharing which occurs as a result of mutual trust between supply chain partners and that which derives from a power imbalance. For example, most literature in this area focuses on agreements where one supply chain partner is significantly more powerful than another (Caglio and Ditilli, 2008). Power asymmetry of this nature clearly works in favour of the more powerful partner in a relationship, but often does not necessarily foster mutual trust in favour of the whole supply chain. This point is illustrated by considering Seal et al's (2004) example of such an imbalance. In this example, Dextron, a UK electronics company, represented a small player to some of its larger suppliers. Many of these suppliers typically possessed sophisticated market knowledge that would have been beneficial for Dextron but would not be shared. Conversely, in other relationships where it was the dominant player, Dextron could require a much higher level of disclosure of accounting information.

It is clear that there can be mutually reinforcing links between the sharing of accounting information and the establishment of trusting relationships. In Calio and Ditilli (2012)'s study of why firms 'open their books' and share management accounting information, the authors found that participation of individuals in an exchange of this nature can foster additional openness (trust) that is beneficial to the management and maintenance of that inter-

organisational relationships. Similarly, Seal et al's (1999) action research study of two UK manufacturing companies seeking to improve co-ordination and strategic collaboration, found that that in both inter and intra organisational environments, accounting tools, such as an open book agreement, play a fundamental role in the establishment and management of trusting and collaborative business relationships.

As supply chain partnerships mature, they go through different phases. Supply base segmentation and sourcing models can take many forms but begin with the autonomous firm, moving through various stages of transactional co-operation with suppliers, until a mutually dependant partnership is reached for some critical components.

Considering the inter-organisational control literature, Berry et al (2000) suggest that management accounting practices and systems tend to evolve to facilitate supply chain relationships at different levels of maturity. Initially, for example, where no integration exists, sourcing tends to be very price sensitive, where tendering and off shore accounting may be the norm and lowest cost option. Cullen and Meira (2010) note that in these early maturity stages, management and accounting tools used are likely to be very economically focused, including total cost control, target costing and inter-organisational cost management. As relationships move through the maturity cycle, inter-organisational accounting techniques tend to be used differently. At increased maturity levels, Cullen and Meira (2010) note that techniques such as open-book accounting become more acceptable since the parties engaged in the relationship can gain mutual benefit from improvements made to both cost and quality.

Van Der Meer-Kooistra and Scapens (2008) distinguish four minimal structures for the governance of supply relationships between organisations; economic, institutional, social and technical. The minimal structures framework provides a way of analysing how the broader economic and institutional structures can combine with the social and technical structures to forma package which can be used in the governance of supply chain relationships. (Varoutsa and Scrapens, 2015). Van Der Meer-Kooistra and Scapens (2008) propose that each supply chain maturity stage is likely to encompass a different combination of these four minimal structures. For example, as a supply chain moves through the different phases of the SCMM the governance needs change and consequently the supply chain restructuring is likely to be

accompanied by governance changes. In early transactional stages the governance of the relationship is likely to have a largely economic and institutional structure. In contrast, as the relationship moves towards mutual dependence and the partners are working very closely together, social and technical structures are likely to become more dominant. This study emphasises that as a supply chain matures, it relies less on the use of formal control mechanisms and more on collaboration and trust. In other words, as the buyer-supplier relationship intensifies, accounting techniques go from being asymmetric with a dominant focal firm initially, to being more collaborative, reciprocal and mutually dependant in later stages.

2.7.5   Sense and Respond Strategies

Whilst the concept of 'Sense and Respond' was initially developed several decades ago within the field of control theory, it has since evolved in to a post-industrial managerial paradigm for creating and managing more adaptive organisations. The application of 'Sense and Respond' as a business concept of this nature was first articulated by Stephen Haeckel, director of strategic studies at IBM's Advanced Business Institute, in his Harvard Business Review Article 'Managing by Wire' (Haeckel and Nolan, 1993). Haeckel argued that the concept represented a new business model, approach to business strategy and a set of principles for becoming what he called an adaptive enterprise, able to better sense and respond to what is actually happening around it.

Considering supply chains' as highly dynamic systems in their own right, it is perhaps unsurprising that 'Sense and Respond' thinking has been adopted by operations management scholars. Once relatively simple product and information pipelines, modern supply chains are becoming increasingly global and complex and traditional Just-In-Time inventory management practices are not always able to cope with abnormal disruptions to operations easily. Successful management of modern supply chains requires heightened responsiveness and an ability to adapt to market changes quickly (Butner and Buckley, 2004). In other words, as supply chains become more dynamic, there is a need for a sense-and-respond capability to react to events as they occur, in an adaptive and responsive manor (Kumar and Van der Aalst, 2006).

Whilst sense and respond strategies have traditionally been considered from the perspective of goods flow optimisation when market conditions fluctuate (Dailey et al, 2014), a number of recent disruption events have refocused attention on the theory's role in SCRM practice. As has been noted throughout this chapter, most supply chain managers recognise the need to sense, analyse and respond much more effectively and quickly to market disturbances. However, few believe that their organisations are currently in a position to react with sufficient speed and agility to changing conditions and supply chain risk events (Butner and Buckley, 2004)

Moving towards supply chains which are better equipped to 'sense and respond' to disruptions requires the focal organisation to first collaborate more closely with partners and increase end-to-end supply chain visibility. Dailey et al (2014, p. 4) describe this prerequisite stage as 'getting control of the supply chain' and note that leading companies are increasingly taking the role of supply chain 'orchestrators', responsible for collaborating and aligning the different components of supply chain on many levels. This requires a collaborative peer-to-peer value network having visibility and control all the way back to tier n suppliers. Whilst it is clear that some companies are becoming adept at this, generally, the literature notes that many struggle with a lack of information integration internally, among partners and among suppliers (Williams et al, 2013). Fragmented information flows and a lack of visibility hinder the development of effective SCRM strategies and inhibit the ability to make quick, well-informed decisions to address urgent issues. Supply chain managers must adopt analytical tools and frameworks to make sense of the visibility data and generate usable supply chain insight. Cross enterprise knowledge sharing can promote an open and integrated operating environment, providing the foundation for analysing risk trends and how often problems occur, to better assist teams in determining corrective action. Butner and Buckley (2004), suggest that this increased visibility and collaborative working can be used to consistently and continuously measure the desired performance metric (in this case corporate-level risk) across the entire chain, thereby becoming more responsive. In a practical sense, tools such as alert messaging systems can be set up to warn decision makers when action should be taken at a given node of the supply chain in response to an event or emerging trend.

Taking a proactive stance of this nature towards risk, as appose to a purely reactive one, can create a sharp competitive edge for companies in terms of responsiveness. 'Sense and respond' strategies and capabilities can be used to optimise supply chain performance, allowing for rapid decision making in the case of a risk event occurring and the ability to take corrective action before problems escalate.

2.7.6   Specific Mitigation Strategies for Economic Risk

In addition to the more strategic level risk mitigation strategies discussed above, there are a number of tactical approaches to the management of economic risk discussed specifically in the literature. Returning to the WEF (2012) report discussed above, which segmented

economic risk as one of several corporate-level disruption risk groups outside of the immediate operational control of an organisation, but which can have a significant direct impact on its supply chain, it seems appropriate to briefly consider this area of the literature.

A number supply side economic risks which can adversely impact upon an organisations supply chain have previously been considered, these include: Fluctuations in commodity prices, labour costs, currency exchange and general economic instability (WEF, 2012). In the context of corporate-level supply chain disruption risk, minor economic fluctuations in the above categories can be seen as a 'normal' risk of globalised business operations. For example, small fluctuations in currency, commodities and labour markets. There is a considerable amount of literature concerning the instruments with which to manage 'normal' economic supply chain risk, which falls beyond the remit of this review. Suffice to say that organisations usually employ a combination of three financial instruments to hedge risk in this area, forward, futures and options contracts (Hull, 2006). Forward contracts involve the organisation agreeing to purchase commodities or currency at a fixed price in the future, futures contracts involve the organisation agreeing to purchase a pre-defined amount of a given commodity or currency at a given time in the future, and, options contracts involve the organisation paying a premium price for the ability to purchase a commodity or currency at any time during the contract period, but not being obligated to do so.

Conversely, more extreme events such as sharp, short term fluctuations in certain commodity or labour prices, as well as more prolonged extreme instability in the wider financial markets can be seen as having a more serious 'abnormal' impact upon suppliers, causing distress (such as inability to meet order quantities) or even failure. As has been discussed above, it is often difficult to draw firm lines between different risk groups. For example, extreme fluctuations in commodity or labour markets are often preceded by a number of other risk events occurring. This can be demonstrated by considering the 2012 Arab Spring's impact on global oil and gas prices or the almost doubling of cotton prices in 2010 due to adverse weather and poor crops in China. Where once supplier default risk was most prevalent in outsourced developing economies such as China, Vietnam or Indonesia (Sodhi and Tang, 2012), the recent economic climate in many western nations, coupled with a lack of liquidity in the credit markets has meant that supplier default through bankruptcy is now one of the most widely

reported supply chain risks globally. Whilst in some circumstances, organisations may be able to swiftly switch suppliers, this is not always the case. Where a supplier for a critical component is facing distress or bankruptcy, the SCRM literature suggests a number of financial instruments which may be employed to reduce risk. These include the provision of short term financial assistance or subsidies (Tang, 2006) and the transfer of risk through factoring (or reverse factoring) where an organisation will encourage suppliers to sell their accounts receivable at a discounted rate to specialist financial institutions in exchange for a short term cash injection (see Corsten and Saraf's, 2008 case study on Nestle Russia's supplier finance programme).

Again, as was discussed above, the literature suggests that there is rarely a formula, whereby a single mitigation tool is perfectly aligned to a given risk type and often a combination of mitigation tools is the most appropriate strategy. This is certainly the case for many of the economic risks discussed above. In this context, disruption is often caused by either the failure of suppliers or their inability, as a result of economic risk, to meet orders. As such the aforementioned tools associated with alignment, flexibility and buffer building strategies still remain significant and will often be applied in parallel.

2.7.7   Quantitative Risk Management

The previous discussion centred primarily upon the literature surrounding broad strategic approaches to manage corporate-level supply chain risk. Although this review does not seek to give an exhaustive account of the SCRM literature with regards to quantitative mitigation tactics in this area, those approaches which have relevance in the current context briefly be discussed. Considering the aforementioned distinction between 'normal' and 'abnormal' risks, it can be said that the majority of more quantitative SCRM literature stems from more traditional supply chain management roots and focuses primarily on approaches to managing 'normal' operational risks. That said, there are clearly some quantitative areas of traditional supply chain management literature, which could be extended to mitigate against 'abnormal' disruption risks (Tang, 2006).

One such area is supplier selection, where a number of authors have sought to develop quantitative techniques to improve the robustness of the process. Boer et al. (2001) provide

a comprehensive review of the various methods supporting the supplier selection process. They note that both expert systems and interpretive structural modelling have been used to inform initial supplier selection criteria. For final selection, Sodhi and Tang (2012) found a number of decision methods have been employed, including mathematical programming models (linear programming, goal programming, data envelopment analysis etc), linier weighting models, simulation models of uncertainties and total cost ownership (whole life-cycle). Whilst different techniques may be employed by organisations, Choi and Hartley (1996) found in their empirical study of 26 automotive partners, that for the most part supplier selection criteria remained fairly constant throughout the supply chain. Interestingly, even when this study was undertaken, financial stability and technological capability were seen as significantly more important criteria than price. Conversely, the flexibility, as defined above, was seen as a lesser concern. This area of the literature could be extended through the introduction of more robust SCRM criterion into the process and through the use of more quantitatively grounded supplier selection methods. The supply chain network design literature has also proposed a number of quantitative approaches to dealing with 'abnormal' supply chain risk, including Huchzermeier and Cohen's (1996) multi-period stochastic programming model that demonstrates the benefits of flexibility in global supply chains to hedge against exchange rate fluctuations (Sodhi and Tang, 2012).

Given today's turbulent global operating environment, there has been considerable research undertaken in to the type of relationship organisations develop with their suppliers. There are generally held to be four distinct types of supplier relationship: vendor, preferred supplier, exclusive supplier and partner (Tang, 1999). Although, mostly the preserve of qualitative researchers, the literature around the type of relationship an organisation has with its supplier has presented a number of quantitative approaches. For example, Cohen and Agrawal (1999) developed an analytical model for evaluating the trade-off between short term transactional purchasing from multiple suppliers and longer-term relationships with single suppliers.

As has been discussed previously, information sharing between upstream supply chain partners pivotal in addressing supply chain risk, particularly with regards to reducing response lead times. The traditional supply chain management literature has provided a number of

quantitative models addressing operational risk and improving information sharing amongst downstream supply chain partners, see for example Wu and Blackhurst (2009) who analytically demonstrate the financial benefits of increased information sharing between organisations and retailers. However, this has not been extended to the upstream supply chain or to cover more 'abnormal' (non-operational) risk. Tang (2006) notes the potential benefits that increased understanding of information sharing amongst upstream supply chain partners could have on mitigating or responding to low 'abnormal' supply chain disruption risk.

2.7.8 Targeted Response as a Mitigation Strategy through Improved Supply Chain Transparency

As was discussed above the final element to the SCRM process is 'response'. This is a reactive stage in the process and involves the organisation attempting to reduce impact and hasten recovery following an actual risk event has happened. With a few exceptions, such as Kleindorfer and Saad (2005) this is a relatively underdeveloped area of the SCRM literature, a point 'glaring in light' given the recent well-publicised supply chain disruptions reported in the press (Sodhi and Tang, 2012). Whilst this could be due to a number of factors, the current research adopts the view of Knemeyer et al. (2009), that an effective supply chain risk response mechanism stems from proactively addressing the first three proactive elements of the SCRM process throughout the entire upstream supply chain. 'This process should help managers identify key locations in their supply chains, systematically measure the risk of suffering a catastrophic event at each key location and then select cost effective countermeasures to be adopted at selected key locations'. Increasing response time to a disruption can form one of the most effective most effective mitigation strategies for an organisation.

The effects of supply chain disruptions stemming from corporate-level disruption risk drivers have been outlined in previous sections and include, for example, reduced consumer confidence, loss of market share, stock price fluctuation and reputational damage. However, despite multiple high-profile examples of the detrimental effect supply corporate-level risk can have on organisations, most still acknowledge significant unmanaged vulnerability to external corporate level supply chain disruption risk (Porrier and Quinn, 2003) and there has

not been significant investment in organisational strategy to assess and mitigate supply chain risk in this area (Zsidisin et al., 2004). This Paradox of why organisations often perceive the presence of supply chain risk and yet do not take action to address this is specifically noted by Sodhi and Tang (2012), who conjecture two key reasons for a lack of action (based largely on aforementioned research by Zsidisin et al. 2004 & Rice and Caniato, 2003): 1) firms are not familiar with how to develop effective SCRM strategies, or 2) firms find it hard to justify significant investment in mitigation programmes without exact cost/ benefit figures. In the context of the current research, these two reasons suggest that encouraging engagement in this area relies on increasing practitioner knowledge of novel corporate-level SCRM strategies specifically relevant to their organisation and better understanding the value or reward from investment in those risk mitigation strategies. This second point remains critical given the current drive for cost savings in many organisations. Put simply, what does the company get in return for its investment in a given SCRM strategy?

One powerful tool in highlighting this second point, is by considering how a corporate-level SCRM strategy might improve response lead time following an incident and moreover, how a reduction in response time could be seen as a reward in its own right by reducing organisational recovery time following a disruption. Figure 2-16 (Sodhi and Tang, 2012), illustrates this idea of time-based risk management. Building on localised business continuity literature and applying this in a supply chain context, Sodhi and Tang (2012) note three distinct time elements following a disruption event: D1) time to *detect* the event across the supply chain, D2) time to *design* a response, D2) time to *deploy* the response. This '3-D Framework' surmises that by proactively putting in place effective SCRM strategies to reduce any of these three time elements, organisations are able to reduce overall response time (R1) and therefore overall recovery time (R2).
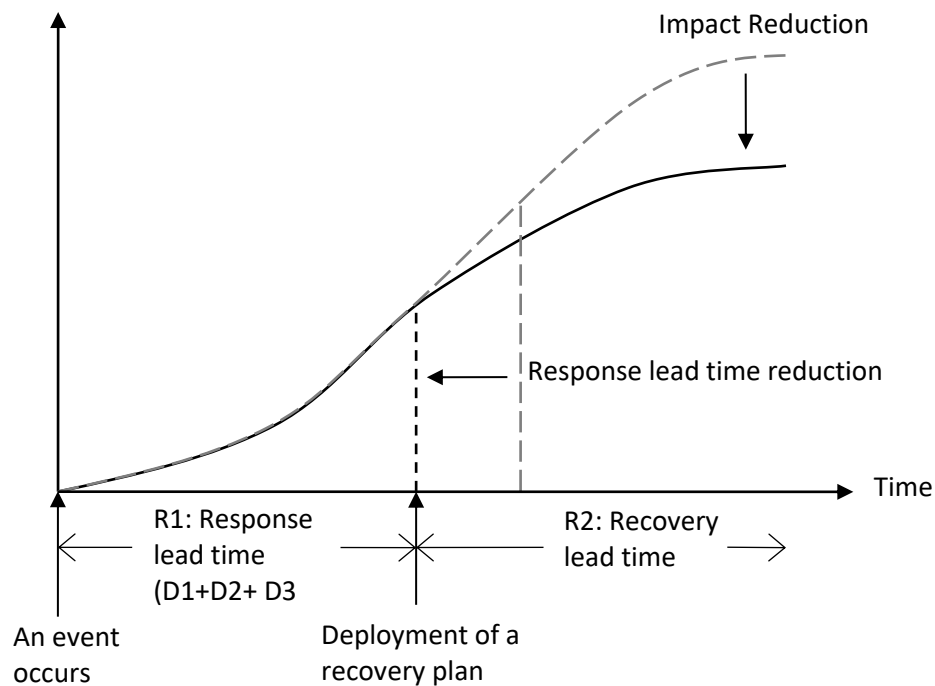
Figure 2-16: The 3-D framework of how reducing detection, risk response design and deployment of a strategy can improve response time and subsequent recovery time following a disruption (Sodhi and Tang, 2012)

This idea of mitigating disruption risk through reducing response lead times is under-developed in the literature and according to Sodhi and Tang (2012) and represents a potentially rich area for future research exploration. It has the joint benefit of being an effective low investment strategy (compared to reserve building etc), whilst also increasing competitiveness by reducing lead time following the occurrence of a given corporate level risk. A number of time-based management techniques are suggested in the literature, which have potential to be developed further to improve understanding in a SCRM context. Sodhi and Tang (2012) note several particular area's which could be focused on, including: 1) how organisations could collaborate beyond tier 1 suppliers to work with their upstream suppliers to map risks, 2) understanding the roles and responsibilities of upstream suppliers to improve communication and co-ordination when responding to a disruption, 3) Progressing mechanisms to develop identification/ monitoring systems for detection of risk, 4) Understanding the design of appropriate recovery plans for various risk events and 5) Development of methods to conduct scenario planning/ stress testing.

In the context of the current research, this area of the literature is especially significant. Through mapping and increasing co-ordination amongst upstream supply chain partners, there is significant scope to reduce both the time taken to detect an event has detrimentally impacted upon a supply chain node, as well as the improved communication and visibility to deploy a pre-designed solution to combat that detrimental impact. For example, detection time can be significantly reduced through increased visibility within the upstream supply chain, as when a disruptive event occurs, the focal organisation is able to assess exactly which suppliers are affected. If the supplier affected has multiple customers, especially when an event has caused a constraint in the market, then there are also significant competitive advantages to reducing this detection time and being able to take advantage of increased communication to identify an appropriate solution before competitors.

This point is exemplified by considering the example outlined previously, where mobile phone manufacturers Nokia and Ericsson were affected by a fire at their joint microchip supplier Philip's, Albuquerque factory. The example outlines the clear relationship between the heightened response lead time (R1) employed by Nokia and subsequent quicker Recovery Time (R2), including associated financial losses, when compared to Ericsson.

2.8   Towards a Stakeholder Salience View of Targeted Corporate-Level SCRM

The above review of the literature has highlighted a clear research gap for applied, case studies exploring how organisations are starting to engage with the management of corporate-level supply chain risk (driven by a range of legislative and regulatory drivers to increase visibility), how this fits with established SCRM practices and understanding how real-world practice fits with more theoretical SCRM literature. This will form the basis of Case Study 1. However, there is also a clear need to build upon increased visibility to develop improved awareness and strategic understanding of corporate-level risks within the upstream supply chain. Building upon the previous discussion, the following section considers stakeholder theory as an appropriate organisational lens with which to frame this more targeted approach to corporate-level SCRM, using a real-world, critical automotive component, this will be explored in Case study 2.

A key question is raised in the above review, namely, how can increased supply chain visibility (increasingly being required from various legislative and regulatory drivers) be used to better assess and target mitigation strategies for upstream corporate level disruption risk, without significant investment in additional financial and human resource? (As in the vast majority of cases it is simply financially impractical to take measures to mitigate risk within every node of the upstream supply chain). Answering this question requires the development of a more targeted management approach to identify and assess upstream, corporate level supply chain disruption risk. With this in mind, it is argued that considering the problem through the organisational lens of stakeholder theory, allows this research to critically conceptualise the challenge and develop a novel framework with which to assess stakeholder salience in targeting corporate level supply chain disruption risk. Moreover, using the technological example of the Li-ion battery, this conceptual framework is empirically tested in order to assess its suitability to addressing the problem.

Although the stakeholder concept is discussed in literature as early as 1965, Edward Freeman's 1984 book 'Stakeholder Management: A Stakeholder Approach', is widely cited as being the first to fully articulate the stakeholder framework (Laplume et al., 2008). Freeman (1984, p. 25) had observed that fundamental changes were occurring amongst both internal and external stakeholders and noted that managers needed to 'take into account all of those groups and individuals that can affect, or are affected by, the accomplishment of the business enterprise'. This now classical definition still remains the most widely cited. Although, as will be discussed, two dichotomous views can be said to have presented themselves in the literature which effectively divide Freeman's definition of what constitutes a stakeholder, the 'claimant' definition and the 'influencer' definition (Kaler, 2002).

Several approaches to categorising stakeholders have been suggested in the literature (For example, Frooman, 1999 and Winn, 2001). However, it is Mitchell et al's (1997) paper proposing a 'Theory of Stakeholder Identification and Salience' that remains one of the more dominant categorisation models. Mitchell et al. (1997, p. 862) considered that Freeman's 'broad concept of stakeholder management must be better defined in order to serve the narrower interests of legitimate stakeholders. Otherwise, influencing groups with power over the organisation can disrupt operations so severely that legitimate claims cannot be met and

the organisation may not survive'. In their analysis of 20 studies on stakeholder identification, Mitchell et al. (1997, p. 854) concluded that stakeholders are those 'who have power in relation to the organisation, who are deemed legitimate and who can muster urgency', where, **Power** refers to the ability or capacity of a stakeholder to influence or produce an effect on organisational behaviour, outcomes, processes or direction and **Urgency** can be considered the implication that a stakeholder's claim is time sensitive and in some way critical demanding attention of the organisation. Whilst these two attributes are well defined and understood in the literature, central to this and other definitions of 'what constitutes a stakeholder' is the notion of **Legitimacy** and what makes one organisational entity legitimate whilst another not, the so called 'broad vs. narrow' debate (Phillips, 1997). Whilst various authors have adopted a narrow view in arguing that a legitimate stakeholder should only be one for whom a moral, ethical obligation is owed by an organisation, this conception risks failing to consider those constituencies for whom no immediate moral obligation is owed, but who could significantly affect organisational performance. Conversely, adopting a definition which is too broad would obviously negate the whole concept of 'stakeholder'; If everyone is a stakeholder of everyone else, little value is added by the theory (Phillips, 2003).

In his paper on 'stakeholder legitimacy', Phillips (2003, p. 30) addresses this point specifically and creates a distinction between normative stakeholder legitimacy, 'those stakeholders to whom the organisation has a moral [or ethical] obligation' and derivative stakeholder legitimacy, those stakeholders for whom there is no direct moral obligation but who have the 'ability to affect the organisation and its normative stakeholders'. He notes that identifying and understanding the distinction between these two groups of stakeholders is vital to both scholars and managers and that both will dictate different sorts of management strategy.

Whist Freeman (1984), Mitchell et al (1997) and Phillip's (2003) definition of 'stakeholder' make reference to the reciprocal nature of influence, i.e. that an organisation's actions can affect stakeholders, but those stakeholders can also affect the organisation, subsequent papers in this area have largely focused only on an organisation's corporate responsibility towards its stakeholders (Fassin, 2012). Laplume et al (2008, p. 1169) affirm that 'the normative base serves as the critical underpinning for the theory in all its forms'. They cite a number of normative frameworks which have been applied to the field including 'property

rights', 'the principle of fair play', 'critical theory', 'Kantian ethics' and 'organisational justice' to name but a few. This, perhaps, over-emphasis of the literature on ethical grounds for adopting a normative stakeholder approach, largely stems from the fact that the theory emerged at time when there were many reports of ethical misconduct and negligence in the corporate world in perusal of what Jenson (2002) refers to as 'the single valued objective' of a corporation, to make a profit. However, over the past two decade there has been a significant rise in environmental and social awareness of large organisations. A recent study by Spada (2008) of Environmental Reporting practices in FTSE 100 companies found that organisations are paying more attention to 'the role of the stakeholder' more than ever before. It can be said that the stakeholder concept is now undeniably the standard model for analysis of corporate responsibility (Fassin, 2008b).

The success of 'stakeholder theory' in this normative sense, both as an academic concept and practical business tool is due in large part due to the simplicity of the model, but also, as Fassin (2008a) notes, the clarity of Freeman's powerful visual conceptualisation. However, it should be acknowledged that at its core, the stakeholder model, 'is a theory of organisational strategy [as well as] ethics' (Phillips et al. 2003, p. 34) and the success of stakeholder theory in its more normative applications should not detract academic attention from the more instrumental rationales for stakeholder theory application from a strategic perspective, regardless of the moral or ethical considerations (Fassin, 2008b, Laplume, 2008).

As an organisational theory, the stakeholder model remains, perhaps appropriately, a high-level concept where, although there have been many attempts to categorise salience between 'stakeholder groups', there is considerably less insight into what could be termed 'within-group categorisation'. Moreover, the stakeholder literature suggests that there can be academic merit in separating and strategically dealing with primary stakeholder groups individually (Clarkson, 1995). This is illustrated in figures 2-17 and 2-18.
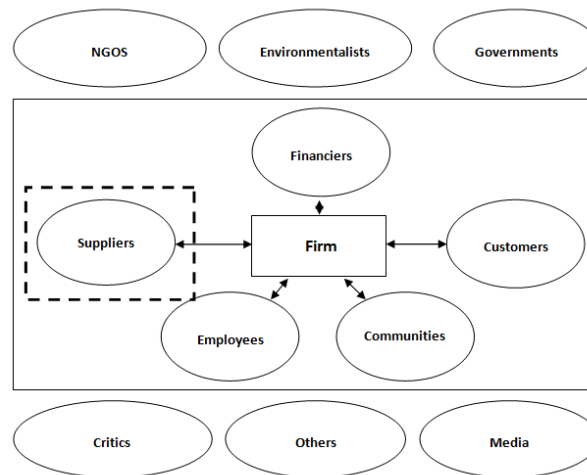
Figure 2-17: Separating out the supplier group from Freeman's redefined stakeholder model (2003)

Fassin (2008a) has noted that previous scholars often fail to sufficiently link their analysis with Freeman's accepted graphical scheme and as such often overlook inconsistencies within their approach. From Freeman's original (1984) model of the stakeholder framework to his more recent (2003) refined model, the basic graphical representation has changed little. Whilst it can be said that the powerful simplicity of the stakeholder concept has contributed to its success as an organisational theory, over the years, critics have attacked the vagueness and ambiguity of the model, as discussed by Kaler (2003) and Fassin (2008a). Fassin (2008a) warns that alterations of Freeman's overall stakeholder model should be minimal if the visual power of the accepted framework is to be maintained. However, adapted versions of Freeman's original model which undoubtedly offer valuable insight to the stakeholder literature, have been proposed, such as Rowley's (1997) network model of stakeholder theory which takes into account each stakeholder's subset of stakeholders and Post et al's (2002) wider environmental model which takes into account the resource base, industry structure and social political arena.

This research does not seek to add specifically to the wider debate around how the overall stakeholder framework should represent network or environmental structure. Instead, it seeks to focus on a single stakeholder group: 'suppliers'. As has been discussed, the stakeholder literature suggests that there can be academic merit in separating and strategically dealing with primary stakeholder groups individually (Clarkson, 1995). The significance of exploding and interrogating individual groups is illustrated by considering the supplier subset. For example, whilst for visual simplicity, the upstream supply chain of an

organisation is often grouped together as 'suppliers', in reality this is not a simple dyadic relationship as represented in Freeman (1984) original model, instead, the 'supplier' stakeholder group is a complex multiple tiered network of suppliers, raw material producers and traders (figure 2-18). It is appropriate to relate this observation to Phillip's (2003) distinction between 'normative' and 'derivative' groups of stakeholder legitimacy where, normative stakeholders are those 'to whom the organisation has a moral [or ethical] obligation', and, derivative stakeholders are those for whom there is no direct moral obligation but who have the 'ability to affect the organisation and its normative stakeholders'. The traditional Freeman model would dictate the high-level 'suppliers' group as having normative legitimacy. However, upon segregating and breaking down this group into its constituent supply chain parts and considering the observations regarding the relationship between organisation and upstream partners, it can be argued that those constituents who do not form part of the low level supply chain may be more accurately described as having derivative stakeholder legitimacy.
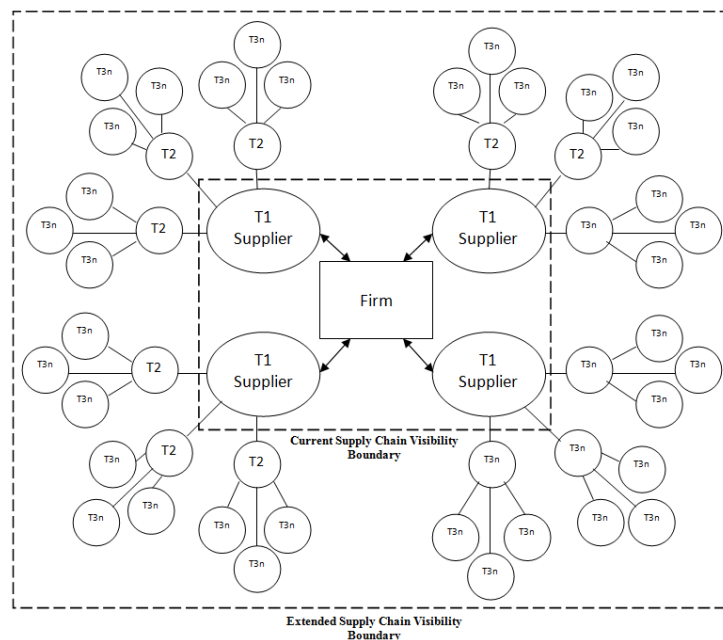
Figure 2-18: *Example of exploded supply chain stakeholder group, including current and extended supply chain visibility boundaries of the focal firm*

Figure 2-18, above, represents a simplified example of an organisation's upstream supply chain and demonstrates the number of relationships between supply chain nodes present. As has been highlighted in the above literature, many organisations have poor visibility of their upstream supply chain, contracting purely with lower tier suppliers and having limited

visibility of operations further upstream (Zsidisin, 2004). The management of upstream supply chain risk in this sense is often seen as the responsibility of those lower tier organisations, a model which has several intrinsic problems which have been discussed above. As a number of new legislative and policy measures are driving organisations to increase their upstream supply chain visibility, there is a need to address how organisations can use this increased visibility to better assess and target mitigation strategies for upstream corporate level disruption risk, without significant investment in additional financial and human resource.

It is this contention which underpins the development of the current conceptual framework. To this end, the conceptual framework proposed in this research seeks to extend the principles of stakeholder theory to categorise the salience of constituents within the organisational 'supplier' group. It seeks to identify critical hotspots of risk so that often limited resources can be appropriately targeted onto the mitigation and strategic management of corporate level supply chain disruption risk; This conceptual framework is discussed in more detail below. It builds upon the principles of Mitchel et al (1997, p. 854) that stakeholders are those 'who have power in relation to the organisation, who are deemed legitimate and who can muster urgency'. However, it is considered that the reciprocal nature of influence, i.e. that whilst an organisation's actions can affect stakeholders, those stakeholders can also affect the organisation (noted by Freeman, 1984, Mitchel et al, 1997 and Phillips, 2003), has been under-emphasised in the recent literature. Instead, papers in this area have largely focused only on normative legitimacy and an organisation's corporate responsibility towards its stakeholders (Fassin, 2012, Laplume et al, 2008). The current research therefore seeks to refocus attention upon the role of stakeholder theory as a theory of organisational strategy and not just ethics, and further develop the strategic application of stakeholder theory in management decision making. Considering, the above literature review, no application of stakeholder theory was found from a SCRM perspective. Moreover, there has been very little application of stakeholder theory in the field of supply chain management generally, with a small number of notable exceptions such as Co and Barro's (2009) work on 'stakeholder theory and dynamics in supply chain collaboration'. It is considered that this approach answers calls by leading authors in the stakeholder theory literature, that recent developments in the field should not detract academic attention from the more instrumental

rationales for stakeholder theory application from a strategic perspective, regardless of the moral or ethical considerations (Fasin, 2008, Laplume, 2008).

Figure 2-19, presents a conceptual stakeholder salience framework, visualising how geographical supplier data, gained through an increasing organisational visibility of upstream supply chain tiers, can be modelled alongside three weighted groups of existing corporate-level disruption risk indicators (identified from the World Economic Forum (WEF) and Accenture report on Understanding Global Supply chain and Transport Risk, 2012) to identify potential upstream risks. These can then be assessed, alongside 'in-house' supplier significance (i.e. for high significance suppliers) to determine the most critical hotspots of upstream, corporate level risk to then target resources at as well as reduce lead time following a disruption. Case study 2 of the current research will explore this conceptual framework, utilising Geographic Information Systems software, with a real-world critical automotive component, the Li-ion Battery.
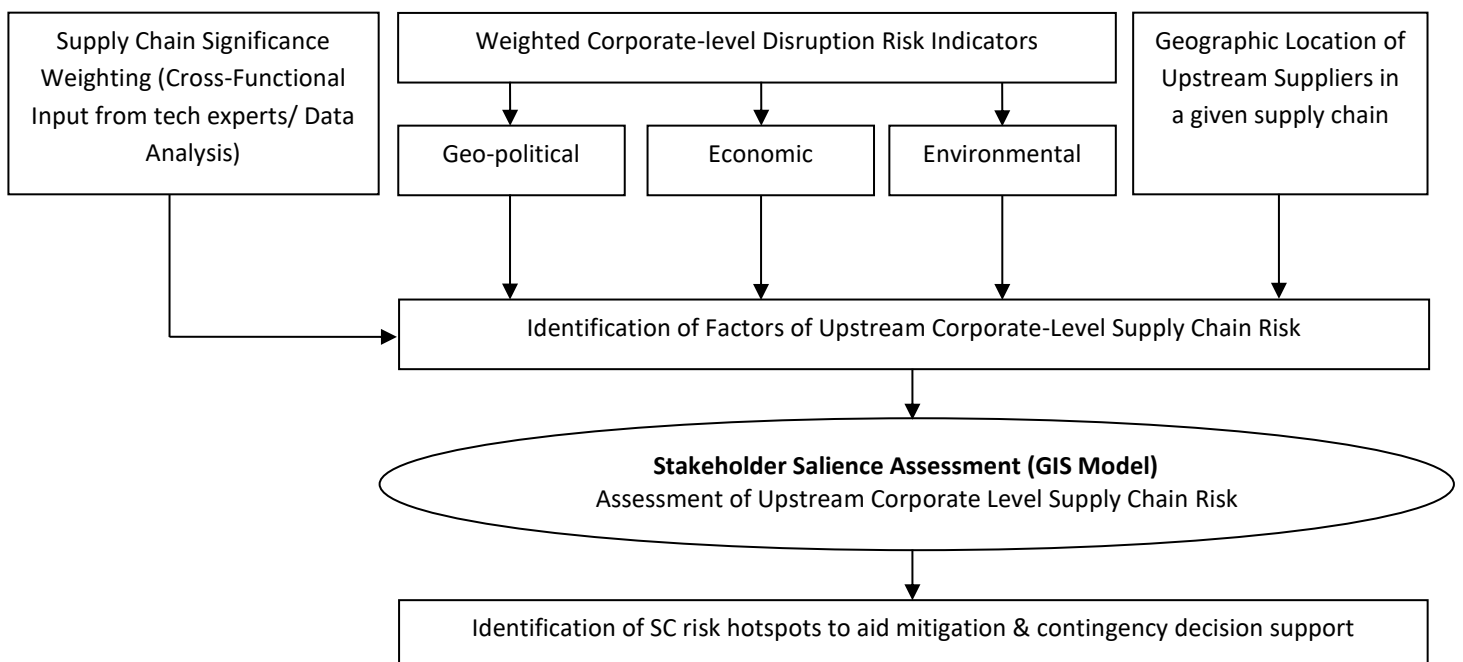
Figure 2-19: Conceptual stakeholder salience model for use in the assessment of upstream corporate-level supply chain risk

2.9   Knowledge Gaps

The previous review of the SCRM literature has highlighted a number of research gaps which this research seeks to address through two case studies within the automotive sector. The identified gaps are set against a background of increased frequency and susceptibility of many organisations to external corporate-level risks in recent years (Juttner and Maklan, 2011) and highlight the fit of this research's objectives to key themes within the contemporary SCRM literature.

The identified research gaps can be summarised as follows:

- **RG1 – Corporate-level supply chain risk management remains an area of the literature in its infancy**

  The academic literature concerning strategic management of corporate-level supply chain disruption risks is still in its infancy (Pereira et al, 2014, Sodhi and Tang, 2012). Moreover, the value of proactive and holistic approaches to managing supply chain risk in this area remains largely unexplored, especially from an applied perspective.

- **RG2 – The risk of corporate-level supply chain disruption remains unaddressed by many organisations**

  Research highlights that whilst most managers know that they should protect their supply chains from serious and costly corporate-level disruptions, comparatively few take sufficient action (Chopra and Sodhi, 2014). In other words, while many managers appreciate the impact of supply chain disruptions of this nature, they have done very little to prevent such incidents or mitigate their impacts (Tang, 2006, Saenz and Revilla, 2014).

- **RG3 – Many organisations do not understand the complexities of their upstream supply chain where disruption risks are most likely to occur**

  Whilst corporate-level disruption events may impact any node throughout the supply chain, the literature suggests that supply chain disruptions of this nature are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of the chain. Moreover, the literature suggests that this risk is amplified as these tiers of the supply chain are less likely to be understood and managed by UK businesses, as many have little visibility beyond the lower tiers of their supply chain (Owen and Barrett, 2014, CCC, 2014). A lack of upstream supply

chain visibility inhibits managerial ability to understand, even at a basic level, how susceptible their upstream supply chain is to various corporate-level disruption risks (Colicchia and Strozzi, 2012).

- **RG4 – There is a lack of understanding around how real-world organisations engage with SCRM generally and in-particular corporate-level SCRM.**

   The literature highlights a lack of applied work in the area of SCRM, especially in terms of real world qualitative case studies. Saenz and Revilla (2014) highlight the significant gap in the academic literature for best practice case studies of companies that are taking steps to proactively manage supply chain risk, especially corporate-level disruption risk. There is a clear need to understand how organisations are implementing new strategic approaches to the management of corporate level disruption risk, how these approaches fit in to their traditional SCRM processes and their relationship to the more theoretical literature.

- **RG5 – A number of legislative and regulatory drivers are forcing organisations to increase upstream supply chain visibility which provides significant opportunities for SCRM**

   Various legislatively prescribed measures are forcing organisations to significantly increase their supply chain transparency. A gap exists in the supply chain literature to understand these drivers which are applying pressure on organisations to increase upstream supply chain visibility and understand how forward-thinking organisations are reacting to them. The timeliness of these drivers makes this a pertinent time to consider real-world examples of engagement in this area.

- **RG6 – A need to develop more targeted approaches to the management of upstream corporate-level supply chain risk**

   As organisations a driven to increase visibility, there is a need to consider better ways to assess which areas of the extended upstream supply chain are most susceptible to corporate-level disruption in order to better target limited SCRM resources (Tang, 2006). Corporate level disruption risks are usually subjected to a more 'gut instinct' assessment, which is fraught with subjective difficulties (Zsidisin et al, 2004). Therefore, exploring methods to fully utilise historical & forecast geographical data is needed, to allow for more objective assessment of organisational susceptibility throughout the upstream supply chain.

RG1: Corporate-level supply chain risk management remains an area of the literature in its infancy

RG2: The risk of corporate-level supply chain disruption remains unaddressed by many organisations

RG3: Many organisations do not understand the complexities of their upstream supply chain where disruption risks are most likely to occur

RG4: There is a lack of understanding around how real-world organisations engage with SCRM generally and in-particular corporate-level SCRM.

RG5: A number of legislative and regulatory drivers are forcing organisations to increase upstream supply chain visibility which provides significant

RG6: A need to develop more targeted approaches to the management of upstream corporate-level supply chain risk

Objective 1: To review key drivers increasing the susceptibility to corporate-level disruption risk within organisation's supply chains and critically analyse the latest SCRM literature in this area.

Objective 2: To assess how a leading automotive manufacturer currently manages corporate level disruption risk within its immediate supply chain partners (T1) and attitudes toward increasing supply chain visibility beyond this.

Objective 3: To review legislative and policy drivers placing pressure on organisations to increase upstream supply chain visibility.

Objective 4: To propose a framework for how increased visibility might be used to better target mitigation strategies for corporate-level supply chain disruption risk and test this using the Li-ion battery supply chain (as an example of new technology exposing automotive manufacturers to new risks) in this area.

Case Study 1:

An Explorative Case Study of Corporate-Level Disruption SCRM Practices at a Leading Automotive Manufacturer

Case Study 2:

Towards a Stakeholder Salience Framework of Upstream Corporate-Level SCRM: A Case Study of the Li-ion Battery Supply Chain

Figure 2-20: Linking key knowledge gaps to objectives of the current research

2.10   Summary

This chapter has reviewed and critically analysed the academic and wider literature relevant to the current research.

An academic review of the Supply Chain Risk Management (SCRM) literature has been undertaken, with emphasis being placed upon the identification, assessment and mitigation of those disruption risks that are geographically driven and external to the supply chain, defined as corporate level disruption risk. A number of knowledge gaps in the academic literature have been drawn out and used to inform specific objectives of the research.

Through the identification of key drivers increasing organisational susceptibility to corporate-level supply chain disruption, as well as analysis of key trends in the field, this chapter contributes towards the completion of Objective 1 of this research.

Consideration is given to the use of Stakeholder Theory as an appropriate organisational lens with which to develop a conceptual framework for improved assessment and management techniques of these types of risk and the relevant literature is thoroughly reviewed. This conceptual framework will form the basis for exploration of Objective 4 of this research and be explored with the use of a practical case study within the automotive sector, the Li-ion battery.

3   Chapter 3 – Methodology

3.1   Introduction

This chapter is concerned with the methodological paradigms and process that have helped to meet the aims of this research. These are to:

− O_1) Review key drivers increasing the susceptibility to corporate-level disruption risk within organisation's supply chains and critically analyse the latest SCRM literature in this area.

− O_2) Assess how a leading automotive manufacturer currently manages corporate level disruption risk within its immediate supply chain partners (T1) and attitudes toward increasing supply chain visibility beyond this.

− O_3) Review legislative and policy drivers placing pressure on organisations to increase upstream supply chain visibility.

− O_4) Propose a framework for how increased visibility might be used to better target mitigation strategies for corporate-level supply chain disruption risk and test this using the Li-ion battery supply chain (as an example of new technology exposing automotive manufacturers to new risks) in this area.

Following a comprehensive review of the relevant academic literature, presented in Chapter 2, a largely qualitative inductive research methodology is developed from the interpretivism and constructivism perspectives. However, as will be discussed below, some quantitative analysis is also undertaken. In the first section, these epistemological and ontological paradigms are considered in full and discussed in relation to the current research. A case study approach was selected as appropriate in the current context, utilising both semi-structured interviews and analysis of organisational documents as primary research tools and the rationale and obstacles in choosing these particular research methods is discussed in detail. A case study approach of this nature is in keeping with the aforementioned theoretical finding that there is a lack of fine-grained qualitative narratives in the chosen field (Saenz and Revilla, 2014) and will allow for exploration of other identified research gaps in a more applied, practical context. As highlighted in Chapter 1, two in-depth, applied case studies have been undertaken in meeting the aims and objectives of the current research.

Case Study 1	Case Study 2
An Explorative Case Study of Corporate-Level Disruption SCRM Practices at a Leading Automotive Manufacturer	**Towards a Stakeholder Salience Framework of Upstream Corporate-Level SCRM: A Case Study of the Lithium-Ion Battery Supply Chain**
Aim: To gain an in-depth understanding of strategic approaches to SCRM within a leading automotive manufacturer, developing specific insight of how and why traditional processes are evolving to manage corporate-level disruption risks.	**Aim:** Using the Li-ion battery supply chain as an example of a real-word 'critical' component, to develop a conceptual framework exploring how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk.

Figure 3-1: Case Study Aims

In addition to thematic analysis of qualitative data, which provides a foundation for both case studies, this chapter also considers how more quantitative supply chain and risk data have been utilised in Case Study 2. This data, collected primarily during the interview process, but also from a range of secondary sources, has been used to develop a conceptual framework exploring how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk. Using the Li-ion Battery supply chain (as an example of a critical automotive component), geographical supply chain data and weighted risk metrics are combined to create a multi-layered Geographic Information System (GIS) map, highlighting the susceptibility to various forms of corporate-level supply chain risk. This example supply chain case study is used to conceptualise many of the challenges associated with limited upstream supply chain visibility.

3.2 Research Strategy

There are widely held to be two distinct research approaches, the quantitative and qualitative. The traditional dichotomy provides that a quantitative enquiry examines numerical data, generally adopting a deductive approach, whereas a qualitative enquiry examines narrative data, generally adopting an inductive approach. (Easterby-Smith et al, 2001). At its most basic level, deductive strategy, which represents the most common view of the relationship between theory and research (Bryman and Bell, 2011), involves the researcher deducing a hypothesis, which is then subjected to empirical scrutiny. Conversely, an inductive theoretical strategy involves drawing generalisable inferences out of

observations (Bryman and Bell, 2011), in other words theory becomes the outcome of research.

This research has adopted an inductive, largely qualitative approach. However, as will be discussed below, in combining supply chain data with various geographical risk metrics, more quantitative methods have also been applied in Case Study 2.

3.3   Research Paradigms: Epistemological & Ontological Considerations

In any study, the researcher bases their work on a certain view of the world and the results they hope to obtain will aim to 'predict, prescribe, understand or explain' (Thietart, 2001, p. 13). An epistemological issue concerns the question of what is (or should be) regarded as acceptable knowledge in a discipline (Bryman and Bell, 2011). In the social sciences, the central question often centres on whether or not the social world can be viewed according to the same principles and perspectives as the natural sciences. Through the understanding epistemological presuppositions, Thietart (2001, p. 13) notes that 'researchers can control a research approach, increase the validity of results… and ensure the overall legitimacy of their work'.

Where quantitative research entails the collection of numerical data with the aim to test theories specified at the start of a study (Bryman and Bell, 2007), qualitative theory departs from this more traditional positivist approach. Instead, qualitative enquiry is distinguished by its inductive view of the relationship between research and theory generation where emphasis is on looking at the interpretations of research participants to understand a given social phenomena. Wright (1971) notes the epistemological clash between traditional positivist views and hermeneutics, the theoretical development of how human action is interpreted. This 'clash' can be denoted by the divide between positivist approaches, which place emphasis on the *explanation* of human behaviour and those of the social sciences which seek to *understand* human behaviour. Wright's contrast of these two epistemologies, echoes Max Webbers (1864-1920) 'Verstehen' approach, where he described sociology as a 'science which attempts the interpretive understanding of social action in order to arrive at a causal explanation of its course and effects' (in Bryman and Bell, 2015, p. 28).

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The contrasting epistemological position to positivism is interpretivism, which takes the view that the subject matter of the social sciences is inherently different to that of the natural sciences. Therefore, a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action (Bryman and Bell, 2007).

Taking an interpretivist view of the research is particularly appropriate for the current research, as an interpretive view will allow for a better understanding of the social motivations behind particular actions (Bryman and Bell, 2007), a factor which is paramount in understanding 'how' and 'why' the chosen organisation has decided to configure their supply chain and management strategies in a certain way. Although quantitative analysis does allow the researcher to for the establishment of causal relationships between concepts and generalisation/ replication beyond the confines of the research it is not appropriate for all research, especially beyond the natural sciences. Bryman and Bell (2007), for example, note several weaknesses to quantitative research including failure to distinguish people and social institutions from the natural order, heavy reliance on research instruments and control hindering the connection between research and everyday life and the use of artificially assumed measurement processes.

Ontological considerations concern the nature of social entities. Bryman and Bell (2011) describe the central issue as being whether social entities can and should be considered objective entities that have a reality external to social actors (objectivism), or whether they can and should be considered social constructions built up from the perceptions and actions of social actors (constructivism).

This research project and the author's emphasis, or belief, is in accordance with the constructivism paradigm. From an Ontological perspective, this asserts that social phenomena and categories are not only produced through social interaction but that they are in a constant state of revision, for example, their meanings are continually being accomplished by social actors (Bryman and Bell, 2011).

Gubrium and Holstein (2003) go further to describe the four contrasting traditions, or 'languages of', qualitative research: Naturalism, the epistemological view of methods for knowledge acquisition, irrespective of personal view; Postmodernism, the view that social reality cannot be described objectively but instead places emphasis on methodological issues; Ethnomethodology, the understanding of social orders which are used by different people to make sense of the world and Emotionalism, the use of social enquiry to understand different peoples experiences. As this research has adopted an interpretivist epistemology and a constructivist ontology, there are closest links with the tradition of naturalism. Whilst, naturalism as a term in business research ethics has several meanings, Gubrium and Holstein's (2003) view of naturalism is that it seeks to understand social reality in its own terms, i.e. as it really is, realising that people attribute meaning to their behaviour and are authors of their social world rather than passive objects (Bryman and Bell, 2011), this is especially relevant considering the current context.

3.4   Justification of Research Process

Qualitative research approaches can generally be divided into five groups: Phenomenological Research, Biographical Research, Ethnographic Research, Grounded Theory and Case Study Research.

A case study design was chosen to address the current research question. The case study approach can be viewed, not a method, but as research strategy which employs numerous methods. Case study research consists of a detailed investigation, often with data collected over a period of time of phenomena within their own context. As the case study approach provides a vehicle through which several methods can be combined, it avoids too greater reliance on a single approach (Knights and McCabe, 1997). Bryman and Bell (2011) note that case study research can be distinguished from other methodological designs by its focus on a specific bounded situation or system (i.e. an entity with a functioning purpose or parts). The aim is to provide an analysis of the context and processes which illuminate the theoretical issues being studied (Hartley, 2004).

Whist case study research is often associated with purely qualitative methods, this is not always the case and in business research case studies have often employed both qualitative

and quantitative methods (Bryman and Bell, 2011), as in the current research. In terms of the operations management research, Yin (2003) notes that the case study approach is particularly appropriate for understanding how managers make global sourcing decisions and how they mitigate risk. Furthermore, Kaoulikpoff-Souviron and Harrison (2005) discuss how the method is particularly relevant for supply chain research because it helps to gather better information, about the realities of supply chains and develop better, more complete theories about them.

Stake (1995), suggests three different types of case study that researchers can align themselves with, based on what the desired opportunity to learn is. He states that intrinsic case studies are taken primarily to gain insight in to a particular situation, rather than to compare with other cases or generalise. Conversely, instrumental case studies provide an opportunity to use a case to understand a broader issue and to challenge generalisations. Finally, multiple/ collective cases are undertaken jointly to understand a general phenomenon.

The current research adopts a largely intrinsic approach as its aim is to gain insight in to a single organisation and its supply chain. Yin (1994) defines this type of case study as 'revelatory', where the investigator has an opportunity to observe and analyse a phenomenon previously inaccessible to scientific investigation. However, both Yin (1994) and Stake (1995) acknowledge that there these types can sometimes be construed as rather narrow and are not isolated as there lines are often blurred. For example, the current research has some instrumental features in that it seeks to also highlight and examine a broader problem which exists beyond the focal case, upstream corporate-level supply chain risk management.

Although used less than other research methods, case studies involving the extensive examination of a single organisation are amongst the most powerful research methods employed in operations management, particularly in the development of new theory (Mangan et al, 2004). The literature reviewed in chapter 2 (section 2.6) clearly highlights the contribution that in-depth, single case studies can make to the field of operations management; see for example Saenz and Revilla's (2014) impactful case study on Cisco

Systems. Outside of the operations management literature, the single case study approach has been widely used in broader business research (Eisenhardt and Graebner, 2007). See for example Born's (2004) in depth study of managerialism at the BBC or Pettigrew's (1985) research in to continuity and organisational change at Imperial Chemical Industries (ICI), now part of AkzoNobel. Again, both of these studies are highly commended for their insights in to the complexity and particular nature of a single organisational case (Stake, 1995). After all, understanding meanings attached to experiences of individuals or organisations, enabled through single-case analysis, is the hallmark of good qualitative research (Harrison, 2013).

An often-cited criticism of the case study approach relates to the aforementioned research design criterion of external validity more specifically the question, how can one depth case be generalised? This topic is discussed in more detail in section 3.8. However, briefly addressing this point in relation to the current discussion, Lee, Collier and Cullen (2007), suggest that the main strength of case study research is particularisation and understanding the complexity and uniqueness of a case rather that generalisation. It has also been suggested that in some circumstance case study research can be extended to produce a degree of theoretical generalisability (Bryman and Bell, 2011). For example, Yin (1994) notes that the crucial question is not whether or not the findings can be generalised to a wider universe, but how well the research generates theory out of the findings.

3.5 Case Study Design and Research Tools for Data Collection

Two applied case studies have been undertaken in meeting the aims and objectives of the current research. Figure 3-2, provides an overview of the different research tools employed in undertaking each case study, including semi-structured interviews, analysis of internal organisational documents, legislative/ regulatory review and analysis of geographical supply chain data. An overview of these are presented in the following sections.

Data Collection Method

5 Semi-Structured Interviews (VM1-5) with Functional Experts at a Leading Vehicle Manufacturer

Access to and Analysis of Internal SCRM Organisational Documents

Review of Current Academic and Practitioner SCRM Process Literature

Legislative and Regulatory Review of the Drivers for UK Organisations to Increase Upstream Supply Chain Visibility

Case Study 1: An Explorative Case Study of Corporate-Level Disruption SCRM Practices at a Leading Automotive Manufacturer

Focal Firm Input in to the Choice of a 'Critical' Supply Chain for Use in the Research (Drawing on Aforementioned Interviews)

5 Semi-Structured Interviews (SCP1-5) with the Focal Organisation's Li-ion Battery Supply Chain Partner (Supply Chain and Technical Experts)

Access to and Analysis of Internal Organisational Documentation from both the Vehicle Manufacturer and their Li-ion Battery Supply Chain Partner

Direct (from SCP) and Indirect (Secondary Raw Material Market Data) Geographic/ Component Supply Chain Data

Review and Expert Opinion of appropriate datasets to use as proxy for key Corporate-Level Risk Types

Case Study 2: Towards a Stakeholder Salience Framework of Upstream Corporate-Level SCRM: A Case Study of the Lithium-Ion Battery Supply Chain

Figure 3-2: Data Collection Methods Utilised in the Two Research Case Studies

3.5.1   Semi-structured Interviews

Yin (2003) notes that the use of semi-structured interviews as a data collection method as part of a case study approach provides a flexible instrument to obtain information from the field and helps to develop a consistent and reliable account of the issues under study, providing a firm founding for conclusions.

Bryman and Bell (2015, p. 213) define semi-structured interviews as typically referring to 'a context in which the interviewer has a series of questions that are in the general form of an interview schedule but is able to vary the sequence of questions'. This helps retain the open quality of an unstructured interview, putting the interviewee at ease and allowing them to express themselves, but also adds a dimension of control through the addition of a list of questions and subjects to be covered. As Kahn and Cannell (1957, p. 149) describe it, 'the semi-structured interview is a conversation with a purpose'. Semi structured interviews are widely held to the most appropriate method to capture an interviewees thoughts on a particular subject as it helps them to express their conceptions on a given topic in more detail. They allow an interviewer to probe much deeper into an individual's motivations and attitudes, something which is essential to a study of this nature and will allow for a richer narrative as a result.

As with other methods, semi-structured interviews have a number of inherent weaknesses, which should be addressed. Perhaps the most commonly cited include a lack of standardisation and comparability due to the fact that inclusion of a 'semi-structured' element will inevitably take each interview in a different direction (Bryman and Bell, 2007). Subjectivity of the interviewer and subsequent bias are also concerns which should be addressed. Drever (2003) notes that the researcher can impose information on the interviewee, either by selecting the theme and topics, by ordering the questions or by wording questions in his or her language. Whilst this concern cannot be completely mitigated, care must be taken to reduce any risk of bias by having a thoroughly prepared and controlled interview topic schedule.

Following identification of the automotive industry as an appropriate sector for the current research, contact was made with the focal organisation, who were known to the researcher to be actively involved in the area of SCRM.

The initial point of contact within the organisation was in the company's procurement department. Following initial discussion with this contact around the research aims and objectives, appropriate subsequent interviewees across the organisation and its supply chain were identified and contacted about participation. Figure 3-3 provides a full overview of interviews undertaken as part of the current research between August 2012 and Sep 2013.

All interviewees were initially contacted by email or telephone, where the nature of the research was explained. A more detailed information sheet, covering confidentiality and anonymity options, as well as an interview schedule were then emailed to interviewees prior to the interview taking place. Interviews lasted for a period of 1-2.5 hours and either took place in person at the respective organisation's offices or over the telephone, where this was not possible (i.e. when the interviewee was travelling).

Both organisations involved in the study were interested in contributing to the work, realising that the subject was an important area for investigation. In addition to continued engagement in semi-structured interviews, both companies provided access to a range of organisational documents, presentations and figures which were invaluable in building upon interview findings. These documents are discussed in section 3.5.2.

Interview Number	1	2	3	4	5
Interview ID	VM1	VM2	VM3	VM4	VM5
Date	03/08/12	06/12/12	06/12/12	05/02/13	09/05/13
Length of Interview	2.5hrs	2hrs	1.5hrs	2hrs	2hrs
Type of Organisation	Vehicle Manufacturer	Vehicle Manufacturer	Vehicle Manufacturer	Vehicle Manufacturer	Vehicle Manufacturer

Interview Number	6	7	8	9	10
Interview ID	SCP1	SCP2	SCP3	SCP4	SCP5
Date	22/01/13	02/04/13	15/05/13	28/06/13	13/09/13
Length of Interview	1.5hrs	1hr	1hr	1.5hrs	2hrs
Type of Organisation	Supply Chain Partner (Li-ion Battery)	Supply Chain Partner (Li-ion Battery)	Supply Chain Partner (Li-ion Battery)	Supply Chain Partner (Li-ion Battery)	Supply Chain Partner (Li-ion Battery)

Figure 3-3: Overview of Interviews Undertaken for Case Studies

3.5.2   Analysis of Internal Organisational Documents

A range of organisational documents were analysed to contextualise the data collected through semi-structured interviews. Some of these documents are already in the public domain, for example, company/ strategy reports, industry statistics and corporate social responsibility statements. Other documents, however, such as consultancy reports, forecasted production numbers and supplier data, are not publicly available and have been provided during the course of conducting interviews. Christopher et al (2011) notes that analysis of secondary data such as this allows for the triangulation of information gathered from the interviews. Bryman and Bell (2011) also note that if a researcher can gain access to and analyse organisational documents such as these, it is a powerful addition to the data collected during qualitative interviews for case study research. This is evidenced when considering Pettigrew's (1985) highly regarded research in to continuity and organisational change at Imperial Chemical Industries (ICI) where he was allowed wide access to company archives to supplement data collected during interviews.

It is also paramount that the researcher bears in mind the differing quality of various organisational documents when attaching weight to them. Bryman and Bell (2011), referencing Scott (1990), suggest four criteria for assessing the quality of such documents. These are: Authenticity – is the evidence genuine and from a credible source? Credibility – is the evidence free from error? Representativeness, is the evidence typical of its type? And meaning – is the evidence clear and comprehensible?

3.5.3   Secondary Literature (Academic, Practitioner and Regulatory)

A number of secondary literature sources have fed in to the development of this research's case studies. Chapter 2 presented a review and analysis of the academic literature relevant to the research aims and objectives. Findings from case study 1 are critically reviewed in relation to this literature. Moreover, regulatory and legislative analysis is undertaken to complement interview findings in pursuance of Objective 3 (To identify the key legislative and policy drivers placing pressure on UK organisations to increase upstream supply chain visibility). A number of sources were used for this analysis (referenced in text) including, primary/ secondary legislation, regulatory review papers, policy papers and other secondary sources.

3.5.4 Supply Chain Mapping (Component and Geographical) and Risk Data

The concept of supply chain mapping is now well established in the operations management literature. A strategic supply chain map is a tool to align supply chain strategy with corporate strategy, and to help organisations manage and modify the supply chain (Gardner and Cooper, 2003). It is an approach whereby the focal organisation engages with both its lower tier suppliers and external market experts to identify supply chain partners, flows of goods or information (Tumalla & Schoenherr, 2011). However, with the increasingly global nature of supply chains, organisation's now face a significant challenge in attempting to do this. The process of mapping an organisation's upstream supply chain is considerable requiring large volumes of data. As noted by Farris (2010) the resource in terms of harvesting, processing and presenting the data is significant once an organisation moves beyond the macro (tier 1) level.

In addition to this, understanding the type of visibility required is paramount to choosing the correct mapping technique. For example, there are a number of different supply chain mapping methodologies which each aim to illustrate a different type of visibility. Mapping methodologies such as IDEF0 (Icam DEFinition for Function Modeling) and SCOR Model (Supply Chain Operations Reference) aim to analyse how existing business processes work, offering both standardised processes that can be applied to companies in different industries or unique process capture for novel operations. Whilst IDEF0 and SCOR Model are adept at mapping specific processes within a particular organisation, they are less capable of geographically capturing how a supply chain network works. For this, methodologies such as VSM (Value Stream Mapping) are more appropriate. VSM was originally developed by Toyota as part of the Toyota Production System and involves looking beyond individual processes to assess the entire value chain. The aim of VSM is to identify, demonstrate and decrease waste in processes according to lean manufacturing principles. This involves selecting a product/distribution channel and then collecting physical locational data, process data and material flow data at each stage of the chosen supply chain.

Again, understanding the visibility required to address a given business problem is key to understanding the type of supply chain mapping needed. The current research is concerned with understanding the impact of corporate-level disruption risk upon a specific automotive supply chain. The geographic nature of this form of risk, means that primarily, visibility is

required of who upstream suppliers are at each stage of the supply chain, for a given structural component and that suppliers geographical location – rather than specific process data. As will be discussed in more detail below, primary supply chain data (from both employee's expert knowledge and existing organisational data) was collated alongside secondary raw material market data to build detailed maps of the Li-ion Battery Supply Chain. Moreover, mapping was limited to fixed geographical supply chain nodes at a country level as this is both an accurate representation of the current level of data available for upstream suppliers (by the focal organisation) and also the lowest level available for risk datasets used in the research.

The challenges associated with the mapping process highlight the need of the focal organisation to consider the nature of the relationship it has with its supply chain. An active engagement by suppliers during the mapping process, providing meaningful data and working alongside the focal organisation is likely to yield a more accurate supply chain map, which will in turn increase the accuracy of any future work undertaken with that data. The quantitative supply chain and risk data used in pursuance of Case Study 2 are discussed in section 3.10.

3.6 Research Framework

The research framework set out below, was developed from the concepts of Bryman and Bell (2011) and Edmondson and McManus (2007) and sets out the sequential approach applied during the course of this research project. The first planning stage involved formulating the research problem and reviewing the literature to refine this problem in to a tangible set of research aims and objectives. Following this, an appropriate methodology to address the research problem was designed and a conceptual framework for the problem formulated. The primary data used in this research derives from semi-structured interviews and organisational documents. As will be discussed, qualitative data has been interpreted and analysed thematically, whereas quantitative data has been analysed and applied in order in order to explore the aforementioned conceptual framework for assessing susceptibility to upstream, corporate-level supply chain risk. Finally, more contextual conclusions have also been drawn from the research findings and written up.
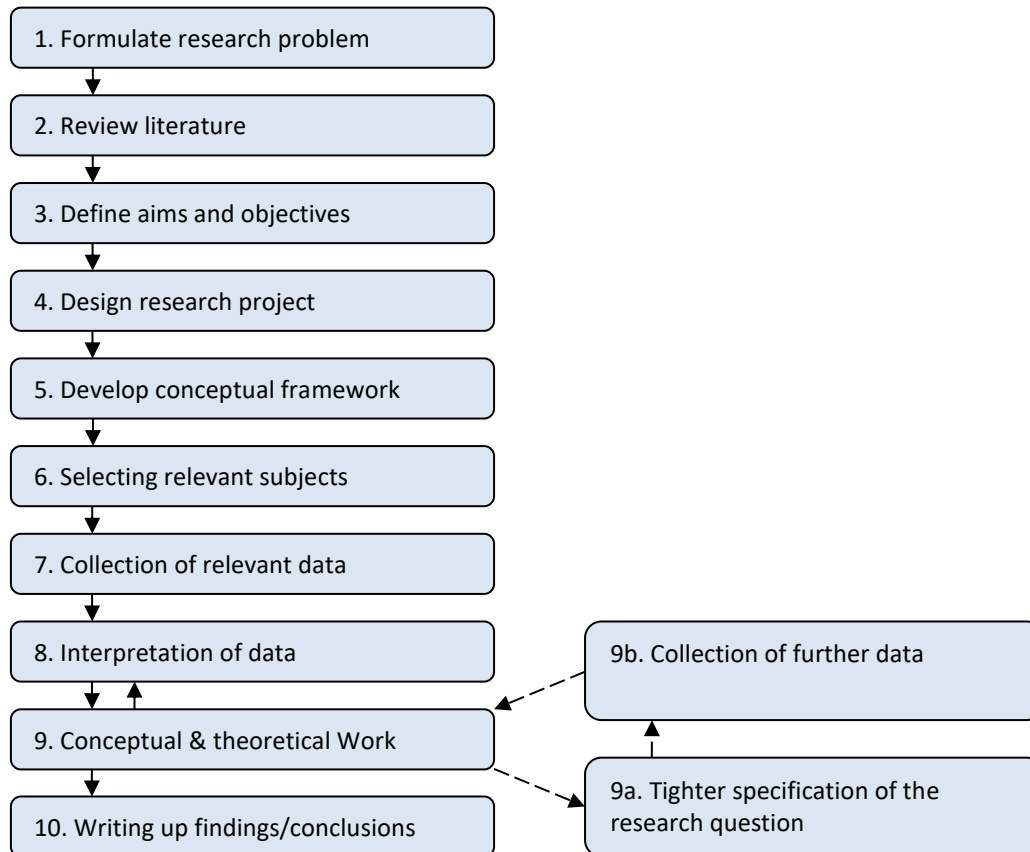
Figure 3-4: Case study research framework (adapted from Bryman and Bell, 2011 and Edmondson and McManus, 2007).

3.7   Reliability and Validity of Research

Adopting the largely qualitative research methods discussed above presents a number of associated challenges which warrant discussion. The term 'qualitative management research' embraces an array of non-statistical research practices. Johnson et al (2006) argue that this is an outcome of many competing philosophical assumptions which produce distinctive research perspectives. Due to the variability of qualitative management research, providing criteria for its evaluation can be a problematic process, because what constitutes 'good' research becomes a polysemous, and therefore somewhat elusive, concept (Johnson et al, 2006). Confusion can specifically arise when evaluation criteria constituted by a particular philosophical stance are universally applied to all forms of management research. This idea of misappropriation, where for example positivist criterion are applied to qualitative research, is often ignored in reviews of evaluation criteria for management research, where it would seem that 'one size' is presumed to fit all (Mitchell, 1985).

In considering this problem, Johnson et al (2006) undertook a study to compare various approaches to undertaking qualitative management research with the positivist mainstream and thereby develop different sets of evaluation criteria to be contingently deployed so that they fit the researcher's mode of engagement. They considered that key philosophical differences emerge between qualitative and quantitative management research over the significance of human inter-subjectivity in explaining behaviour and its appropriateness to scientific investigation. The authors go on to discuss that these philosophical boundaries are not arbitrary, and that it is possible to identify how particular epistemological and ontological positions do legitimate particular research aims, make certain methodological commitments, and suggest the contingent application of specific evaluation criteria.

The proposition of specific evaluation criteria for qualitative management research is not a new one. Lincoln and Guba (1985) were amongst the first to emphasise the need for more tailored evaluative criteria for qualitative research. Since Luncoln and Guba's (1985) paper, a number of authors have attempted to revise positivist evaluation criteria to reflect the inductive approach, through articulating alternative ways of demonstrating the qualitative researcher's scientific rigour. See for example, Morse's (1994) study upon criteria for inductive analysis of qualitative data or Yin's (2003) reinterpretation of positivist quality measures of quality for case study research.

Johnson et al's (2006) own comprehensive study in this area reviewed and critically evaluated the existing literature in this area and proposed that when considering reliability and validity, qualitative management scholars should consider the following alternatives forms of traditional positivist evaluation criteria.

Internal validity   >   Credibility (authentic representation)

External validity   >   Transferability (the extent of applicability)

Reliability   >   Dependability (minimisation of researcher idiosyncrasies)

Objectivity   >   Confirmability (researcher self-criticism)

Internal validity > Credibility

The purpose of internal validity is to 'establish causal relationships and distinguish them from spurious ones' (Christopher et al, 2011, p. 73). As Yin (1994) notes internal validity checks ensures the right cause and effect relationships are established. According to Shenton (2004) and Johnson et al (2006), the qualitative researcher's equivalent concept, credibility, deals with the question, how congruent are the findings with reality?

Credibility has been ensured in the current research through a number of actions including; an extensive pre research literature review (the examination of previous research findings), the use of multiple interviews and methods within the case studies drawing on different sources of both primary and secondary evidence and sending a case report to interviewees to check for misunderstandings or omissions.

External Validity > Transferability

Traditional notions of external validity and generalisability aim to establish a domain in which the research can be generalised. Due to comparatively small sample sizes, the qualitative researcher can rarely make claims about their research's representativeness of the wider population, and therefore any claims to positivist conceptions of external validity are always going to be difficult (Johnson et al, 2006).

This traditional definition of external validity shows confusion between the procedures appropriate for making inferences from survey research and those which are appropriate to more qualitative methods, such as in the current research. Johnson et al (2006) argue that case study research should not seek to derive its generalisability from sampling but instead seek to demonstrate transferability or logical inference from the demonstrated power of the inductively generated theory. Bryman and Bell (2015, p. 71), go on to suggest the qualitative research has an ability to 'generalise the theory rather than the population'.

Based on the literature reviewed, both stakeholder theory and supply chain management, there has been found to be a distinct lack of industry specific studies of this nature. As such, it may be difficult to generalise the specific findings of the study, especially case study 1, to different industries. However, through conducting an in depth case study for the Li-ion

battery supply chain in case study 2, to explore the proposed conceptual framework, it is hoped that certain research findings will be generalisable within the industry and will have implications for other related industries which rely on, the global Li-ion supply chain, such as consumer electronics manufacturers.

Reliability > Dependability

Bell (2005, p. 117) describes reliability as 'the extent to which a test or procedure produces similar results under constant conditions on all occasions'. There are inherent difficulties with transparency and replication of qualitative research due to the often-unstructured nature of process (Bryman and Bell, 2007). For example, the promise of replication is much more problematic in qualitative research due to the social setting in which the research takes place. Whilst unstructured elements of the methodology are essential in gaining a holistic understanding of the research problem, steps were undertaken to maintain maximum transparency of interview process through recording/ note-taking and interviewee reviewed transcriptions.

Dependability may be further demonstrated through use of triangulation, as in the current study. This involves the contingent use of multiple primary and secondary data sources and collection methods to cross reference and substantiate the objectivity of the findings (Johnson et al, 2006). The literature suggests that the contingent use of mixed method triangulation is not only viable but can actually significantly improve management research (Johnson et al, 2006).

Objectivity > Confirmability

Qualitative research is often criticised due to a lack of objectivity. However, this criticism has been rebutted in the literature with the assertion that, whilst qualitative studies have smaller sample sizes and are generally more subjective, they are also more holistic, involving in-depth analysis and systematic description. The concept of confirmability is often held to be the qualitative researcher's comparable concern to objectivity. Here steps must be taken to help ensure as far as possible that the work's findings are the result of the experiences and ideas of the informants, rather than the characteristics and preferences of the researcher (Shenton, 2004).

The role of triangulation in promoting such confirmability is paramount. For example, it is argued that bias often inferred in single method qualitative approaches can be avoided through use of mixed method triangulation; the use of both qualitative and quantitative methodologies to investigate a management problem. In the context of the current research, confirmability was further ensured through minimising researcher bias in the interview schedule and by producing detailed, cross checked transcripts to reduce misinterpretation.

3.8   The Role of Methodological Hybridisation in Management Research

The use of methodological hybridisation is nothing new in the social sciences (Modell, 2009) and is a growing methodological approach in several disciplines, including operations management (Harrison, 2013, Mangen et al, 2004). However, despite calls for its use in business research (Edmundson and McManus, 2007), application and discussion of this methodological approach has lagged behind other areas (Harrison, 2013). This is perhaps strange considering that management research has long called for methods and approaches which provide a middle ground between the contrasting positivist and phenomenological paradigms and perspectives (Mangen et al, 2004). The low prevalence of good quality, mixed method research design by management scholars may be due to a number of different factors, including: the historical precedent of favouring quantitative research in business, the lack of attention to interpretative methods in graduate training and the difficulty in learning both qualitative and quantitative methodologies (Harrison, 2013).

Mixed methods research can be defined as:

> *'When a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration' (Johnson et al. 2007, p. 123).*

The case for mixed methods research has generally been stated in terms of its propensity to enable researchers to combine breadth and depth in empirical enquiries, to enhance the validity of research finding through triangulation and to facilitate the mobilisation of multiple theories in examining management practices (Modell, 2010). For example, Harrison (2013), observes that whilst quantitative research is more apt for answering questions about

relationships between specific variables, and questions of who, where, how many and how much; qualitative research is more apt for answering why and how questions.

The benefit of mixing methodologies is utilising the strengths of each approach. For example, the strength of qualitative research lies in the depth of knowledge gained from analysing the experience of participants. Whereas, the multi-layered analytic approach used in qualitative methodologies allows for a much deeper understanding of a phenomenon (Harrison, 2013). In this sense, mixed methods approaches provide a deeper understanding of meaning, behaviours, or particular phenomena (Harrison, 2013), bringing together scholars and ideas associated with different paradigms and offsetting the weaknesses presented by any singular method (Modell, 2010). They can provide a deeper understanding of context specific meanings, reflecting a much richer understanding of the phenomenon being studied. (Modell, 2009) and have been shown to provide multidimensional insight in to many management research problems (Harrison, 2013). Harrison (2013) specifically demonstrates the potential for qualitative data collection to inform quantitative follow-up, as in the current research. This is especially true in commercially focused business research that uses interviews or focus groups at the outset to inform 'empirical' quantitative investigations.

Mengan et al (2004), specifically summarise the case for combining qualitative and quantitative methodologies in operations management research, providing evidence for methodological triangulation. They conclude that it is necessary to use both quantitative and qualitative methods to really develop and advance operations management research. To this end, methodological triangulation allows operations management scholars to fully understand the phenomena they are trying to research.

3.9   Confidentiality and Research Ethics

The current research has been granted full ethical approval in accordance with the University of Sheffield's 'Research Ethics Framework'. As much of the data collected during the study has had the potential to be commercially sensitive, both the vehicle manufacturer and their tier 1 supplier have utilised their right to remain anonymous. Therefore, any confidential or identifying information provided by the focal organisation has been omitted from the final version of this thesis. All interviews were either recorded or extensive notes taken. Following

each interview, this audio or the associated notes were transcribed and shared with the interviewee to check for any transcription errors and for clarification. Any data provided has been treated as confidential and not shared with other participants in the study unless otherwise agreed.

3.10   Data Analysis

3.10.1 Qualitative Data - Thematic Template Analysis (Case Studies 1 and 2)

Interviews have either been recorded or detailed notes taken and then transcribed. Copies of interview transcripts were shared with participants to check for errors and where necessary amendments made. The analytical process undertaken to analyse this qualitative data largely follows the conventions of template analysis, where a list of codes, or template, were produced which represent different themes in the data (King, 2004).

Whilst consideration was given to the use of a software package, such as NVivo, to analyse data, due to the small sample size and in order to avoid words being taken out of context a decision was taken to manually code the findings. Furthermore, software such as NVivo only aids in organisation of the material and does not perform interpretation/ analysis.

Broad themes from the transcripts and organisational documentation were identified using template analysis (King, 2004), based on both the interview schedule and the research aims and objectives – I.e. largely structured around aspects of the SCRM process for Case Study 1 and more exploratory in nature to understand supply chain dynamics, challenges and structure for Case study 2. Each broad theme was analysed, and more specific sub-categories also identified. In doing this broad code helped provide a general overview of the data, while detailed lower-level codes help enable fine distinctions to be made within case (King, 2004). Cassell et al. (2005) note that although using themes and categories in this way allows for the exploration of data and a comparison of the similarities and differences, it can destroy the bigger pictures. Care has been taken therefore, to ensure that codes are both meaningful in relation to the data as well as each other (Cassell et al., 2005).

3.10.2 Quantitative Data – Geographic Information System Model (Case Study 2)

Figure 3-5 presents the conceptual stakeholder salience framework discussed in Chapter 2. It visualises how geographical supplier data, gained through an increasing organisational visibility of upstream supply chain tiers, can be modelled alongside three weighted groups of existing corporate-level disruption risk indicators (WEF and Accenture report on Understanding Global Supply chain and Transport Risk, 2012) to identify potential upstream risks. These can then be assessed, alongside 'in-house' supplier significance (i.e. for high significance, 'critical' supply chains), to determine the most susceptible areas to upstream, corporate level risk. It is considered that analysis of this nature could permit better understanding of susceptibility to corporate-level disruption risk in the upstream supply chain and aid targeting of limited SCRM resources in this area. Case study 2 of the current research will explore this conceptual framework, utilising Geographic Information Systems software, with a real-world critical automotive component, the Li-ion Battery (LFP and NCM chemistries).
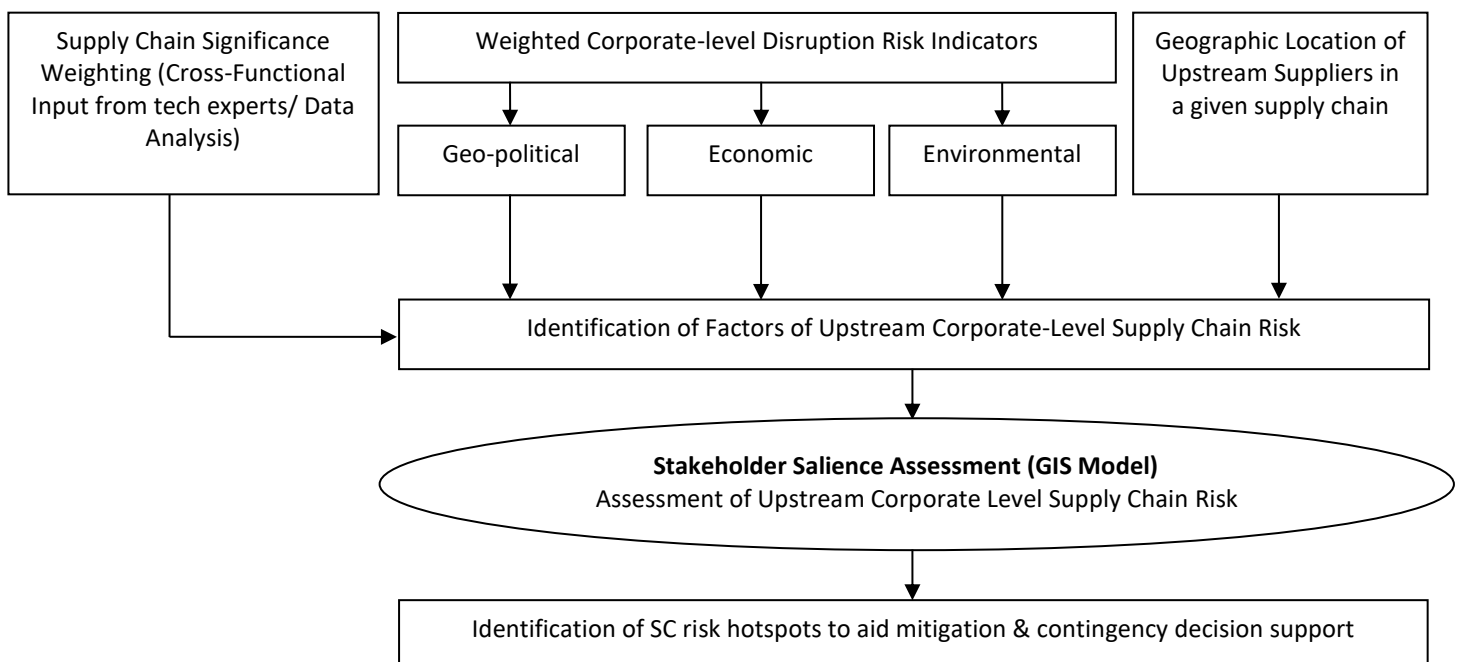
Figure 3-5: Conceptual stakeholder salience framework for use in the assessment of upstream corporate-level supply chain risk

3.10.3 Geographic Information System (GIS) Analysis

Whilst organisations have access to a considerable amount of data from various sources, with which to assess corporate-level supply chain risk, this is often under-utilised (Sodhi & Tang, 2012). Combining often complex, quantitative risk datasets, existing supplier information and geographic supply chain information in a single decision support dashboard could offer valuable support for organisations in increasing visibility of the susceptibility of various nodes of their upstream supply chain to corporate-level risk – aiding in resource targeting and reducing potential lead times following a disruption.

This research considers the utilisation of GIS, as a tool to visualise and assess corporate-level disruption risk throughout a given supply chain:

> *A GIS 'integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information'. It allows an organisation to 'view, understand, question, interpret, and visualise data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts'. (ESRI Online, 2012)*

Compiling a comprehensive history of the development of GIS has been described as a difficult task due to the fact that it has developed along a number of parallel paths (Pickles, 1999). Whilst early GIS utilisation can be traced back to the late 1960s and early 1970, it is generally agreed that commercial and wider application of GIS as a general geographic data and analysis tool began following the release of ARC/INFO by Environmental Systems Research Institute (ESRI) in 1981 and gained significant momentum as computing costs declined in the 1990s.

GIS is now utilised across both public and private sectors for various applications, including visualisation of key social indicators to better target public sector spending, emergency/ disaster response, residential/ retail store planning, transport logistics/ route optimisation, infrastructure development and mapping of natural resource reserves such as oil and gas. Considering its diverse application, it is perhaps not surprising that a range of packages now exist offering powerful desktop GIS solutions, including ESRI's ArcGIS/ ArcView, Autodesk's AutoCAD/ Map3D and Pitney Bowes' MapInfo software.

Its use has increased significantly in the light of the EU INSPIRE Directive (2007/2/EC) entering into force in May 2007. The Directive specifically aimed to ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context. At a member-state level, this has led to the inclusion in many legislative frameworks of a requirement to generate, spatial data and spatially specific outputs as well as encouraging this across the EU. The increased availability of geo-spatial datasets resulting from this legislation has facilitated and promoted the application of GIS for a number of applications across various sectors.

Use of GIS as an academic decision support and mapping tool has also increased significantly over recent years, with application in the fields of geography (Sieber, 2006), environmental science (Antunes et al, 2001, Gonzalez Del Campo, 2011) and health economics/ immunology (Eisen and Eisen, 2011, Beni et al, 2011).

Whilst recent research has begun to broaden academic application of GIS, for example Participatory GIS or P-GIS, which aims to broaden public involvement in policy making (Sieber, 2006), academic utilisation of the tool outside of the aforementioned areas has generally been narrow. Whilst GIS have had some application in a supply chain management context, this has largely been from a cross discipline logistics perspective. For example, transport route optimisation and basic supply chain visualisation. To the authors' knowledge, there has been little theoretically grounded academic discussion in the management literature, with regards to the utilisation of GIS as a SCRM tool. The lack of academic consideration of GIS as an appropriate tool in this area is perhaps strange when considering that at its most basic level, existing research can be categorised as seeking to model the geographic impact of an event, most often a risk, and/or any potential future impact of that risk. For example, the mapping and spread prediction of vector borne diseases (Eisen and Eisen, 2011), utilising existing data to improve public health response following natural disasters (Holt et al, 2008), assessment and simulation of food safety breaches (Beni, et al, 2011) or modelling the effect of Volcano Eruptions (Biass and Bonadonna, 2013). As has been discussed, understanding the susceptibility to corporate-level disruption risk within the upstream supply chain is a problem that is fundamental in contemporary supply chain management research.

3.10.4 Data Groups used in the Conceptual GIS Framework

The conceptual framework outlined above requires three primary data input groups, which are the combined in a GIS environment:

Figure 3-6 – Data groups used in the conceptual GIS framework

Data Group 1: Choice of a critical supply chain (Supplier Significance)

As the criticality of suppliers will vary depending upon the significance or importance placed upon a given automotive component by the focal organisation, it is necessary to assign a weighting to supply chains being assessed against each other. Supplier segmentation of this nature is already widely undertaken within the automotive industry, even if only at a basic level. In considering an appropriate automotive component to assess for the current study (Case Study 2), interviewees highlighted the Li-ion battery (LFP and NMC chemistries) as an appropriate example of a 'critical' component due to its key role in the increasing electrification of vehicle drive trains (both standard fuels and alternative EV/HEV models). Interviewees also highlighted that the Li-ion battery, also contained novel sub-components which it was believed, potentially exposed the company to new supply chain partners and regions, again making it a particularly appropriate example case study to consider.

Data Group 2: Supply Chain Mapping

Section 3.5.4 has considered several supply chain mapping techniques presented in the operations management literature and justified the geographic focus employed by the current study in relation to the business problem it seeks to address. This process will now be discussed.

Mapping the supply chain for the two Li-ion battery chemistries used by the focal organisation (LFP and NMC chemistries), was a process which involved first seeking input from the focal organisation (VM-1 and VM-5) to understand the current level of visibility they had for these

specific two supply chains and gain an appreciation for how the supply chain was configured at its highest level, as discussed above. Support was then obtained by the focal organisation to work with their first-tier supplier of Li-ion battery packs/ modules.

After gaining this support, interviews were carried out with a number of employees at this organisation (highlighted as SCP-1 to SCP-5). Primary supply chain data (from both employee's expert knowledge and existing organisational data) was collated alongside secondary raw material market data to build two detailed maps of the LFP and NMC (the two chemistries currently utilised by the focal vehicle manufacturer) Li-ion Battery Supply Chains. By working with both the organisation's tier 1 supplier and indirectly their higher tier suppliers, a detailed breakdown was obtained of:

1. The structural components within both LFP and NMC battery cells (tiers 1-4)
2. Who upstream suppliers were at each stage (tiers 1-3)
3. Supplier's geographical location at country level (tiers 1-3), including key producer regions for raw materials (tier 4)

This supply chain data was then combined with weighted corporate-level risk metric (see below) in a multi-layered Geographic Information System (GIS) model to visualise this supply chain and identify which nodes are more susceptible to this type of risk.

Data Group 3: Weighted Corporate-Level Disruption Risk Groups Utilised in the Model
For the purposes of this research, three groups of external, corporate-level disruption risks are identified, that are not within the immediate operational control of an organisation, but can have a significant direct impact on the supply chain. These are 1) geo-political, 2) economic and 3) environmental. Within each of these broad groups, sit a number of individual risks, for example, extreme weather and natural disasters both fall within the environmental risk group, whereas corruption and political unrest/ conflict fall within the geo-political group. Identifying which individual risk metrics to include in each indicator and then weighting the relevant significance of each metric against each other, to create three specific indicators of corporate-level risk (geo-political, environmental and economic) is a significant step in understanding the relative importance of different types of risk on organisational supply

chains. For example, weighting will allow the framework to incorporate the fact that different corporate level-risk groups may have different impacts upon the organisation.

From a methodological perspective, there are several approaches to weighting that would be suitable in the current context. A critical appraisal of key weighting and aggregation methods is presented in the OECD's (2008) handbook on constructing corporate indictors. These range from Expert Opinion Polling and Budget Allocation Processes, where experts on risk would be asked to score risk indictors, to more quantitative methods of weighting such as Analytical Hierarchy Process which systematically extracts opinions through a series of pair-wise comparisons.

The current conceptual framework's weighting of corporate-level risk metrics utilises the World Economic Forum's New Models for Addressing Supply Chain and Transport Risk Report (2011). This report was developed from multifaceted analysis conducted between April and December 2011. This included:

- Analysis of published studies and datasets from a wide range of secondary sources
- A series of six workshops held in New York, Cape Town, Vienna, Dalian, Abu Dabai and Singapore as part of the World Economic Forum's Industry Partnerships Programme in Mobility. These workshops brought together over 100 supply chain and risk experts from the Automotive, Aviation and Logistics Sectors.
- An in-depth interview series with 40 of the world's foremost academic, industry and government experts.
- An online survey of supply chain and risk experts from a wide range of backgrounds including logistics, aviation, automotive and government.

In compiling the report, participants were asked to rank the exogenous disruptions most likely to provoke significant and systemic effects on their supply chain. These identified disruptions were then categorised according to four risk categories: environmental, geopolitical, economic and technological.

The first three categories ranked highest and in keeping with the academic literature, this fourth 'Technological' group, is excluded as a corporate level disruption risk here, as technological risks (such as network issues and IT security) are thought to be within the controllable remit of most organisations and furthermore are not affected by geography in the same way other risk groups here are. Additionally, as the current research is concerned with fixed geographical supply chain nodes, several specific disruption risks were removed from the weighting as they related to logistics and transport risk or were not upstream risks.

Although work by the WEF in this field is well regarded for its practically driven approach, developed through close consultation with leading industry and academic stakeholders, use of this data set, for weighting purposes in the current study, does offer some limitations which should be acknowledged here. Firstly, the dynamism of supply chain risk means that any weighting methodology reliant upon subjective participation to identify 'key risks', will likely show some bias towards risk events that have impacted the organisation (or similar ones within its industry) in recent history. This is an assertion reflected in the literature; see for example Sodhi and Tang (2012), who discuss a tendency for firms to over focus mitigation resources on areas where a particular recent incident had had a significant impact on the organisation. The limitation of within-industry over focus on certain supply chain risks is partly overcome in the WEF methodology by including participants from a broad range of key industries. However, this presents a second limitation for the current study, in that cross-sector weightings are being applied to a single industry (automotive). It is acknowledged that this could have been partially overcome by undertaking a primary industry-specific, measure development study as part of the current research. However, due to the aforementioned limitations of single sector focus for SCRM, coupled with resource constraints and the fact that the proposed framework is intended to be viewed as a conceptual model, this was not pursued. The three corporate-level risk indicators created for use in the current research analysis (and the individual risk weightings which feed in to them) are as follows:

Environmental Indicator: This group incorporates various environmental risk factors, including a wide spectrum of natural disasters, extreme weather events and contagious disease outbreaks. Given a number of high-profile recent events, such as the Japanese earthquake/ tsunami or Thai floods in 2011, it is perhaps unsurprising that natural disasters

were indicated by 59% of experts surveyed by the WEF, as the most likely environmental risk to cause systemic supply chain disruption. The related risk and impact of extreme weather events also ranked highly in this category with 30% of respondents it as a significant concern. Finally, 11% of the weighting was attributed to the risk of pandemic or contagious disease.

Geo-political Risk Indicator: Geo-political disruptions include a range of potential disruptions encompassing corruption, crime, terrorism and political unrest/ conflict. Whilst events of this nature can have a direct effect on organisational supply chains, the resulting regional disruption and change can be equally damaging. See for example, major supply chain disruptions in the wake of the 9/11 terrorist attacks in the US. In the WEF study, 40% of respondents, identified conflict and political unrest as their key geo-political supply chain concern. Closely behind this was terrorism with 28% of the weighting. Corruption, Illicit Trade/ Organised Crime and Access to Nuclear and Heavy Weaponry completed the indicator group with 15%, 13% and 6% respectively.

Economic: A number of economic risks have the potential to interrupt organisational supply chains and this group covers a range of issues. Economic Risk within the supply chain has been specifically highlighted, following the 2008 global financial crisis. See for example, in the automotive sector, where bankruptcy filings of suppliers doubled between 2007 and 2008 (United Nations, 2013). In the WEF study, key corporate-level risks were identified as Currency fluctuations with 42% of the weighting, Energy shortages with 31% and a lack of skilled labour with 27%.

For each individual risk metric identified as significant (i.e. within each of the three broader corporate-level risk indicator groups), a number of data sets are available that could be used as an appropriate proxy in the creation of an indicator. After reviewing various risk datasets, as well as engagement with subject-specific experts within the University, 11 datasets were identified as appropriate to create the final three indicators used in this research. These are set out below in brief (within Table 3-7) and in full, including weightings and fuller description, within Chapter 5 (Table 5-11). With the exception of datasets for skilled labour and energy shortages (which included 59 and 123 counties respectively), all datasets used covered 171 of the 193 UN member countries and had minimal bias to a specific region (i.e. there were no

single government backed datasets). Of those 21 countries not included, most were small island states such as St Lucia or St Kitts and Nevis and some were inaccessible due to the current political situation such as Syria or Somalia. None of the missing entries impacted the chosen supply chain case study.

Indicator	Data Source Used as Indicator Proxy
Pandemic (Communicable Disease) Indicator	**World Bank** Population Data [2013], **World Health Organisation (WHO)** Observatory Data Repository: 5 Year statistics on key communicable diseases and spread by country [2013]
Extreme Weather Indicator	**Germanwatch** Global Climate Risk Index [2014]
Natural Disaster Indicator	**United Nations (UN)** Natural Disaster Index: World Risk Report [2012]
Conflict and Political Unrest Indicator	**World Bank** Worldwide Governance Indicators: Political Stability and Absence of Violence [2012]
Terrorism Indicator	**Institute for Economics and Peace (IEP)** Global Terrorism Index [2012]
Corruption Indicator	**World Bank** Worldwide Governance Indicators: Control of Corruption [2012]
Illicit Trade and Organised Crime Indicator	**World Bank** Worldwide Governance Indicators: Rule of Law [2012]
Nuclear and Heavy Weapons Indicator	**Institute for Economics and Peace (IEP)/ Economist Intelligence Unit (EIU)** Global Peace Index: Nuclear & Heavy Weapons Capability [2014], **World Bank** Worldwide Governance Indicators: Political Stability and Absence of Violence [2012]
Currency Fluctuation Indicator	**XE** Forex Currency Analysis and Trading Forecasts [2014]
Global Energy Shortage Indicator	**World Economic Forum (WEF)/ Accenture** Global Energy Architecture Performance Index [2014]
Shortage of Skilled Labour Indicator	**Economist Intelligence Unit (EIU)** Global Talent Index [2012]

Table 3-7 – List of Data Sources Used as Indicator Proxies in Case Study 2

In order to use the data for the current research, each of these 11 datasets (for 171 specific countries) was normalised on a 0-100 scale, where 0 means a country is most susceptible to that form of risk and 100 means it is least susceptible to that form of risk. Following this, individual datasets were split in to their three broader risk groups and weighted using the above figures to create three individual indicators for Environmental, Geo-political and Economic Corporate-Level Risk. Each of these three indicator sets was then combined with the geographical Li-ion battery supply chain mapping data presented earlier in this chapter, within the GIS environment, to identify where the key areas of susceptibility to corporate-level disruption risk (Environmental, Geo-political and Economic) are.

3.11   Summary

This chapter has developed the methodology and process applied in pursuance of the current research aims and objectives, as well as their philosophical underpinnings.

An inductive research methodology is developed from the interpretivism and constructivism perspectives. These epistemological and ontological paradigms are considered in full and discussed in relation to the current research. A case study approach was selected as appropriate in the current context, utilising both semi-structured interviews and analysis of organisational documents as primary research tools and the rationale and obstacles in choosing these particular research methods is discussed in detail. A case study approach of this nature is in keeping with the aforementioned theoretical finding that there is a lack of fine-grained qualitative narratives in the chosen field (Saenz and Revilla, 2014).

In addition to thematic analysis of qualitative data, which provides a foundation for both case studies 1 and 2 of this research, this chapter also considers how more quantitative supply chain and risk data has been utilised in Case Study 2. This data collected primarily during the interview process, but also from a range of secondary sources, has been used to empirically explore a conceptual framework exploring how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk. Using the Li-ion Battery supply chain (as an example of a critical automotive component), geographical supply chain data and weighted risk metrics are combined to create a multi-layered Geographic Information System (GIS) map, highlighting the susceptibility to various forms of corporate-level risk throughout the upstream supply chain.

4   Chapter 4 – An Explorative Case Study of Corporate-Level Disruption SCRM Practices at a Leading Automotive Manufacturer

4.1   Introduction to the Case Study

This Chapter presents an in-depth case study in to SCRM practices at a leading multinational automotive organisation. It aims to critically assess both existing approaches to SCRM by the focal organisation, as well as how and why these processes are evolving to manage corporate-level disruption risks.

Undertaking this in-depth case study has involved semi-structured interviews with experts at the selected vehicle manufacturer (highlighted as VM1-VM5) and their tier 1 Supply Chain Partner for Li-Ion batteries; the chosen supply chain for Case study 2 (SCP1-5). All interviews were undertaken over a 13-month period between August '12 and September '13. Interviewees were initially contacted by email or telephone, where the nature of the research was explained. A more detailed information sheet, covering confidentiality and anonymity options, as well as an interview schedule were then emailed to interviewees prior to the interview taking place. All interviews either took place in person at the respective organisation's offices or over the telephone, where this was not possible. Interviews undertaken took place over a period of 1-2.5 hours. During the research period, participants provided ongoing access to a range of organisational reports, presentations and other documents. For a more detailed overview of the data collection process, please refer to the relevant methodological considerations in Chapter 3 (Section 3.5).

For reasons of confidentiality, the manufacturer has chosen to remain anonymous and will be referred to throughout as 'the focal organisation'. However, in order to provide context and enable potential future comparison with similarly sized organisations, there seems merit in providing a brief overview of the organisation's scale and production capability. The focal organisation is a volume car manufacturer whose principle operation involves the design, development, manufacture and marketing of consumer vehicles. The organisation employs staff split between several sites and its primary markets are Europe, the US and more recently China.

4.2 Organisational Structure and Supply Base

Before turning to discuss strategic understanding and approaches to managing supply chain risk within the organisation, it seems logical to provide an overview of both the general supply base and organisational structure with regards to procurement and SCRM more widely.

Management of overall procurement at the organisation is separated in to functional areas, aligned to either, a class of key vehicle components, a specific purchasing function or a transformation project. Each of these functional areas has an appointed director who reports to the overall 'director of purchasing' and is responsible for staff, split between managers, buyers and analysts. In 2012, the purchasing department contracted with suppliers that were based predominantly in Europe, with some global supply from countries such as the US and Japan

4.2.1 Supply Base Categorisation

As well as functional categories, the company's tier 1 supplier base can be categorised using a model that considers both the value of buy from a given supplier, as well as the nature of the focal organisation's relationship with that supplier, or the level of integration. Low value/ low integration suppliers are termed as 'transactional' relationships and mostly consist of legacy or non-strategic components, which are not difficult to resource. High value/ low integration suppliers are termed as 'leverage' relationships and generally refer to low technology items which have minimal re-sourcing difficulties. Low value/ high integration suppliers are termed as 'critical' relationships and consist largely of more advanced technologies which do not at present form part of main production lines. However, they are seen as critical technologies for future products. Finally, high value/ high integration suppliers are termed as 'partnership' relationships and represent high technology, strategic components which form part of main production lines.

Figure 4-1: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.3   Drivers and Establishment of a SCRM function

There is a need to understand the key organisational drivers that have facilitated an increased focus on supply chain risk. Specific questions around general organisational motivation for engagement in supply chain risk initiatives were included in the interview schedule. These answers were then considered alongside analysis of organisational documents and key drivers became apparent (see figure 4-2).

Whilst supply chain risk has always been recognised by the organisation and steps taken to manage this, until fairly recently this has been on a more informal basis. Development of the formal SCRM processes currently in place at the organisation began in 2008 following impacts stemming from the global financial crisis (VM-4).

'At its most basic level, it comes down to protecting the brand' acknowledged VM-4, highlighting the recent reputational damage suffered by supermarket Tesco in the wake of

the horsemeat scandal as an example of poor supplier management. However, as a business, reducing financial impact stemming from production delays/ supplier disruption is also an obvious driver (VM-4). The 2008 global financial crisis has had a significant impact on the automotive industry as a whole and the supply chains which underpin it. *[This text has been removed upon request as it contains information considered commercially sensitive].* VM-2/3 noted that the focal organisation is one of few manufacturers who came out of the recession in a strong position, increasing its year on year supplier spending. Whilst this strong performance has allowed the focal organisation to improve its own turnover, many of its supply chain partners have been less fortunate, with the number of upstream suppliers entering administration increasing significantly since 2008. There was also concern that an already large supply base of Tier 1 suppliers was creating a situation where the business had become increasingly susceptible to external environmental risks such as those discussed in chapter 2, where a disruption at even one node of the upstream supply chain can cost the organisation a significant amount of money (VM-2/3). Moreover, the financial crisis also raised questions for the focal organisation with regards to how lean its supply chain is. For example, the flexibility of suppliers to meet significant demand changes.

In addition to increased insolvency and inflexibility to meet demand amongst suppliers throughout the upstream supply chain, organisational focus on the area of SCRM gained significant momentum following a number of natural disasters in the following years. Several key environmental risk events, which occurred in a period of less than two years, had the cumulative effect of highlighting the fragility of the organisation's global supply chain and stressing that new procurement strategies were needed to address external disruptions of this nature. These included the April 2010 Icelandic Ash Cloud which caused significant delays for lower tier suppliers due to flight restrictions across much of Europe, the 2011 Japanese Tohoku earthquake/ resulting tsunami and the 2011 Thai floods, both of which caused significant delays to upstream suppliers of many key automotive components, especially electronics. Impacts such as this can resonate and magnify within the supply chain, for example, the floods in Thailand caused supply disruption for many Asian automotive manufacturers, which directly led to financial problems for one of the focal organisation's key components manufacturers. In the same way that the aforementioned 'Albuquerque Incident', represented a turning point for how mobile phone manufacturer Ericsson

approached supply chain risk (Norrman and Jansson, 2004), so too do the collective incidents above for the current organisation.

The role of legislation and policy is also a clear driver of organisational change and engagement with regards to SCRM. VM4 specifically notes that 'legislative and policy changes have had the effect of focusing the organisation's attention on supply chain risk in recent years'. Section 4.14 provides a comprehensive review of the key legislative and policy drivers which are requiring an increased understanding of upstream supply chain partners operations. These can largely be segmented in to three categories: 1) product quality/ safety 2) environmental and 3) social. VM-4 notes specifically compliance with the EU REACH chemical regulation, the US Dodd Frank conflict-mineral provisions and adherent to various ISO standards such as TS16949 as being imminent concerns requiring increased upstream supply chain knowledge and understanding. Considering the above, it can be said that the UK has few direct legislative and policy instruments that necessitate immediate organisational due diligence specifically from a supply chain risk disclosure perspective (such as the Sarbanes-Oxley Act in the US). However, failure to comply with legislation and policy in any of the above categories could cause significant reputational damage to an organisation. It is this damage which the organisation sees as a key concern (VM-4). Moreover, by engaging fully to comply with this legislation the organisation is beginning to understand the potential benefits from a SCRM perspective.

Although the focal organisation has only a small direct supply base outside of the EU, this statistic represents only those suppliers at a first-tier level. Beyond this the organisation has very little visibility (VM4). Many of the specific risk events discussed during the interviews were a direct result of disruptions in the extended geographical supply chain beyond tier 1, amplified by an increased lead time in responding to events caused by poor visibility of where suppliers are located. This finding is in keeping with aforementioned consideration in the literature that supply chains today are more vulnerable to unanticipated disruption from seemingly self-contained events than they were in the past (Craighead et al., 2007). Whilst supply chain globalisation has produced significant benefits in terms of productivity and profitability, the extended geographical spread of many modern supply chains has led to increased susceptibility to external corporate-level disruption risks, many of which are

dictated by geography. Organisations that operate a global supply chain are exposed to an increased amount of risk due to the complex and uncertain environment in which they are involved (Tang and Tomlin, 2008). As Peck (2005) describes 'the more complex a network is, the more interfaces exist and the higher the vulnerability will be'. Moreover, when disruptions occur at a critical node of the supply chain, the resulting effects can ripple throughout the entire value chain, a phenomenon described by Forrester's Bullwhip Effect (1961).
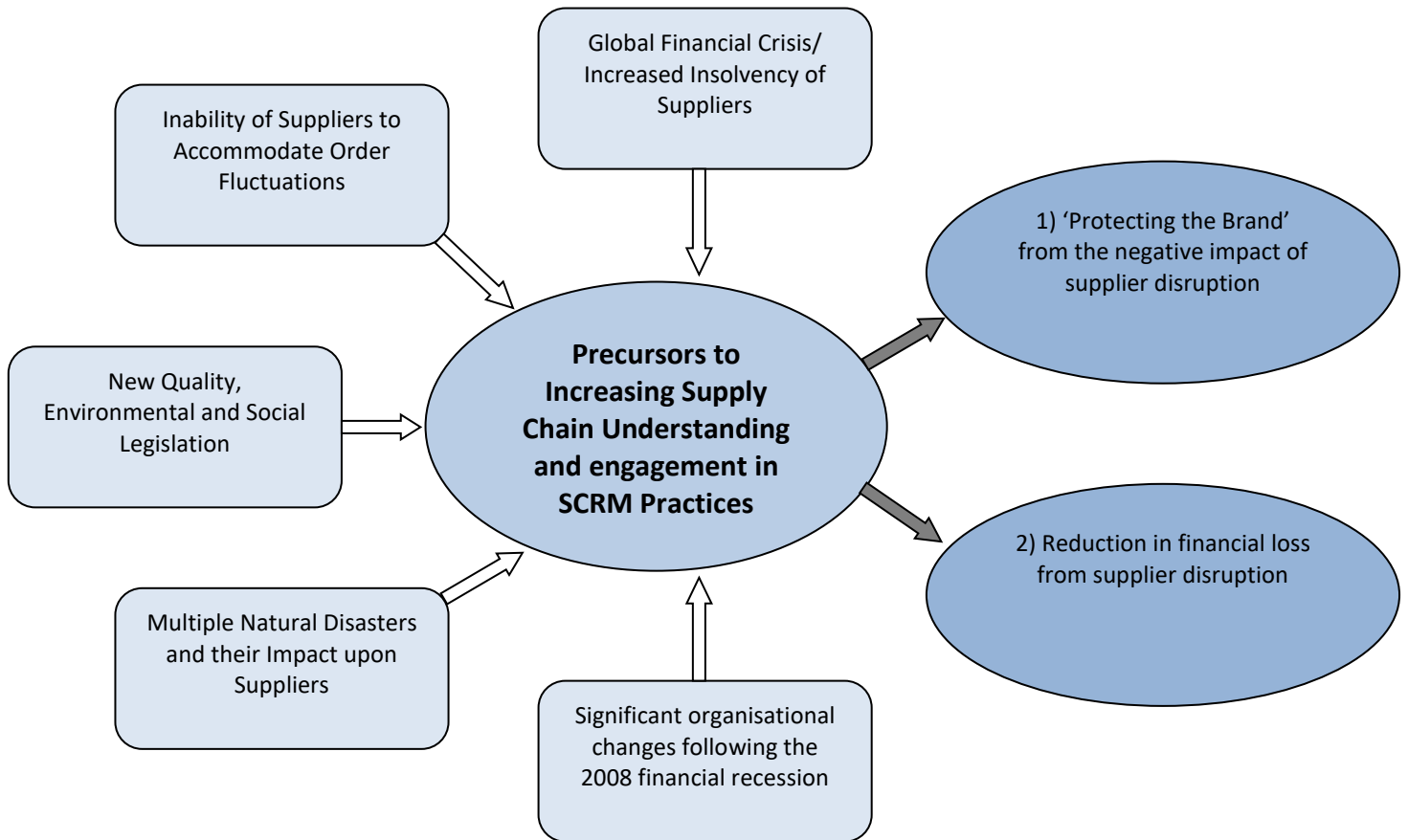
Figure 4-2: Precursors to increasing organisational supply chain understanding, as well as engagement in SCRM practices and key desired outcomes

Co-ordination of the organisation's overall approach to managing identified supply chain risk relies on two specialised central purchasing departments: the Supply Chain Risk (SCR) team and the Financial Risk (FR) team. Initially, high-level risk indicators are passed to these teams from the central business office, who remain informed of strategies put in place to address them (VM-3).The SCR team is responsible for the 'analysis and management of purchasing and supply chain risk generally, specifically, the development of a number of tools to manage/ monitor risk and ensure wider business engagement in this area' (VM-4). The closely related FR team has a more specialised focus on financial risk and is tasked with the 'analysis and management of supplier financial risk, development of new monitoring processes and ensuring wider business engagement in this area' (VM-3). This team also monitors the Supplier Risk database, a key process that will be discussed in more detail. Above the SCR and FR teams, sit a panel of senior staff who form the Supplier Risk Assessment Committee. This

is an ad-hoc committee whose principle purpose is to make decisions with regards to risk that has been escalated from the two specialised risk management teams. A final escalation can also be made to the overall purchasing director where needed.

The primary role of both SCR and FR teams, are as developers and co-ordinators of risk strategy, a fact reflected in their staffing numbers. As such, both teams rely heavily on the formation of close relationships with a number of other organisational functions for both implementation and on-going engagement with these strategies. These departments include the business office, general counsel, supplier support, engineering and individual buyers/ teams of buyers. The SCR and FR teams have also contracted external support from a number of consultancies, both in the development of processes and also the training of staff in other departments.

Figure 4-3: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.4   The Organisational Supply Chain Risk Management Process and Work Stream

In Chapter 2 it was identified that diversity in field of SCRM has led to a number of differences in how researchers view the scope of the SCRM process. It was concluded, based on a number of leading authors (including Zsidisin and Ritchie, 2008, Sodhi and Tang, 2012, Waters, 2007), that at its most basic strategic level, SCRM can be segmented in to a four-stage process: 1) Identification, 2) Assessment, 3) Mitigation and 4) Response.

In order to best analyse the focal organisation's own SCRM strategy in relation to existing literature there is merit in using this four-stage process as a frame of reference with which to discuss the current case.

Figure 4-4 illustrates the focal organisation's strategic SCRM workflow and was developed through analysis of interview transcripts and organisational documents. It depicts a 6 stage process which, as can be seen from the hatched overlay, bears some resemblance to the aforementioned 4-stage process discussed widely in the literature. This process will be broken down and analysed through the course of this chapter, however, at the outset several differences are apparent. Firstly, the response stage forms a part of mitigation strategy (as a subset of prioritised risk) rather than being a separate stage. This appears to be in keeping with the previous view, expressed by Knemeyer et al. (2009), that an effective supply chain risk response mechanism stems from proactively addressing the first three elements of the SCRM process. Figure 4-4 also departs from traditional depictions of the high level SCRM process by including a feedback loop of continued monitoring and improvement which recognises the dynamic nature of supply chain risk and need for continued assessment. The addition of a feedback loop is also significant as it signifies the organisation's desire to learn from historical events, aiming to reduce the likelihood or at least impact of similar future events.
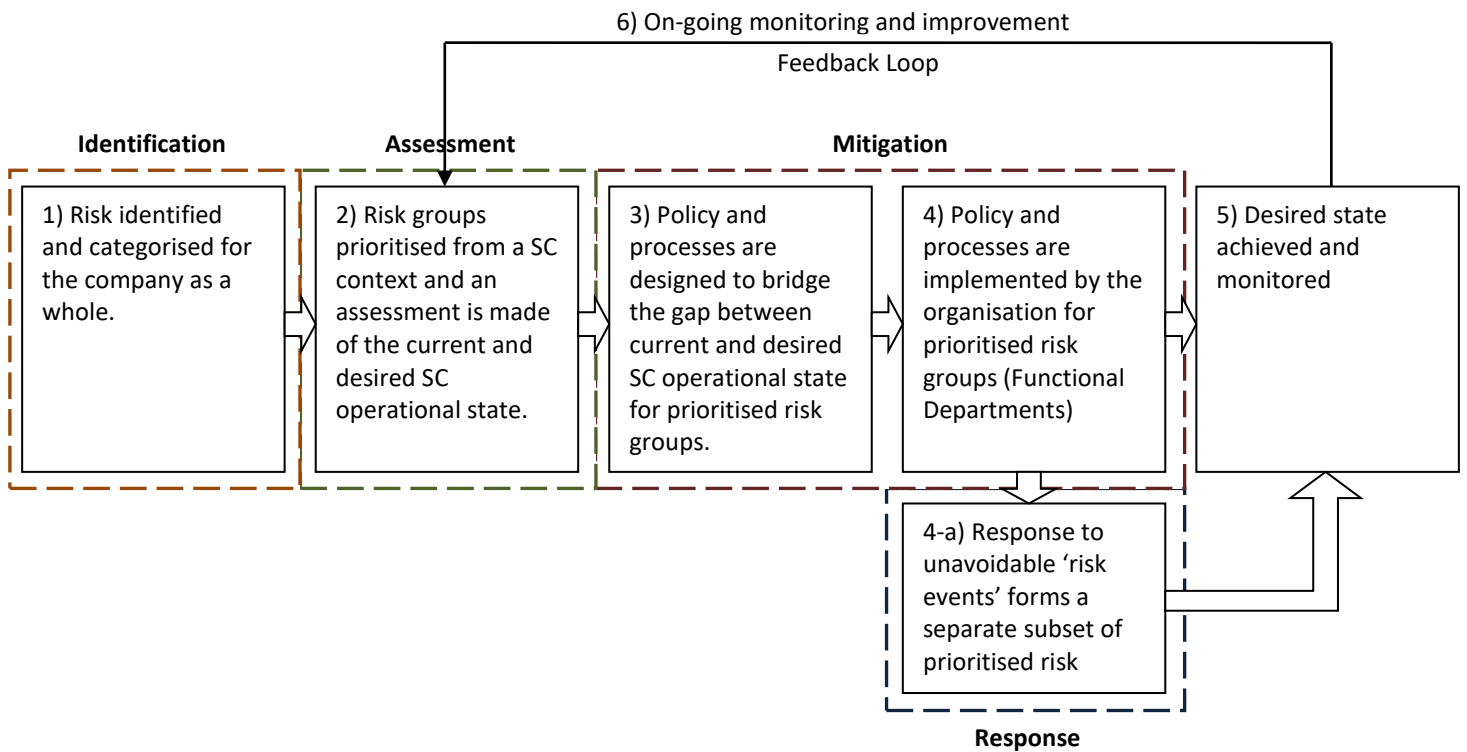
Figure 4-4: Organisational workflow of SCRM and comparison to the traditional 4-stage approach of Identification, Assessment, Mitigation and Response

4.5 Identification, Prioritisation and Categorisation of Risk

Interviewees generally gave very broad definitions of how supply chain risk was viewed within the organisation. For example, VM1 stated that 'There is no one definition of risk, but it is broadly understood to be anything which may impede the reputation or commercial positioning [of the vehicle manufacturer]. This could be for example from a safety, technical or financial perspective'. Similarly, VM2 and VM3 discussed risk in the context of an internal company motto, 'Don't stop the line', whereby supply chain risk is defined as being 'anything that could impact or stop production'. This is generally in keeping with Tummala & Schoenherr's (2011, p. 474) generalist view that supply chain risk is 'an event that adversely affects supply chain operations and hence it's desired performance measures, such as chain-wide service levels and responsiveness, as well as cost'.

Whilst it is clear that interviewees understood supply chain risk in general terms, the lack of a single cohesive definition throughout the organisation reflects the multitude and complexity of various risks might impact it. Instead of broad definitions, the organisation adopts a

centrally driven, identification and prioritisation model in order to identify and allocate the most pertinent risks likely to affect the organisation's operations or reputation.

4.5.1 Central Risk Identification and Prioritisation

Considering figure 4-4, the first step in the focal organisation's SCRM process involves the central identification of key risks that might adversely affect the organisation as a whole (i.e. not just its supply chain). This process is dynamic and conducted by the organisation's business office. The identification of high-level, un-prioritised risk groups at this stage draws upon cross functional expert opinion, analysis of risks that have adversely impacted the industry (and organisation) previously and marco-level external analysis of market and economic trends. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

In order to prioritise macro-level supply chain risks, a high-level assessment of impact and likelihood is undertaken using a combination of historical figures of risk impact on the automotive industry, as well as external market forecast analysis to determine the likelihood of a range of risk events impacting upon any part of the organisation. This echoes Rich and Caniato's (2003) finding that most organisations have developed at least basic methods to help prioritise risk and is also in keeping with the aforementioned finding that the typical approach to assessment of supply chain risk is through risk mapping exercises, where the frequency or probability of an event occurring in a given time frame is weighed against the likely impact of the event on the organisation (Sodhi and Tang, 2012). The process adopted by the organisation's central business office to assess macro-level risk involves combining the likelihood and probable impact of an event. This information is then presented as an impact/ probability matrix. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

The impact/probability matrix used by the organisation bears close resemblance to the theoretical impact/ probability matrix depicted in Thun and Hoenig's (2011) study in to the German automotive industry (figure 2-13), suggesting some similarities within the industry's approach to high level assessment. In the current context the output of this risk mapping exercise feeds into a prioritisation list of macro-level risks which is used to determine where mitigation efforts on the part of the SCR and FR teams should be directed.

Figure 4-5: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Table 4-6: [This table was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Interestingly at this macro-level assessment stage, the purchasing department does not consider its-self to have complete control at present over these risk groups, suggesting, control improvement is possible for most areas. This indicates a departure from previous findings in the literature that assert organisations often mistakenly consider themselves to have robust supply chains (Zsidisin and Ritchie, 2008) and are mostly satisfied with current supply chain risk management strategies (Sodhi and Tang, 2012). In the current organisation, this increased awareness of supply chain vulnerability to risk stems from several recent drivers (that will be discussed in detail throughout this chapter), including, a number of disruptions which have had a systemic effect on organisational operations, as well as a number of legislatively prescribed measures/ policy initiatives necessitating increased supply chain visibility. *[This text has been removed upon request as it contains identifying information.]*

4.5.2 Functional Categorisation of Risk

Output from This first stage in the SCRM process directly informs which areas of risk should be prioritised by the SCR and FR teams, who are then tasked with developing and allocating resources to implement mitigation processes. In the context of the current research, the importance of drawing a distinction between those day-to-day assessed risks in the immediate operational environment of an organisation (operational risks), and those risks which occur outside of this environment (termed corporate-level disruption risk) has been discussed in detail, specifically, the importance of those geographically driven external risks which can impact an organisation, throughout the supply chain.

In Chapter 2, three groups of corporate level disruption risk were distinguished: environmental, geopolitical and economic. Whilst economic risk is particularly highlighted as a significant supply chain risk, geo-political and environmental disruption risks (leading to supplier failure) are less represented and identified as a single entity in the exercise. The increased focus on economic risk is perhaps unsurprising in the light of the 2007/08 financial crisis and reaffirms earlier academic findings that many organisations have a tendency to over focus mitigation resources on areas where a particular recent 'incident' had a significant impact on the organisation (Sodhi and Tang, 2012). However, the literature also notes the

danger of failing to distinguish between the 'assessment' of risk and assessment of the 'perception' of risk (Slovik, 1987).

Whilst various definitions of 'risk' as an organisational concept have been discussed above, there are clear challenges with defining such a broad term and in reality, authors suggest there to be little practical use in such an exercise. The principal method proposed in the literature, to make sense of the multitude of diverse risks that can affect organisational performance is through adoption of a categorisation model. A number of these were discussed in chapter two, including:

- Jurttner et al, (2003) – Environmental risks, network risks and organisational risks.
- Sodhi and Lee (2007) – Supply risks, demand risks and contextual risks.
- Christopher et al (2011) – Supply risks, process risks, demand risks, control risks and environmental risks.
- Oke and Gopalakrishnan (2009) – Supply risks, demand risks and miscellaneous risks.
- Manjuj and Mentzer (2008) – Supply risks, operations risks, demand risks and other risks (including security and currency).
- Tang and Tomlin (2008) – Supply risks, process risks, demand risks, intellectual property risks, behavioural risks and political social risks.
- Bogataj and Bogataj (2007) – Supply risks, process risks, demand risks and control risks.
- Sodhi & Tang (2012) – Supply risks, process risks, demand risks and corporate-level risks.

Although it is clear that the focal organisation understands the distinction between many of the key academic categorisations of risk discussed above, it does not conform fully to any of the formal theoretical models discussed in the literature. Interviewees acknowledged, in keeping with the literature, that for the most part, diversification of risk categorisation frameworks is largely down to definitional differences and the vocabulary adopted, rather than physical divides in the categories used. As such, a primary distinction is drawn between risk that occurs as part of the normal course of operations (operational risk) and that which is wholly externally driven (corporate-level disruption risk) (VM-2/ VM-3), in keeping with Kleindorfer and Saad's (2005) high-level distinction between risk which arises from problems

in the co-ordination of supply and demand and risk which arises from a disruption to normal activities. However, in practical terms, interviewees clearly indicated that there was a need to align the management of different risks, with an appropriate organisational entity (VM-2/ VM-3). This is very much in keeping with recent developments in the field that have suggested a key flaw in existing categorisation models is a lack of alignment with standardised organisational structure. For example, Sodhi and Tang (2012) state that 'as organisations have invested significant money in establishing supply chain, and wider organisational structures, it seems logical for each categorisation to be split between the organisational entities which should be charged with its management'. At the focal organisation, therefore, 'supply chain risk is driven by the SCR and FR teams but dealt with on an application by application basis (VM-1), where 'risk is separated by functional area' (VM-2 and VM-3) rather than type. For example, financial and legal risks are distinguished from each other' (VM-1). Sodhi and Tang's (2012) discussion around the need for strategically focused entities within the organisation to co-ordinate the management of external corporate-level disruption risks has previously been highlighted. In this respect, this approach would seem logical, where, the SCR and FR teams fulfil this role and act as operational co-ordinators, highlighting prioritised supply chain risk to the appropriate organisational function and developing mitigation/ management tools for them to implement.

The key functional categorisation divisions are as follows:

Financial Risk Team:

See above – The FR team has a specialised focus on financial risk. The team is tasked with the 'analysis and management of supplier financial risk, development of new monitoring processes and ensuring wider business engagement in this area' (VM-3). It also monitors the supplier risk database, a key process that will be discussed in more detail below.

Raw Materials Team:

This team sits within the purchasing division and has a principle responsibility to analyse raw material market developments for a range of directly purchased raw materials. The raw materials team forecast future trends and potential market risks which are feed in to a weekly report distributed amongst buyers and the SCR and FR teams. This report also feeds directly in to procurement contracts. The raw materials team is also looking at ways to share key procurement routes and forecasts with selected SMEs to improve purchasing power and improve security of supply.

Supplier Support Team:

The supplier support team again sits directly within the purchasing division and is predominantly made up of engineering specialists. The team's principle role is to analyse and ensure consistent supplier quality throughout the manufacturing process, through to eventual delivery. Experience is gained where suppliers have presented a risk before which the focal organisation has had to bare the impact of such as inadequacies in managing their own supply chain or failure to meet programme delivery milestones. This experience feeds in to a system of metrics to check supplier performance.

Engineering:

The organisation's engineering department plays a key role in the SCRM process, both in supporting the supplier support team and also in their primary function, which is continual

technical improvement/ assessment of automotive components and the materials they are made from. The department has recently been tasked with reducing organisational dependence upon some materials due scarcity of supply and narrow geographical sourcing options. One example of this in action concerns a recent project to assess the capabilities of a component that utilises less rare earth metals, thus meaning less reliance on this potentially volatile supply chain.

General Council (Legal):

Acting as a shared service function, the legal team plays a significant role in the organisation's supply chain risk management strategy. The team offer continual analysis of policy/ legislation and the extent to which the company either already complies with or needs to adapt to newly introduced measures. Legislative and policy drivers concerning supply chain operations come from an array of perspectives including, social, environmental, health and safety. Whilst basic legislative compliance issues are handled internally by the SCR team, more complex issues are dealt with in co-operation with the legal team who provide specialist analysis and interpretation services. The in-house legal team also has the ability to provide legislative and policy analysis for key demand and supply markets to identify potential areas of opportunity or risk. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Individual Buyers in Purchasing Departments:

Individual Buyers form the backbone of the purchasing department and are split by functional purchasing categories, aligned to either, a class of key vehicle components or a specific purchasing function or transformation project. Individual buyers operating in a particular category have the responsibility for costing, sourcing and resourcing components within their category as well as overall management of supplier relationships. Working with strategic guidance from the SCR and FR teams, individual buyers adopt and operate on a day-day basis the SCRM processes put in place, managing both operational and corporate level disruption risks, escalating them when necessary.

External Consultancies:

External consultancies are contracted by the organisation to provide technical expertise or specialist knowledge in a number of areas which fall outside of standard operational remit. Most recently, from a SCRM perspective, a leading firm have been contracted for the purpose of develop an internal risk database (this will be discussed in more detail later on). Prior to formal contracting, requirements and process planning stages are conducted internally by the organisation, with an external consultant being engaged to deliver and in some cases assist implementation. For example, through the training of staff etc.

Senior Leadership Team:

A senior leadership team form the Supplier Risk Assessment Committee. This ad-hoc committee's principle purpose is to make decisions with regards to risk that has been escalated from the two specialised risk management teams. A final escalation can also be made to the overall purchasing director where needed.

4.6   SCRM and the Challenges Posed by a Lack of Visibility

Issues associated with a lack of upstream supply chain visibility within organisations, have emerged as a significant theme within contemporary supply chain management (Choi and Sethi, 2010, Williams et al, 2013). In Chapter 2, it was concluded that whilst corporate-level disruption events may impact any node throughout the supply chain, they are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of the chain. For example, those higher tier stages of the supply chain, that involve the raw material extraction, refining and processing of materials before they are transformed in to a final product to be sold. In the context of the automotive industry, the Tohoku earthquake and tsunami in March 2011 proved to be a catalyst with regards to focusing attention upon supply chain visibility. This event, perhaps more than any other, demonstrated the vulnerability of global automotive supply chains to external shock, when many upstream suppliers to the automotive industry, were severely impacted by the event and its after-effects. The focal organisation's approach to responding to this event and the lessons it learned will be discussed in more detail later in this chapter (Section 4.11.8).

In order to ascertain an understanding of base level visibility, interviewees were asked whether risk played a factor in the organisation's current supply chain configuration and to what extent risk was currently considered and assessed throughout the upstream supply chain. For example, was this only at a lower tier 1 level or beyond?

As will be evidenced later in this chapter, Interviewees stated that risk did play a role in how the organisation had chosen to configure its supply chain, however this is only at a lower tier level (VM-1). Similarly, VM-4 noted that, beyond a first tier level the organisation largely had very little visibility of its supply chain (VM4). As was noted earlier, in 2012, the purchasing department, as a whole, contracted with suppliers that were based predominantly in Europe. VM-1 acknowledged that, for the most part, the organisation only has visibility of these tier 1 suppliers. However, it was also noted that 'a small number' of these companies did provide directed visibility of their immediate suppliers (VM-1). The issues associated with an 'outsourced approach' such as this, are well noted and have been discussed in the previous review of relevant literature. These include the time delay between a disruption occurring and the focal becoming aware of an issue, as well as difficulties around how different suppliers

might view the severity of a particular disruption and whether it merits reporting to the focal firm. Moreover, the focal organisation's current supplier geographical breakdown is likely to be very different when taking in to account suppliers further upstream.

At this stage it seems appropriate to discuss how this fits with existing literature. The diagram below was discussed in chapter 2 and depicts an adapted version of Sodhi and Tang's (2012) risk categorisation model, where organisational visibility is layered over various forms of supply chain risk. The focal organisation's current supply chain visibility level is in keeping with Zsidisn and Ritchie's (2008) finding that, many large organisations have a good visibility of risk in their immediate operating environment (white and grey hatched areas), but due to the resource constraints rarely take a proactive approach to identifying and managing risk beyond this (black area).
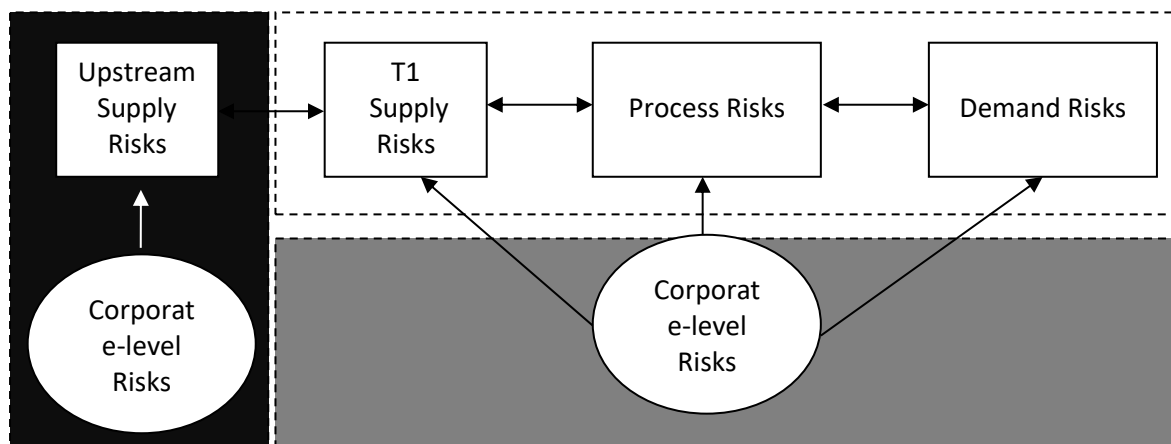
Figure 4-7: Traditional organisational visibility of supply chain risk: adapted from Sodhi and Tang's (2012) categorisation model

A common assertion repeated throughout the literature is that 'a supply chain is only as strong as its weakest link'. As such, the literature suggests SCRM must go beyond simply the lower level boundaries of the focal organisation and its immediate suppliers, in order to discover and quantify hazards in the extended supply chain (Colicchia and Strozzi, 2012). In the focal organisation there is clearly a drive to engage with upstream supply chain visibility projects. For example, VM-1 noted that 'In today's turbulent environment, there is an ever increasing need to understand supply chain operations beyond a tier 1 level' (VM-1). Similarly,

VM-2/ VM-3 acknowledge a 'significant organisational appetite to understand suppliers further upstream'. (VM-2/ VM-3).

There are a number of drivers to the organisation's decision to look at ways in which supply chain visibility can be increased. Some of these have been discussed above, such as changing legislative/ policy requirements (Reviewed in full in Section 4.14) and a desire to understand and account for scope 3 carbon emissions, as well as recent supply chain disruptions such as the Tohoku earthquake and tsunami. Many of the specific risk events discussed during the interviews were a direct result of disruptions in the extended geographical supply chain beyond tier 1, amplified by an increased lead time in responding to events caused by poor visibility of where suppliers are located. However, others are more operational in nature, such as such as the unexpected increase in demand for a recently launched model, which placed significant stress on the organisation's whole supply chain. VM-1 acknowledged that experiences such as this, have forced the organisation to re-evaluate company-wide SCRM challenges and management.

Work has already begun to understand how this might work and the focal organisation is currently working with other key manufacturers, as well as a third-party company to develop this area. Again, emphasis will initially be upon internal risk, especially financial/ operational (VM-2/ VM-3). The company's collaborative strategy in this area is discussed in Section 4.13, before moving on, in Chapter 5, to explore some of the key questions around how increased visibility can aid in increasing organisational understanding of susceptibility to upstream corporate-level disruption risk.

4.7   A Benchmark of SCRM Performance

Since 2008, the focal organisation's vision with regards to SCRM has been to 'establish a leading risk assessment and mitigation approach aligned to the business operating model – with a pro-active and collaborative focus to ensure a long-term sustainable business'. A number of key, short to medium term, priority areas have also been identified by the organisation and include: identifying key growth areas and assessing the suppliers needed to fulfil them, assessing financial and operational supplier failure and its risk to supply, better

cross-industry integration/ shared knowledge and improving the security of raw material supply needs.

In moving towards this vision, a benchmarking exercise was undertaken in 2011 within the organisation, whereby internal organisational performance was scored across a number of SCRM indicators. To avoid bias an external consultant was brought in to complete the final scoring process which included an internal staff weighting as well as analysis of metrics to; review the effectiveness of current processes, assess progress with key SCRM projects, identify the number of suppliers to have posed a risk to operations and assess how effective the companies auditing procedures were. *[This text has been removed upon request as it contains information considered commercially sensitive].* The focal organisation's aspiration is to become an industry leader in SCRM over the coming years. In the following section, consideration is given as to how the focal organisation is responding to this challenge.

Figure 4-8: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.8 The Organisation's Supply Chain Risk Processes

A significant amount of resource has been attributed to the development of a new range of SCRM processes. This investment demonstrates the value being placed on effective risk mitigation and contingency strategies by the focal organisation. The antecedents for this increased focus on SCRM have been discussed previously and set out earlier in this chapter. They include the global financial crisis which led to an increase in insolvency amongst suppliers, a raft of new quality, environmental and social legislation, the impact of natural disasters upon the supply chain and an inability for key supply nodes to accommodate significant order fluctuations.

The newly developed supply chain risk processes have incorporated SCRM throughout the end-to-end purchasing function, including, new sourcing and resourcing processes, a continuous supplier monitoring process and emergency response processes for insolvency and unavoidable disruption. In addition to these processes a number of ancillary functions contribute to the overall organisational SCRM strategy including, for example teams considering legal, raw material and macro-economic factors. The aims and timing of these key new processes can be summarised in table 4-9. The following section seeks to explore these processes and their functionality in more detail.

Sourcing Process	Supplier Risk Database and Escalation Process	Response Process
To 'catch risk at the Source'	To 'continually Monitor risk in the organisation'	To 'minimise the costs and disruption to the organisation in case of an unavoidable risk event'
Occurs at the sourcing or resourcing stage	Continuous monitoring of all T1 suppliers	Follows the occurrence of an unavoidable risk event such as insolvency or natural disaster.

Table 4-9: High level summery of the aim and timeframe of key supply chain risk processes

4.9 Supplier Risk Database and Escalation Process

The centrepiece of the organisation's supply chain risk processes is the supplier risk escalation process, which has the principle purpose of 'preventing a supplier from disrupting the supply chain and stopping production as a result of distress' (VM-2/ VM-3).

4.9.1 Supplier Risk Database

Underpinning this process is the supplier risk database, which was designed and implemented (including staff training) by an external consultant to securely hold and monitor detailed information for all of the organisation's tier 1 suppliers. The supplier risk database contains both financial and operational data about a given supplier which is used throughout the supplier risk escalation process. A monthly supplier risk report is automatically produced highlighting at risk suppliers which will then enter the supplier risk escalation process (this will be discussed in more detail below). The literature suggests that improved access to supplier financial information such as this can be a powerful actor in the development and maintenance of close supply networks (Meira et al, 2010). At a Tier 1 level, all suppliers are required to provide accurate financial information in order to qualify as a 'preferred supplier' of the focal organisation. This information can help the focal organisation understand their supplier's business in more detail and better anticipate potential problems. Whilst provision of this information by suppliers is clearly invaluable from a SCRM perspective, it is not current practice to share organisational data with suppliers. It is worth consideration that for smaller suppliers, without reciprocation by the focal organisation, a power-imbalance can occur, which may prohibit the ability to foster mutual trust between the two parties (Caglio and Ditilli, 2008, Seal et al, 2004).

Table 4-10: [This table was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Figure 4-11: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.9.2 Supplier Risk Escalation Process

The supplier risk escalation process is a 3-stage approach for suppliers highlighted as 'high risk' or 'potentially high risk'. There are three distinct ways a supplier can enter the escalation process. The first, and most common, is when a supplier is highlighted as 'high risk' in the automated monthly supplier risk report. In addition to this, suppliers can be reviewed for strategic reasons, i.e. if there have been internal or external informal concerns regarding the organisation, or for operational reasons, i.e. if there have been inconstancies with product quality. Considering the overall supplier risk escalation process, suppliers enter the top and go through the process with decisions being made on at monthly meetings of the supplier risk committee

4.9.3 Calculation of the Supplier Risk 'Financial Assessment' Score

The supplier risk score is calculated by analysis of financial indicators, including: Supplier's profit and loss account, balance sheet and credit rating. Combining these indicators is intended to give a rounded picture of the financial health of the supplier. The focal organisation uses separate finance companies to undertake this assessment.

Figure 4-12: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Table 4-13: [This table was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.9.4   Operational Review

If the revisited supplier risk financial assessment score remains red, indicating the supplier is 'high risk', then a full operational review is instigated. This review consists initially of a desk-top analysis of the operational data already held within the supplier risk database to gain a clear picture of both the performance and significance of the supplier. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Although led by the FR team, operational reviews are undertaken by the buyer, or team of buyers, associated with the suppliers account. By doing this, buyers are able to also incorporate their previous experiences of dealing with the supplier in to their assessment of the operational stability of that supplier. If there is still concern about the supplier, following this internal purchasing review, then other functional expertise can be brought in to undertake more practical assessments of the supplier. These include, for example, sending a team of engineers to visit the production site or undertaking more detailed quality assessments on the products supplied to check for consistency.

4.9.5   Decision Point and Implementation

Following escalation from both financial and operational reviews, one of three decisions is made with regards to the organisation's future relationship with the supplier. These include the decision to:

- Support the supplier through the period of difficulty and put on *watch* with targets set to encourage return to the organisation's standard commercial terms

- Commence a re-source If the organisation decides not to remain with a supplier. This is seen as a rare option to immediately instigate as the organisation's primary policy is to support suppliers throughout the life cycle of component sourcing (VM-4). Where resourcing takes place, the purchasing department will complete a full operational re-source plan. This can be independently or in collaboration with the original supplier and will include, the timing cost and ease of resourcing a component, whether a stock-build should be carried out and whether the legal group needs to analyse the implications of resourcing.

- Watch a supplier if there is not deemed to be an immediate security of supply risk or if the supplier has taken active steps to rectify the problem itself. The supplier risk watch process involves, continued financial and operational review by the supply chain risk team and/ or onsite reviews being carried out. In essence the supplier remains within the supplier risk escalation process for an agreed period of time, with targets set to encourage return to the organisation's standard commercial terms.

4.10   Sourcing Process

The sourcing and re-sourcing process is completed by the organisation's individual category buyers, with specialist functional support from other departments and teams where necessary. During the early stages of a products design, engineers may work with a number of suppliers and due to the limited number (and often niche nature) of components being sourced, this can be on an ad-hoc basis, as risk to the organisation is fairly limited (VM-2/3). However, once a product enters mainstream production and its associated products become integral to the organisation's operations, more formalised sourcing procedures are followed. Usually, this will involve a shortlist of approved suppliers for any given component, of which several will be fully costed, before choosing a final, single supplier (VM-2/3).

VM-1 acknowledged the organisation has two main categories of supplier. These can be seen as 'standard T1 suppliers' and also SMEs. Each of these has separate sourcing considerations for the buyer. For example, the organisational preference is clearly toward consolidating supply amongst a smaller number more traditional T1 suppliers (See above). This is primarily because more market intelligence and commercial information is available for the more established T1's and they are usually able to develop cost and reliability targets more effectively (VM-1). This said, both VM-1 acknowledged that there were some components which cannot be sourced from the larger T1's, either because they are novel technologies or particularly difficult to source. VM-2/3 referred to these as 'niche component lines', which the organisation has little control or choice over with regards to sourcing. In these instances, the organisation often works with smaller, less established, suppliers. When this is the case, the organisation aims to offer its full support in forging a close relationship with the supplier in order minimise disruption risk. Additionally, where the SME has limited production capacity, the organisation may also act as an intermediary in forging production partnerships.

As with many large organisations in recent years, price is no longer the fundamental indicator used to make sourcing decisions. Instead, buyers look at a wide range of selection criteria to inform their choice of supplier. When discussing the criteria which most inform sourcing decision, VM-1 and VM-2/3 noted the following in addition to cost competitiveness: Quality standards (ISO9001), Safety Requirements (ISO9001), Technical requirements, Financial Stability, Environmental Standards (ISO14001), Automotive production experience, Fail-

safing/ Poka-yoke activities, Current customer groups, Experience of the current customers with the supplier, Applicable technologies and Forecast R&D investment.

In addition to these considerations, potential suppliers undergo standard supplier risk financial assessment by the FR team. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

4.10.1 Resourcing

If during the supplier risk process, the decision is made to re-source, then prior to standard action being taken under the traditional sourcing procedure (as described above), buyers must additionally assess the likely impact upon the organisation of exiting the existing supplier. This includes estimating the cost and timing of a re-source, identifying the criticality of parts affected (i.e. any problematic parts to source) and understanding the broader implications of re-source.

It is likely that upon exiting a supply agreement, some components will have been paid for but delivery not yet taken. The buyer is therefore obliged in these situations to undertake a full tooling assessment. This involves collating all paperwork to demonstrate proof of stock ownership and identifying where any owned stock is located (i.e. on site with the organisation, at the T1 suppliers' site or at a 3rd party premises such as a T2 parent company).

If a particular component is identified as being difficult to re-source or critical to the production of a given product, then buyers must also analyse how long current stock of a component will last and how long it would take to re-source from a potential supplier (i.e. any capacity constraints they may have). They must analyse what the impact of a supply delay would cause the organisation. For example, if the parts fit into a non-changeable sequence, what implications would a delay have on the production process.

A stock-build is seen as one solution by the organisation to mitigate risk here in the short-medium term (buyers must establish the availability and cost of storage, packaging and any other temporary costs in doing this). Longer term if a delay risk still can't be mitigated through re-sourcing, they must also assess the timing and cost of a product/ manufacturing redesign

4.10.2 Sourcing and Resourcing Example

[This example was provided by the organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.11   Response to Unavoidable Risk Events

As discussed above, not all supply chain risk events can be prevented and therefore, emergency response to unavoidable risk events forms an increasingly important part of the organisation's supply chain risk management strategy; Tomlin (2006) call's these aspects of an organisation's SCRM strategy contingency planning. The organisation distinguishes between two types of specific, unavoidable risk events: 'financial failure from insolvency (resulting from both internal failings and external pressures)' and 'multi-supplier failure from an external disruption'. Separate processes and considerations are given for each of these response groups as will now be discussed.

4.11.1 Emergency Response Process – Financial Failure of Suppliers

Whilst the supplier risk database and escalation process actively monitor's the financial stability of T1 suppliers contracted by the organisation, financial failure cannot always be prevented, a point which has been highlighted in recent years. Financial failure of suppliers is defined by the organisation as when a supplier enters administration, liquidation (voluntary or compulsory), a company voluntary agreement (CVA) or administrative receivership. Whilst there are many antecedents to financial failure, the organisation generally acknowledges two outcomes once a supplier enters financial failure proceedings. Either the business will be sold and continue trading under a new name/s (with limited impact upon supply) or it will be liquidated, in which case the focal organisation will need to re-source.

It has already been noted that the 2007/08 financial crisis had a significant impact upon global automotive supply chains and has acted a key driver in shaping the focal organisation's SCRM strategies. Whilst the economic downturn had a direct impact upon automotive manufacturers through reduced sales, the ripple effect throughout the wider supply chain was unparalleled. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

In response to the significant cost and disruption caused by supplier insolvency in the aftermath of the financial crisis, the organisation invested significant resource in developing and implementing a new approach to managing insolvency and financial distress amongst suppliers. As well as continued monitoring through the supplier risk escalation process (discussed above), the organisation has developed a high-level process for managing risk once a supplier fails financially.

Figure 4-14: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Figure 4-15: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Figure 4-16: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.11.2 Options Analysis and Support Considerations

The main aim for the organisation, when deciding whether to re-source or support a supplier during insolvency is to ensure that the production line is not stopped (VM-2/3). If during options analysis the decision is taken to re-source then the organisation's standard re-source process will be followed as detailed above. If, however, the decision is made to support a supplier, or a significant delay is identified during re-sourcing, an inter-departmental group is established to handle the disruption event and mitigate potential impact upon the organisation (VM-2/3). This group consists of representatives from the following departments and business divisions.

Senior Purchasing Manager/ Director
Supply Chain Risk Team
Business Office
General Council
Finance
Engineering
Supplier Support
Sales
External Consultancies

Table 4-17: Table of organisational roles involved in the response to suppliers in financial failure

Throughout the entirety of the insolvency proceedings, the inter-departmental group will provide daily communication with all relevant department heads, which includes, an overview of updates, any issues which will have an impact on production, knowledge of sub-suppliers beyond Tier 1 and any senior assistance requirements.

4.11.3 Insolvency beyond Tier 1

In addition to the direct financial impact sustained through re-source and support strategies, the organisation has also suffered disruptions from insolvency amongst suppliers beyond the tier 1 level. Disruption was found to occur when, for example, multiple tier 1 suppliers relied

upon a single source for a strategically important component and that 2nd or 3rd tier supplier entered insolvency proceedings.

The company motto with regards SCRM, 'Don't stop the line', has been discussed several times in this chapter. With this in mind, there is concern within the organisation that the financial failure of key suppliers beyond tier 1 could have impacts upon production – again, this is a key driver of the organisation's ambition to gain increased knowledge of its upstream supply chain (see below). The impact of insolvency amongst upstream suppliers upon the focal organisation is difficult to quantify. Due to the increased number of suppliers at each tier of the supply chain (i.e. each of the focal organisation's tier 1 suppliers will have a number of their own sub-suppliers, who will in turn have their own suppliers and so on), the likely number of suppliers entering insolvency at each tier increases. However, this is not to say that each insolvency of an upstream supplier will have the same direct impact upon the organisation as a tier 1 insolvency would have. For example, in the case of many easy-to-source components, an upstream supplier entering insolvency proceedings will simply be replaced by the tier 1 firm in question without the focal organisation experiencing any disruption. Where an issue does present itself is when an upstream supplier forms part of the supply chain for a critical component and is not easily replicable. In these circumstances the failure of a key supplier through insolvency could have a ripple (or Bullwhip) effect throughout the supply chain, impacting the focal organisation. Identification of where these critical 'supply chain pinch points' are, is essential in developing a robust SCRM strategy.

In an effort to increase business intelligence of insolvency amongst lower tier suppliers, the organisation is seeking to increase their upstream visibility of suppliers generally. At the time of writing, the organisation was developing a number of strategies to do this which will be discussed below. The organisation provided a snapshot of the number of supplier insolvencies at both a first and second tier (directed visibility) level over a 6-month period. This is interesting from a SCRM perspective as it illustrates that more tier 2 suppliers entered insolvency proceedings over the period than tier 1 suppliers. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Figure 4-18: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.11.4 Financial Failure Example

[This example was provided by the organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.11.5 Emergency Response Process – Disaster response

The focal organisation has been affected by a number of unavoidable natural and man-made disasters in recent years, including the Icelandic Ash Cloud (2010), which caused significant delays for lower tier suppliers due to flight restrictions across much of Europe, the Japanese Tohoku earthquake/ resulting tsunami (2011) and Thai floods (2011), both of which caused significant delays to upstream suppliers of many key automotive components, especially electronics. In response to these events, and others, the organisation has developed a new rating system to categorise the level of response for supply chain disruptions of this nature, as well as a new high-level response process for disruptions deemed 'major' or 'severe'.

Figure 4-19: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Table 4-20: [This table was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.11.6 Response for 'Major' and 'Severe' Disruptions

For response to disruptions which are categorised as 'major' or 'severe', an inter-departmental group is established to handle the disruption event and mitigate potential impact upon the organisation (VM-2/3). This group consists of representatives from the following departments and business divisions.

Senior Purchasing Manager/ Director
Supply Chain Risk Team
Business Office
General Council
Finance
Engineering
Supplier Support
Sales
External Consultancies

Table 4-21: Table of organisational roles involved in the response to supply chain disruption events

4.11.7 Ongoing Support for Established Suppliers and Feedback

If a decision is taken to use alternative supply routes (i.e. a re-source) throughout the course of an unavoidable disruption, such as a natural disaster, there is an organisational preference to return to original suppliers where possible – rather than exiting them completely. Whilst the final decision lies with the group leader, this expressed preference builds upon the company's views with regards to supporting suppliers as well as its wider ethos with regards to corporate social responsibility (VM-2/3). Returning to the original supplier following an unavoidable event ensures trust between the two parties which the literature makes clear is often difficult to establish (Meira et al, 2010, Caglio and Ditillo, 2008). Establishment of ongoing trusting relationships between buyer and supplier is invaluable from a SCRM perspective (Tang, 2012).

As has been described above, there is also an organisational focus on creating a feedback loop to ensure that lessons learnt by the group in dealing with a major or severe disruption are

documented and used to improve procedures going forward. The Japanese Tōhoku Earthquake and Tsunami example illustrated below, for example, highlighted the issues associated with a lack of upstream visibility; which was subsequently addressed. Organisational learning in this sense is described by Dailey et al (2014) as a prerequisite stage for 'getting control of the supply chain', allowing the development of supply chains which are better equipped to 'sense and respond' to disruptions. This can be seen by considering the following example.

4.11.8 Disaster Response Example

As the world's third-largest economy, and a key producer or components for many major industries, the 2011 Japanese Earthquake and associated Tsunami presented a major challenge for supply chains globally. For the focal organisation, the incident served as a catalyst moment with regards to their approach to supply chain risk management and disaster response. VM-2/3 provided a breakdown of the impact of this event upon the organisation's supply chain. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Initial analysis of immediate T1 suppliers only, suggested that the organisation's supply chain partners were largely functional. Over subsequent days and weeks, it became apparent there were significant impacts upon the wider supply chain. However, whilst the organisation was aware there would likely be wider disruption, due to a lack of visibility beyond tier 1 level, these were not fully acknowledged immediately. More in-depth assessment found that nearly all Japanese tier 1 suppliers had disruptions within their own upstream supply chain (tiers 2-5), their logistics operations and/ or their engineering capabilities.

In the immediate aftermath of the earthquake and tsunami and as the focal organisation began to realise that the event would have a 'major' impact upon upstream suppliers, a cross functional response group was assembled. The strategy adopted in the wake of this event would eventually form the basis for the aforementioned response process. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Adopting this approach allowed the focal organisation to minimise impact upon the supply chain when compared to many other automotive manufacturers. However, this is not to say the organisation did not suffer any disruption from the event. For example, the most significant disruption involved the supply of a component used in the engine control unit of many key vehicle lines. Whilst a supply issue wasn't immediately identified amongst the organisation's T1 suppliers, a significant disruption further upstream was identified after a two-week delay period, where a single Japanese supplier was supplying several automotive manufacturers. In managing this complex supply chain event, the focal organisation took away a number of learning points, especially around a lack of upstream visibility and the need for close relationships between key suppliers and manufacturers in the industry. In this respect, the 2011 Japanese Earthquake and Tsunami can be seen as a key precursor to engagement with the collaborative supply chain mapping project (discussed below).

Figure 4-22: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

Table 4-23: [This table was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

4.12   Raw Material and Macro Economic Analysis

Analysis of key raw material markets and macro-economic trends have begun to play an increasingly important role in the focal organisation's SCRM strategy.

Traditionally, raw material analysis has focused purely on key markets such as those which the company buys directly (i.e. where the raw material producer is a tier 1 supplier). However, significant cost fluctuations in recent years have meant that the company has now established a specialised raw material team, who work closely with wider purchasing to monitor a number of raw material markets. These not only include primary materials such as aluminium and steel, but also materials used in wider component production, as well as a number of commodities including energy (natural gas and electricity) and oil.

The raw material department sits within the purchasing division and use a number of, to forecast future trends and potential market risks which are feed in to a weekly report distributed amongst buyers and the SCR/FR teams. The raw materials team is also currently looking at ways to share key procurement routes and forecasts with selected SMEs to improve purchasing power and improve security of supply (VM-5).

[This text has been removed upon request as it contains information considered commercially sensitive.]

VM-5 also acknowledges that there is significant concern that a lack of supply chain visibility means that the organisation is not aware of all raw materials used in all components.

Beyond raw materials, the focal organisation, particularly the business office, also utilise existing macro-economic models to assess the potential of key sales markets. This allows the organisation to chart its standard sales projections and analyse the impact a number of scenarios on these.

Whilst at present this data has principally been used from a sales forecasting perspective, there are clear ways in which the use of modelling of this nature could be extended to assess

the macro-economic stability of various geographic regions where key suppliers are located throughout the supply chain.

4.13   Going Forward: A Strategy to Increase Visibility through Supply Chain Mapping

The previous section has focused upon the organisation's supply chain risk processes, from sourcing, to active monitoring, though to response to unavoidable events. However, whilst these processes have developed significantly in recent years, for the most part, the organisation only has visibility of these tier 1 suppliers – with 'a small number' providing directed visibility of their immediate suppliers (VM-1). As has previously been noted, this level of visibility is in keeping with Zsidisn and Ritchie's (2008) finding that, many large organisations have a good visibility of operational risk in their immediate operating environment, but due to the resource constraints rarely take a proactive approach to identifying and managing risk beyond this. Building on the common assertion that 'a supply chain is only as strong as its weakest link', the literature suggests SCRM must go beyond simply the lower level boundaries of the focal organisation and its immediate suppliers, in order to discover and quantify hazards in the extended supply chain (Colicchia and Strozzi, 2012). The impacts associated with a lack of supply chain visibility are clearly demonstrated through some of the practical cases highlighted in this chapter, specifically the Japanese Earthquake and Tsunami example (Section 4.11.8).

In a further continuation of the increasing value being placed upon risk mitigation and continuity strategies by the focal organisation, a clear drive now exists to increase upstream supply chain visibility. For example, VM-1 noted that 'In today's turbulent environment, there is an ever increasing need to understand supply chain operations beyond a tier 1 level' (VM-1). Similarly, VM-2/ VM-3 acknowledge a 'significant organisational appetite to understand suppliers further upstream' (VM-2/ VM-3). There are a number of antecedents which led to increased organisational focus on strategies to increase supply chain visibility, which have been discussed and set out in figure 4-2. They include, the global financial crisis which led to an increase in insolvency amongst suppliers, a raft of new quality, environmental and social legislation (reviewed in detail below), the impact of natural disasters upon the supply chain and an inability for key supply nodes to accommodate significant order fluctuations. In response to these drivers and to move closer towards the companies wider SCRM objectives (1. protecting the brand from the negative impact of supplier disruption and 2. reducing the financial loss from supplier disruption generally), the organisation has begun to proactively seek out opportunities to discuss SCRM in a number of industry settings. In recent years this

has involved developing a strong, active presence within a number of EU and international forums to specifically discuss SCRM strategy.

As part of their collaborative participation within these forums, a clearer picture began to emerge about what the key challenges with regards to SCRM were, not only for the focal organisation, but also for similar large automotive manufacturers. As has emerged in the review of current processes above, the key challenge for SCRM echoed throughout the automotive industry was around upstream visibility (VM-4). VM-5 stated that 'visibility is definitely something which is missing from the automotive industry'. In order to begin to address this, in 2012, work began to identify a suitable platform which would allow supply chain mapping. The successful organisation from this process was a leading provider of supplier management solutions who have proven experience in developing supplier sourcing tools, not only within the automotive industry, but also a number of other sectors, including construction and utilities.

When discussing what the focal organisation hopes to achieve from this collaborative project, VM-4 identified a number of objectives the organisation hopes to realise. Primarily, it is hoped that increased supply chain visibility will allow for the development of more proactive SCRM processes, including the extension of many of those discussed above beyond a tier 1 level. An understanding of the upstream supply chain (including engagement with CSR activities for example) would also allow for improved compliance reporting for many of the legislative and regulatory measures which are discussed below. Adopting a collaborative approach was seen internally as being the most cost-effective way to tackle this problem, whilst also promoting wider industry collaboration in gaining accurate SCRM data generally, as well as sharing best practice between manufacturers. The approach was also seen to reduce unnecessary burden on suppliers (i.e. adopting an industry standardised approach removes the need for multiple requests for information from different manufacturers). This is important as supplier engagement is key in any supply chain mapping project. The following section begins with a review of the legislative and policy drivers currently placing increased pressure upon organisations to increase upstream supply chain visibility. It then moves on to assess how the focal organisation is strategically approaching this challenge – gaining real-world insight in to this dynamic and highly significant area of supply chain management.

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4.14 Review of the Legislative and Policy Drivers for Increased Upstream Supply Chain Visibility

The problems associated with a lack of visibility in many organisational supply chains is clearly a central theme in contemporary supply chain management literature and has been examined by a number of authors, most notably from the perspectives of supply chain risk management (Thun and Hoenig, 2011, Christopher et al., 2011, Sodhi & Tang, 2012) and green supply chain management (Acquaye et al, 2011, Björklund et al, 2012) amongst others. However, whilst some attention has been given to the commercial costs associated with a lack of supply chain visibility, the current literature largely overlooks the legislative and policy drivers. Understanding key drivers in this area is important, as the imposition of law and penalties provides a powerful incentive to behavioural change, and is very effective in focussing organisational attention (Hitchcock, 2012).

The principal aim of this section is to give a broad overview of the diverse legislative and policy framework, which is currently driving UK organisations to increase visibility of their upstream supply chain partners operations. It is set against the introduction of a host of new legislation and policy, both at UK and EU level, as well as a backdrop of several recent high-profile events that have had the effect of focusing public attention towards the issue of supply chain visibility. However, it is increasingly difficult to treat UK organisations in isolation. As a member state of the European Union, the UK is increasingly subject to the direct or indirect effect of EU legislative Directives and Regulations and an increasing amount of UK statute is imposed from EU legislation written in Brussels. Moreover, whilst the UK and EU are leading the way in creating a framework for increased supply chain visibility, it should be noted that UK organisations are also subject to local legislation in the regions they operate outside of the EU. As such, some key examples of key legislation and policy outside of the EU are also given.

In terms of legislation and policy, the authors consider there to be three distinct strands of driver: (1) product quality, safety and labelling, (2) environmental and (3) social. Each of these will now be discussed:

4.14.1 Product Quality, Safety and Labelling Drivers

Product quality, safety and labelling legislation have traditionally formed the regulatory back-bone of why organisations seek increased visibility of supply chain activities. Whilst this section does not seek to give a comprehensive review of UK/ EU product quality, safety and labelling regulation, it would be remiss not to briefly discuss some of the key provisions in this area before moving on to discuss more recent social and environmental drivers.

In the UK, the Sale of Goods Act (1979) denotes that all products must be 'fit for purpose', be of satisfactory quality and fit its description. Product safety legislation, such as the General Product Safety Regulations (2005), place a general duty on organisations to ensure that products are safe in normal or reasonable foreseeable use, recognising various European safety standards as the benchmark for this. As a member of the European Union, many products, such as electrical products, construction products and toys, sold in the EU area must also conform to a range of specific European Directives and Regulations, which differ from product to product. For example, the sale of machinery, equipment and safety components is governed by the Supply of Machinery (Safety) Regulations (2008). These products require organisations to comply EU health and safety legislation and by affixing the letters 'CE' on a product, a manufacturer is declaring, on their sole responsibility, conformity with all the legislative requirements ensuring validity for the product to be sold throughout the EEA. In the UK, there are also specific legislative instruments for various products which aren't covered by the EU 'CE' regulations and directives, such as for fireworks and cosmetics. Food products are also governed by specific legislation. Primarily, The Food Safety Act (1990) (as amended) provides the general framework for food legislation in the UK and covers food which falls below quality, safety and labelling standards. This legislation imposes the requirements set forth in the General Food Law Regulation (EC) 178/2002 on general food quality, safety and labelling.

Much of this legislation has its own regulatory remedies for failure to adhere to specific provisions, ranging from fines to full criminal prosecution. In the UK, the Consumer Protection Act (1987), for example, makes manufacturers strictly liable for death, injury, loss or damage cause by unsafe or substandard products. It is also noteworthy, that much recent legislation at UK and EU level, seems to have placed more emphasis on the focal firm proactively working

with and seeking high standards from their supply chain partners, as opposed to simply taking reactive measures when a product failure or concern arises. Recent product recalls in the UK food sector go some way in demonstrating this point. For example, due to increasing supply chain complexity in the retail food sector, it is becoming increasingly difficult to simply direct blame on to a single supplier in a complex supply chain and it is becoming more common for the organisations to share responsibility (if not always strict liability) with the upstream partner who failed.

4.14.2 Environmental Drivers

The impact of environmental sustainability on the field of supply chain management and practice has been significant in recent years. Integrating carbon management and sustainable development in to supply chain operations (Green Supply Chain Management) is a complex, multi-disciplinary topic that has received significant attention in the literature (see for example, Sarkis et al., 2011). In moving towards a greener supply chain, organisations are forced to look beyond their own factory walls and are increasingly expected to know that their suppliers are as mindful of their environmental and social responsibilities as they are themselves. In other words, they are expected to look after the sustainability of their entire supply chain (Cucchiella and Koh, 2012).

Carbon Reporting:

The UK's primary framework for establishing commitment to reducing greenhouse gas emissions is the Climate Change Act (2008). This Act enshrined in to statute an increased target of reducing net UK emissions of all six of the greenhouse gases (GHG) at least 80% by the year 2050 based on the 1990 baseline. It empowers the UK government to go beyond the remit of the EU Emissions Trading Scheme and establish its own trading schemes. One such scheme is the UK is the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme, enabled in Part 3 of the Act, which imposes a mandatory carbon emissions reporting and pricing scheme that covers a wide range of large public and private sector companies. Whilst initial reporting will be limited to material GHG emissions in CO2 equivalent for scope 1 (direct) and scope 2 (indirect from purchased electricity, heat or steam) emissions, there is widespread lobbying by various multi-national organisations and bodies. For example the GHG Protocol, a multi-stakeholder partnership of businesses, NGOs, governments, and others

convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), have recently developed a 'Corporate Value Chain (Scope 3) Accounting and Reporting Standard' which builds upon and complements the existing 'GHG Protocol Corporate Accounting and Reporting Standard'. The seemingly inevitable future implementation of scope 3 emission reporting, coupled with the financial and performance benefits various companies have gained through engagement with understanding the carbon footprint of supply chain operations (see for example, the Carbon Disclosure Project's Supply Chain Report, 2012), is already encouraging many large organisations to go beyond what is mandated in the CRC Energy Efficiency Scheme. Furthermore, a number of organisations have developed tools and mapping packages to allow organisations accurately map their extended supply chain and subsequently, scope 3 emissions, in house. These include, PE International's SoFi sustainable supply chain software and Enablon's Sustainability Management Software, as well as software which goes beyond mapping to also identify potential interventions to 'carbon hotspots' using a hybrid life cycle analysis/ input-output analysis methodology, such as the Centre for Low Carbon Future's Supply Chain Environmental Analysis Tool (SCEnAT).

Material Disclosure:

Aside from understanding the operational activities of upstream supply chain partners for GHG reduction reporting measures, as discussed above, a host of recent legislation has placed increasingly stringent regulations on organisations to ensure the sustainability of materials used in their products. For example, the EC regulation on chemicals and their use (EC 1907/2006), REACH, entered in to force in June 2007 and aims to place greater responsibility on organisations to manage the environmental and health risks posed by chemicals they use. Manufacturers and importers are required to gather information from their suppliers on the properties of chemical substances and assess potential risks from use. They must then communicate this information upstream to suppliers as well as registering this information with the European Chemicals Agency (ECHA) in Helsinki. In a similar vein, recent amendments in 2011 to the RoHS Directive (2011/65/EU) now require manufacturers and importers of electrical equipment in the EU to comply with certain substance restrictions. Again, emphasis is on the focal firm to ensure that their suppliers have conformed with the Directive. Failure to comply with RoHS has resulted in both fines and lengthy import bans on products.

In October 2010, the European Union Regulation laying down the obligations of operators who place timber and timber products on the market (EU) 995/2010, often referred to as the FLEGT Law, came in to force and laid down the obligations of companies who use timber and timber products (including print) in their manufacturing. The regulation seeks to prohibit the use of illegally logged timber in EU products and requires all companies who utilise timber products to exercise 'due diligence' towards their suppliers. This 'due diligence' obligation again places pressure on the focal organisation to understand their upstream supply chain in seeking information about the origin of timber, harvest conditions, and compliance with national laws.

4.14.3 Social Drivers

The final broad category of legislative and policy change that this section discusses, considers how organisations are being driven to increase supply chain visibility from a social perspective, in order to reduce the risk of potential human rights abuses or corruption.

Arguably one of the most notable pieces of legislation to impact British supply chains in recent years from a social perspective is the UK Bribery Act (2010), which came in to force in April 2011. The UK Bribery Act is widely seen as one of the most thorough pieces of legislation to target corruption globally, with several provisions that go even further than the United States Foreign Corrupt Practices Act (1977). The Act has had the effect of creating new offences for direct or indirect (i.e. a bribe paid for an organisation by a third party) bribery, defined as 'the offering, promising or giving of a bribe and requesting, agreeing to receive or accepting a bribe'. The act also has extra territorial jurisdiction, so that it applies to UK nationals both at home and abroad as well as any businesses operating in the UK. Most notably, from a supply chain perspective, the Act is especially significant as organisations, as well as individuals, can be liable for offences under the Act. Section 7 of the Act creates a specific offence for 'commercial organisations' that do not adequately prevent either direct or indirect bribery. The Ministry of Justice's draft guidance in respect of adequate procedures notes as a key principle that, 'the commercial organisation [should have] due diligence policies and procedures which cover all parties to a business relationship, including the organisation's supply chain, agents and intermediaries, all forms of joint venture and similar relationships and all markets in which the commercial organisation does business.' Where some social

legislation in this area has been criticised for lack the regulatory 'stick' needed for enforcement, breaches of the Bribery Act (2010) are investigated by the Serious Fraud Office and subject to the risk of full criminal prosecution (up to 10 years in prison) and unlimited fines.

In addition to corruption, there has also been significant dialogue from policy makers and legislators around the creation of regulatory measures to ensure UK organisation's extended supply chains are free from human rights abuses and slavery. Whilst the proposed UK Transparency of Supply Chains (Eradication of Slavery) Bill, failed to complete its passage through parliament before the end of the 2013 session, it demonstrated the increasing concern for these issues amongst policy makers. The forthcoming EU Corporate Reporting Directive, set to come in to force in 2016, is largely expected to include legislation against the use of slavery in organisation's extended supply chains – adopting similar measures to the influential Californian Transparency in Supply Chains Act. In the lead up to 2016, the department for Business Innovation and Skills in the UK have developed a series of recommendations for how organisations can begin to remove human rights abuses from their supply chains (BIS, 2014). Visibility forms a central theme to these recommendations and the government is currently working with a range of leading businesses to implement these recommendations and develop best practice case studies.

In addition to those UK and EU regulatory measure discussed above, UK companies are increasingly subjected to local legislation in the markets they are operating in. Whilst the EU and UK are widely held to be leading the way in encouraging supply chain visibility, there are specific legislative frameworks, which have not yet been adopted. One such example is the US Dodd-Frank Act (2010), Section 1502 of which, places a requirement on companies to disclose whether certain minerals (defined as gold, tin, tungsten and tantalum) originate from conflict zones in central Africa, such as the Demographic Republic of Congo. Again, due diligence is required by the focal firm to assess suppliers of raw materials and product components compliance with the Act. Even If an organisation is not currently operating within the remit of the Dodd-Frank Act, following an Internal EU workshop in Dec 2012, it is widely expected that similar legislation will be passed in the near future.

There are also an increasing number of 'soft' law standards requirements which companies are being voluntarily encouraged to abide to. From a more social perspective these include requirements such as those set forth in the United Nations (UN) Guiding Principles on Business and Human Rights, adopted in June 2011 by the UN Human Rights Council, and the revised Organisation for Economic Co-operation and Development (OECD) Guidelines on Multinational Enterprises adopted in May 2011. The UN Guiding Principles of Human Rights places a responsibility on organisations to identify, prevent, mitigate and account for how they address adverse human rights impacts that the business enterprise may cause or contribute to through its own activities, or which may be directly linked to its operations, products or services by its business relationships. Principle 17 specifically defines the parameters for ongoing human rights due diligence as implementing a process 'assessing the actual and potential human rights impacts, integrating and acting upon the findings, tracking responses, and communicating how impacts are addressed'. It is also acknowledged that due diligence 'will vary in complexity with the size of the business enterprise, the risk of severe human rights impacts, and the nature and context of its operations'.

The OECD Guidelines on Multinational Enterprises are a broader set of recommendations addressed by OECD governments to multinational enterprises providing agreed voluntary principles and standards for responsible business conduct consistent with applicable national and international laws. The Guidelines form part of the OECD Declaration on International Investment and Multinational Enterprises. As well as human rights commitments similar to the aforementioned UN framework, there is a general policy (No 6) to support and uphold good corporate governance principles and to develop and apply good corporate governance practices. From a supply chain visibility perspective, general policy 10, places an obligation to specifically encourage business partners, including suppliers and sub-contractors, to apply principles of corporate conduct compatible with the Guidelines.

It is clear that there exists a diverse range of perspectives currently driving the 'supply chain visibility' agenda and contributing towards the wider debate around supply chain visibility in general. The growing number of regulatory measures in this area, is seemingly shifting the traditional balance of who is responsible for supply chain failures. The focal firm is being increasingly required to implement 'due diligence' in ensuring it's upstream supply chain

partners are operating within the boundary of the specific act in question, be that with regards to, for example, bribery, working conditions or use of prohibited materials. Whilst difficult economic times have undoubtedly placed increased commercial pressure on many organisations, investing resources in effective supplier relationship management programmes are critical to managing the risks associated with reduced supply chain visibility and it is often a lack of supplier knowledge beyond the tier 1 level which increases large organisations susceptibility.

It is argued that organisations that get this right have a significant opportunity to create strong relationships with their upstream supply chain partners, drive efficiency and protect consumer confidence in the organisation. Whilst failure to act is becoming less of an option considering the speed at which the regulatory landscape is changing, there is a clear need to harness the current focus on 'supply chain visibility', to better engage academics and practitioners in this debate.

4.15   Towards an Industry Wide Supplier Portal

It is clear that the focal organisation is aware of the potential impact failing to comply with the legislation and policy outlined above could have in terms of reputational damage. Indeed, Section 4.6 highlighted examples from VM-4 of the type of legislation imminently concerning the organisation and driving engagement in this area. In this respect, whilst increased visibility will no doubt be essential from a compliance perspective (the current principal driver for engagement), there is also a need to understand how it can contribute towards more effective SCRM strategy. This will be considered fully in the following chapter using a real-world example of a critical component. However, prior to this, the final section of this chapter will briefly explore how the focal organisation is currently approaching the challenge of increasing the visibility of their upstream supply chain.

As seen throughout this case study, the focal organisation already undertakes operational and financial assessment of their tier 1 suppliers. As a precursor to beginning a formalised supply chain mapping process, it was thought necessary to encapsulate key supplier data within a central automotive database. Initially this will only be at a tier 1 level. However, as the mapping process progresses, data will be included from upstream suppliers also. As with the supplier mapping process, the database is administered by a third-party company and will be accessible to all automotive manufacturers who have agreed to engage in the collaborative project. Again, as was discussed earlier, increased financial transparency between supply chain partners can be a powerful tool in the development of the close supply chain networks needed for effective SCRM strategy (Meira et al, 2010).

In order to establish a base level of data, the focal organisation, along with other automotive manufacturers in the project, create a link between their own supplier portal (containing basic details of tier 1 suppliers) and the third-party company's own central automotive database. Whilst much of the internal supply chain risk management data analysis described above was omitted, basic-level operational and financial information was shared. Suppliers were then contacted directly to register on this new database and provide any missing data, with registration being mandatory in order to remain a preferred supplier of the focal organisation. This provides a powerful incentive for engagement amongst tier 1 suppliers. Data from the

following categories (if not already provided by the focal organisation) was collected and cross-referenced to pre-qualify for sourcing.

Company Information
Financial Information
Quality Data
Corporate Social Responsibility Data
Environmental
Health and Safety
Products and Services
Carbon Foot Printing

Table 4-24: Key data items categories contained within the newly created central automotive database

Pre-qualification in this central automotive database was not a replacement for internal company sourcing processes, as discussed above, as every automotive company using it will have different specific requirements in this respect. Rather, it adds an additional first step in the focal organisation's sourcing process, whereby the details of approved suppliers who have been successfully used within the industry and who have had the financial and operational compliance details reviewed by a third-party company, are stored in a single location that is accessible by multiple automotive manufacturers. Once a supplier is validated on the database, they enter an audit cycle, whereby regular quality and operational checks are carried out to ensure the accuracy of data contained within the database. Again, this is not a replacement for company specific auditing. However, it reduces the resources needed to carry out audits of basic supplier information, which ordinarily would be carried out by each automotive manufacturer, creating additional burden for both the automotive manufacturer and supplier in turn.

Whilst this central automotive database only holds tier 1 data at present, the long-term aim is that, though a supply chain mapping exercise (discussed in the next section), upstream

suppliers can also be included to develop a strategic souring database which can be used by the whole industry (VM-5). Whilst this is certainly several years away at present, the idea of embedding the aspiration to integrate supply chain mapping in to an eventual automotive database which can be used to make strategic sourcing decisions would be a significant step in terms of strategic management of supply chain risk across the industry. In the current analysis this central automotive database is discussed in its context as an essential building block for the focal organisation's supply chain mapping work.

4.15.1 The Supply Chain Mapping Process

The focal organisation has already invested significantly in SCRM process development, as is evidenced above. However, supply chain visibility beyond a tier 1 level is clearly an area of existing weakness for the organisation in its management of corporate-level disruption risk. Engagement in this collaborative supply chain mapping exercise is in part driven from a compliance perspective. However, in the longer term there is significant opportunity to improve SCRM strategy at the organisation too. In the current context, the focal organisation defines supply chain mapping as 'the identification, qualification and monitoring of suppliers and their links along the supply chain – beyond tier 1'. The supply chain mapping process is again driven by a third-party company, building upon the aforementioned supplier registration and pre-qualification process, seeking to eventually create a fully populated central automotive database of all suppliers at each tier of the supply chain. This will be a database shared between the multiple automotive manufacturers and suppliers, which entered in to a collaborative contract for this project. Moreover, the database will have functionality to produce operational reports in order to support SCRM activities.

4.15.2 How the Supply Chain Mapping Process Will Work

The process itself requires the focal organisation to identify which tier 1 suppliers it wishes to engage, and a campaign is created to 'onboard' these suppliers on to the system – if they are not already included in the central automotive database through pre-qualification described above. At a tier 1 level, the focal organisation will already have access to a range of data gained through implementation of the above SCRM processes. However, in order to satisfy many of the social and environmental legislative requirements requiring immediate action (discussed in section 4.14) a more detailed self-assessment questionnaire on CSR and

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sustainability is filled in by tier 1 suppliers at this stage. Following receipt of this completed questionnaire, tier 1 suppliers are invited to add details of their own sub-suppliers on to the system. Where details are not received, tier 1 supplier is required to provide a reason. *[This text has been removed upon request as it contains information considered commercially sensitive.]*

Sub-suppliers are then invited to join the system (if they are not already included already) and confirm the link with their customer that provided their details. At this stage sub-suppliers are asked to provide more specific company data, as well as details of their own sub-suppliers. Again, where details are not received, the sub-supplier is required to provide a reason. Sub-suppliers are then invited to join the system (if they are not already included already), confirming the link with the customer that provided their details and the cycle continues. The focal organisation will then begin to build a picture of their supply chains and interactions between nodes.

Figure 4-25: [This diagram was provided by the focal organisation and has been removed upon request as it contains information considered commercially sensitive.]

The focal organisation is supported throughout this process by a third-party company, who operate a series of automated chase cycles, when suppliers throughout the process do not respond to requests for information within a set time-frame. These chase cycles not only serve to drive efficiency and encourage participation in the process, but also seek to achieve wider acceptance in the values of the scheme. The chase cycles provide a communication platform where the third-party company are able to deliver a consistent message throughout the supply chain around issues such as benefits for the industry/ individual supplier, confidentiality and specific aspects of the process itself. This is also reinforced through the distribution of marketing materials, brochures, fliers and a project specific website.

Confidentiality is obviously a key consideration in this process considering the large amount of data that is being captured, expressing a commercial relationship between buyers and suppliers at different tiers of the supply chain. Ensuring confidentiality is particularly important, considering that this is a voluntary process which has not yet matured. The focal organisation has stated that confidentiality will be ensured by limiting each supplier to downstream visibility of their supply chain only. In other words, whilst the focal organisation eventually aims to have visibility of its full supply chain, suppliers and sub-suppliers will only be able to view their immediate operational environment. Whilst this ensures confidentiality, it also limits the potential appeal of the system for suppliers beyond the first-tier level engaging voluntarily in the process if they are not able to gain complete supply chain visibility themselves. For example, a disruption event may occur which impacts a tier 4 supplier within a component supply chain. In this case, whilst the focal organisation might be made aware of this disruption, a tier 2 supplier (who does not fall within the immediate operational environment of the affected sub-supplier) may not.

The focal organisation has stated that provisions are being considered with regards to supply chain wide alert which will impact all parties impacted by a given disruption within the upstream supply chain. However, it seems likely that this will only be in the most severe of cases and at the time of writing discussions were still ongoing within the steering group regarding this.

4.16 The Need for Improved Risk Assessment

There is a significant appetite within both the focal organisation and wider industry to engage in supply chain visibility projects such as this. This partly stems from recent negative and financially costly experiences caused by a lack of upstream visibility, many of which have been discussed above. However, the sense of urgency with which the problem is being addressed, primarily stems from the many legislative and regulatory drivers which are forcing companies to assert more control over quality, social and environmental problems throughout their supply network (see analysis of these drivers in section 4.14). As Hitchcock (2012) asserts, the imposition of law and penalties provides a powerful incentive to behavioural change and is very effective in focussing organisational attention.

From a SCRM perspective, it seems clear that engagement with this collaborative mapping project has the potential to significantly increase visibility throughout the focal organisation's upstream supply chain and as a result, enable more accurate supply chain analysis to be conducted.

The project offers significant opportunities to both the focal organisation and its suppliers in how they manage supply chain risk, strengthening both information flow and relationships throughout the supply chain. However, increasing supply chain visibility is only the first stage in developing an effective strategy for managing risk in the focal organisation's upstream supply chain and this project is not an all-in-one SCRM solution. Instead, the increased supply chain intelligence gained through engagement with this project will feed in to and act as a facilitator for the development future SCRM strategy, with the focal organisation deciding how the data is best utilised.

Questions around what the focal organisation can do with better supplier data and visibility throughout their upstream supply chain have already been raised. For example, VM-4 notes that from the outset that data gained from this mapping exercise could have significant potential to feed in to both existing and new SCRM processes to allow for the development of tailored solutions and managements strategies for the focal organisation.

As has been discussed previously, although the organisation has engaged significant resources in developing a range of end-to-end SCRM process, these are very much focused upon the management of operational risk within a manageable base of tier 1 suppliers, largely and perhaps unsurprisingly given the recent crisis, from a financial perspective.

Findings from the above case study are in keeping with Colicchia and Strozzi's (2012) conclusion, following a systematic literature review, that whilst organisations are becoming more adapt at managing operational supply chain risk, there is insufficient focus on understanding the dynamics of external disruptions and how they might affect that organisation. Although several recent global events have led to the development of a new response process for unavoidable disruption, 'the emergency response process', this is largely reactive in nature and there currently exists minimal opportunity to proactively analyse and assess which upstream suppliers might be susceptible to various geo-political, economic and environmental corporate-level disruption risks.

Increased upstream visibility through supply chain mapping will yield a significant amount of supply chain data within which to consider these challenges. However, whilst the focal organisation has to date been able to maintain a relationship with its tier 1 suppliers, the resources necessary to manage risk at every node of the supply chain (beyond tier 1) will dramatically increase.

Whilst the supply chain risk processes discussed above will still play a central role in the organisation's operational SCRM strategy, understanding the dynamics of the upstream supply chain, will allow for novel risk analysis which would not have been possible with tier 1 visibility alone. Going forward the focal organisation will need to develop tools and processes with which to proactively identify potential hotspots of risk and develop a strengthened resource targeting strategy in their mitigation efforts beyond tier 1. Using a real-world supplier example, the following chapter will seek to explore some of the key questions around how increased supply chain visibility can be used to improve the identification and assessment of external, corporate-level risks within the supply chain, by adopting an approach which combines upstream geographic supply chain data with weighted geo-

political, economic and environmental indicators to identify potential areas of susceptibility to this type of risk.

4.17   Summary – Key Findings Table (Case Study 1)

Company Scale
• Volume car manufacturers • Principle operation includes design, development, manufacture and marketing of consumer vehicles • Employees across several sites • Primary Markets - Europe, the US and China
Tier 1 Supply Base
• Significant tier 1 supply base • Geographical T1 supplier spread predominantly Europe and US • Reduction in supply base since 2008 • Supplier consolidation has increased total procurement spend
Supply Base Segmentation
• Management of overall procurement split in to functional areas • Tier 1 supply base segmented considering both the value of the buy from a given supplier and the nature of the relationship with that supplier (how mature it is) • Segmented maturity model – Transactional, Leverage, Critical and Partnership
Drivers for establishing a SCRM function
• Supply chain risk has always been recognised by the organisation and steps taken to manage this, however, until recently this has been on a more informal basis • At its most basic level engagement comes down to protecting the brand and reducing financial loss from supplier disruption • Key Drivers include: Several recent disruption events impacting suppliers; New quality, environmental and social legislation; An Inability for suppliers to remain flexible to changing requirements; and the global financial crisis causing an increase insolvency amongst suppliers.
SCRM Organisational Structure
• Co-ordination of SCRM relies on two specialised central purchasing departments: the supply chain risk (SCR) team and the financial risk (FR) team. • Above SCR/FR teams sit a panel of senior staff who form the 'supplier risk assessment committee' • Primary role of both SCR and FR teams, are as developers and co-ordinators of risk strategy • SCRM facilitating departments include - the business office, general council (legal), supplier support, engineering and individual buyers/ teams of buyers
Identification of Risk
• Risk is broadly defined at the focal organisation. • 'There is no one definition of risk, but it is broadly understood to be anything which may impede the reputation or commercial positioning [of the vehicle manufacturer]'. (VM1) • Internal company motto - 'Don't stop the line' (VM2/3) where by supply chain risk is defined as being 'anything that could impact or stop production'. • The first step in the SCRM process involves the identification of key risks that might adversely affect the organisation as a whole (i.e. not just its supply chain). • In order to prioritise this list of macro-level supply chain risks, a high-level assessment of impact and likelihood is undertaken. • The purchasing department does not consider its-self to have complete control at the time of writing over the majority of risk groups identified.
Categorisation of Risk
• Output from this first stage in the SCRM process directly informs which areas of risk should be prioritised by the SCR and FR teams, who are then tasked with developing and allocating resources to implement mitigation processes. • The focal organisation does not conform fully to any of the formal theoretical models discussed in the literature – although it clearly understands them. • A distinction is drawn between risk that occurs as part of normal operations (operational risk) and that which is wholly externally driven (corporate-level disruption risk) (VM-2/ VM-3) • In practical terms, interviewees clearly indicated that there was a need to align the management of different risks, with an appropriate organisational entity (VM-2/ VM-3).

- Therefore, supply chain risk is driven by the SCR and FR teams, but dealt with on an application by application basis, where 'risk is separated by functional area' rather than type (VM-2/ VM-3).

Mitigation and Response to Risk

The focal organisation has developed supply chain risk processes which have incorporated SCRM throughout the end-to-end purchasing function.

Initial Sourcing and Re-sourcing:
- The sourcing and re-sourcing process is completed by the organisation's individual category buyers
- Organisational preference is toward reducing exposure to risk by consolidating supply amongst a small number of traditional T1 suppliers
- VM-2/3 acknowledged that there were some components which cannot be sourced from the traditional T1 suppliers. These as 'niche component lines', which the organisation has little control or choice over with regards to sourcing.
- Price is no longer the fundamental indicator used to make sourcing decisions. Buyers look at a wide range of criteria, Including: Technical requirements, Financial Stability, Environmental Standards
- Analysis of key raw material markets and macro-economic trends, have begun to play an increasingly important role in the focal organisation's sourcing strategy

Continual Monitoring of Risk:
- The centrepiece of the organisation's SCRM strategy is the supplier risk escalation process to continually monitor financial and operational risk amongst all T1 suppliers.
- The process is underpinned by the supplier risk database, which securely holds and monitors detailed financial and operational data on all of the organisation's tier 1 suppliers.
- The supplier risk escalation process is a multi-stage approach for suppliers highlighted as 'high risk' or 'potentially high risk'
    - Calculation o*f the supplier risk* 'Financial Assessment' Score
    - Operational Review
    - Decision Point and Implementation (Support, Re-source or Watch)

Response to Unavoidable Risk Events:
- Not all supply chain risk events can be prevented and therefore, emergency response to unavoidable risk events forms an increasingly important part of the organisation's SCRM strategy.
- The organisation distinguishes between two types of specific, unavoidable risk events: 'financial failure from insolvency and 'multi-supplier failure from an external disruption'.
- For response to disruptions which are categorised as 'major' or 'severe', an inter-departmental group is established to handle the disruption event and mitigate impact (VM-2/3)
- Separate processes and considerations are given for each of these response groups.

Going Forward: A Strategy to Increase Visibility

- At present, the organisation only has visibility of tier 1 suppliers – with 'a small number' providing directed visibility (VM-1).
- 'In today's turbulent environment, there is an ever increasing need to understand supply chain operations beyond a tier 1 level' (VM-1).
- 'Visibility is definitely something which is missing from the automotive industry' (VM-5).
- The visibility agenda is gaining momentum following several legislative and policy drivers.
- The focal organisation, in collaboration with a third-party integrator, is pioneering the development of a fully populated central automotive database of all suppliers at each tier of the supply chain.
- It is hoped that increased supply chain visibility will allow for the development of more proactive SCRM processes beyond a tier 1 level.

4.17.1 Summary

This chapter has presented an in-depth analysis of SCRM strategy and practices at a leading, multinational automotive organisation. Data was collected through a series of semi-structured interviews with supply chain managers and risk experts at the organisation, as well as analysis of a range of internal organisational reports, presentations and other documents.

A broad overview of the focal organisation's structure, supply base and segmentation strategy is given, before discussing some of the key drivers for engagement with SCRM. In completion of Objective 2 of this research, a critical review of the organisation's current SCRM processes and work stream is then given, highlighting several real-world supplier examples of various strategic approaches in practice. Particular attention is paid to evolving organisational strategies to address corporate-level disruption risks and how current approaches are often undermined by a lack of upstream supply chain visibility. This is significant as the literature notes a lack of understanding around how real-world organisations engage with SCRM generally and in-particular corporate-level SCRM.

In completion of Objective 3 of this research, a review is undertaken of the legislative and regulatory drivers, driving many UK organisations to increase visibility of their upstream supply chain. A review of this nature was identified as lacking in the current literature. The final section of this chapter considers how the focal organisation is strategically approaching this challenge – contributing real-world insight in to this dynamic and highly significant area of supply chain management.

5   Chapter 5 – Towards a Stakeholder Salience Framework of Upstream Corporate-Level SCRM: A Case Study of the Lithium-Ion Battery Supply Chain

5.1   Introduction to the Case Study

The previous chapter presented an in-depth analysis of how a leading, multinational automotive manufacturer strategically approaches the area of Supply Chain Risk Management (SCRM) and how processes are evolving to manage corporate-level disruption risks in the upstream supply chain. In undertaking this case study, the key motivational drivers for organisational engagement in SCRM activities were outlined, as well as how these have led to the development of new SCRM processes and work-streams, based on a centrally defined and prioritised list of risks identified as being most likely to impact the organisation. It is clear that the organisation's cross-functional supply chain risk processes, covering sourcing, continuous monitoring and response to unavoidable events, has transformed how SCRM is approached amongst its first-tier suppliers. Moreover, the development of these new SCRM work processes and tools clearly represents a significant investment in resource for the organisation and has provided a more structured, effective approach to managing tier 1 supply chain risk, especially in terms of operational and financial risk. However, a SCRM benchmarking exercise, various legislative drivers (Section 4.14) and numerous supplier failures caused by disruption beyond a first-tier level, have shifted attention towards corporate-level disruption risk and led to increased focus on improving understanding of the upstream supply chain. See for example, the impact of upstream supplier failures (beyond T1) stemming from the 2011 Japanese Earthquake and Tsunami.

Chapter 4 closed with a critical discussion around how the focal organisation is capitalising on this increased focus and interest in transparency to undertake a collaborative upstream supply chain mapping exercise with the aim of significantly increasing visibility. It is clear that engagement with a collaborative supply chain mapping process such as this will offer significant opportunities to both the focal organisation and its suppliers in how they manage upstream corporate-level supply chain risk, strengthening both information flow and relationships throughout the supply chain. However, in Chapter 4, it was concluded that increasing supply chain visibility through this project alone should not be viewed as an all-in-

one upstream SCRM solution. Instead, it should be thought of as the first stage in developing an effective strategy for managing corporate-level risk in the focal organisation's upstream supply chain, whereby data from the exercise feeds in to and acts as a facilitator for the development of tailored SCRM strategies, with the focal organisation deciding how the data is best utilised. Developing methods to better understand and utilise supply chain visibility data of this nature is in keeping with the literature in this area discussed in Chapter 2 (Williams et al, 2013, Caridi et al, 2014).

The current chapter seeks to explore and begin to answer key questions around what the focal organisation can do with better supplier data and visibility throughout their upstream supply chain, in terms of understanding the risks posed by external disruptions (corporate-level risks). For example, it is clear that increased upstream visibility through supply chain mapping exercises such as this will yield a significant amount of supply chain data about geographical supply chain nodes throughout the wider supply chain. Whilst the organisation has to date been able to maintain a relationship with each of its tier 1 suppliers, the resources necessary to manage risk at every node of the supply chain (beyond tier 1) will dramatically increase. As such, the current chapter seeks to explore some of the key questions around how increased supply chain visibility can be used to improve the identification and assessment of external, corporate-level risks within the upstream supply chain, by adopting an approach which combines upstream geographic supply chain data with weighted geo-political, economic and environmental indicators to proactively identify potential hotspots of risk and develop a strengthened stakeholder resource targeting strategy in their mitigation efforts beyond tier 1. A conceptual framework for this approach has been developed in Chapter 2 (Figure 2-19) and is explored and critically discussed, through the use of a real-world example of a real-world, critical component supply chain, in the current Chapter – The Li-ion battery.

5.2   The Li-ion Battery Supply Chain as an Appropriate Case Study

This chapter draws on primary data collected during interviews with both the Vehicle Manufacturer (highlighted as VM-1 & VM-5) and one of its Tier 1 supply chain partners for the production of Li-ion Batteries (highlighted as SCP-1 to SCP-5), as well as through analysis of a number of internal organisational documents. Primary supply chain mapping data, used in analysis throughout this chapter, was also obtained through engagement with these companies during the research process.

At the outset of this research, a decision was made to identify a real-world supply chain with which to conceptualise key issues around supply chain visibility and the impact of corporate-level risk throughout the upstream automotive supply chain. The Li-ion battery cell was specifically chosen for a number of reasons. After discussion with VM-1, the Li-ion battery cell was highlighted as a 'critical' component in the organisation's future production strategy. As per the organisations supplier categorisation approach discussed in the previous case study, 'critical' components can be defined as aspects of the organisation's supply base that are technology driven and high priority for future business needs, whilst not yet necessitating high volume production. There is a significant appetite to understand the dynamics of these supply chains by the focal organisation (VM-1) which adds increased justification to choosing this particular supply chain to focus on. Additionally, for the purpose of stability throughout the research process, the Li-ion battery cell supply chain was considered to have a relatively established supply chain with which to analyse. For example, unlike many other novel 'critical' technologies within the automotive industry, key suppliers within the Li-ion battery supply chain are already well established and supply in volume to the consumer electronics industry. Whilst, scale and chemistries change for automotive application, the fact that many supply routes are established already provides for a more stable and robust case with which to explore in the current research. Finally, the Li-ion battery supply chain also introduces a range of novel materials in to the organisation's supply base, many of which are identified as critical raw materials by the EU (2014). These have the potential to create vulnerability to new external (corporate-level) disruption risks.

5.3   The Growing Importance of Li-ion Batteries in the Automotive Sector

As discussed from the outset, the automotive sector is critical to the UK's economy. It is also a key sector in terms of the transition towards a low carbon economy. For example, domestic road transport in the UK accounts for 23.2% (133mtco2e) of total GHG emissions (DECC, 2014), 58% of which are from cars and taxi's (DfT, 2011). Meeting the UK's ambitious reduction targets of 80% across all sectors (as legislated for in the Climate Change Act, 2008) will require a technological shift that goes beyond efficiency improvements of current Internal Combustion Engines (ICEs). It is widely believed that, given the investment landscape and current technological readiness, deep decarbonisation of the domestic road transport sector can only be achieved through the introduction of electrified drivetrains in the form of Electric and Plug-in Hybrid Electric Vehicles (EV/PHEV) (CCC, 2012), for which Li-ion batteries are a key component.

5.3.1   The Current Electric/ Plug-In Hybrid Electric Vehicle Market

Prior to discussing the focal organisation's positioning in this market and the Li-ion battery supply chain in more detail, there seems merit in briefly discussing the EV/PHEV market in more general terms, as this will be the key driver of the automotive industries demand for Li-ion batteries.

Latest sales figures indicate that 2012 saw a substantial growth in the EV market with 110,000 domestic EVs and PHEVs sold globally. Whilst this is still a small fraction of conventional vehicle sales of 82 million in the same period, it represents a doubling of 2011 sales which were around 40,000 (OICA, 2013). Demand is currently led by the US, Japan and China, with 6 European Countries (including the UK) in the top 10 (ACEA, 2013). Considering the UK market for electrified vehicles specifically, as of March 2013 there were 3,900 on the read. Whilst sales of new electric vehicles in the UK remain low (when compared to conventional vehicles), sales between 2011 and 2012 have more than doubled and look set to increase again when 2013 figures are released (CCC, 2013). In the UK this significant increase in sales can be attributed to a number of factors, including: the government backed Plug-in Car Grant introduced in 2011 which contributes up to £5000 towards the price of a new EV or PHEV, the introduction of the Nissan Leaf (the first high quality UK mid-sized electric vehicle) and the increased focus on infrastructure development (such as the plugged in places scheme) (CCC,

2013). Going forward, current research suggests that there will be a significant increase in global electric vehicle supply and demand, with analysis based upon announced production capability and scale-up plans suggesting manufacturers will produce 1.5 million electric vehicles annually by 2015 (OICA, 2013). This steep trajectory which will need to be maintained if global electric vehicle adoption targets of 18.5 million units (based on cumulative national targets) are to be achieved by 2020 (CCC, 2013).

In order to achieve national and global EV/ PHEV adoption targets there are a number of perceived barriers to uptake which need to be removed. Based on attitudinal research in to the factors which most strongly differentiate the purchase of an electric vehicle (CCC, 2013), five key barriers to uptake are generally accepted to exist. These are 1) vehicle price and running costs 2) brand and segment supply 3) access to charging 4) driving range and charging time and 5) the consumers' receptiveness to electric vehicles. It is clear that financial incentives (such as the UK Plug-in Car Grant discussed above) will be crucial in mitigating the current price premium associated with electric vehicles. Moreover, the number of brands and models of electric vehicles available in the UK are increasing significantly (with forecasts suggesting there will be over 30 models of EV/ PHEV by 2015). This said, other concerns such as range anxiety and access to charging infrastructure are more complex to address, requiring not only investment but also a change in public perception (OICA, 2013). The Committee on Climate Change (2013), through an extensive review of international evidence found that delivering a national uptake pathway which addresses these issues will require several measures, including: Continued release of new EV/ PHEV models at a rate at least equivalent to the current market, a co-ordinated and sustained promotional campaign that draws on the marketing experience of major automotive players to raise awareness and acceptance of electric vehicles, increased investment in charging infrastructure and most significantly, in terms of the current research, continued policy support, not just in terms of sales incentives, but also to support wider growth of the sector and the supply chains which underpin it (CCC, 2013).

Developing an efficient global supply chain to underpin the transition to EVs is essential, both in terms of coping with increasing production volumes and delivering cost efficiencies. Whilst some aspects of the EV/ PHEV supply chain will already be established within the automotive

sector, others, such as the Li-ion battery supply chain, will expose the industry to new technologies, materials and supply routes. The UK government clearly recognises the importance of building effective supply chains in this area and has committed to a major investment programme aimed specifically at the development and interrogation of the supply chain to support low carbon transport. This programme, announced in July 2013, will see the government and automotive industry each invest £500 million over the next 10 years in a new Advanced Propulsion Centre, which has the objective of improving the positioning of the UK in low carbon vehicle development and manufacturing, as well as increasing the UK's global market share for the production of low carbon vehicles (CCC, 2013).

5.3.2 The Focal Organisation's positioning in the EV/PHEV Market

The focal organisation's current and future positioning in the EV/PHEV market was established through interviews with VM-1 (Aug 2012) and VM-5 (May 2013) who have direct visibility and input into the organisation's overall electrification strategy and positioning.

When asked specifically about the focal organisation's current and planned future positioning in the EV/PHEV market, VM-1 noted the difficulties involved with creating accurate forecast models due to market and technological uncertainties, as well as consumer concerns such as cost, range and a lack of charging infrastructure. This said, the organisation sees EVs/ PHEVs as being the most viable of all current alternative fuel vehicle technologies and is actively pursuing this market, which it sees as becoming increasingly important to the organisation's future strategic market positioning. Although in the nine-month period between interviewing VM-1 and VM-5, the organisation had developed firmer production dates and forecasts, they are subject to several uncertainties.

The focal organisation's current electrification production strategy can be categorised in to three distinct stages: Prototype and Technological Assessment, Short Term Limited Volume and Medium-Term Volume Production. At present, due to the uncertainties discussed above, longer term forecasts beyond 2020 are difficult to accurately predict.

Prototype and Technological Assessment: Prior to the current research being undertaken, the organisation had been engaged in a number of R&D streams associated with the potential for electrification of the automotive drive train to varying degrees. However, VM-1 acknowledged that it was the consolidation of much of this R&D activity into a single programme, which really gave a boost to the company's electrification programme. In 2012/13 (throughout this research's data collection period), the organisation was actively engaged in three prototype projects. Engagement in these early-stage, non-volume, prototype projects allowed the organisation's engineers and buyers to work with numerous first tier EV/PHEV supply chain partners to trial new technologies and build new supply chain relationships prior to moving towards volume production.

Short Term - Limited Volume Production: Building upon supply chain readiness testing and technology prototyping, the organisation will launch two limited volume production vehicles in the 2013/14 financial year.

Medium Term – Volume Production: By 2017, current organisational forecasts show the market will have reached a sufficient level of maturity, both in terms of demand and infrastructure, to warrant an increased volume of production and more diverse product offering (VM-5). It is anticipated that demand for hybrid electrified vehicles across the range will increase roughly in-line with industry average forecasts out to 2020; see recent report by the Climate Change Committee (2013). At present the organisation does not foresee the market will be in a position to warrant full scale, volume production of a pure EV model in the short term. However, it does anticipate some limited production runs for small-scale, application specific use.

5.4   Li-ion Battery Technology

As has been discussed above, the Li-ion battery is a key component, in terms of both economics and performance, for both Electric (EV) and Plug-in Hybrid Electric Vehicles (PHEV). A range of battery chemistries have been used in early EV/ PHEV models, such as nickel metal hydride in the first-generation Toyota Prius. However, more recently focus has shifted to the lithium family of chemistries due to a number of advantages, most notably the significant energy density gains. It is believed that the dominance of Li-ion battery cells in domestic transport electrification is likely to remain in the short-medium term (to 2030). This is because the time interval between laboratory demonstration and vehicle deployment is currently observed as 15-25 years, indicating that as there are currently no 'breakthrough' technologies in the testing phase, a large technological shift is unlikely (CCC, 2012).

Whilst the focus of this research is Li-ion battery application in the transport sector, the wider significance of this technology in other sectors should be noted. For example, whilst the automotive sector represents a significantly expanding share of the market at present this remains quite small at around 5% (CCC, 2012). By far the largest Li-ion demand market is the consumer electronics sector, which although utilises smaller, less complex cells, still account

for the majority of current production output. Figure 5-1 presents a series of high-level structural diagrams, depicting the Li-ion prismatic cell and module assembly for EV/ PHEV usage
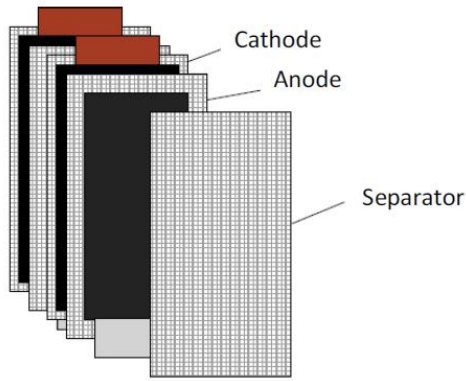
Prismatic Li-ion Cell for EV/ PHEV Usage (A123 Systems, 2014)
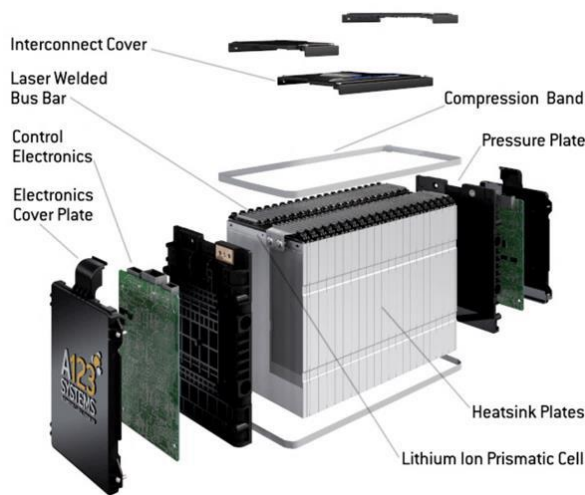
Assembling multiple Prismatic Li-ion Cells to form a battery module for EV/PHEV Usage (A123 Systems, 2014):
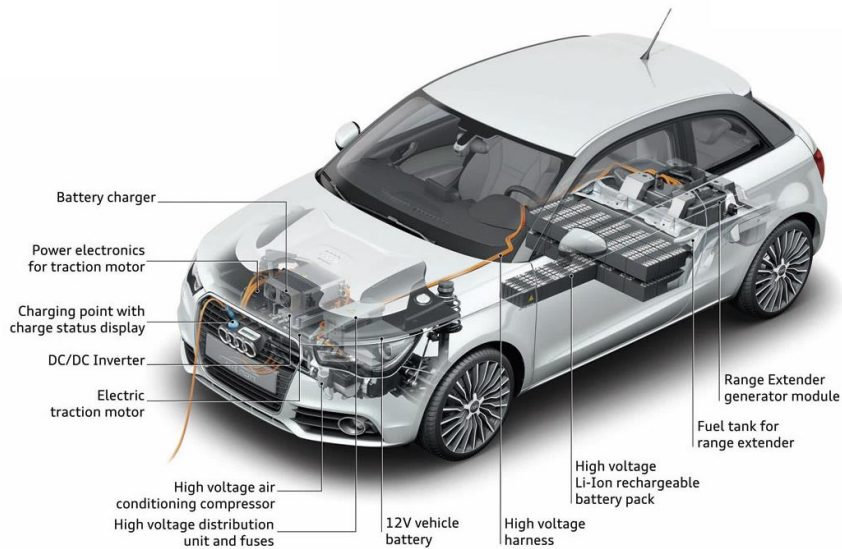
Example of integrating battery modules in to the electric drive train

Figure 5-1: High-level Structural Diagrams of Li-ion prismatic cell and module assembly for EV/ PHEV usage.

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5.4.1   The Li-ion Battery Cell and Assembly of Module Packs

To understand the Li-ion battery supply chain, it is first useful to briefly discuss what a standard cell consists of. Whilst there exist a number of different Li-ion battery chemistries (as will be discussed below), the basic principle of the cell remains the same, where lithium ions flow back and forth in a lithium salt electrolyte solution, between two intercalating electrodes, an anode, usually made from graphite and a cathode, usually made from either a lithium metal oxide or lithium iron phosphate. When the battery discharges (i.e. when it is in operation), the flow of positive (ions) and negative (electrons) charges leave the anode for the cathode, with the flow of electrons across a potential difference used, in the case of EVs/PHEVs, to drive an electric motor while the ions move across the electrolyte solution (CCC, 2012). The cell also contains a number of other key components, including for example, aluminium (cathode) and copper (anode) current collectors as well as a porous separator, separating electrodes whilst remaining permeable to the conducting ions.
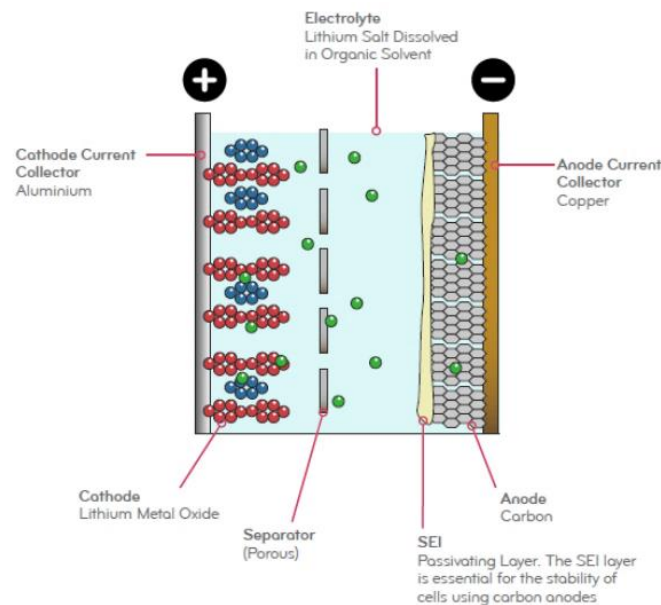
Figure 5-2: Schematic of Li-ion cell (Provided by Supply Chain Partner)

A typical battery cell voltage will be fairly consistent (around 3-4V), while capacity will change dependent upon cell design and size (CCC, 2012). In order to build sufficient voltage and capacity for utilisation in EVs/PHEVs, multiple cells are brought together to form a module pack (see figure 5-1). In addition to bringing multiple Li-ion cells together (in series or parallel depending on whether it is voltage or capacity building required respectively), module packs also contain a number of additional components to ensure optimal performance of the cells.

These components include: A Battery Management System (BMS), Power electronics/ safety devices, a wiring harness, internal cell/ module support and temperature control equipment.

5.4.2 Li-ion Battery Chemistries for Automotive Application and Trade-offs

Li-ion batteries for application in EVs/PHEVs comprise of a family of battery chemistries which differ based on the combination of materials used in their anode and cathode. The principle technologies for automotive use at present are: Lithium-Nickel-Cobalt-Aluminium (NCA), Lithium-Nickel-Manganese-Cobalt (NMC), Lithium-Manganese Spinel (NMO), Lithium-Titanate (LTO) and Lithium-Iron-Phosphate (LFP) (BCG, 2010).

There are a number of trade-offs between each of these five battery chemistries in terms of safety, life span (number of charges cycles and battery age), specific energy (how much energy can be stored by the battery per kg of weight), specific power (how much power can be stored by the battery), performance (peak power, thermal management and charging performance) and cost. As would be expected for automotive application, safety is seen as being a key constant and is a leading factor in why Li-ion chemistries for automotive application have moved away from Lithium-Cobalt Oxide (LCO), the traditional chemistry used in the consumer electronics industry.
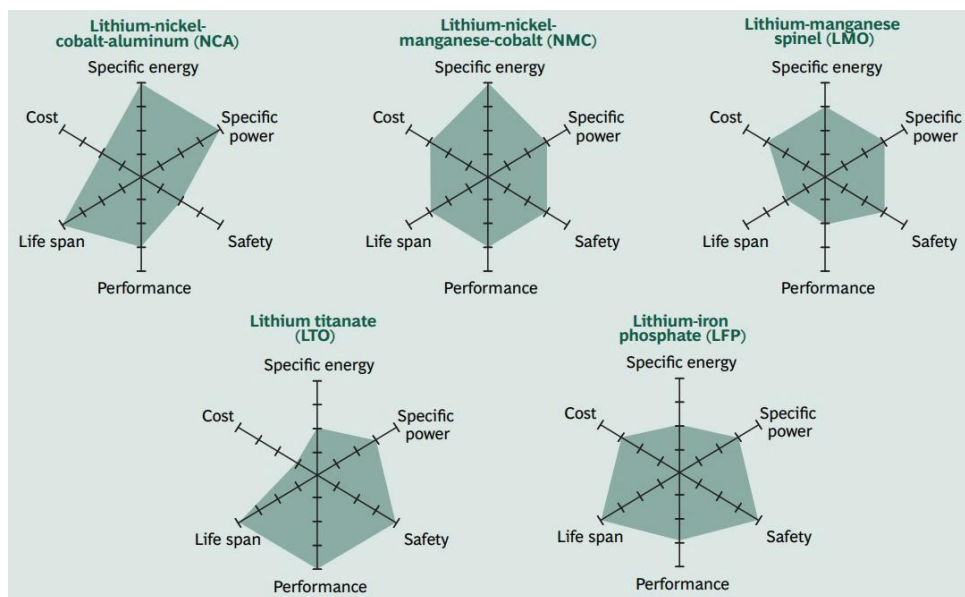
Figure 5-3: Trade-offs amongst the five Principal Li-ion Battery Chemistries (Boston Consulting Group, 2010)

The diagram above, from the Boston Consulting Group's well regarded 2010 report on 'Batteries for Electric Cars', illustrates the key chemistries and comparative trade-offs' associated with each of them. As can be seen, no single chemistry performs equally highly amongst all six dimensions and as such most manufacturers are currently using a number of chemistries for differing applications (i.e. for pure EV or PHEV). For example, of the five chemistries discussed above NCA batteries offer significantly high performance, power and energy, but present cost and relative safety challenges. Conversely, LFO batteries perform extremely well in terms of safety, but compromises are made in terms of specific energy. The popularity of LFP batteries in automotive application, in spite of energy storage challenges, illustrates the significant emphasis being placed on safety by the industry. Research suggests that the co-existence of multiple battery chemistries for different automotive applications is likely to remain for some time (BCG, 2010).

5.4.3 Chemistries Used by the Focal Organisation

For these aforementioned models, as well as future models forecast in the run up to 2020, the focal organisation uses two principal types of Li-ion battery chemistry (VM-1):

1. Lithium-Iron-Phosphate (LFP)
2. Lithium-Nickel-Manganese-Cobalt (NMC)

In discussing the consideration given by the organisation in choosing these two specific types of Li-ion battery chemistries, VM-1 provided some of the key drivers. Applicability of battery chemistry is application driven, with each specific vehicle design, driving its own battery choice. For example, aside from safety obviously being a key requirement, PHEVs require more specific power than specific energy, where as pure EVs require a battery with uncompromised specific energy performance in order to extend range. In addition to this, VM-1 noted the importance of choosing and settling on a small number of battery chemistries to maximise future scalability and standardisation across all markets. In this sense ongoing performance reliability becomes a key issue, as in markets such as the US, legislation prescribes that vehicles are sold with extended 10 year warranties. Finally, on a more practical note, the organisation realises the importance of day-to-day consumer use in dictating battery choice, opting to choose single unit designs which don't compromise storage space, as appose to load spread battery pack designs.

5.5   Introduction to the Li-ion Battery Supply Chain

The upstream Li-ion battery supply chain for electric vehicles is generally accepted to consist of five stages. Raw material extraction and processing, Component production, Cell production, module and pack assembly and finally vehicle integration (BCG, 2010/ Lowe et al, 2010). A brief description of each of these stages is included in Table 5-4.

Stage	Description	Supply Chain Tier
Raw Material Extraction and Processing	The extraction, processing and trading of the raw materials and chemical feedstock's used in component production.	Tier 4
Component Production	Manufacturing of the individual components needed to create each of the battery cell's constituent parts	Tier 3
Cell Production	Production and assembly of cell components (including the anode, cathode and electrolyte) in to single Li-ion battery cells	Tier 2
Final Module and Pack Assembly	Configuration of multiple individual Li-ion battery cells in to larger modules and combination with an integrated Battery Management System (BMS) to form the final battery pack.	Tier 1
Vehicle Integration	Integration of this final battery-pack in to the final vehicle structure.	Focal Organisation

Table 5-4: The Supply Chain for Li-ion Batteries for Automotive Application

SCP-3, outlined how automotive manufacturers have adopted 4 distinct supply chain configurations, each with varying levels of vertical integration. The 4 varying levels of supply chain integration are illustrated in Figure 5-5. These include supply chain configuration 1, where the supply chain is fully integrated in the form a joint venture between an automotive company and a large-scale cell manufacture. Examples of this configuration tend to include mature market participants such as the Nissan and NEC or Toyota and Panasonic's joint ventures, where (aside from raw material production) the supply chain, from component production to vehicle integration is fully integrated within a single plant.

Supply Chain configuration 2 has been termed as an 'integrated supplier' approach, where Li-ion battery production is outsourced by the automotive manufacturer to an experienced large

cell manufacturer who offer integrated component, cell and module/ pack production. This differs from supply chain configuration 1 as the automotive manufacture's relationship with the cell manufacturer is a typical buyer/supplier one as appose to a formal joint venture, which often takes the form new joint company both parties have a vested financial interest in. Outsourcing to an 'integrated supplier' arrangement is currently quite common in the market. See for example BMW's Li-ion battery supply relationship with Samsung or Tesla's Li-ion battery supply relation with Panasonic. Interestingly, Tesla has recently announced plans to strengthen their relationship with Panasonic and move towards a joint venture model (as per supply chain configuration 1). This development is in keeping with SCP-3's view that as manufacturer's EV/PHEV programmes become more mature their Li-ion battery supply chain becomes more integrated.

Supply chain configuration's 3 and 4, are significantly more fragmented, where, instead of forming a direct relationship with the cell manufacturer, a specialist module/ pack assembler acts as an intermediary to deliver bespoke battery packs for vehicle integration. SCP-3 explains that this more fragmented approach is beneficial to many vehicle manufacturers who are in the earlier phases of their electrification programmes and wish to utilise various battery technologies for a number of different prototype and production applications. Working with a tier 1, module/ BMS integrator, in this sense, provides the vehicle manufacturer with a number of advantages, including, access to specialised skills, the ability to buy from multiple cell manufacturers who each have their own benefits with regards to different cell technologies, having more technical input into battery pack design without the significant cost of a full joint venture and increased flexibility with regards to reconfiguring the supply chain, if necessary, as production levels increase.
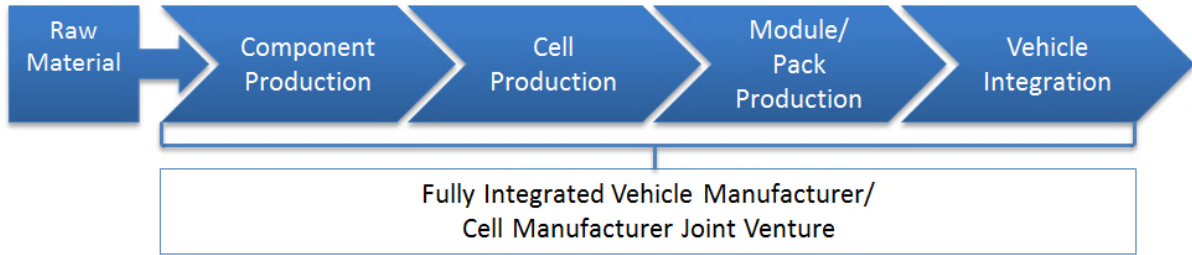
Supply Chain Configuration 1 – Fully Integrated Approach
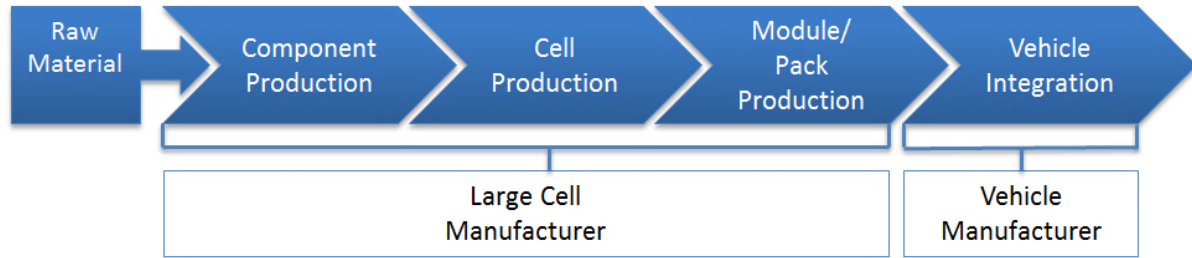
Supply Chain Configuration 2 – '2 tier' Integrated Supplier Approach
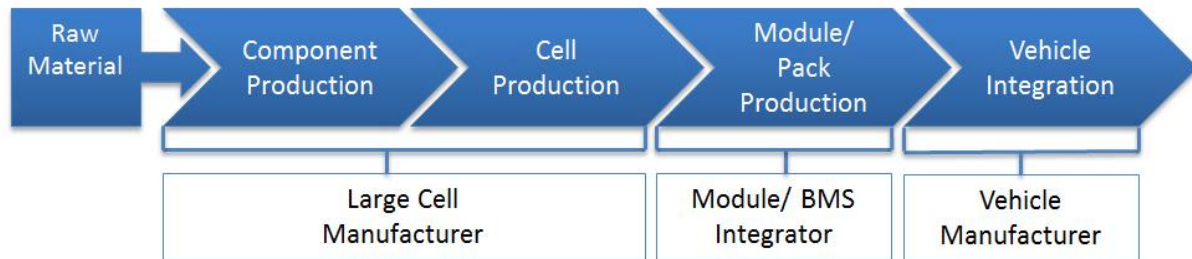
Supply Chain Configuration 3 – '3 Tier' Fragmented Approach
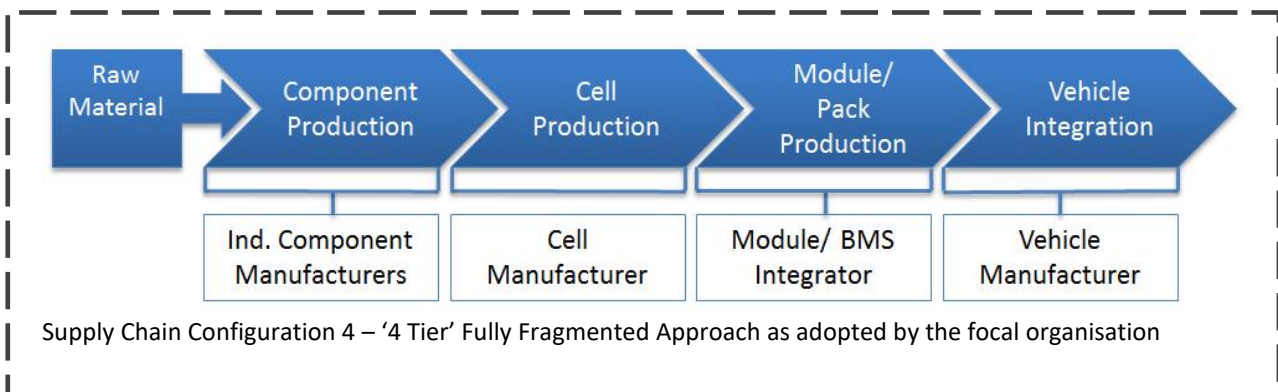
Supply Chain Configuration 4 – '4 Tier' Fully Fragmented Approach as adopted by the focal organisation

Figure 5-5: The 4 Varying Degrees of Li-ion Supply Chain Configuration (Interview with SCP-3)

5.5.1   The Focal Organisation's Chosen Li-ion Battery Supply Chain Configuration

Prior to undertaking a full supply chain mapping exercise for the two Li-ion battery chemistries used by the focal organisation, interviewees (from both the focal organisation and their suppliers) were asked to consider a high-level matrix of the key stages (as identified in Table 5-4), indicating which organisations were involved in which aspects of the supply chain. Following this basic exercise, as well as wider contextual discussion around supply chain positioning of the focal organisation generally (with VM-1, SCP-3 and SCP-4), a high-level picture of the organisation's Li-ion battery supply chain began to emerge. This aligns closely with the four tier, fully fragmented supply chain configuration discussed above (Supply Configuration 4), in that that the Focal organisation has chosen to adopt a fully outsourced approach, working with a well-established tier 1, module/ BMS integrator. This tier 1, module/ BMS integrator in turn work with a number of cell (tier 2) and component (tier 3) manufacturers, who source a number of raw materials throughout production (tier 4), in the development of bespoke Li-ion battery solutions for automotive application. When discussing with VM-1 and VM-5 the decision to adopt this wholly outsourced approach to the supply of Li-ion batteries, a number of reasons were cited, including, the high capital expenditure of bringing activities in-house, especially whilst the market is in its relative infancy and whilst there are still demand and technological uncertainties.

During the initial 'prototyping and technological assessment' stage of the focal organisation's electrification strategy (discussed above), it became clear that, from a technological perspective, certain aspects of the production process were more critical than others. For example, VM-1 stated that getting module and pack design right was extremely important, as mistakes here could increase the likelihood of future battery failure. As such, the focal organisation initially worked with a number of specialist T1 organisations who had expertise in the area of bespoke application specific module/ pack assembly. The decision to work with the current T1 supply chain partner (engaged in this research) was due to a number of reasons. Firstly, the T1 partner is a specialist module/ pack assembler, not aligned to a single cell manufacturer. This is important as it provides the T1 supplier (and in turn the focal organisation) increased flexibility over which cell manufacturers are used for each specific application. For example, different cell manufacturers have different strengths (VM-1). Secondly, with primary production facilities being based within Europe, proximity to the focal

organisation is obviously desirable in terms of: Access and Proximity during R&D, locality during development and testing stages as well as reduced time in potentially uncontrolled shipping containers (VM-5). Working within this centre has allowed both the focal organisation and Tier 1 supplier's engineers to work collaboratively (drawing also on academic research) to accelerate the commercialisation of electrification technology such as Li-ion batteries (VM-1). Interestingly, VM-1 also suggests that a preference by many vehicle manufacturers for more localised (European) supply chain partners in the wake of recent disruptions, is leading a lot of 'big players' in the Asian and US battery markets to establish an EU presence – in at least sales support and sometimes pack assembly.

When discussing different levels of integration amongst automotive manufacturers in the Li-ion battery supply chain, the focal organisation indicated that they no immediate plans to bring either tier 1 (module/ pack assembly) or tier 2 activities in house. VM-1 suggested that the current collaborative approach was a good short-medium term compromise for bringing tier 1 activities in house as it provided many of the advantages of an integrated tier 1 approach (in terms of control and technological expertise) without the associated capital expenditure. In the longer term, however, as the market develops and the company increases its technological experience, VM-1 suggests that module/ pack assembly is an area the organisation has some strategic ambition to enter. With regards to integration of T2 (cell manufacturing) activities, both the focal organisation and its current T1 supply chain partner (SCP-1) expressed no desire to enter this market. This is principally due to significant overcapacity in the cell manufacturers market as a result of numerous government-backed financial investments/ incentives during the recession to offset the high capital expenditure ($2-300 million) associated with building Li-ion cell manufacturing plants. See for example, the substantial US government grants to A123 Systems and LG-Chem to build US Li-ion cell manufacturing plants, which are operating far below optimal capacity level due to over-capacity in the market and lower than expected demand (VM-1).

Turning to consider risk and whether this factored in to the focal organisation's chosen supply chain configuration, as was discussed in the previous chapter Interviewees stated that risk did play a role in how the organisation had chosen to configure its supply chain, however this was only at a tier 1 level (VM-1). In terms of the Li-Ion battery supply chain specifically, whilst the

organisation is aware of the various 'big players' in the tier 2, cell manufacturing industry and indeed what some of the key raw materials used in production are, they do not have a firm understanding of this and have very little supply chain visibility beyond a T1 level. There is a specific lack of knowledge about the tier 3 component layer of the supply chain. VM-5 acknowledged that there are concerns around a number of potential disruption risks in the Li-ion supply chain for the two chemistries currently employed, specifically mentioning volatility in the lithium and raw materials market, understanding whether instability in certain regions could impact the supply chain and the risk of becoming over-reliant on certain geographical regions that are potentially unstable in terms of geo-politics or regulation.

As previously discussed, the Li-ion battery cell was chosen as a practical case study here due to it being highlighted as a 'critical' component in the organisation's future production strategy. Acknowledging limited tier 1 visibility only, VM-1 noted the need to increase understanding of upstream dynamics within the Li-ion battery supply chain. In a practical sense, the current research seeks to address the disconnect between the organisation's intent to understand contribute towards the active management of risk up to the component level and their current largely outsourced approach to SCRM in this supply chain.

5.6   Mapping the Focal Organisation's Li-ion Battery Supply Chain

The purpose of this chapter is to explore and begin to answer key questions around what the focal organisation can do with better supplier data and visibility throughout their upstream supply chain in terms of understanding the risks posed by external disruptions (corporate level risk).

In Figure 2-19, a conceptual stakeholder salience framework was presented, considering how upstream geographical supply chain mapping data can be combined with weighted geo-political, economic and environmental (corporate-level) risk indicators, in a GIS model to identify potential hotspots of corporate-level disruption risk, aiding in better targeting of mitigation strategies and contingency decision support.

As discussed above, in order to conceptualise key issues around supply chain visibility and the impact of corporate-level risk throughout the upstream automotive supply chain, a real-world supply chain example was selected. The Li-ion battery cell was identified as particularly appropriate for this task as it has been highlighted as a 'critical' component in the organisation's future production strategy and also introduces a range of novel materials in to the organisation's supply base that have the potential to create vulnerability to new external (corporate-level) disruption risks. Li-ion batteries for automotive application in EVs/PHEVs comprise of a family of battery chemistries which differ based on the combination of materials used in their anode and cathode. The focal organisation's current and future electrification strategy includes two principal types of Li-ion battery chemistry (VM-1):

1. Lithium-Iron-Phosphate (LFP)
2. Lithium-Nickel-Manganese-Cobalt (NMC)

Based on the analysis and discussion above, four high-level Li-ion battery supply chain configurations were identified as being used within the automotive industry. These differed principally upon the level of vertical integration between each of the 4 key tiers of the supply chain. Based on data obtained from both the focal organisation and their Li-ion battery cell supplier, it was identified that the focal organisation's high-level Li-ion battery supply chain

aligned closely with the four tier, fully fragmented supply chain configuration (Supply Configuration 4 in Figure 5-5).

This configuration represents the focal organisation's Li-ion battery supply chain at its most basic level. Although the focal organisation has both an ambition and longer-term strategy in place to increase their understanding of supply chain operations beyond a tier 1 level (as has been discussed in Chapter 4), currently, there is very low visibility beyond a first tier level within this 'critical' component supply chain.

Gaining an increased visibility of the supply chains which underpin these two Li-battery cell chemistries (in terms of structural breakdown, suppliers and their geographic location), is the essential first stage in identifying critical hotspots of corporate level supply chain risk. As such, over the coming pages, this 4-tier, high-level supply chain will be exploded and explored in detail through a supply chain mapping process.

5.6.1 Supply Chain Mapping

The process of supply chain mapping was discussed fully in Chapter 3 (3.5.4, 3.10.4) and is a well-established concept within the operations management literature. Supply chain mapping can be defined as an approach whereby the foal organisation engages with its lower tier suppliers and conducts external market analysis to identify partners and flows of goods throughout the supply chain (Tumalla & Schoenherr, 2011). However, with the increasingly global nature of supply chains, organisation's now faces a significant challenge in attempting to do this. For example, as Farris (2010) notes, the cost in terms of harvesting, processing and presenting the data is significant once an organisation moves beyond the macro (tier 1) level.

There are various mapping techniques discussed within the operations management literature, depending upon the type of visibility required by an organisation. Understanding the visibility required to address a given business problem is key to understanding the type of supply chain mapping needed. The current research is concerned with understanding the impact of corporate-level disruption risk upon a specific automotive supply chain. The geographic nature of this form of risk, means that primarily, visibility is required of who

upstream suppliers are at each stage of the supply chain, for a given structural component and that suppliers geographical location – rather than specific process data.

As such, mapping the supply chain for the two Li-ion battery chemistries used by the focal organisation (LFP and NMC), was a process which involved first seeking input from the focal organisation (VM-1 and VM-5) to understand the current level of visibility they had for these specific two supply chains and gain an appreciation for how the supply chain was configured at its highest level, as discussed above. Support was then obtained by the focal organisation to work with one of their first-tier suppliers of Li-ion battery packs/ modules.

After gaining this support, interviews were carried out with a number of employees at this organisation (highlighted as SCP-1 to SCP-5) and primary supply chain data (from both employee's expert knowledge and existing organisational data) collated to build detailed map of what these two specific supply chains looked like. By working with both this tier 1 supplier and indirectly their higher tier suppliers, a detailed breakdown of the following was created:

1. The structural components within both LFP and NMC battery cells (tiers 1-4)
2. Who upstream suppliers were at each stage (tiers 1-3)
3. Supplier's geographical location at country level (tiers 1-3)

These feed directly in to the supply chain maps in Figure's 5-7 and 5-8.

5.6.2   Practical Problems with the Supply Chain Mapping Process

Whilst this research is not primarily focused on addressing the problems associated with the practical supply chain mapping process itself, four key practical challenges have been highlighted throughout the data collection process and are discussed briefly below.

On-boarding/ Issues of confidentiality:

Gaining support from lower-tier supplier chain partners is a key first step in any successful supply chain mapping process. Although, the tier 1 supply chain partner in the current research was extremely supportive in contributing towards the work and interested in the outputs, SCP-4 noted that their organisation would have increased concerns if this were a commercially driven project (i.e. feeding back in to commercial decision making). A specific

concern centred on the fact that in a competitive tender environment, there would be a strong disincentive not to voluntarily highlight areas of potential risk in the extended supply chain if competitors were not doing the same.

Power Imbalances between low-mid tier suppliers:

A related issue to the on-boarding of suppliers initially, specifically concerns how mid-higher tier suppliers, who are significantly larger than their lower tier partners, can be incentivised to engage in supply chain mapping projects. Whilst the current academic supply chain mapping process was unaffected, due to the fact that the first-tier supplier had a strong relationship with its supply chain partners and was aware how they were configured, this remains a concern for wider supply chain mapping exercises. For example, there are many automotive supply chains which consist of both SMEs (as lower tier suppliers) and large multi-nationals (as mid-high tier suppliers). In this instance, the larger organisation often lacks incentive to commit the significant resource needed to engage in the mapping process, at the request of the SME, who will likely represent a very small percentage of their overall business. The third party, bottom up approach, which links engagement with becoming a preferred supplier (discussed in chapter 4), only offers sufficient incentive when the focal organisation represents a significant customer of the 2nd tier supplier.

The Dynamic nature of supply chains (especially raw materials markets):

This area is a specific concern from a supply chain mapping perspective. For example, a standard approach to supply chain mapping (such as the method discussed in Chapter 4), involves a request originating from the focal organisation being passed to first tier suppliers and from there, data is collected from various upstream partners in turn, before all supply chain data is returned the focal organisation. The length of time this takes is significant and can be problematic in dynamic areas of the supply chain, such as price sensitive raw material markets. In part, this challenge can be mitigated by taking a broader analysis of the wider market for key raw materials as this research has done. However, this approach does not take in to account changes in other aspects of the supply chain, such as integration of tiers or switching of suppliers. The only way to fully address this problem would be through real-time supplier reporting and monitoring through sufficiently close chase cycles.

Setting the boundaries for the supply chain mapping exercise:

A final challenge which presented itself with the supply chain mapping exercise employed in this research, concerns where to set the system boundary. A conscious decision was made, in the context of the current research, to map the macro (country) level locations of all upstream suppliers. This decision was taken, as data for many corporate-level disruption risk metrics is only available at a macro level. Moreover, interviewees highlighted that in higher tiers, this represented a realistic level of obtainable data in practice. As such and for the purposes of this research (a conceptual framework to illustrate how increased visibility can be used for SCRM purposes), this macro-level country data is believed to be appropriate. However, there are obvious benefits to modelling both logistics and transportation routes, as well as more detailed 'within-country' site data. For example, especially in the case of environmental risk, certain areas of a country may be more susceptible than others.

5.6.3   A Disconnect between Tier's 1-3 and Tier 4

Whilst the above supply chain mapping process provided a structural breakdown of material and components for all tiers (1-4), it also illustrated a disconnect between identification of suppliers at tier's 1 – 3 (component, cell and pack/ module production), where a specific supplier and location could be identified and those at tier 4 (raw material/ feedstock markets), where one could not. This is primarily because the majority of raw materials (especially mineral commodities) are traded in global markets (either directly by the T3 supplier or through a merchant) which are extremely dynamic in nature and price sensitive. For example, commodities bought through third party traders or associations could be from various sources globally, so it is extremely difficult to state categorically, that a single raw material is from a single producer country. Much more likely is the scenario that, when large quantities of a raw material are sourced in a given time period, they are from a range of producer regions. This consideration has factored in to the decision to conduct broader raw materials analysis in this chapter, where a number of key producer regions for each material has been analysed, rather than a single one.

It is also important to note that the supply location of raw materials can be affected by various strategic risk mitigation strategies undertaken by upstream supply chain partners. For example, whilst multiple-sourcing and market hedging can both offer protection against

potential bottlenecks in the event of a risk event limiting supply, from a geographical perspective, they can also mean that the 4th tier becomes quite fragmented with multiple suppliers from various countries.

Sourcing from multiple suppliers offers increased security of supply by spreading a company's risk profile. For example, if a raw material is sourced from several suppliers in different regions, a risk event in one would have a lesser impact upon the supply chain. There are however, clear disadvantages in terms of supply chain inefficiencies and additional expense which impact the amount of companies which adopt this mitigation strategy. A recent study by supply chain consultancy Inverto (2011) reported that less than half of the 200 executives it surveyed were expanding their supplier base in this way. Additionally, the supply of several critical raw materials such as Graphite, Rare Earth Metals and Cobalt are concentrated in an extremely narrow geographical area, making dual sourcing for some materials, in practice, very difficult (see the 2014 Report on Critical Raw Materials for the EU discussed later).

Market hedging on futures exchanges such as the London Metal Exchange in London, UK (LME), ABX Global in Brisbane, Australia (ABX) or the Central Japan Commodity Exchange in Nagoya, Japan (CJCE) is also used as a strategy to mitigate against supply fluctuations in raw materials markets. This process involves an organisation offsetting potential price fluctuations of its key raw materials by securing a long term purchase price through the purchase of futures contracts on a commodities exchange such as those mentioned above. The aforementioned report by supply chain consultancy Inverto (2011), suggested that although 91% of those surveyed found that raw material supply bottlenecks were having an adverse effect on their respective business, financial hedging to offset supply risk (and diversify supply) remained comparatively low. This is evidenced by considering the finding in chapter 4, that whilst the focal organisation monitors a number of raw material markets, it only engages in market hedging (on the LME) for a very limited number of high-volume commodities it uses directly in the manufacturing process itself. Whilst price fluctuations (to a limited degree) are written in to many first tier supply contracts, the focal organisation does not currently operate a joint raw material hedging programme with upstream suppliers to mitigate supply risk in the chosen supply chain. Instead, in the case of the Li-ion battery supply chain, it is the responsibility of upstream partners to manage raw material supply risks.

Respondents to the Inverto survey (2011) indicated that financial hedging activities aren't pursued for a number of reasons, including, low purchasing volumes (especially true of small organisations in the upstream supply chain), the fact that hedging markets don't exist for many raw material (i.e. they are principally used for non-ferrous metals) or that the company does not have the necessary specialist know-how.

It is clear that until an organisation has full visibility of their upstream supply chain, it is extremely difficult to identify to what extent key suppliers are engaging in raw material risk mitigation strategies. Moreover, even where risk mitigation strategies, such as dual sourcing and market hedging are employed, they can be problematic in their ability to effectively mitigate risk for downstream partners (such as the focal organisation) in practical terms. For example, research suggests that the majority of companies who do protect a proportion of their raw material base, hedge less than 20% of their annual requirements (Inverto, 2011). This suggests that for an upstream supplier with multiple customers, those further down the supply chain (such as the focal organisation) may still be susceptible to any disruption within that raw material market and would benefit from increase knowledge of that market.

Based on the above discussion and in order to overcome limitations posed by the dynamic nature of raw material markets relevant to the Li-ion battery supply chain, secondary market data (from the Natural Environment Research Councils' World Mineral Production Dataset, 2012) was used to analyse more broadly, the key producer regions involved in the 4th tier of the Li-ion battery supply chain. Understanding the potential for external disruption within multiple key producer regions for each raw material, rather than a single supplier, provides a more accurate picture of how the raw material supply market operates, with supplier switching and multiple regions supply based on price and other factors being commonplace.

5.6.4   Raw Material Market Analysis

Through undertaking the supply chain mapping exercise discussed above, this research was able to structurally breakdown and analyse both upstream components and raw materials used in the eventual production of LFP and NCM battery cells. In total 21 individual Tier 4, raw materials were identified. These can be categorised in to two groups, traditional raw mineral commodities and petro-chemical derivative commodities.

Traditional Raw Mineral Commodities	Petro-Chemical Derivative Commodities
Lithium	Vinylidene Fluoride
Nickel	Styrene (A derivative of Benzene)
Cobalt	Butadiene (a by-product of Ethylene production)
Manganese	Propylene
Flake Graphite	Ethylene Carbonate
Coal	Diethyl Carbonate
Copper	Y-Butyrolactone (GBL)
Silicon	Methylamine (MMA)
Aluminium	
Alumina	
Phosphate	
Fluorspar (Key mat in Hydrogen Fluoride)	
Iron	

Table 5-6: Table of Key Raw Materials and Chemical Feedstock's

The following market analysis has concentrated primarily on the 13 traditional raw mineral commodities. The decision to omit detailed market analysis of specific petro-chemical products was taken due to the difficulties in obtaining accurate synthesis and supply data. Whilst these petro-chemicals derive from a shared base of either petroleum or another fossil fuel such as coal or natural gas, they vary significantly in their synthesis. Some, such as Styrene and Butadiene are by-products of petro-chemical products produced through steam cracking. Others are prepared commercially by reacting intermediary chemical compounds, such as ammonia and methanol to create Methylamine. From a supply chain perspective, petro-chemicals are produced in extremely large volumes at large chemical plants globally. Roland Berher (2012) identify key production regions as Europe (14%, especially the UK, Germany and the Netherlands), the US (16%), China (17%) and Japan (7%). A trend is also noted in the localisation of tier 3 material producers to regional petro-chemical manufacturing to induce integrated manufacturing or 'industrial symbioses', building economies of scale such as material and utility efficiency. Based on this, an assumption is adopted (accepted as a potential limitation) that chemical compounds used in the production of T3 components (in Japan, China, the USA and Canada) are sourced on a regional basis.

Geographical Spread of Raw Material Supply – Producer Tables

The following producer tables were produced from analysis of the Natural Environment Research Councils' World Mineral Production Dataset (2012) on global commodities. Included are producer tables for each of the 13, tier 4, raw material commodities used in the

production of LFP and NMC battery cells. Countries highlighted in green are classed as 'key producer regions', meaning that they each, individually produce over 10% of global output for that specific raw material. As discussed above, for the purposes of the current research and in order to overcome the dynamic nature of raw material markets, an assumption is made that raw materials could be supplied from any 'key producer region'. Rather than focusing on a single region, this assumption (which feeds in to the two supply chain maps and risk analysis later in this chapter) allows for a broader understanding of current and future supply regions and associated risks for each given raw material.

Global Production of Fluorspar		
Total Production (Tonnes)	7,100,100	
China	4,400,000	62%
Mexico	1,237,091	17%
Mongolia	428,900	6%
South Africa	240,000	3%
Spain	113,570	2%
Russia	100,000	1%
Kenya	95,000	1%
Namibia	90,834	1%
Morocco	78,000	1%
Bulgaria	69,700	1%
Other Countries Combined Output	247,005	

Global Production of Nickel		
Total Production (Tonnes)	1,895,000	
Philippines	317,621	17%
Russia	268,700	14%
Indonesia	253,400	13%
Australia	244,000	13%
Canada	204,461	11%
New Caledonia	131,693	7%
China	93,300	5%
Brazil	87,300	5%
Cuba	68,300	4%
Colombia	51,595	3%
Other Countries Combined Output	174,630	

Global Production of Lithium		
Total Production (Tonnes)	27000*	
Chili (Lithium Carbonate)	71,594 (13,230*)	49%
Australia (Spodumene Mineral)	45,2921 (8,100*)	30%
Argentina (Lithium Carbonate and Chloride)	15,000 (2,430*)	9%
USA (Li Content)	1,500 (1350*)	5%
China (Various)	60,000 (1080*)	4%
Portugal (Lepidolite Mineral)	20,698 (270*)	1%
Brazil (Spodumene Mineral)	8,000 (270*)	1%
Other Countries Combined Output	(270*)	

*Actual Lithium Content, various mineral sources

Global Production of Cobalt		
Total Production (Tonnes)	128,000	
Democratic Republic of Congo	86,433	68%
China	7,000	5%
Zambia	5,665	4%
Australia	5,413	4%
Cuba	3,700	3%
Canada	3,652	3%
Brazil	3,650	3%
New Caledonia	2,631	2%
Philippines	2,269	2%
Russia	2,186	2%
Other Countries Combined Output	5,401	

Global Production of Coal		
Total Production (Tonnes)	7,924,000,000	
China	3,660,000,000	46%
USA	964,500,000	12%
India	603,540,000	8%
Australia	447,000,000	6%
Indonesia	380,000,000	5%
Russia	354,000,000	4%
South Africa	258,575,793	3%
Germany	196,992,000	2%
Poland	144,134,676	2%
Kazakhstan	120,528,000	2%
Other Countries Combined Output	794,729,531	

Global Production of Iron Ore		
Total Production (Tonnes)	2,969,000,000	
China	1,309,637,000	44%
Australia	519,693,000	18%
Brazil	400,600,000	13%
India	136,518,000	5%
Russia	104,000,000	4%
Ukraine	67,149,000	2%
South Africa	67,100,474	2%
USA	53,200,000	2%
Kazakhstan	52,614,000	2%
Iran	48,000,000	2%
Other Countries Combined Output	210,488,526	

Global Production of Phosphate Rock		
Total Production (Tonnes)	215,000,000	
China	95,296,000	44%
USA	29,200,000	14%
Morocco	27,000,000	13%
Peru	10,345,925	5%
Russia	10,282,400	5%
Jordan	8,000,000	4%
Brazil	6,500,000	3%
Tunisia	2,762,300	1%
Israel	2,488,496	1%
Egypt	2,456,562	1%
Other Countries Combined Output	20,668,317	

Global Production of Bauxite (Aluminium Ore)		
Total Production (Tonnes)	248,000,000	
Australia	76,282,000	31%
China	40,000,000	16%
Brazil	34,955,800	14%
Indonesia	30,000,000	12%
Guinea	17,400,000	7%
India	15,195,000	6%
Jamaica	9,339,291	4%
Kazakhstan	5,170,000	2%
Russia	600,000	2%
Suriname	2,904,509	1%
Other Countries Combined Output	16,153,400	

Global Production of Graphite		
Total Production (Tonnes)	2,100,000	
China	1,800,000	86%
India	129,765	6%
Brazil	80,000	4%
Democratic People's Republic of Korea	30,000	1%
Canada	20,000	1%
Russia	14,000	1%
Mexico	7,520	0.40%
Norway	6,992	0.30%
Ukraine	4,600	0.20%
Zimbabwe	4,421	0.20%
Other Countries Combined Output	2,702	

Global Production of Copper		
Total Production (Tonnes)	16,800,000	
Chile	5,433,900	32%
China	1,642,300	10%
Peru	1,298,654	8%
USA	1,170,000	7%
Australia	914,000	5%
Russia	720,000	4%
Zambia	629,020	4%
Democratic Republic of Congo	608,400	4%
Canada	578,586	3%
Mexico	500,275	3%
Other Countries Combined Output	3,304,865	

Global Production of Ferro-silicon/ silicon metal		
Total Production (Tonnes)	4,583,956	
China	1,050,000	23%
Russia	964,000	21%
USA	437,000	10%
Brazil	404,000	9%
Norway	373,886	8%
France	190,000	4%
South Africa	180,000	4%
Ukraine	150,265	3%
Iceland	131,818	3%
Indian	130,000	3%
Other Countries Combined Output	572,987	

Global Production of Manganese		
Total Production (Tonnes)	48,300,000	
China	15,000,000	31%
South Africa	8,943,415	19%
Australia	7,172,000	15%
Gabon	3,600,000	7%
Kazakhstan	2,975,000	6%
Brazil	2,400,000	5%
India	2,294,000	5%
Ghana	1,490,634	3%
Ukraine	1,234,007	3%
Malaysia	1,099,585	2%
Other Countries Combined Output	2,091,359	

Global Production of Alumina		
Total Production (Tonnes)	95,600,000	
Australia	20,914,000	22%
China	37,715,000	39%
Brazil	10,320,600	11%
USA	4,370,000	5%
Jamaica	1,757,693	2%
Canada	1,498,600	2%
Ukraine	1,429,000	1%
Spain	1,100,000	1%
Russia	2,719,000	3%
Republic of Ireland	1,924,000	2%
Other Countries Combined Output	11,852,107	

Key Producer Regions (Regions that individually produce over 10% of global output for a given raw material)

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T4 - Raw Materials/ Chemical Feedstock's

Raw Material	Source(s)
Lithium	Chile (49%); Australia (30%)
Iron	China (44%); Australia (18%); Brazil (13%)
Phosphate	China (44%); USA (14%); Morocco (13%)
Vinylidene Fluoride	USA (Localised to T3 Production)
Coal (Tar Pitch)	China (46%); USA (12%)
Methylamine (MMA)	USA (Localised to T3 Production)
Y-Butyrolactone	USA (Localised to T3 Production)
Bauxite Aluminium Ore	Australia (31%); China (16%); Brazil (14%); Indonesia (12%)
Coal (Tar Pitch)	China (46%); USA (12%)
Butadiene (Ethylene by Product)	USA (Localised to T3 Production)
Styrene (from Benzene)	USA (Localised to T3 Production)
Coal (Tar Pitch)	China (46%); USA (12%)
Methylamine (MMA)	USA (Localised to T3 Production)
Y-Butyrolactone	USA (Localised to T3 Production)
Copper	Chile (32%); China (10%)
Propylene	USA (Localised to T3 Production)
Phosphorus Pentachloride	China (Localised to T3 Production)
Lithium	Chile (49%); Australia (30%)
Hydrogen Fluoride (Fluorspar)	China (62%); Mexico (17%)
Ethylene Carbonate	China (Localised to T3 Production)
Propylene Carbonate	China (Localised to T3 Production)
Diethyl Carbonate	China (Localised to T3 Production)
Ethylene Carbonate	Japan (Localised to T3 Production)
Aluminium Oxide (Alumina)	Australia (22%); China (39%); Brazil (11%)
Aluminium Ore (Bauxite)	Australia (31%); China (16%); Brazil (14%); Indonesia (12%)
Aluminium Ore (Bauxite)	Australia (31%); China (16%); Brazil (14%); Indonesia (12%)
Aluminium Ore (Bauxite)	Australia (31%); China (16%); Brazil (14%); Indonesia (12%)
Silicon	China (23%); Russia (21%); USA (10%)
Copper	Chile (32%); China (10%)

T3 – Component Production

Component	Location
Active Material (LFP)	Canada
Binder (PVDF)	USA
Conductive Additives (Acetylene Black)	Japan
Solvent (NMP)	USA
Current Collector (Aluminium)	Japan
Active Material (Graphite)	Japan
Binder (SBR)	USA
Conductive Additives (Acetylene Black)	Japan
Solvent (NMP)	USA
Current Collector (Copper)	Japan
Separator (PP Dry)	USA
Lithium Salt (LiPF6)	China
Electrolyte Solvent (PC:EC:DEC)	China
Additive (Vinylene Carbonate)	Japan
Safety Reinforced Separator (Alumina Ceramic)	Japan
Tab (Aluminium)	Japan
Exterior/ Case (Aluminium)	USA
Safety Components (Silica, Aluminium, Copper)	Japan

T2 – Cell Production

Cell Component	Location
Active Cathode	China (T2 Cell Production Partner)
Composite Cathode	China (T2 Cell Production Partner)
Active Anode	China (T2)
Composite Anode	China (T2 Cell Production Partner)
Electrolyte	China (T2 Cell Production Partner)
Other Cell Components	China (T2 Cell Production Partner)

T1 – Module/ Pack Production

Stage	Location
Module/ Pack Production	T1 Supply Chain Partner

T0 – Vehicle Integration

Stage	Location
Vehicle Integration	The Focal Organisation

T4 - Raw Materials/ Chemical Feedstock's

Material	Source	Material	Source
Lithium	Chile (49%)	Manganese	China (31%)
	Australia (30%)		South Africa (19%)
			Australia (15%)
Cobalt	Democratic Republic of Congo (68%)	Nickel	Philippines (17%)
			Russia (14%)
			Indonesia (13%)
			Australia (13%)
			Canada (11%)
		Vinylidene Fluoride	Japan (Localised to T3 Production)
		Natural Flake Graphite	China (86%)
Methylamine (MMA)	Japan (Localised to T3 Production)	Y-Butyrolactone	Japan (Localised to T3 Production)
		Bauxite Aluminium Ore	Australia (31%)
			China (16%)
			Brazil (14%)
			Indonesia (12%)
		Coal (Tar Pitch)	China (46%)
			USA (12%)
Butadiene (Ethylene by Product)	Japan (Localised to T3 Production)	Styrene (from Benzene)	Japan (Localised to T3 Production)
		Natural Flake Graphite	China (86%)
		Deionized Water	Japan (Localised to T3 Production)
		Copper	Chile (32%)
			China (10%)
		Propylene	Japan (Localised to T3 Production)
Phosphorus Pentachloride	Japan (Localised to T3 Production)	Lithium	Chile (49%)
			Australia (30%)
		Hydrogen Fluoride (Fluorspar)	China (62%)
			Mexico (17%)
Ethylene Carbonate	Japan (Localised to T3 Production)	Propylene Carbonate	Japan (Localised to T3 Production)
		Diethyl Carbonate	Japan (Localised to T3 Production)
		Ethylene Carbonate	Japan (Localised to T3 Production)
		Aluminium Oxide (Alumina)	Australia (22%)
			China (39%)
			Brazil (11%)
		Aluminium Ore (Bauxite)	Australia (31%)
			China (16%)
			Brazil (14%)
			Indonesia (12%)
		Aluminium Ore (Bauxite)	Australia (31%)
			China (16%)
			Brazil (14%)
			Indonesia (12%)
Aluminium Ore (Bauxite)	Australia (31%)	Silicon	China (23%)
	China (16%)		Russia (21%)
	Brazil (14%)		USA (10%)
	Indonesia (12%)	Copper	Chile (32%)
			China (10%)

T3 – Component Production

Component	Source
Binder (PVDF)	Japan
Conductive Additives (Graphite)	Japan
Solvent (NMP)	Japan
Current Collector (Aluminium)	Japan
Active Material (Hard Carbon)	Japan
Binder (SBR)	Japan
Conductive Additives (Graphite)	Japan
Solvent (DI Water)	Japan
Current Collector (Copper)	Japan
Separator (PP Dry)	Japan
Lithium Salt (LiPF6)	Japan
Electrolyte Solvent (PC:EC:DEC)	Japan
Additive	Japan
Safety Reinforced Separator (Alumina Ceramic)	Japan
Tab (Aluminium)	Japan
Exterior/ Case (Aluminium)	Japan
Safety Components (Silica, Aluminium, Copper)	Japan

T2 – Cell Production

Component	Source
Active Cathode	China (T2 Cell Production Partner)
Composite Cathode	China (T2 Cell Production Partner)
Active Anode	China (T2)
Composite Anode	China (T2 Cell Production Partner)
Electrolyte	China (T2 Cell Production Partner)
Other Cell Components	China (T2 Cell Production Partner)

T1 – Module/ Pack Production

Module/ Pack Production	T1 Supply Chain Partner

T0 – Vehicle Integration

Vehicle Integration	The Focal Organisation

5.7 Building on Supply Chain Visibility: Towards a Stakeholder Salience Framework for Assessing Corporate Level Risk in the Upstream Supply Chain

The previous section of this chapter has interrogated the focal organisation's supply chain configuration for automotive Li-ion batteries (both LFP and NMC chemistries). This supply chain has been deemed as an appropriate case study example in the current research context as it is both a 'critical' component in the organisation's future production strategy and also introduces a range of novel materials in to the organisation's supply base that have the potential to create vulnerability to new external (corporate-level) disruption risks. Based on data obtained from the focal organisation, Its tier 1 supply chain partner for Li-ion battery production and a number of secondary sources (for raw material market analysis), this chapter has developed two detailed, 4 tier supply chain maps of both LFP and NMC battery cell chemistries (see Figure 5-7 and 5-8), which aligns with the 4 tier, fully fragmented supply chain configuration discussed above. These two maps present a structural breakdown of both battery chemistries (tier 1 – tier 4), suppliers, their macro-level geographical location (tier 1 – tier 3) and key producer regions for raw materials (tier 4). Using this example of a real-word 'critical' component supply chain, focus will now turn to explore how increased upstream visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk (Objective 4), building on the conceptual stakeholder salience framework developed in Chapter 2 (see figure 5-9).
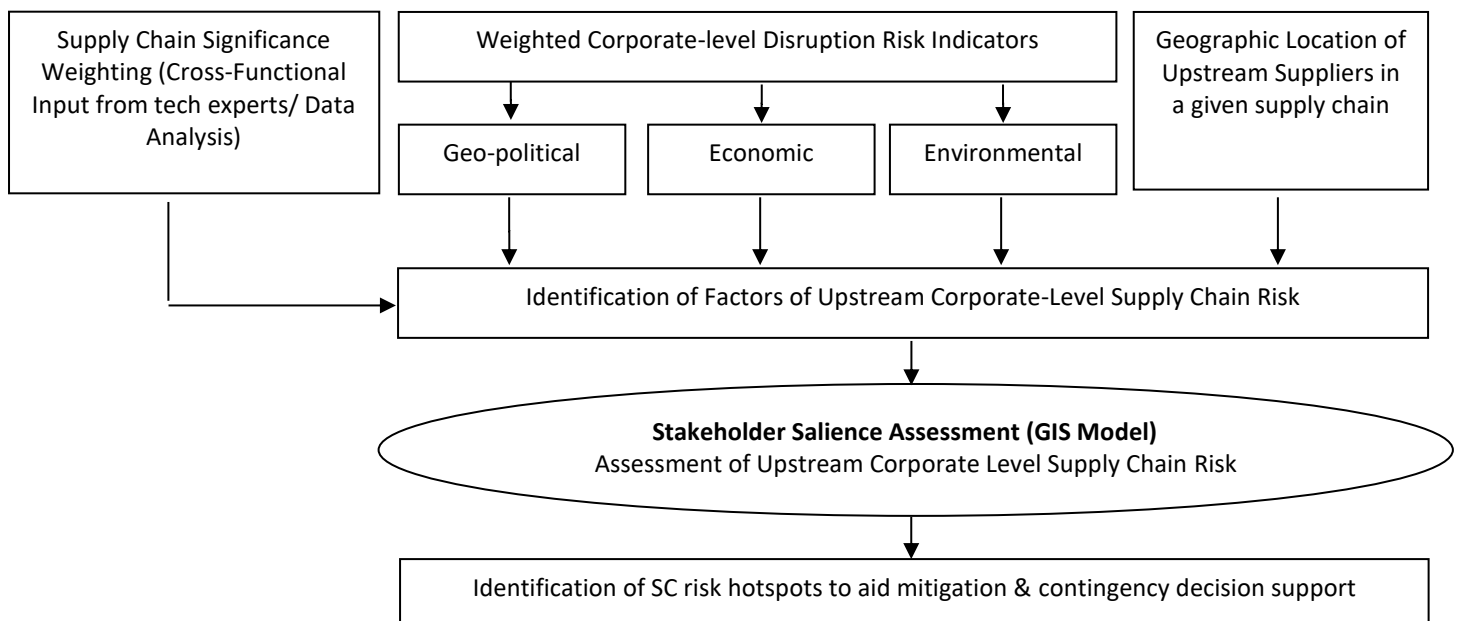

Figure 5-9: Conceptual stakeholder salience model for use in the assessment of upstream corporate-level supply chain risk.

The need to consider more targeted approaches to the management of upstream-corporate level disruption risk was highlighted as a key research gap in the SCRM literature reviewed in Chapter 2 (Tang, 2006, Colicchia and Strozzi, 2012). Whilst it is acknowledged that corporate-level disruption risk can impact upon any node of an organisation's supply chain, the literature suggests that supply chain disruptions are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of the chain. This research considers that the failure of many organisations to understand the potential susceptibility of their upstream supply chain to risk of this nature (and often underestimate it) is intrinsically linked to a lack of visibility beyond lower tiers. Chapter 4 highlighted that, in keeping with the literature (CIPS, 2014), the focal organisation has limited visibility of suppliers beyond a T1 level for most of its components and has a limited understanding of their upstream supply chain (beyond tier 1) in general (VM-1/ VM-4). Moreover, it is clear from interviewees and from the various supplier failure examples highlighted in Chapter 4, that this lack of visibility somewhat restricts the full implementation of proactive organisational SCRM strategies in this area, again in keeping with the literature (Colicchia and Strozzi, 2012). Chapter 4 concluded with a critical discussion around the focal organisation's future strategic ambition to increase its supply chain visibility in the coming years, through a collaborative upstream mapping exercise. A number of antecedents have led to increased organisational attention in this area, including various legislative and regulatory measures necessitating increased supply chain visibility (see section 4.14 for a full discussion of these).

It is clear that increasing visibility through supply chain mapping has the potential to offer significant opportunities to both the focal organisation and its suppliers in how they manage upstream corporate-level disruption risk. For example, the data gained from mapping an entire upstream supply chain of a given component will be invaluable in understanding which nodes of that supply chain are most susceptible to different forms of external disruption risk, allowing for better targeting of limited resources in their mitigation. However, increasing upstream supply chain visibility is simply the first step in achieving more robust SCRM capabilities in this area. To this end, not only must organisation's decide what type of visibility data is needed from (Caridi et al, 2014) and how to overcome barriers to obtaining that data (Kembro et al, 2014), practical issues which have been critically discussed in this chapter and the previous one, but they must also develop ways to use that data to aid decision support.

In other words, if the objective of increasing supply chain visibility is to improve company performance through supporting improved decision making, in this case for corporate-level SCRM (Wang and Wei, 2007), then increasing visibility should be seen as an enabler with which to make these improvements rather than the solution itself (Caridi et al, 2014).

Consideration around how supply chain visibility can be better utilised to improve organisational decision making is a key theme in contemporary supply chain management literature. Especially, given that that there is often a lack of knowledge amongst supply chain managers regarding how to interpret and build upon visibility data in order to improve business decision making, referred to as low internal integration (Willians et al, 2013). Whilst the issue has been explored from a number of perspectives, these tend to be associated with downstream activities such as forecasting or inventory management (Caridi et al, 2013) and have rarely considered the link between visibility and SCRM (Yo and Goh, 2013).

Building upon this, the following section seeks to explore, using a practical example, how increased supply chain visibility can be used to better assess and target mitigation strategies for upstream corporate level disruption risk, without significant investment in additional financial and human resource. As, in both the existing literature and findings from the previous case study, the resource cost of developing and implementing strategies to address corporate-level disruption risk at every node of the supply chain was seen as both impractical and undermining of broader supply chain efficiency measures (Chopra and Sodhi, 2014). Addressing this problem therefore requires the development of a more targeted management approach to identify and assess upstream, corporate level supply chain disruption risk. With this in mind, it is argued that considering the problem through the organisational lens of stakeholder theory, allows this research to critically conceptualise the challenge and develop a novel conceptual framework with which to assess stakeholder salience amongst suppliers. It is intended that this will allow for improved decision making and better targeting of limited resources in the management of corporate-level supply chain risk. Moreover, using a real-world, technological example of the Li-ion battery, this conceptual framework is empirically tested in order to assess its suitability to addressing the problem.

In chapter 2, Freeman's (1984) classical definition of the stakeholder concept was discussed - a need for manager's to 'take into account all of those groups and individuals that can affect, or are affected by, the accomplishment of the business enterprise'. Although this classical definition remains the most widely cited in the literature, it has been refined significantly over the subsequent three decades, through the introduction of numerous categorisation models which seek to better define who constitutes a 'legitimate stakeholder' (including Mitchell et al, 1997, Frooman, 1999 and Winn, 2001). After all, if everyone is a stakeholder of everyone else, little value is added by the theory (Phillips, 2003). It can be said that two dichotomous views have presented themselves in the literature which effectively divide Freeman's definition of what constitutes a stakeholder, the 'claimant' definition and the 'influencer' definition (Kaler, 2002). In his paper on 'stakeholder legitimacy', Phillips (2003) addresses this point specifically and creates a distinction between normative stakeholder legitimacy, 'those stakeholders to whom the organisation has a moral [or ethical] obligation', and derivative stakeholder legitimacy, those stakeholders for whom there is no direct moral obligation but who have the 'ability to affect the organisation and its normative stakeholders'. He notes that identifying and understanding the distinction between these two groups of stakeholders is vital to both scholars and managers and that both will dictate different sorts of management strategy.

Whilst much stakeholder theory research makes reference to the reciprocal nature of influence, Laplume et al (2008) affirms that it is 'the normative [ethical] base serves as the critical underpinning for the theory in all its forms'. This, perhaps, over-emphasis of the literature on ethical grounds for adopting a normative stakeholder approach, largely stems from the fact that the theory emerged at time when there were many reports of ethical misconduct and negligence in the corporate world (Jenson, 2002). This said, the literature acknowledges that, at its core, the stakeholder model, 'is a theory of organisational strategy [as well as] ethics' (Phillips et al. 2003) and the success of stakeholder theory in its more normative applications should not detract academic attention from the more instrumental rationales for stakeholder theory application from a strategic perspective, regardless of the moral or ethical considerations (Fassin, 2008b, Laplume, 2008). In other words, in keeping with the current research, the literature suggests that there is clear academic benefit in

developing the application of stakeholder theory and salience models from a more strategic, decision making perspective.

Although there have been many attempts to categorise salience between 'stakeholder groups', there is considerably less insight into what could be termed 'within-group categorisation', where focus is on a single stakeholder group. The stakeholder literature suggests that there is academic merit in separating and strategically dealing with primary stakeholder groups individually (Clarkson, 1995), in the case of the current research, the 'supplier' group.

The framework proposed in this research (see figure 5-9) seeks to extend the principles of stakeholder theory to categorise the salience of constituents in the organisational 'supplier' group and explore which nodes are most susceptible to corporate-level risk, enabling limited resources to be more appropriately targeted onto the mitigation and strategic management in those areas. It builds upon the principles of Mitchel et al (1997) that stakeholders are those 'who have power in relation to the organisation, who are deemed legitimate and who can muster urgency'. However, it is considered that the reciprocal nature of influence, i.e. that whilst an organisation's actions can affect stakeholders, those stakeholders can also affect the organisation (noted by Freeman, 1984, Mitchel et al, 1997 and Phillips, 2003), has been under-emphasised in the recent literature. Instead, papers in this area have largely focused only on normative legitimacy and an organisation's corporate responsibility towards its stakeholders (Fassin, 2012, Laplume et al, 2008). The current research therefore seeks to refocus attention upon the role of stakeholder theory as a theory of organisational strategy and not just ethics, and further develop the strategic application of stakeholder theory in management decision making.

It is considered that this approach answers calls by leading authors in the stakeholder theory literature, that recent developments in the field should not detract academic attention from the more instrumental rationales for stakeholder theory application from a strategic perspective, regardless of the moral or ethical considerations (Fasin, 2008, Laplume, 2008). Moreover, considering, the literature review in Chapter 2, no application of stakeholder theory was found from a SCRM perspective specifically. There has also been very little

application of stakeholder theory in the field of supply chain management generally, with a small number of notable exceptions such as Co and Barro's (2009) work on 'stakeholder theory and dynamics in supply chain collaboration', making this a novel application in the field.

5.7.1   The Importance of Geographical Nodes in the Supply Chain

The geographical location of suppliers is of critical importance when considering corporate-level supply chain risk. As has been discussed, although supply chain globalisation has produced significant benefits in terms of productivity and profitability, the extended geographical spread of many modern supply chains has led to increased susceptibility to external corporate-level risks, many of which are dictated by geography. The modern supply chain is now often a complex network with multiple dependencies. This has the potential of increasing corporate-level risk susceptibility throughout the supply chain, but especially in the upstream (BCI, 2014, Pereira et al, 2014). Organisation's that operate a global supply chain are exposed to an increased amount of risk due to the complex and uncertain environment in which they are involved (Tang and Tomlin, 2008). As Peck (2005) describes 'the more complex a network is, the more interfaces exist and the higher the vulnerability will be'. Moreover, when disruptions occur at a critical node of the supply chain, the resulting effects can ripple throughout the entire value chain.

In the supply Chain Mapping exercise discussed above, macro (country) level geographical nodes at each tier of the focal organisation's supply chain for automotive Li-ion battery cells (See figures 5-7 & 5-8) were identified. Focusing on risk at this level was necessary in order to utilise many of the risk datasets adopted in the model which were at a macro (country) level. In total both supply chains involved up to 17 geographical supplier regions (as set out in Table 5-10). To break this down further, for the LFP battery chemistry there were a total of 19 T4 raw materials identified (with 11 geographic supply nodes), there were a total of 18 T3 components (with 4 geographic supply nodes), there was a single T2 battery cell manufacturer, producing 6 cell components (with 2 supply geographic supply nodes) and finally a single T1 module/ Pack producer (with 1 geographic supply node). For the NCM battery chemistry there were a total of 22 T4 raw materials identified (with 13 geographic supply nodes), there were a total of 17 T3 components (with 1 single geographic supply node),

there was a single T2 battery cell manufacturer, producing 6 cell components (with 2 supply geographic supply nodes) and finally a single T1 module/ pack producer (with 1 geographic supply node).

T4 Raw Material Producer Countries	T3 Component Production	T2 Cell Production	T1 Module/ Pack Production
China Mexico Philippines Russia Indonesia Australia Canada Chile DRC USA Brazil Morocco South Africa Japan USA	Japan USA Canada China	China Germany	

Table 5-10: Key Geographical Nodes at each tier of the supply chain for both LFP and NCM battery chemistries

The conceptual stakeholder salience framework developed above (figure 5-9), considers how quantitative risk metrics could be combined with macro-level geographical supply chain mapping data, in a GIS model, to assess susceptibility to upstream corporate level disruption risk in the supply chain and better target mitigation strategies. Fusing the geographical supply chain mapping data developed throughout this chapter with three weighted groups of existing corporate-level disruption risk indicators (identified from the World Economic Forum 'Understanding Global Supply chain and Transport Risk' 2012 report), in a GIS environment, will contribute towards the identification of key areas susceptible to upstream, corporate level risk throughout a given supply chain. Combing quantitative risk datasets, existing supplier information and geographic supply chain information in a single decision support dashboard will offer valuable support for organisations in increasing visibility of their upstream supply chain and understanding the susceptibility of different supply chain nodes to corporate-level risk. Whilst recent research has begun to broaden academic application of GIS, for example Participatory GIS or P-GIS, which aims to broaden public involvement in policy making (Sieber, 2006), academic utilisation of GIS has generally been narrow outside of the fields of geography, environmental science and immunology. Whilst GIS has had some application in a business and supply chain management context, this has largely been from a

cross discipline logistics perspective. For example, transport route optimisation and basic supply chain visualisation. To the authors' knowledge, there has been little theoretically grounded academic discussion in the management literature, with regards to the utilisation of GIS as a SCRM tool.

5.7.2 Identification of Risk Metrics to Include in the Indicator and Weighting

For the purposes of this research, three groups of external, corporate-level disruption risks are identified, that are not within the immediate operational control of an organisation but can have a significant direct impact on the supply chain. These are 1) geo-political, 2) economic and 3) environmental. Within each of these broad groups, sit a number of individual risks, for example, extreme weather and natural disasters both fall within the environmental risk group, whereas corruption and political unrest/ conflict fall within the geo-political group. Identifying which individual risk metrics to include in each indicator and then weighting the relevant significance of each metric against each other, to create three specific indicators of corporate-level risk (geo-political, environmental and economic) is a significant step in understanding the relative importance of different types of risk on organisational supply chains. For example, weighting will allow the model to incorporate the fact that different corporate level-risk groups may not have the same end impact upon organisation.

From a methodological perspective, there are several approaches to weighting that would be suitable in the current context. A critical appraisal of key weighting and aggregation methods is presented in the OECD's (2008) handbook on constructing corporate indictors and includes. These range from Expert Opinion Polling and Budget Allocation Processes, where experts on risk would be asked to score risk indictors, to more quantitative methods of weighting such as Analytical Hierarchy Process which systematically extracts opinions through a series of pair-wise comparisons.

The current conceptual framework's weighting of risk metrics utilises joint industry/ academically led work undertaken by the World Economic Forum (WEF) and Accenture (2012), on 'Understanding Global Supply chain and Transport Risk'. As part of this work, a survey was conducted of 400 executives, spanning 10 industrial sectors, which focused

specifically on 'supply chain and transport risk that was outside the direct control of the organisation'. Survey respondents weighted the external disruptions in each corporate-level risk group most likely to provoke significant and systemic effects on the supply chain. In total 4 groups were included in the exercise: Environmental, Geo-political, Economic and Technological. In keeping with the academic literature, this fourth 'Technological' group, is excluded as a corporate level disruption risk here, as technological risks (such as network issues and IT security) are thought to be within the controllable remit of most organisations and furthermore are not affected by geography in the same way other risk groups here are. Additionally, as the current research is concerned with fixed geographical supply chain nodes, several specific disruption risks were removed from the weighting as the related to logistics and transport risk or were not supply-side risks.

Work by the WEF in this field, is well regarded for its practically driven approach, developed through close consultation with leading industry and academic stakeholders. The three corporate-level risk indicators created for use in the current research analysis (and the individual risk weightings which feed in to them) are as follows:

Environmental Indicator: This group incorporates various environmental risk factors, including a wide spectrum of natural disasters, extreme weather events and contagious disease outbreaks. Given a number of high-profile recent events, such as the Japanese earthquake/ tsunami or Thai floods in 2011, it is perhaps unsurprising that natural disasters were indicated by 59% of experts surveyed by the WEF, as the most likely environmental risk to cause systemic supply chain disruption. The related risk and impact of extreme weather events also ranked highly in this category with 30% of respondents it as a significant concern. Finally, 11% of the weighting was attributed to the risk of pandemic or contagious disease.

Geo-political Risk Indicator: Geo-political disruptions include a range of potential disruptions encompassing corruption, crime, terrorism and political unrest/ conflict. Whilst events of this nature can have a direct effect on organisational supply chains, the resulting regional disruption and change can be equally damaging. See for example, major supply chain disruptions in the wake of the 9/11 terrorist attacks in the US. In the WEF study, 40% of respondents, identified conflict and political unrest as their key geo-political supply chain

concern. Closely behind this was terrorism with 28% of the weighting. Corruption, Illicit Trade/ Organised Crime and Access to Nuclear and Heavy Weaponry completed the indicator group with 15%, 13% and 6% respectively.

Economic: A number of economic risks have the potential to interrupt organisational supply chains and this group covers a range of issues. Economic Risk within the supply chain has been specifically highlighted, following the 2008 global financial crisis. See for example, in the automotive sector, where bankruptcy filings of suppliers doubled between 2007 and 2008 (United Nations, 2013). In the WEF study, key corporate-level risks were identified as currency fluctuations with 42% of the weighting, Energy shortages with 31% and a lack of skilled labour with 27%.

5.7.3 Choice of appropriate datasets in the creation of three risk indicators

For each individual risk metric identified as significant (i.e. within each of the three broader corporate-level risk indicator groups), a number of data sets are available that could be used as an appropriate proxy in the creation of an indicator. After reviewing various risk datasets, as well as engagement with subject-specific experts within the university, 11 datasets were identified as appropriate to create the final three indicators used in this research. These are set out in Table 5-11. With the exception of datasets for skilled labour and energy shortages (which included 59 and 123 counties respectively), all datasets used covered 171 of the 193 UN member countries and had minimal bias to a specific region (i.e. there were no single government backed datasets). Of those 21 countries not included, most were small island states such as St Lucia or St Kitts and Nevis and some were inaccessible due to the current political situation such as Syria or Somalia. None of the missing entries impacted the current supply chain.

In order to use the data for the current research, each of these 11 datasets (for 171 specific countries) was normalised on a 0-100 scale, where 0 means a country is most susceptible to that form of risk and 100 means it is least susceptible to that form of risk. Following this, individual datasets were split in to their three broader risk groups and weighted using the

above figures to create three individual indicators for Environmental, Geo-political and Economic Corporate-Level Risk.

Table 5-11: Table of Datasets and Weightings used in the Supply Chain Mapping Process

Indicator	% Weighting base on WEF Study on Supply Chain Disruption Risk	Data Source Used as Indicator Proxy	Description and Appropriateness for Purpose
Environmental Risk Group Indicator			
Pandemic (Communicable Disease) Indicator	11%	**World Bank** Population Data [2013], **World Health Organisation (WHO)** Observatory Data Repository: 5 Year statistics on key communicable diseases and spread by country [2013]	Data from the WHO Observatory Data Repository was used to compile an indicator of communicable disease impact and spread. Country-level data for 5 years (2009-13) was compiled indicating the average number of cases per year of 18 WHO key communicable diseases (such as TB, Diphtheria, Influenza, Measles and Malaria). These were then averaged by population (World Bank dataset) to create a high level indicator of how susceptible a given country is to communicable disease.
Extreme Weather Indicator	30%	**Germanwatch** Global Climate Risk Index [2014]	The Germanwatch Global Climate Risk Index assesses to what extent counties have been affected by standard weather related loss (both socio-economic and physical) between 1993 and 2012 and assesses the probability of future impact. Importantly, it does not cover non-climatic (geo-logical) natural disasters such as earthquakes, volcanic eruptions or tsunamis. The UN Natural Disaster Index below is utilised for this purpose.
Natural Disaster Indicator	59%	**United Nations (UN)** Natural Disaster Index: World Risk Report [2012]	The UN Natural Disaster Index analyses the potential likelihood of countries exposure to and impact from extreme natural hazards (such as severe flooding, cyclones, tsunamis or earthquakes). This ranked index includes assessment of existing UN datasets to determine how probable an extreme natural event is in a given country, as well as the level of societal vulnerability in hotspots.
Geo-Political Risk Group Indicator			
Conflict and Political Unrest Indicator	40%	**World Bank** Worldwide Governance Indicators: Political Stability and Absence of Violence [2012]	The World Bank Worldwide Governance Indicators report on six specific dimensions of governance for 2015 countries between 1996 and 2012. The political stability and absence of violence indicator used here collates data from a number of well-regarded sources to measure political stability and the likelihood that a countries government will be destabilised as a result of civil unrest.
Terrorism Indicator	28%	**Institute for Economics and Peace (IEP)** Global Terrorism Index [2012]	The Global Terrorism Index provides a detailed assessment of the global risk of terrorism at a country level. The Index is produced by the Institute for Economics and Peace, building on data from the Global Terrorism Database at the University of Maryland's renowned START Centre. The index combines a number of factors

			associated with terrorism including historical analysis of the global impact and trends over a 10-year period.
Corruption Indicator	15%	**World Bank** Worldwide Governance Indicators: Control of Corruption [2012]	The World Bank Worldwide Governance Indicators report on six specific dimensions of governance for 2015 countries between 1996 and 2012. The Control of Corruption Indicator used here brings together a number of datasets assessing the level of corruption in a number of contexts, such as amongst politicians and public officials, irregular payments in a number of sectors, petty corruption at a street level, border corruption and wider corporate corruption.
Illicit Trade and Organised Crime Indicator	13%	**World Bank** Worldwide Governance Indicators: Rule of Law [2012]	The World Bank Worldwide Governance Indicators report on six specific dimensions of governance for 2015 countries between 1996 and 2012. The Rule of Law Indicator used here measures a number of factors associated with illicit trade and organised crime. The indicator captures the extent to which citizens and organisations abide by the rules of society (including the likelihood of crime and violence). In particularly the quality of contract enforcement, property rights, the police and the courts.
Nuclear and Heavy Weapons Indicator	6%	**Institute for Economics and Peace (IEP)/ Economist Intelligence Unit (EIU)** Global Peace Index: Nuclear & Heavy Weapons Capability [2014], **World Bank** Worldwide Governance Indicators: Political Stability and Absence of Violence [2012]	The Global Peace Index is developed by the IEP, with data collated and calculated by the Economist Intelligence Unit. The Index is composed of 22 individual indicators, of which the 'Nuclear and Heavy Weapons' Indicator was used for the current research. This is a quantitative assessment of countries access to heavy, chemical, biological weaponry, as well as nuclear material. The aforementioned World Bank Indicator on Political Stability and Absence of Violence was used to incorporate political stability in to the indicator.
Economic Risk Group Indicator			
Currency Fluctuation Indicator	42%	**XE** Forex Currency Analysis and Trading Forecasts [2014]	XE Forex Analysis software was used to determine currency fluctuation (high and low) in 172 global currencies against GBP over a 5 year period. These were then used to create an index of the amount of fluctuation of countries over the period.
Global Energy Shortage Indicator	31%	**World Economic Forum (WEF)/ Accenture** Global Energy Architecture Performance Index [2014]	Prepared in collaboration with Accenture, the WEF Global Energy Architecture Performance Index is a global ranking of 124 countries ability to deliver secure, sustainable and economically stable access to the energy needed for its businesses and citizens.
Shortage of Skilled Labour Indicator	27%	**Economist Intelligence Unit (EIU)** Global Talent Index [2012]	The EIUs Global Talent Index, provides a global assessment of the availability of skilled workers in 60 key labour markets globally. The report benchmarks through quantitative metrics and interviews with executives country-level capacity for developing, attracting and retaining talent both in 2011 and projected to 2012.

5.8   Practical Analysis and Theoretical Application

The principle objective of this chapter is to explore key questions around how increased organisational visibility, gained through supply chain mapping, can be utilised to better assess the susceptibility of upstream suppliers to corporate-level disruption risk. To this end, the 'stakeholder salience' framework developed above considers how geographical supply chain mapping data can be combined with Environmental, Geo-political and Economic risk metrics, using GIS software, to improve assessment of corporate-level disruption risk throughout the supply chain and better target limited resources on those areas most susceptible.

In order to empirically explore this conceptual framework, the Li-ion battery (NCM and LFP) supply chain is used as an example of a real-world critical component within the focal organisation's supply base. As outlined above, in order to do this, geographic data obtained from the supply chain mapping process, was combined with the 11 weighted risk datasets outlined above for Environmental, Geo-political and Economic corporate-level risk groups.

The output of this process is presented below in the form 3 GIS outputs (Figures 5-12, 5-13 and 5-14) for each weighted indicator group. These three individual indicators were then combined to create an overall corporate-level disruption risk indicator, which has been layered on top of the original supply chain mapping data for both LFP and NCM battery chemistries (Figures 5-15 and 5-16). This type of output is significant, as it provides a very clear visualisation of the overall supply chain, including which nodes are most susceptible to corporate level disruption risk. Whilst this data could be represented in a spreadsheet package such as Microsoft excel, overlaying output from detailed weighted datasets on top of a geographical map or the original supply chain map, provides a simple reference for decision makers to assess both which nodes of the supply chain are most susceptible to corporate-level risk and, in the case of the supply chain map, how these nodes connect in production of the final battery.
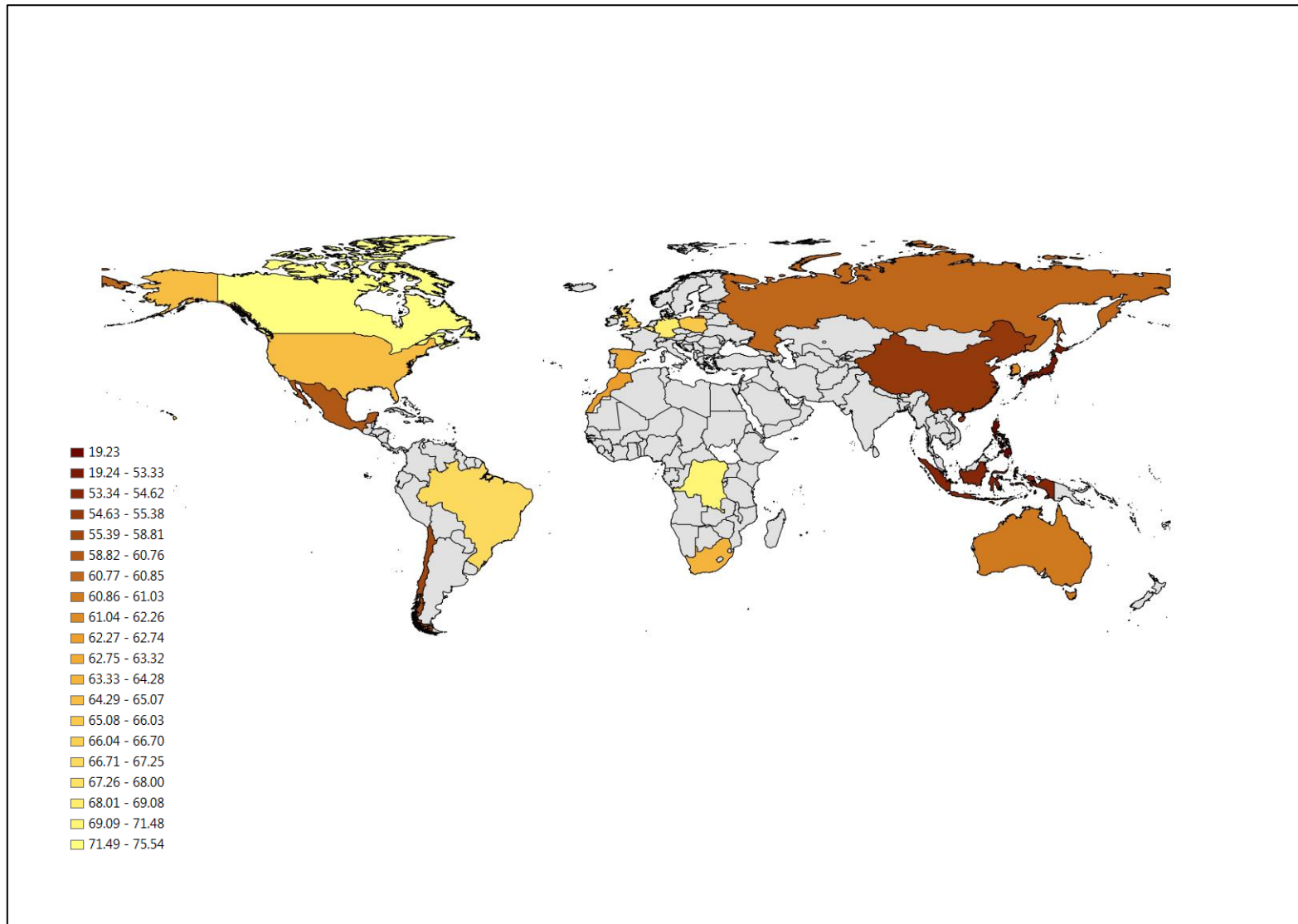
■	19.23
■	19.24 - 53.33
■	53.34 - 54.62
■	54.63 - 55.38
■	55.39 - 58.81
■	58.82 - 60.76
■	60.77 - 60.85
■	60.86 - 61.03
■	61.04 - 62.26
■	62.27 - 62.74
■	62.75 - 63.32
■	63.33 - 64.28
■	64.29 - 65.07
■	65.08 - 66.03
■	66.04 - 66.70
■	66.71 - 67.25
■	67.26 - 68.00
■	68.01 - 69.08
■	69.09 - 71.48
■	71.49 - 75.54

Figure 5-12: GIS Map of Environmental Risk Group Indicator for Li-ion (LFP and NCM) Battery Supplier Regions

11.70
11.71 - 20.06
20.07 - 21.10
21.11 - 32.38
32.39 - 33.23
33.24 - 45.40
45.41 - 45.46
45.47 - 64.95
64.96 - 65.10
65.11 - 65.31
65.32 - 66.03
66.04 - 68.38
68.39 - 72.62
72.63 - 74.71
74.72 - 81.09
81.10 - 82.86
82.87 - 86.25
86.26 - 87.16
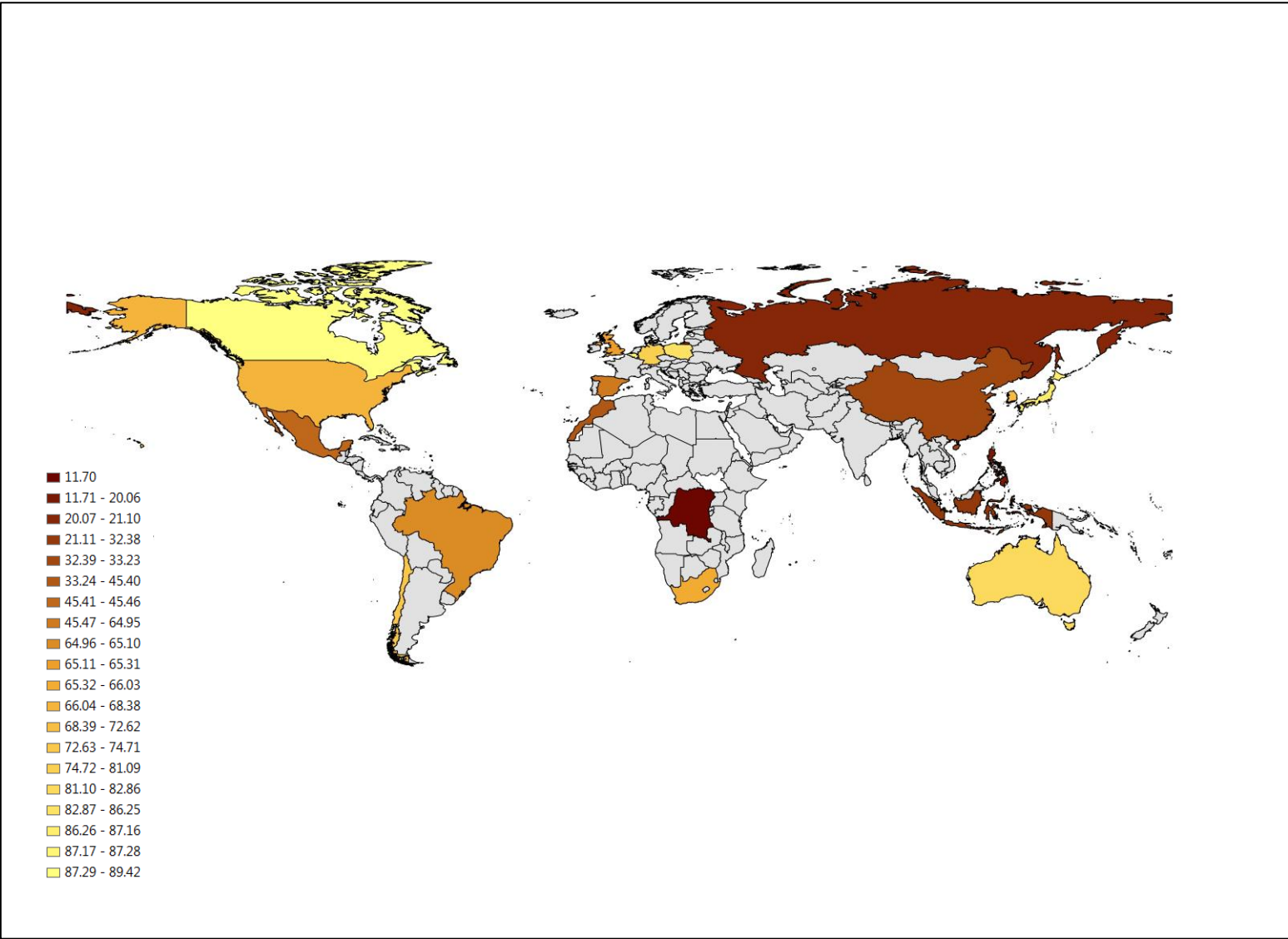87.17 - 87.28
87.29 - 89.42

Figure 5-13: GIS Map of Geo-Political Risk Group Indicator for Li-ion (LFP and NCM) Battery Supplier Regions
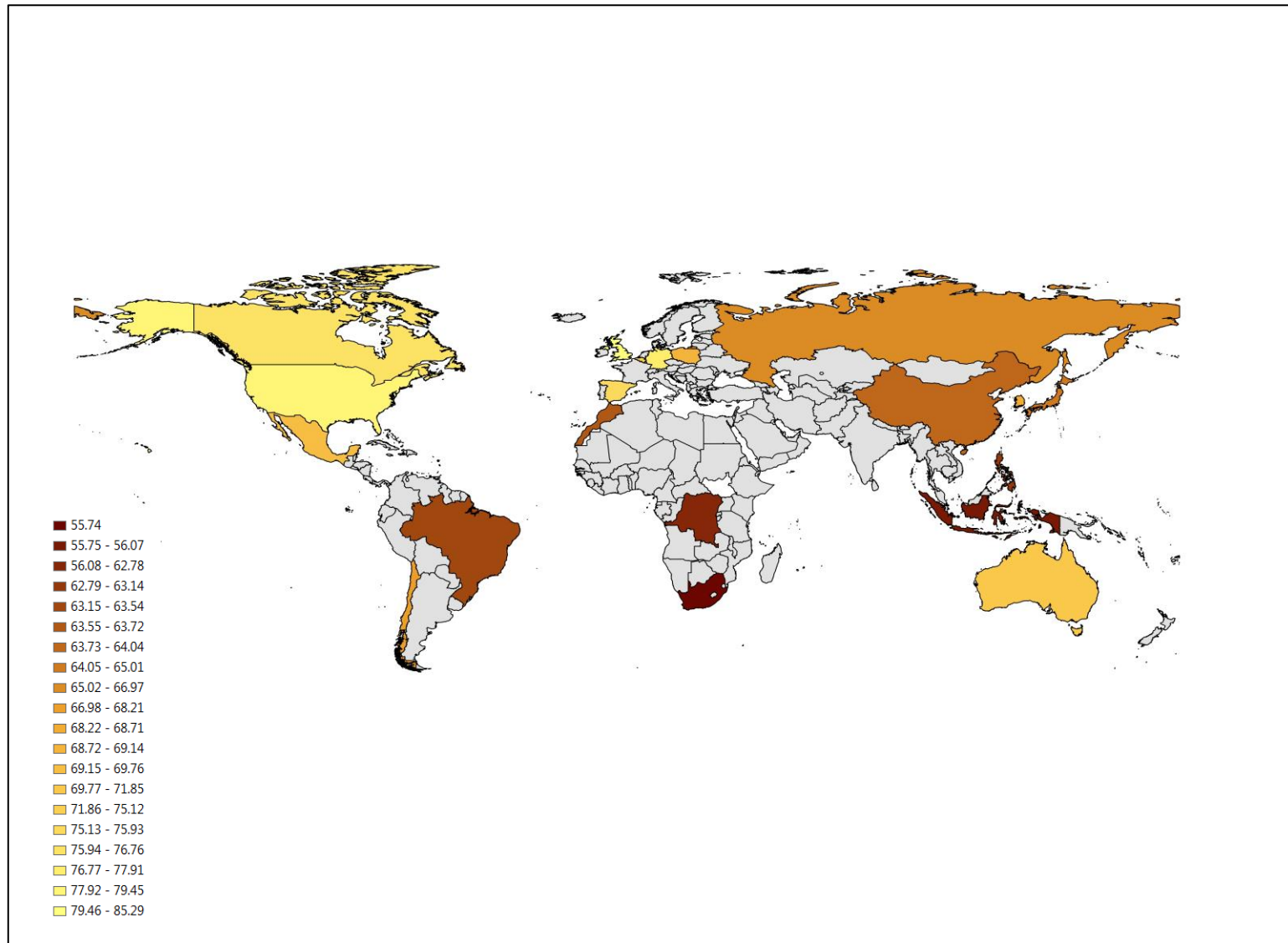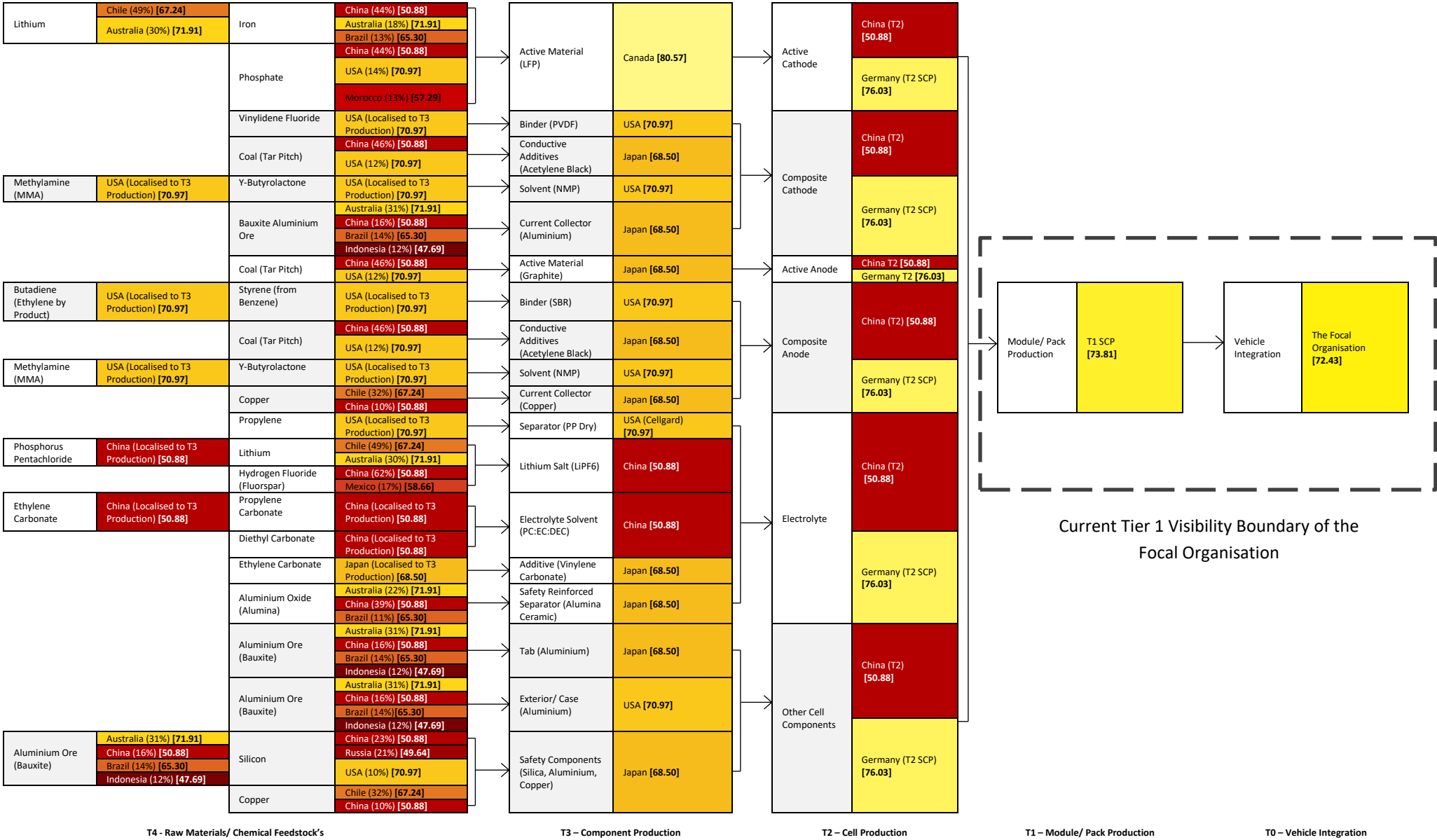
Figure 5-14: Economic Risk Group Indicator for Li-ion (LFP and NCM) Battery Supplier Regions

Figure 5-15: Corporate Level Supply Chain Risk Map for the Lithium Iron Phosphate (LFP) Battery Cell

Current Tier 1 Visibility Boundary of the Focal Organisation

T4 - Raw Materials/ Chemical Feedstock's   T3 – Component Production   T2 – Cell Production   T1 – Module/ Pack Production   T0 – Vehicle Integration

Figure 5-16: Corporate Level Supply Chain Risk Map for the Nickel-Cobalt Manganese (NCM) Battery Cell

Current Tier 1 Visibility Boundary of the Focal Organisation

T4 - Raw Materials/ Chemical Feedstock's   T3 – Component Production   T2 – Cell Production   T1 – Module/ Pack Production   T0 – Vehicle Integration
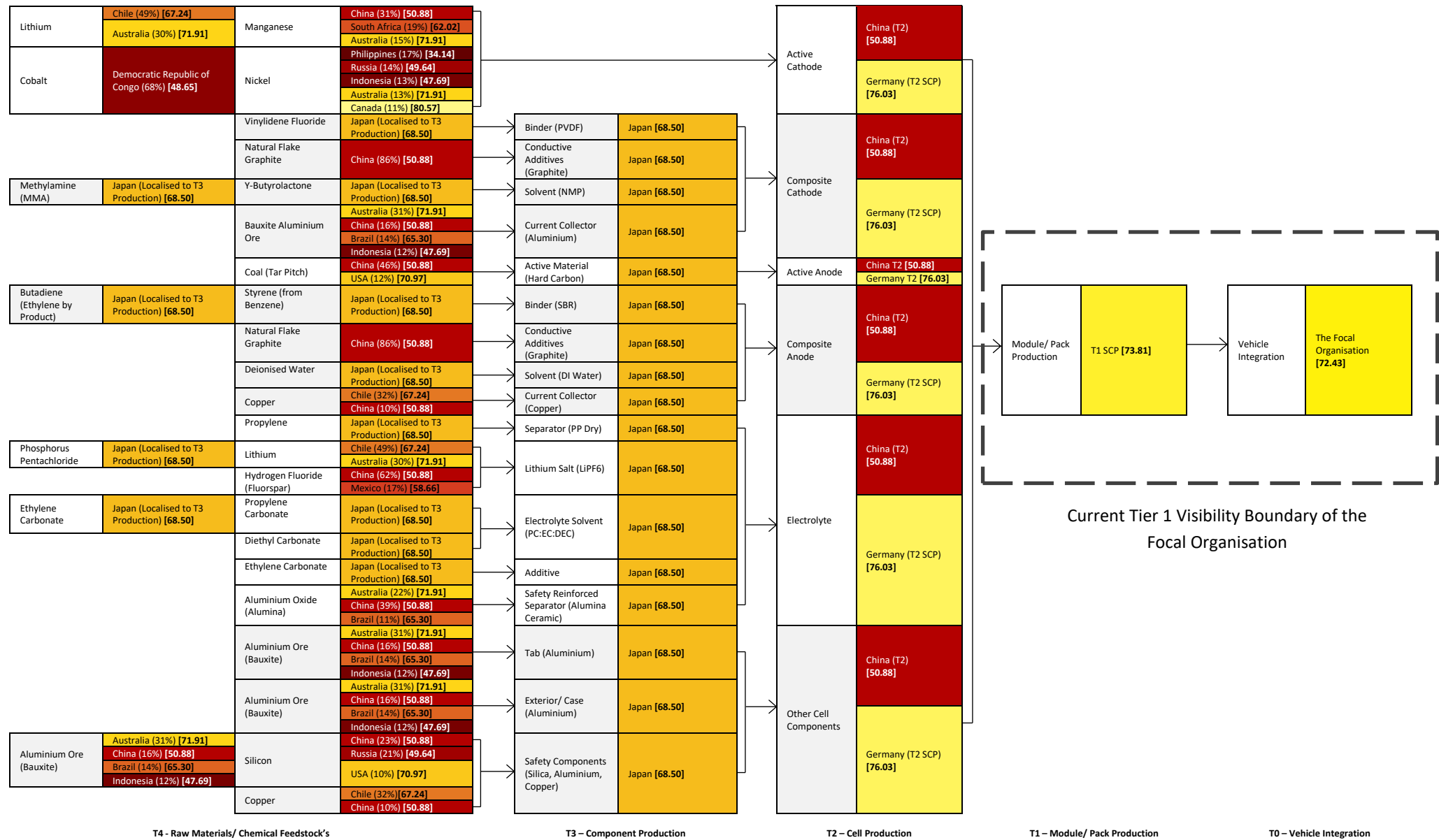
As can be seen from both the GIS output maps (figures 12, 13 and 14) and supply chain maps (figures 5-15 and 5-16) presented above, the global nature of the Li-ion battery supply chain, exposes it to significant corporate-level disruption risk. Considering these outputs, it is clear that the majority of this risk exists within the higher tiers, especially in the raw material market. This is in keeping with the literature in this area, which suggests supply chain disruptions are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) the further upstream they occur. Moreover, most areas of susceptibility to corporate-level disruption risk in this supply chain occur beyond first tier suppliers where the focal organisation currently has visibility. This again, provides support for the notion that supply chain managers often underestimate supply chain susceptibility to corporate-level disruption risk due to a lack of visibility beyond these initial tiers (Saenz and Revilla, 2014). This analysis gives a clear overview of how susceptible each geographical region involved in the Li-ion battery supply chain is to Environmental, Geo-Political and Economic disruption risk. Using the above model, comparison can be made between the 13 key T4 raw mineral commodities used in the Li-ion battery supply chain (for both chemistries). By creating an average weighted score of each of the key supply markets, the susceptibility of each of them to corporate-level disruption risk (see table 5-17) can be ranked and the most salient materials and supply regions from this perspective identified. Undertaking assessment of this nature is significant, as increasing visibility and organisational knowledge around which nodes of a key product's supply chain are most susceptible to corporate-level disruption risk, will allow for better SCRM decision making in this area (Chopra and Sodhi, 2014).

T4 Raw Mineral Commodities	Mean CL Risk Score Weighted Between all Key Producer Regions
Cobalt	**48.65**
Flake (Natural) Graphite	**50.88**
Fluorspar	**52.55**
Silicon	**54.11**
Nickel	54.67
Coal	55.03
Phosphate	**56.01**
Iron	58.43
Manganese	58.99
Alumina	59.52
Copper	61.74
Aluminium	62.05
Lithium	69.01

Table 5-17: Final Ranked List of Raw Materials. Weighted Corporate-Level Risk Score by Key Producer Countries (Commodities highlighted in Red indicate those Raw Material also deemed 'Critical' in the Report on Critical Raw Materials for the EU, 2014)

This ranking can be combined with other market data, to add further rigor to the identification of critical raw materials within the Li-ion battery supply chain. For example, whilst the above data considers susceptibility of raw material producer regions to external, corporate-level disruption risk within supply markets, it does not consider the quantity of each raw material available. Taking this in to account is important, as whilst current key markets for raw materials such as coal, may currently be susceptible to corporate-level risk, over-supply in that market means there is unlikely to be a security of supply concern. One of the best regarded study's on security of supply (taking in to account reserves and current extraction data) is the 'Report on Critical Raw Materials for the EU' (2014). This report assesses 54 raw materials against their economic importance to industry and relative supply quantities. As can be seen from Figure 5-18, 20 critical raw materials are identified in this report. By combining this analysis, with that of the current research, 5 raw materials in the Li-ion battery supply chain are identified as critical. These are: Cobalt, Flake (Natural) Graphite, Fluorspar, Silicon and Phosphate (Highlighted red in figure 5-17). Interestingly, although much media attention has focused upon the potential supply risks associated with Lithium shortages and supply issues, in terms of both susceptibility to corporate-level disruption risk and when combined with supply constraints (in the EU study), this commodity is seen as comparatively lower risk.
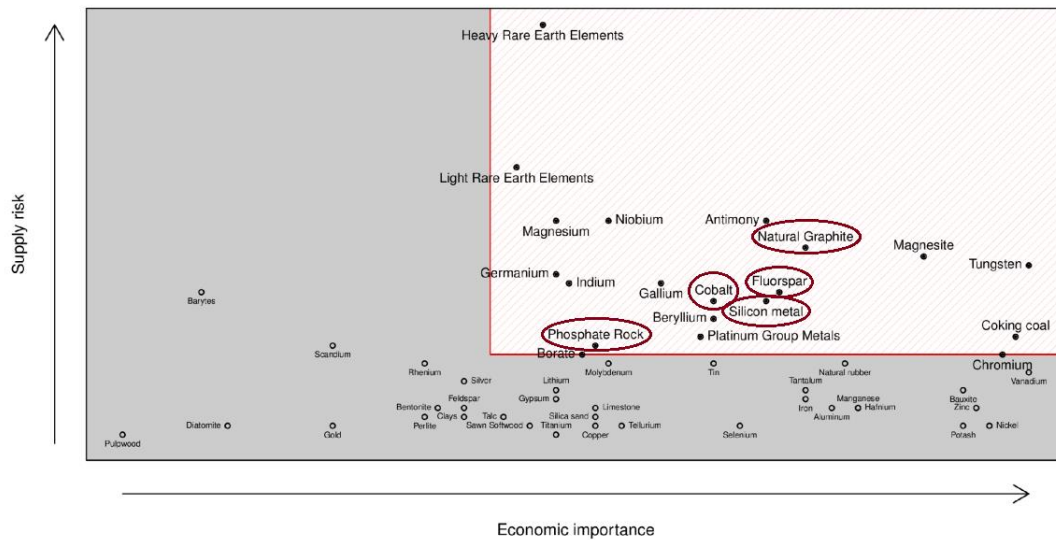

Figure 5-18: Matrix of Critical Raw Materials by Economic Importance and Relative Supply Risk (Report on Critical Raw Materials for the EU, 2014)

Through undertaking the above supply chain mapping and GIS analysis, geographical regions which are extremely significant to a given supply chain, due to the number of suppliers

located within a narrow geographical cluster, can also be identified. Understanding key geographical supply clusters is critical from a corporate-level SCRM perspective, as over-reliance on a single region creates a weak-point that can affect operation of the whole supply chain. This is evidenced in the previous chapter by considering the impact of the Japanese Tsunami upon automotive supply chains globally. Chopra and Sodhi (2014) suggest that better understanding regional reliance throughout the supply chain, will allow managers to make better SCRM decisions with regards to segmenting and de-regionalising that supply chain where necessary.

In the Li-ion battery example significant supplier cluster regions are identified as China, the USA and Japan. Both the USA and Japan have a significant presence in the 3rd tier of the supply chain, Component production. For the NCM chemistry, all 17 T3 components are produced in Japan, by 9 organisations. For the LFP chemistry, 9 components are produced in the Japan by 8 organisations and 6 components are produced in the USA by 6 organisations. As discussed previously, both Japan and the USA also have significant petrochemical industries and T4 petrochemicals used in component production are likely to be localised to that T3 production. Whilst Japan and the USA are considered comparatively lower risk in this supply chain assessment, any significant disruption in either region would likely have a significant impact upon Li-Ion battery production due to the number of suppliers clustered together within that region. Considering the 4th Tier raw material market analysis above, a similar supply cluster emerges, with China being placed as a primary (1st or 2nd largest global supplier) for 10 of the 13 raw mineral commodities utilised in both Li-ion battery Chemistries. Considering the 5 raw materials identified as being both 'critical' in terms of supply and significantly susceptible to external disruption risk, China is a primary producer for all but Cobalt. This finding echoes the EU Critical Raw Material Report (2014), which highlighted the dominance of Chinese supply of both critical and non-critical raw materials as a significant risk. This finding, coupled with the consideration of China's significant petrochemical industry and high susceptibility to corporate-level risk (50.88) in the above analysis, means that this is an extremely significant region in the Li-ion battery supply chain.

By considering various industry reports in this area, it can be seen that this reliance on a narrow range of geographical markets in tier 3 is replicated outside of the current case study.

For example, reports by Lowe et al (2010) and Roland Berger (2012), suggest that the significant majority of component producers are based in either the US or Asia; Specifically Japan and South Korea for Anode and Cathode Materials; Japan, South Korea and China for the Electrolyte and South Korea, Japan, China and the US for the separator. Whilst tier 2 cell production continues to have a significant presence in Japan and China, industry reports suggest that there is a significant growth in US production capability, due to a number of significant government backed grants to open factories there. This was discussed at length earlier in this chapter. Considering where other suppliers in this industry are based is important as it demonstrates that beyond tier 1, the focal organisation and other European automotive organisations have very little localised production alternatives. Additionally, In a practical sense, referring back to the aforementioned discussion on various Li-ion supply chain configurations within the automotive industry (see Figure 5-5), the above analysis suggests that from a corporate-level SCRM perspective, increased integration between tier's 1 and 3, does not fully insulate the supply chain from external corporate-level risk. For example, whilst the focal organisation gains more control over its lower and mid-tier suppliers in an integrated joint venture, many of the primary nodes of corporate-level disruption risk exist within the raw material tier of suppliers, which (for the most part) still operate independently of even a fully integrated configuration.

5.8.1 The role of Stakeholder Assessment in the Development of more Targeted Corporate-Level Risk Mitigation Strategies

The above section has provided a practically focused analysis of the results stemming from empirical application of the proposed conceptual 'stakeholder salience' framework on the Li-ion battery (NCM and LFP) supply chain. This application has allowed for empirical exploration of the proposed framework and critical discussion using an example of a real-world critical component within the focal organisation's supply base.

As discussed above, stakeholder theory was viewed as a particularly appropriate organisational lens with which to consider the current research, allowing for critical conceptualisation of the proposed framework from a strong theoretical grounding. Moreover, development of a framework to categorise the salience of different nodes within a supply chain, to aid organisational SCRM decision support, contributes to the growing body

of literature citing the need to refocus attention upon the role of stakeholder theory as a theory of organisational strategy and not just of ethics (Fassin, 2012). For example, understanding the importance of within group categorisation of stakeholders, in this case suppliers (Clarkson, 1995) and acknowledging reciprocal nature of stakeholder influence, in that suppliers can have an adverse impact upon the organisation as well as the other way around (Laplume et al, 2008). Although not the primary focus of this case study, in order to fully articulate the potential benefits of adopting a stakeholder salience approach in this area, consideration is given to how the above findings could contribute towards more targeted corporate-level SCRM strategy at the focal organisation. Considering the previous case study, it was noted that in keeping with the literature (Kleindorfer and Saad, 2005), the focal organisation acknowledged the susceptibility of their supply chain to corporate-level disruption risk (VM-2/ VM-3). However, due to a current lack of upstream visibility, coupled with an emphasis on primarily addressing risk within the immediate operational environment, there has been little focus on proactively addressing this susceptibility. Moreover, whilst organisational appetite to understand upstream corporate-level risk has increased significantly in the wake of a number of recent events, such as the Japanese Earthquake and Tsunami, approaches to SCRM beyond T1 in this area remain mostly reactive.

This research argues that developing an empirical understanding of stakeholder salience within a given supply chain (in this case the Li-ion supply chain), can be a powerful tool to inform management decision making. Understanding the complexities associated with an upstream supply chain in its entirety and identifying which nodes are more susceptible to corporate-level disruption risk than others, will contribute to reducing uncertainty. This is significant, as the literature suggests there is often a misconception amongst supply chain managers that the uncertainty presented by corporate-level supply chain risk is unmanageable without significantly sacrificing supply chain efficiency. As such, few companies develop risk mitigation strategies to handle what is often perceived as unavoidable corporate-level disruptions (Sodhi and Tang, 2012). Whilst it is acknowledged that corporate-level disruptions can indeed impact upon any node of the supply chain, it is clear from this research that some nodes are more susceptible than others. In this sense, reducing uncertainty through increased understanding of susceptibility, allows for optimum

use of resources in targeting SCRM strategies at high-risk areas of the supply chain (Koh and Saad, 2003, Koh and Saad, 2006).

In Chapter 2 (Section 2.7.3), a number of strategic supply chain risk mitigation approaches were critically discussed. The following section considers how the framework developed above could aid in deployment of these strategies for key hotspots of corporate-level risk. The following discussion around strategic mitigation approaches, builds upon the assumption that, for the most part, corporate-level risk incidents themselves cannot be avoided and instead, suggests that emphasis should be placed upon reducing the eventual impact upon the supply chain, in the focal organisation's own words, by not stopping the line (VM-2/3). Moreover, these strategies should not be viewed in isolation and there are clear overlaps between each approach.

Improved alignment with strategically important upstream suppliers: Through the identification of which areas of a given supply chain are strategically important in terms of corporate-level supply chain disruption risk, the focal organisation has an opportunity develop strategic alignments with 'at risk' suppliers. In its simplest form, this could simply involve creating strategic relationship with upstream suppliers who are particularly susceptible to corporate-level risk. Lee (2004) suggests that alignment such as this can facilitate close communication, co-operation and collaboration between supply chain partners, a strategy which provides a significant benefit for the most critical areas of production. In a practical sense, improving information sharing between the focal organisation and upstream suppliers who are particularly 'at risk', could involve, gaining an increased understanding of how that particular supplier manages corporate-level risk in its supply base and whether this is sufficient to insulate the focal organisation from a potential disruption (tools such as disruption scenario plans could be used to identify weaknesses). As has been discussed several times in this chapter, increased bi-lateral accounting transparency with critical suppliers could help develop more open, trusting relationships (Meira et al 2010, Mouritsen and Thrane, 2006). Tools, such as open book accounting, where one or both companies in a supply relationship 'open their books' to their counterpart and disclose internal information (Cullen and Meira, 2010), could play a significant role here.

In the case of a smaller supplier (or large supplier with an underdeveloped SCRM strategy), the focal organisation could share market intelligence from its own raw material market analysis team or provide best practice support in the development of suitable SCRM strategies. The benefits gained from targeted information sharing such as this could act as an incentive for the supplier to keep the focal organisation directly aware of any actual or potential issues with production (removing the delays caused by information slowly working its way down the supply chain). This issue of incentivisation is an important aspect of improving alignment from a SCRM perspective (Narayanan and Raman, 2004).

Increasing supply chain flexibility in risk 'hotspots': Increased flexibility was observed in the literature, to be one of the most commonly used organisational supply chain risk management strategies (Chopra and Sodhi, 2004). Increased understanding of which nodes of a supply chain are most susceptible to corporate-level disruption risk, can be a powerful tool in enabling the focal organisation to refine and specifically target which areas of its supply chain to build increased flexibility in to. This could be in terms of either reducing reliance on a single, critical supplier, identified as being particularly susceptible to corporate-level disruption risk or similarly reducing over-reliance on a whole region which has a significant number of supply chain nodes (such as China or Japan in the Li-ion battery Example above). In a practical sense, as discussed in Chapter 2, there a number of ways to increase flexibility in the supply chain, including dual/ multiple sourcing (Treleven and Schweikhart, 1988) and building flexibility in to supply contracts to allow to shift order quantities between suppliers (Tsay and Lovejoy, 1999 and Chopra and Sodhi, 2004). Where, as in the current Li-ion battery example, the majority of suppliers are based within a geographically small number of locations, other forms of flexibility may need to be employed, such as building buffers which is discussed below. The role of increased flexibility in mitigation and contingency planning for supply chain disruptions is clearly demonstrated in two examples discussed in chapter two; Griffy-Brown's (2003) account of the damage Hurricane Mitch caused to Dole and Chiquita and Norrman and Jansson's (2004) case study on mobile phone manufacturer Ericsson following a serious supplier failure.

Building Buffers: Building buffers or 'reserves' of critical 'at risk' components or raw materials, was identified in Chapter 2 as being a powerful strategy to reduce the impact of

certain unavoidable corporate-level disruptions (Chopra and Sodhi, 2010). It also complements other forms of flexibility such as identifying alternative supply routes. However, the literature suggests that this strategy is underutilised in practice due to the significant costs involved with building large buffer inventories of large numbers of components (Sheffi, 2005). Chopra and Miendl (2004) refer to this as 'the newsvendor problem', where an organisation must determine the optimum number components or raw materials to build buffers of, before the act becomes more financially damaging than the mitigated risk itself. See for example Chopra and Sodhi's optimisation curve (2010). By identifying those components which are most susceptible to corporate-level supply chain risk, the focal organisation is able to more intelligently plan which stock would most likely benefit from building buffers of. Moreover, in better understanding the dynamics of a given supply chain and each node's susceptibility to corporate-level risk, the focal organisation will be able to work more closely with its 'at risk' upstream suppliers to ensure that where necessary, they themselves have a sufficient buffer of critical components or raw materials. An example of this could be working with the 2nd tier cell supplier to better understand current storage reserves of Cobalt, identified as a particularly at-risk material.

Heightened Response as a Form of Mitigation: Finally, there is a need to consider how, improving response in itself can be used an effective supply chain risk mitigation strategy for corporate-level disruption risk. With limited exceptions, such as Kleindorfer and Saad (2005), few authors have looked in to this relatively undeveloped area of the literature, a finding which Sodhi and Tang (2012) describe as 'glaring in light' given a series of recent high-profile disruptions to global supply chains. In chapter 2, this issue was discussed in relation to Sodhi and Tang's (2012) 3D time-based framework of response to a disruption, in which response efforts are separated in to three sections: D1) time to detect the event, D2) time to design a response and D3) time to deploy a response. It is argued that by reducing any of these three-time elements, an organisation is able to significantly reduce its overall response and therefore recovery time. In terms of this area of the literature, the current research is significant as, by understanding the dynamics of a given supply chain, as well as the level of susceptibility to corporate-level disruption risk of specific suppliers or wider regions, the focal organisation is able to both improve response time and develop more tailored response strategies, such as those described above. For example, whilst the focal organisation has a

robust 'response to unavoidable events' strategy in place, this could be strengthened for critical areas of the supply chain by, for example, having alternative supply routes for 'at risk' nodes already identified (thus reducing both D2 and D3 delivery times). The above example also highlights how the focal organisation can keep track of the developments in key markets (such as China, Japan or the DRC in the Li-ion battery example) and understand which aspects of the supply chain are most likely to be impacted in the event of a corporate-level disruption risk event occurring in a given region (reducing D1).

5.9   Summary

This chapter has sought to explore key questions around how increased organisational supply chain visibility can be utilised to better assess the susceptibility of upstream suppliers to corporate-level disruption risk. To do this, the Li-ion battery (both NCM and LFP chemistries) was identified as a real-world example of a 'critical' automotive component. Working with both the focal organisation and its Tier 1 supply chain partner a mapping exercise was undertaken to discover key supply nodes for both battery chemistries, as well as contextualise market dynamics and the focal organisation's positioning in relation to this increasingly important component.

In completion of objective 4 of this research, a conceptual 'stakeholder salience' framework is developed, considering how geographical supply chain mapping data can be combined with Environmental, Geo-political and Economic risk metrics, using GIS software, to improve assessment of corporate-level disruption risk throughout the upstream supply chain, allowing for better targeting of limited resources on the most susceptible areas. This contributes to the need, identified in the literature, to explore more targeted approaches to the management of upstream corporate-level supply chain risk. The conceptual framework is empirically explored, utilising practical supply chain data obtained for both NCM and LFP Li-ion battery chemistries. The output from this process is critically discussed, both in relation to theory and its practical implications. Finally, consideration is given to how identifying key areas of the supply chain susceptible to corporate-level disruption risk can contribute towards strategic SCRM in aiding the deployment of more targeted mitigation.

6 Chapter 6 – Conclusion

6.1 Introduction

This chapter provides an overview of the key findings stemming from this work and how they have they have contributed towards meeting the research aims and objectives. This is followed by a summary of both theoretical and practical contributions, before finally discussing limitations of the research and recommendations for areas of further study.

6.2 Meeting the Identified Research Objectives

The current research presents an analysis of corporate-level disruption risk and its management, building upon applied case study analysis with a leading automotive manufacturer. It adopts the position that supply chain risk can be segmented into those risks which are internal to the organisation or its supply chain, operational risks (commonly referred to as supply, process and demand risks) and those which are external to the organisation and its supply chain, corporate-level disruption risks. In keeping with the literature, those external risks which are not within the immediate operational control of an organisation but can have a significant direct impact on the supply chain, can be broken down in to three distinct groups: 1) geo-political, 2) economic and 3) environmental. It is argued that the modern organisation is more susceptible to unanticipated corporate-level disruption of this nature than ever before (Thun and Hoenig, 2011, Tang and Tomlin, 2008, Haraguchi and Lall, 2012, Saenz and Revilla, 2014), often with significant fiscal and operational impacts (Hendricks and Singai 2005, CCC, 2014).

Using applied case study analysis, the aim of this doctoral thesis has been to gain an in-depth understanding of strategic approaches to SCRM within a leading automotive manufacturer, gaining an understanding of how and why traditional processes are evolving to manage upstream, corporate-level disruption risks (Case Study 1). Building upon this and set against a background of significant regulatory drivers for increasing supply chain transparency, the research then seeks to develop a conceptual framework for how increased visibility might be used to better target mitigation strategies for corporate-level supply chain disruption risk (Case study 2). In order to do this a real-world 'critical' component supply chain is use, the Li-

ion battery. To achieve these aims, four specific research objectives were identified and are critically discussed in relation to the research findings in the following sections.

6.2.1 Objective 1: *To review key drivers increasing the susceptibility to corporate-level disruption risk within organisation's supply chains and critically analyse the latest SCRM literature in this area.*

The first objective of the research was to identify key drivers increasing susceptibility to corporate-level disruption risk within organisation's supply chains and analyse the latest SCRM literature in this area. Whilst it is clear that most organisations are aware that corporate-level disruption risks could affect their organisation, the literature suggests that existing SCRM strategies primarily deal with supply chain operational risks, and *not* corporate level disruption risk (Adhitya et al, 2009). This implies that whilst organisations are becoming more adapt at managing operational supply chain risk, there is insufficient focus on understanding the dynamics of external disruptions and how they might affect the focal organisation. A key theme in the literature highlights the fact that supply chains today are more vulnerable to unanticipated disruption from seemingly self-contained events than they were in the past (Craighead et al., 2007). Through analysis of the existing SCRM literature (Chapter 2), as well as semi-structured interviews with expert practitioners, undertaken in completion of Case Study 1 (Chapter 4), four key antecedents for increased susceptibility to corporate-level risks were identified. These are globalisation and increasing supply chain complexity, streamlining and efficiency initiatives, increasing occurrence of impactful disruption generally and a lack of upstream supply chain visibility.

Globalisation and Increasing Supply Chain Complexity: UK businesses increasingly operate as part of the global economy and are heavily reliant on goods and services supplied by overseas markets. A recent report by the Committee on Climate Change Adaption Sub Group (2014), found that the value of UK imports has risen from £149 billion in 1990 to £527 billion in 2012. Although supply chain globalisation has produced significant benefits in terms of productivity and profitability, the extended geographical spread and complexity of many modern supply chains has led to increased susceptibility to external corporate-level risks (Pereira et al, 2014). As Peck (2005, p. 214) describes 'the more complex a network is, the more interfaces exist

and the higher the vulnerability will be'. Findings from case study 1 highlight that whilst the focal organisation has only a small direct, supply base outside of the EU, this statistic represents only those suppliers at a first-tier level. Beyond this the organisation has a significant dependence on global suppliers and raw material markets. Moreover, many of the specific risk events discussed during the interviews were a direct result of disruptions in the extended geographical supply chain.

Streamlining and Efficiency: Findings suggest that organisations are placing more emphasis on streamlining and cost efficiency in their supply chains to increase competitiveness. This is evidenced in the finding that between 2008 and 2012, the focal organisation undertook a significant streamlining initiative, reducing total tier 1 suppliers and increasing lean supply chain operation. The creation of 'lean' supply chains of this nature is advantageous in the sense that it minimises surplus stock and fosters close relationships throughout supply chains. However, the move away from a 'safety stock' culture, also leaves businesses more susceptible to external corporate-level risk (Thun and Hoenig, 2011). For example, 'lean' supply chains utilising 'just in time' delivery principles require an increasing frequency of supply to minimise on site inventory. This results in increased interdependence between supply chain nodes, where disruption at a critical point can have a systemic impact. The difficulty of several of the focal organisation's key suppliers to respond to unanticipated demand spikes for a specific vehicle model is one example provided in case study 1 and illustrates the challenges in flexibility of an increasingly lean supply chain.

Increasing Occurrence of Impactful Disruption Generally: Various studies modelling historical data, surmise that the frequency of natural and man-made disasters has risen significantly since the turn of the century. See for example the Annual Statistical Reviews conducted by the Centre for Research on the Epidemiology of Disasters (2012). Findings from case study 1 identified that several events occurring in a period of less than two years, had the cumulative effect of highlighting the fragility of the organisation's global supply chain and stressing that new procurement strategies were needed to address external disruptions of this nature. These included the April 2010 Icelandic Ash Cloud which caused significant delays for lower tier suppliers due to flight restrictions across much of Europe, the 2011 Japanese Tohoku

earthquake/ resulting tsunami and the 2011 Thai floods, both of which caused significant delays to upstream suppliers of many key automotive components.

A Lack of Upstream Supply Chain Visibility: Whilst corporate-level disruption events may impact any node throughout the supply chain, the literature suggests that supply chain disruptions are significantly more likely (BCI, 2014) and more critical (Pereira et al, 2014) when they occur in the upstream of a supply chain. A key theme in the literature identifies that many large organisations have a good visibility of risk in their immediate operating environment (T1), but due to the resource constraints rarely take a proactive approach to understand the complexities of their supply chains beyond this (Zsidisn and Ritchie's, 2008, CIPS, 2014). Anlaysis from case study 1 highlight that the focal organisation's current supply chain visibility level is in keeping with this finding. Considering many of the most significant disruptions to supply chain operations in recent years have impacted upstream suppliers beyond the lower tiers, it is clear that low visibility can lead to underestimation and underinvestment in proactive SCRM strategy. For example, the reactive approach to disruptions currently adopted, amplify impact due to the increased lead time in responding to events. This is highlighted in a discussion around organisational impact of the 2011 Japanese Earthquake and Tsunami.

6.2.2 Objective 2: *To assess how a leading automotive manufacturer currently manages corporate level disruption risk within its immediate supply chain partners (T1) and attitudes toward increasing supply chain visibility beyond this.*

The second objective of this research was to develop an understanding of strategic SCRM practices within a leading automotive manufacturer, gaining insight as to how and why traditional processes are evolving to manage corporate-level disruption risk.

To meet this objective, an applied case study was undertaken with a leading automotive manufacturer (Case Study 1). Chapter 4 presents the findings and analysis of this case study. It draws on semi-structured interviews with experts within the vehicle manufacturer, as well as collation and analysis of a range of internal organisational reports, presentations and other documents. Findings from this case study were critically assessed in relation to the SCRM

literature discussed in Chapter 2. For reasons of confidentiality, the manufacturer chose to remain anonymous and as such, is referred to throughout the case study as 'the focal organisation'.

At the outset a broad overview is given of both organisational structure with regard to procurement and supply base segmentation. It was found that Management of overall procurement at the organisation is separated in to functional areas, aligned to either, a class of key vehicle components, a specific purchasing function or transformation project. In 2012, the purchasing department, as a whole, contracted with tier 1 suppliers that were based predominantly in Europe. As well as functional categories, the company's tier 1 supplier base is categorised using a four-segment model that considers both the value of buy from a given supplier, as well as the nature of the focal organisation's relationship with that supplier. Categories include transactional, leverage, critical and partnership.

Analysis found that the organisation's SCRM work-flow bared close resemblance to high-level process discussed in the literature of Identification, Assessment, Mitigation and Response. Co-ordination of the organisation's overall approach to managing identified supply chain risk relies on two specialised central purchasing departments, the supply chain risk (SCR) team and the Financial Risk (FR) Team. Initially, potential macro-level organisational risks are passed to these teams from the central business office. Then, drawing upon expert opinion and market analysis, an impact/ probability scoring matrix is used to prioritise risks from a procurement perspective.

The existing controls environment for each risk is also assessed at this stage (prior to implementation of mitigation strategies) and is found by the organisation to be insufficient for a number of areas, especially in areas of corporate-level risk. This indicates a departure from previous findings in the literature that asserts organisations often mistakenly consider themselves to have robust supply chains (Zsidisin and Ritchie, 2008) and are mostly satisfied with current supply chain risk management strategies (Sodhi and Tang, 2012). It is argued that the drivers identified in objective 1 are increasing organisational awareness of the susceptibility to supply chain risk, especially corporate-level risk. It was found that whilst he organisation does draw a primary distinction between supply chain risk that occurs as part of

the normal course of operations (operational risk) and that which is wholly externally driven (corporate-level disruption risk), in general terms supply chain risk is viewed broadly as anything which could impact or stop production. As such, output from the prioritisation exercise is used to directly inform which areas of risk should be prioritised by the SCR and FR teams. Whilst it was clear that interviewees understood many of the formal academic categorisation models discussed in Chapter 2, it was found for the most part that, in keeping with the literature, diversification of risk categorisation frameworks is largely down to definitional differences and the vocabulary adopted, rather than physical divides in the categories used. In practical terms, this meant that management of different risks were aligned to an appropriate functional department within the organisation rather than categorised by type. With SCR and FR teams acting in a co-ordination role, highlighting prioritised supply chain risk to the appropriate organisational function and developing mitigation/ management tools for them to implement. This is very much in keeping with recent developments in the field that have suggested a key flaw in existing categorisation models is a lack of alignment with standardised organisational structure (Sodhi and Tang, 2012).

This case study provides an overview of supply chain risk mitigation and response activities, collectively described as the focal organisation's supply chain risk processes. As above, these processes are developed by SCR and FR teams and have incorporated SCRM throughout the end-to-end purchasing function, including new sourcing and resourcing processes, a continuous supplier monitoring process and emergency response processes for insolvency and unavoidable disruption. In addition to these processes a number of ancillary functions contribute to the overall organisational SCRM strategy including, for example, legal, raw material and macro-economic analysis. Several examples of supplier failure provided by the organisation are highlighted throughout. For example, an overview of organisational response to the Japanese Tōhoku Earthquake and Tsunami is given, considering how the incident served as a catalyst moment with regards to their approach to corporate-level SCRM

Analysis of mitigation and response processes highlighted that whilst proactive strategy is employed for operational risk within the organisation's supply base, a largely reactive approach is adopted with regards to corporate-level risk. Moreover, a key observation within

the case study relates to the focal organisation's low supply chain visibility level. The issue of low supply chain visibility is highlighted in the literature as a key inhibitor in the development of effective corporate-level SCRM strategies, a point also highlighted by interviewees. The final findings and analysis from Case study 1 relate to how the focal organisation is responding to this challenge through a collaborative supply chain mapping process, alongside other automotive manufacturers and supported by an online platform provided by third party organisation. Analysis provides a review of the process and its practical operation, where first tier suppliers are asked to collect data from their own direct suppliers, creating an 'information cascade' to build a complete picture of the upstream supply chain. Practical challenges are critically considered including confidentiality, how data accuracy/ timeliness can be ensured and how chase cycles are implemented for non-respondent suppliers. A need is highlighted to build upon visibility gained through the process, from a corporate-level risk perspective, feeding in to existing organisational SCRM strategy. This collaborative mapping process represents an industry first and as such provides real-world insight in to a highly dynamic and significant area of the literature.

6.2.3   Objective 3: *To Review legislative and policy drivers placing pressure on organisations to increase upstream supply chain visibility.*

Both analysis of the literature and interview findings from the focal organisation found that a lack of upstream supply chain visibility significantly inhibits the effective implementation of corporate-level SCRM strategies. Whilst some attention has been given to the commercial costs associated with a lack of supply chain visibility, the current literature largely overlooks the legislative and policy drivers. Understanding key drivers in this area is important, as the imposition of law and penalties provides a powerful incentive for behavioural change, and is very effective in focussing organisational attention (Hitchcock, 2012). This is certainly true of the focal organisation, with findings highlighting that the imposition of legislative measures is a key driver for increasing supply chain visibility

The principal aim of Objective 3 was to give a broad overview of the diverse legislative and policy framework, which is currently driving UK organisations to increase visibility of their upstream supply chain partners operations. It is set against the introduction of a host of new legislation and policy, both at UK and EU level, as well as a backdrop of several recent high-profile events that have had the effect of focusing public attention towards the issue of supply chain visibility. In terms of legislation and policy, there is found to be three distinct strands of driver which can be categorised as: (1) product quality, safety and labelling, (2) environmental and (3) social. Analysis found that product quality, safety and labelling legislation have traditionally formed the regulatory back-bone of why organisations seek increased visibility of supply chain activities. However, interview findings suggest for the most part this has not led to the significant investment in supply chain visibility programmes discussed in case study 1. Instead, it is argued that significant recent development of both environmental and social legislation and policy is driving organisational change in this area. A critical review of key legislation in this area is provided in Chapter 4.

In terms of environmental legislation, mandatory carbon reporting for scope 1 and 2 emissions (enabled under Act 3 of the Climate Change Act, 2008) was seen as a significant driver. Moreover, the seemingly inevitable inclusion of scope 3 emissions within the reporting remit (in order to meet ambitious GHG reduction targets) is forcing companies to better

understand their upstream suppliers' operations. Similarly, new material disclosure legislation has placed increasingly stringent regulations on organisations to ensure the sustainability of materials used in their products at each stage of production. For example, the EC regulation on chemicals and their use (EC 1907/2006), REACH and recent amendments in 2011 to the RoHS Directive (2011/65/EU).

Legislation and Policy from a social perspective is also reviewed and found to be placing significant pressure upon organisations to increase visibility of their upstream operations. Such legislation includes, the UK Bribery Act (2010) which imposes significant organisational deterrents for corruption throughout the supply chain and the Dodd-Frank Act (2010), which places a requirement on companies to disclose whether certain minerals in their upstream supply chain originate from conflict zones.

Analysis and findings in this area illustrate a diverse range of perspectives currently driving the 'supply chain visibility' agenda and contributing towards the wider debate around supply chain visibility in general. The growing number of regulatory measures in this area is seemingly shifting the traditional balance of who is responsible for supply chain failures, with the focal firm being increasingly required to implement 'due diligence' in ensuring its upstream supply chain partners are operating within the boundary of the specific Act or policy in question.

6.2.4   Objective 4: *To Propose a framework for how increased visibility might be used to better target mitigation strategies for corporate-level supply chain disruption risk and test this using the Li-ion battery supply chain (as an example of new technology exposing automotive manufacturers to new risks) in this area.*

Consideration around how increased supply chain visibility can be better utilised to improve organisational decision making is a key theme in contemporary supply chain management literature. Especially, given that that there is often a lack of knowledge amongst supply chain managers regarding how to interpret and build upon visibility data in order to improve business decision making, referred to in the literature as low internal integration (Williams et al, 2013). In parallel to this, the SCRM literature highlights a clear need to consider more

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targeted approaches to the management of upstream-corporate level disruption risk (Tang, 2006, Colicchia and Strozzi, 2012). Objective 4 has sought to explore how increased supply chain visibility can be used to improve the identification and assessment of upstream, corporate-level risks, without significant investment in additional financial and human resource. As, in both the existing literature and findings from the previous case study, the resource cost of developing and implementing strategies to address corporate-level disruption risk at every node of the supply chain was seen as both impractical and undermining of broader supply chain efficiency measures (Chopra and Sodhi, 2014).

To this end a conceptual 'stakeholder salience' framework was developed in chapter 2. The proposed framework considered the combination of upstream geographic supply chain mapping data with weighted geo-political, economic and environmental indicators in a GIS environment. It is argued that considering the problem through the organisational lens of stakeholder theory, allows this research to critically conceptualise the challenge and develop a novel framework with which to assess stakeholder salience amongst suppliers. Therefore, allowing for the identification of which nodes are most susceptible to corporate-level risk and enabling limited resources to be more appropriately targeted onto the mitigation and strategic management of those areas.

In Chapter 5 (Case study 2), this framework is empirically explored, using a real-world example of a 'critical' component, the Li-ion Battery Cell (LFP and NMC chemistries). This supply chain was specifically chosen, primarily due to its critical future importance to the organisation and fact that it introduces a range of novel materials in to the organisation's supply base.

Prior to application of the framework, Chapter 5 presents findings and analysis from the mapping exercise undertaken to establish a breakdown of materials/ structural components, suppliers and geographic nodes within each tier of the Li-ion battery supply chain. To do this, interviews were carried out with a number of employees at both the focal organisation, as well as its Tier 1 supply chain partner for the production of Li-ion batteries and primary supply chain data (from both employee's expert knowledge and existing organisational data) collated to build detailed map of what these two specific supply chains looked like. The focal organisations supply chain configuration for this component is compared to existing market

configurations utilised by similar organisations and was found to align closely with a four tier, fully fragmented supply chain configuration.

Practical challenges associated with the supply chain mapping process are critically discussed and were found to include confidentiality concerns amongst suppliers, power imbalances between low-mid tier suppliers, dynamism within the supply chain (especially raw material markets) and establishment of appropriate supply chain boundaries. The mapping process also found a clear disconnect between tier's 1-3 (component, cell and pack/ module production) where a specific supplier and location could be identified and those at tier 4 (raw material/ feedstock markets) where one could not. This is primarily because the majority of raw materials (especially mineral commodities) are traded in global markets (either directly by the T3 supplier or through a merchant) which are extremely dynamic in nature and price sensitive. To overcome limitations posed by the dynamic nature of raw material markets relevant to the Li-ion battery supply chain, secondary market data (from the Natural Environment Research Councils' World Mineral Production Dataset, 2012) was used to analyse more broadly, the key producer regions involved in the 4th tier of the Li-ion battery supply chain. A supply chain map, based on this data, for both LFP and NMC battery chemistries is presented in Figures 5-7 and 5-8.

As outlined above, in order to empirically explore the framework developed in chapter 2, geographic data obtained from the supply chain mapping process, was combined using GIS software, with the 11 weighted risk datasets for Environmental, Geo-political and Economic corporate-level risk groups. The output of this process is presented in the form 3 GIS outputs (Figures 5-12, 5-13 and 5-14) for each weighted indicator group. These three individual indicators were then combined to create an overall corporate-level disruption risk indicator, which is layered on top of the original supply chain mapping data for both LFP and NCM battery chemistries (Figures 5-15 and 5-16).

Findings and analysis clearly highlight that the global nature of the Li-ion battery supply chain, exposes it to significant corporate-level disruption risk. Moreover, the majority of this risk exists within the higher tiers, especially in the raw material market, a finding in keeping with the literature in this area. This finding is significant as most areas of susceptibility to

corporate-level disruption risk in this supply chain occur beyond first tier suppliers where the focal organisation currently has most visibility. This provides support for the notion that supply chain managers often underestimate supply chain susceptibility to corporate-level disruption risk due to a lack of visibility beyond these initial tiers.

Analysis gives a clear overview of how susceptible each geographical region involved in the Li-ion battery supply chain is to Environmental, Geo-Political and Economic disruption risk. By creating an average weighted score of each of the key supply markets, the susceptibility of each supply region to corporate-level disruption risk (see table 5-17) is highlighted. By considering this ranking alongside other market data, such as the EU Critical Raw Materials report (2014) which assesses security of supply for raw materials, the most salient materials in a given supply chain are identified. The research highlights 5 raw materials in the Li-ion battery supply chain as potentially critical from this perspective, Cobalt, Flake (Natural) Graphite, Fluorspar, Silicon and Phosphate. Analysis also highlights significant reliance upon suppliers in China (tier 4) and the USA/ Japan (in tier 3). Identification of geographical supply clusters is critical from a corporate-level SCRM perspective, as over-reliance on a single region creates a weak-point that can affect operation of the whole supply chain.

The final section of Chapter 5 considers these findings in relation to the strategic supply chain risk mitigation approaches discussed in both the literature and case study 1. Consideration is given to how identifying key areas of the supply chain susceptible to corporate-level disruption risk can contribute towards strategic SCRM in aiding the deployment of more targeted mitigation approaches. Specific areas of consideration include the ability to improve alignment with strategically important upstream suppliers, increase supply chain flexibility in risk 'hotspots', build buffers or reserves of critical materials and heighten response time to upstream, corporate-level risk in general.

6.3   Academic Contributions

The outcome of this research contributes towards a number of research gaps within the academic literature that were identified following a critical review in chapter 2. There are three key strands of academic contribution which are summarised in Table 6-1 (in relation to the associated research gaps identified in Chapter 2).

Case study 1 presents a critical exploration of how a leading automotive organisation strategically approaches Corporate-level SCRM and how this fits in to established SCRM practices. The literature highlights a lack of applied work in the area of SCRM, especially in terms of real-world qualitative case studies (Saenz and Revilla, 2014). As such the analysis and findings presented in case study 1 of this research, contribute to a significant gap in the academic literature for best practice case studies of companies that are taking steps to proactively manage supply chain risk, especially corporate-level disruption risk. Critical appraisal of the analysis and findings presented in case study 1 has helped develop a clearer picture of why upstream corporate-level disruption risk has traditionally remained unaddressed by many organisations (Tang, 2006, Saenz and Revilla, 2014, Chopra and Sodhi, 2014). Moreover, through analysis of several within-case examples of supplier failure and exploration of the issue with senior supply chain professionals within the focal organisation, Case study 1, affirms the impact low levels of upstream supply chain visibility can have on an organisation (Pereira et al, 2014). Moreover, it also highlights how a lack of understanding around upstream supply chain dynamics can significantly inhibit the implementation of initiatives to manage corporate-level disruption risk (Colicchia and Strozzi, 2012).

Looking forward, this research has presented a critical review of the legislative and regulatory drivers that are forcing organisations to increase supply chain visibility. A review of this nature was highlighted as a significant gap in the literature, as the imposition of law and penalties provides a powerful incentive to behavioural change and is very effective in focussing organisational attention (Hitchcock, 2012). Case study 1 also considered to what extent the focal organisation is driven by these measures to increase supply chain visibility and highlights how it is going about this, in a collaborative manor (an industry first). Considering these significant drivers, the current research presents a conceptual 'stakeholder salience' framework exploring how increased visibility can be fused with weighted geo-political,

environmental and economic risk metric, using GIS software, highlighting potential areas of susceptibility to upstream, corporate-level supply chain risk (salient stakeholders). It is argued that this information can then be used to better target and develop mitigation strategies for corporate-level disruption risk in a given supply chain. This framework is empirically explored in Case study 2, using the Li-ion battery cell as an example of a real-world 'critical' component supply chain.

Development and exploration of this conceptual framework through the lens of stakeholder theory contributes to the growing body of literature citing the need to refocus attention upon the role of stakeholder theory as a theory of organisational strategy and not just of ethics (Fassin, 2012). For example, understanding the importance of within group categorisation of stakeholders, in this case suppliers (Clarkson, 1995) and acknowledging reciprocal nature of stakeholder influence, in that suppliers can have an adverse impact upon the organisation as well as the other way around (Laplume et al, 2008).

From a SCRM perspective, case study 2 also contributes towards a call in the literature for better ways to assess which areas of the extended upstream supply chain are more susceptible to corporate-level disruption in order to better target limited SCRM resources (Tang, 2006). For example, the literature highlights that corporate-level disruption risk is usually subjected to a more 'gut instinct' assessment (Zsidisin et al, 2004). As such, the research considers that exploring methods to fully utilise available data will allow for more objective assessment of organisational susceptibility throughout the upstream supply chain.

Strand 1 Assessing existing SCRM strategies and development at a leading automotive organisation	Strand 2 Going Forward: Drivers and Strategies for increasing upstream, supply chain visibility	Strand 3 Towards a Stakeholder Salience Framework of Upstream Corporate-Level SCRM
The analysis and findings presented in case study 1 of this research, contribute to a significant gap in the academic literature for best practice case studies of companies that are taking steps to proactively manage supply chain risk, especially corporate-level disruption risk (**RG-4**).	The research has presented a critical review of the legislative and regulatory drivers that are forcing organisations to increase supply chain visibility. A review of this nature was highlighted as a significant gap in the literature, as the imposition of law and penalties provides a powerful incentive to behavioural change and is very effective in focusing organisational attention (**RG-5**).	Case study 2 presents a conceptual 'stakeholder salience' framework exploring how increased visibility can be fused with weighted risk metrics, to highlight potential areas of susceptibility to upstream, corporate-level supply chain disruption risk. Development and exploration (using a practical supply chain) of this conceptual framework through the lens of stakeholder theory contributes to the growing body of literature citing the need to refocus attention upon the role of stakeholder theory as a theory of organisational strategy and not just of ethics. For example, acknowledging reciprocal nature of stakeholder influence, where suppliers can have an adverse impact upon the organisation as well as the other way around.
Case study 1 also helped develop a clearer picture of why upstream corporate-level disruption risk has traditionally remained unaddressed by the organisation (**RG-2**).	Case study 1 also considered to what extent the focal organisation is driven by these measures to increase supply chain visibility and highlights how it is going about this, in a collaborative effort; an industry first (**RG-3**).	From a SCRM perspective, this study also contributes towards a call in the literature for better ways to assess which areas of the extended upstream supply chain are more susceptible to corporate-level disruption in order to target limited SCRM resources (**RG-6**).
Associated Research Gaps Identified in Chapter 2		
RG-4 – There is a lack of understanding around how real-world organisations engage with SCRM generally and in-particular corporate-level SCRM **RG-2** – The risk of corporate-level supply chain disruption remains unaddressed by many organisations	**RG-5** – A number of legislative and regulatory drivers are forcing organisations to increase upstream supply chain visibility which provides significant opportunities for SCRM **RG-3** – Many organisations do not understand the complexities of their upstream supply chain where disruption risks are most likely to occur	**RG-6** – A need to develop more targeted approaches to the management of upstream corporate-level supply chain risk
RG-1 – Corporate-level supply chain risk management remains an area of the literature in its infancy. Addressing research gaps 2-6 contributes towards the development of this nascent area.		

Figure 6-1: Table to illustrate three-strand research contribution

6.4 – Practical Contributions and Implications for Other Industries

In addition to academic contributions, the outcome of this research presents a number of more practical implications.

The development of strategies to manage corporate-level disruption risk within the upstream supply chain and integrate this in to existing SCRM processes is a complex and challenging task. Case study 1 provides an overview of how a leading automotive manufacturer is engaged in this area. Findings and analysis from this study not only fulfil a call in the academic literature for research of this nature but may also provide valuable insight for other organisations and their suppliers around key challenges and practices in this area. For example, whilst it evident from the literature that most organisations are aware that corporate-level disruption could impact upon their supply chains (Adhitya et al, 2009), it is also clear that many underestimate the level of vulnerability and therefore do not invest sufficiently in mitigating their potential impact (Zsidisin and Ritchie, 2008, Sodhi and Tang, 2012).

The focal organisation was chosen due to its proactive approach to managing supply chain risk, something which the literature suggests is not standard strategy amongst all companies. Chapter 4 considered the drivers that underpinned the focal organisation's desire to gain an increased understanding of their supply chain, beyond only that which is legislatively prescribed. It was concluded that one of the principle drivers for this engagement with SCRM were a number of disruption events occurring in a short time frame; including, the April 2010 Icelandic Ash Cloud, the 2011 Japanese Tohoku earthquake/ resulting tsunami and the 2011 Thai floods. Together, the impact of these events represented a 'catalyst moment' for the focal organisation and indeed the automotive sector as a whole. This finding reflects those of similar case studies in the literature that highlight the impact of catalyst moments in other organisations, for example, Hurricane Katrina for Cisco Systems (Saenz and Revilla, 2014) or the so called 'Albuquerque Incident' for mobile phone manufacture Ericsson (Norrman and Jansson, 2004). What these watershed moments have in common, is that they represented a turning point for the organisation in question, where SCRM strategy went from being largely superficial, to something that should be proactively addressed and invested in. It is clear from the current case study, that the automotive industry at least, is moving towards a more transparent, collaborative approach towards SCRM, where organisations share learning and

best practice. Whilst the literature makes clear that a one size fits all approach is not suitable for all industries, the similarities between the automotive sector and others, such as aerospace for example, mean there are clear advantages to cross-industry best practice exchange. In the UK, the aerospace is automotive industries share a number of supply chain similarities both in terms of supply chain structure and operation. However, as the aerospace sector is yet to experience the same level of impact on their supply chains from external disruption events as the automotive sector, SCRM strategies in this industry remain less developed.

It is concluded therefore that there is a significant opportunity for organisations in sectors such as the aerospace industry to learn valuable supply chain risk management lessons from other industries, without suffering a catalyst moment of their own. A willingness to increase organisational transparency, as well as to participate in cross-sector forums and highlight the benefits of proactive SCRM will be essential in achieving this.

Case study 2 of this research considers a conceptual framework for how increased supply chain visibility could be utilised (through combination with corporate-level risk metrics using GIS software), to improve organisational SCRM decision making. Through empirical exploration of this 'stakeholder salience' framework, using a practical component example (the Li-ion battery supply chain), the study contributes to practice in a number of ways. Firstly, it highlights key practical challenges involved with the supply chain mapping process including confidentiality concerns amongst suppliers, power imbalances between low-mid tier suppliers, dynamism within the supply chain (especially raw material markets) and the importance of establishing appropriate supply chain boundaries. Secondly, in empirically testing the conceptual framework, practical supply chain mapping data (for LFP and NCM Li-ion battery chemistries) is combined with 11, weighted corporate-level risk datasets using GIS software. Whilst the development of a definitive corporate-level supply chain risk indicator is not the intended outcome of this exploratory study, exploratory testing of this nature highlights the susceptibility of the upstream supply chain to corporate-level disruption risk. Moreover, findings and analysis highlight the practical potential for a framework such as this, identifying the most significant geographical regions within a given supply chain as well as which components and raw materials are most susceptible to corporate-level disruption risk.

Finally, the research argues that developing an empirical understanding of stakeholder salience within a given supply chain (in this case the Li-ion supply chain), can be a powerful tool to inform management decision making. As such, a number of strategic supply chain risk mitigation approaches, highlighted in the reviewed literature, are critically discussed with consideration as to how the framework developed could aid in their deployment for key hotspots of corporate-level risk.

6.5   Limitations and Areas of Further Study

As discussed in Chapter 3, the current research has adopted an inductive, largely qualitative methodology to explore strategic approaches to corporate-level risk within the automotive industry. To this end, two applied case studies are presented. The first, to gain an understanding of strategic approaches to SCRM within a leading automotive manufacturer, gaining an understanding of how and why traditional processes are evolving to manage upstream, corporate-level disruption risks (Case Study 1). Building upon this and set against a background of significant regulatory drivers for increasing organisational transparency, the research then seeks to develop a conceptual framework for how increased visibility might be used to better target mitigation strategies of corporate-level supply chain disruption risk (Case study 2).

The choice of research methodology and type of industry chosen, raise questions around the reliability and generalisability of the findings. For example, a primary criticism of largely qualitative, case study research such as this is that it is difficult to exclude personal bias or subjectivity throughout the research process. Whilst this is accepted as a valid limitation, the researcher has taken steps to maximise internal and construct validity within the study. These include an extensive pre research literature review, the use of multiple interviews within each case study, drawing on different sauces of evidence to build upon findings and sending a case report to interviewees to check for misunderstandings or omissions.

A further criticism of qualitative research relates to the generalisability of findings. However, it is argued that, whilst qualitative studies have smaller sample sizes and are generally more subjective, they are also more holistic, involving analysis and systematic description. As outlined above, there was found to be a distinct lack of industry specific studies of this nature

in the literature. The case study approach, therefore, is believed to be an appropriate method to observe the complexity and particular nature of a single organisational case. This said, an accepted limitation is that it may be difficult to generalise the specific findings of the study without undertaking further case studies. In keeping with Lee, Collier and Cullen (2007), this research argues that the main strength of case study research is particularisation and understanding the complexity and uniqueness of a case rather that generalisation. However, Bryman and Bell (2011) do suggest that this limitation can be partially overcome by 'generalising the theory rather than the population'. As such, it is considered that certain theoretical research findings from case study 2 will be generalisable within the industry and may have implications for other related industries that are facing similar challenges.

A final limitation relates to the data and weighting method used in the empirical exploration of the conceptual framework in case study 2. Supply chain mapping data used in the study was at a macro-geographical (country) level and only covered fixed locations, i.e. not transportation routes. The decision to use data at this level was made partly due to data access and also the difficulty in identifying appropriate risk datasets which provided lower level analysis. Considering the risk data used, as has been discussed, development of a definitive set of weighted risk indicators for corporate-level disruption risks falls beyond the remit of this research. However, the risk metrics and weightings used are considered appropriate for the current context. For example, after reviewing various risk datasets, as well as engagement with subject-specific experts within the University, 11 datasets were identified as appropriate to create the final three indicators used. Moreover, a joint industry/ academically led survey undertaken amongst 400 executives by the World Economic Forum (WEF) and Accenture (2012), on 'Understanding Global Supply chain and Transport Risk' was utilised in order to add further rigour to the weighting of these metrics.

Future research should seek to address these limitations. There is specific scope to undertake similar in-depth case study analysis in other industries and regions to identify how they are responding to the challenges outlined in this research and compare any differences which may arise. In addition, there is scope to extend the findings of the conceptual framework outlined and explored in this research. This could include a more robust indicator development study using primary weighting data or moving beyond macro-level analysis to

include more detailed within country analysis of suppliers and supply routes for a range of 'critical' products.

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Consumer Protection Act (1987)
Climate Change Act (2008)
Food Safety Act (1990)
General Product Safety Regulations (2005)
Sale of Goods Act (1979)
Supply of Machinery (Safety) Regulations (2008)

European Legislation
Regulation (EC) No 178/ 2002 of the European Parliament and of the Council laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety

Directive (EC) 87/2003 of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community

Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

Directive (EC) No 2/ 2007 of the European Parliament and of the Council Establishing and Infrastructure for Spatial Integration in the European Community (INSPIRE)

Regulation (EU) No 995/2010 of the European Parliament and of the Council laying down the obligations of operators who place timber and timber products on the market

Directive (EU) 65/2011 of the European Parliament and of the Council on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment

Non EU Legislation
California Transparency in Supply Chains Act (2010)
Dodd-Frank Wall Street Reform and Consumer Protection Act (2010)
Foreign Corrupt Practices Act (1977)

Non Mandatory Guidelines

Greenhouse Gas Protocol (GHG) Corporate Value Chain (Scope 3) Accounting and Reporting Standard

Greenhouse Gas Protocol (GHG) Protocol Corporate Accounting and Reporting Standard

Organisation for Economic Co-operation and Development (OECD) Guidelines on Multinational Enterprises

United Nations (UN) Guiding Principles on Business and Human Right