PHARMACEUTICAL SUPPLY CHAIN MANAGEMENT:

Buffering & Bridging Response Strategies in Shortage Management

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Thesis Summary

There exists a growing and tenacious challenge in the medicine supply chain, to manage the consequences of supply chain disruptions. Hospitals experience frequent shortages, in a European based study, 45% of respondents indicated that life preserving drugs were affected by shortages (Pauwels 2015). This research seeks to augment theoretical understanding underlying this significant issue and provide advice in the management of shortages which is a critical issue within the pharmaceutical industry. Previous research has focused on the antecedents of supply chain disruptions; what happens after a disruption has received scant attention. This research acknowledges that gap and seeks to build on the Bode et al. (2011), model of organisational responses to supply chain disruptions.

This study uses a research onion design as a stencil to guide the pluralistic methodological approach chosen to release the multifaceted dimensions of the problem under consideration. Data collection instruments were interviews, an online survey, and focus groups. It was based on 318 acute care hospitals in the UK and Ireland. Findings indicate there are patterns of responses, and shortage performances vary depending on the length of time since the disruption and response mixture chosen.

This research gives new insights into the impact of supply chain disruption response behaviour and supply chain performance in shortage management. It provides additional empirical tests to the Bode et al. (2011) normative model, providing insights into the underlying balanced theories, through examination of three constructs: *supply chain disruption orientation; supply chain disruption performance and organisational response*. It extends the concept of supply chain disruption orientation and highlights how response behaviour can feed back into the dynamic decision-making process, augmenting the Bode et al. (2011) framework. It provides insights to managers taking a system-wide view on drug delivery performance.

Keywords: Pharmaceutical supply chain management, Supply chain disruptions, shortage management, pharmaceuticals, performance.

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List of Abbreviations

ABPI Association of the British Pharmaceutical Industry

ABHI Association of British Healthcare Industries

API Active Pharmaceutical Ingredient

ASHP American Society of Health System Pharmacists

BAPW British Association of Pharmaceutical Wholesalers

BGMA British Generic Manufacturers Association

CDC Centre for Disease Prevention and Control

CO Cumulative Odds

CMU Commercial Medicines Unit

DOH Department of Health

EAHP European Association of Hospital Pharmacists

EEC European Economic Community

EDI Electronic Data Interchange

EFPIA European Federation of Pharmaceutical Industries and Associations

EOQ Economic Order Quantity

EMA European Medicines Agency

EU European Union

FDA Food and Drug Administration

GP General Practitioner

GX Generic Medicines

HCP Healthcare Professional

HDMA Healthcare Distribution Management Association

HMO Healthcare Maintenance Organisation

IHI Institute of Health Informatics

ISPE International Society of Pharmaceutical Engineers

MAH Marketing Authorisation Holder

MCA Medical Controls Agency

MHRA Medicine and Healthcare Products Regulatory Agency

MCO Managed Care Organisation

NHS National Health Service

NICE National Institute for Health and Care Excellence

NIH National Institutes of Health

NCE New Chemical Entities

NPA National Pharmacy Association

OECD Organisation for Economic Co-operation and Development

PASA Purchasing and Supply Agency (NHS)

PPA Prescription Price Agency

PPRS Pharmaceutical Price Regulation Scheme

PRS Pseudo R-Squared

R&D Research and Development

REC Research Ethics Committee

RFID Radio-Frequency Identification

SCDO Supply Chain Disruption Orientation

SCM Supply Chain Management

SCS Supply Chain Security

SHA Strategic Health Authorities

SMED Single Minute Exchange of Die

UCLH University College London Hospital

UUDIS University of Utah Drug Information Service

WEF World Economic Forum

WHO World Health Organisation

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1 Introduction

1.1 Research Background

The occurrence of disturbances that negatively affect a supply chain is an unavoidable fact, whereby all supply chains are inevitably at risk (Craighead, Blackhurst, Rungtusanatham et al., 2007). It is crucial for supply chain survival that managers identify, in a proactive manner, the disturbances that may potentially affect the supply chain and take measures, developing, for example, mitigation and/or contingency plans that help make the supply chain more resilient (i.e. less vulnerable) (Barroso, Machado and Cruz-Machado, 2011). Common pressures and responses exist in international industries, such as globalisation, increasing legislation, and a volatile economic environment, which can lead to a turbulent dynamic (Christopher and Holweg, 2011). In the UK, the economic impact of fuel protests in 2000, followed by the outbreak of Foot and Mouth Disease early the following year, influenced policymakers and highlighted the need to understand more about the vulnerability of commercial supply chains (Peck, 2005).

Globalisation has linked low-cost labour economies with consumer markets and, as a result, supply chains have become extended. The uncertainty incumbent in these elongated chains has resulted in supply chains strategies balancing inventory with service levels (Greening and Rutherford, 2011). In many cases, this trade-off leaves the supply chain vulnerable to disturbances, leading to an increased focus on supply chain coordination. The geographical extent of the supply chain has also resulted in an increased vulnerability to disruptions (as opposed to disturbances), such as natural disasters or terrorist attacks (Sheffi and Rice, 2005). A disturbance has a negative impact to a limited extent and for a limited period, whereas a disruption has a strong negative impact normally of wide scope and long duration or effect (Pfohl, Kohler and Thomas, 2010).

Supply chain disruptions are not new, of course; they have existed for as long as supply chains have (Snyder, Atan, Peng et al., 2012). Nevertheless, the results of disruptions have been widespread and their consequences severe, for example, the shortages the pharmaceutical industry has been experiencing as a result of disruptions from both controllable and non-controllable factors, such as manufacturing issues and transportation delays, with resultant negative patient impact (Breen, 2008).

Shortages can occur where the disruption causes a breakdown in the smooth running of the supply chain, which can generate and accelerate shortages. This can produce 'stock out' situations increasing the order lead time, or failing to fulfill the order completely. The result of this may be a loss of future orders or, in the case of a hospital pharmacy, not receiving the correct drug on time which can lead to an adverse patient outcome. Shortages can also ensue when there is a disruption in the flow of information and material. This can be due to prediction inaccuracies, Chopra and Sodhi (2004) identified this can result from *information distortion* within the supply chain. Croson and Donohue (2003) explained that all supply chains have two distinct lead-time pipelines, firstly the order information transfer pipeline, moving upstream from the point of sale to raw material supplier, and secondly the product transfer downstream from raw material to customer.

Where the customer anticipates that supply will not be able to meet demand, they can demonstrate purchasing behaviour which Lee, Padmanabhan and Whang (2007) describes as shortage gaming. This is where customers place larger than average orders, creating an amplification in demand through the supply pipeline, which Forrester (1958) described as the bullwhip effect. Significant extra orders being placed reduces local inventory for distributors, therefore causing a spread of shortages in the market. This distortion of information flow from downstream leads to overproduction upstream, which then leads to eventual oversupply as the production exceeds the demand from downstream. In this case, the supply structure being in a pipeline form, the behaviour of stakeholders throughout the pipeline, in addition to the distortion of information, causes a shortage which reverberates through the marketplace causing its own dynamic.

This harsh reality, coupled with the emergence of ongoing natural and man-made hazards in a volatile environment of financial instability and ongoing crisis, have put concepts that were somehow neglected in the past, such as supply chain resilience and vulnerability, in the forefront of supply chain research in the last ten years, according to Ponis and Kronis (2012). Bakshi and Kleindorfer (2009) note that the primary reason for the increased interest in disruption management and, consequently, supply chain resilience and vulnerability issues is the awareness, promoted by recent research, regarding the magnitude of losses, both direct and indirect, resulting from supply chain disruptions. Supply chains are facing numerous changes that are contributing to increasing their complexity and vulnerability to disturbances, and so to survive, supply chains must be resilient (Carvalho, Barroso, Virginia et al., 2012).

1.2 The General Problem Area

The consistent and unchanging way of business life that many corporate purchasing departments once enjoyed has now been increasingly imperilled. Threats of resource depletion and the scarcity of raw materials, political turbulence, government intervention in supply markets, intensified competition, and globalisation (Kraljic, 1983) marked the rise of the concept of supply chain risk management that emerged in the early 1980s. This meant that purchasing must become supply chain management, which lead to the further development of supply chain management, and as new challenges were intensified the development of research literature on supply chain resilience management commenced. The increased research focus on supply chain resilience has seen it widen in its scope of interest from viewing resilience as merely to rebound from adverse situations to a mechanism of a shock absorbing attribute; something to be incorporated by firms as an active capability and competitive advantage in turbulent times (Lengnick-Hall, Beck and Lengnick-Hall, 2011, Ponis and Kronis, 2012).

Supply chain disruption response management considers the organisational response repertoire but goes beyond the supply chain risk management focus on cost reduction and time-based competition, including early warnings before an event. Production and partnership approach strategies to suppliers and customers (Chopra and Sodhi, 2004, Tang, 2006) can be effective as an escalation of a disruption to improve the handling of catastrophic events (Chadist, 2012, Sodhi and Tang, 2009). However, what effects do actions taken after the disruption has occurred really have?

1.3 Aim of the Research

The aim of this research was to examine post supply chain disruption management, extending the theoretical framework developed by Bode et al (2011) by using a theory testing design that formulates and tests novel propositions to augment the existing academic body of work on disruption and risk management and exploring new insights into this field of study. The research is set in the challenging environment of the pharmaceutical supply chain and specifically examines the post disruption response strategies of buffering and bridging in managing shortages. Where buffering includes techniques such as building safety stock and bridging includes for example building stronger links with suppliers through intense information exchange.

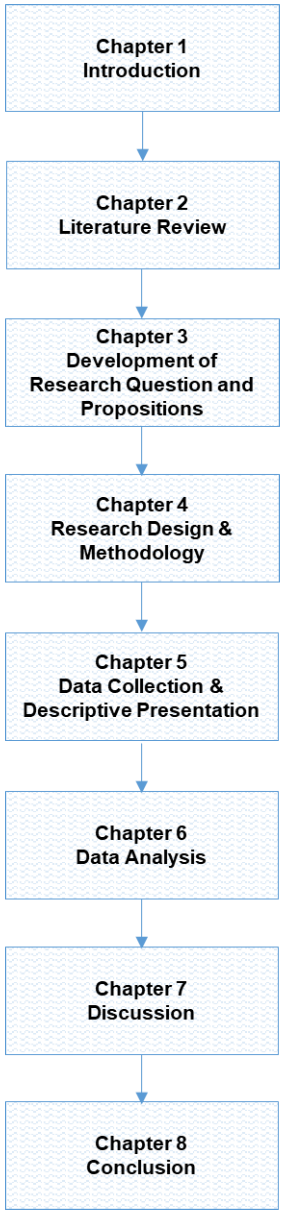
In particular, this research's goal is to understand the interplay of post disruption actions taken after a supply chain disruption event has occurred and to understand how and why those actions are taken and what actually are the subsequent outcomes, rather than relying on the existing normative theory framework. The research question is: How do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management? To answer this question, this research employs a set of propositions, which incorporate fresh aspects of the dynamic and contextual nature of those actions and the resultant conclusions, providing a platform for further study.

1.4 Potential Contribution

The potential contribution of this research is to extend the previous theoretical framework on post supply chain disruption responses to give a deeper understanding of the factors underlying disruption response and subsequent performance. By providing an empirically-based study, testing the three constructs of: *supply chain disruption orientation*, *supply chain disruption performance and organisational response,* to give new insights into the interplay between supply chain disruption response actions to actual disruption events. Based on a thorough literature review, including an in-depth 77 journal review on supply disruption resilience and response management, the testing of the existing model and development of that framework allows other response factors to be newly considered, including feedback, boundary rationality, and dynamic action variations, as well as to provide insights and refinement to the new concept of supply chain disruption orientation. By uniquely incorporating empirically based disruption performance results, it explores the consequences of post disruption actions scenarios for both theory development and practical management application.

1.5 Thesis Structure

The next section outlines the salient structure of the thesis by giving a brief synopsis by chapter as they will appear in this research study, and summarised in the thesis structure diagram below.



Thesis Structure Diagram

Chapter 1: Provides background information regarding supply chain resilience and disruption management to set the scene for the research and to give an overview of the thesis. It includes, as well as the context, the research rationale, research problem, and objectives of this study. A full review of the academic and practitioner literature was conducted to ensure the research is based on current knowledge, is relevant to the research problem, and provides a legitimate foundation for the research argument. The use of the rational, persuasive argument is the stock-in-trade of the researcher. This type of argument uses reasoned discussion or debate to separate fact from fiction (Machi and McEvoy, 2009).

Chapter 2: Is the literature review of the extant body of work for this research. The use of the existing literature on a topic is a means of developing an argument about the significance of a research study and where it leads (Bryman and Bell, 2011). Following the introduction, the literature review is separated into four sections, of which section 2.2 is the first and focuses on the supply chain management literature. Section 2.3 provides a critical overview of the pharmaceutical industry in which this research is based. Section 2.3 is divided into three parts, beginning with the main stimuli in the pharmaceutical industry, and then drilling down into the two main categories within the pharmaceutical industry; the primary manufacturing and the secondary production sectors. Section 2.4 gives a detailed outline of the of supply chain disruption literature, supply chain risk management, supply chain resilience management, and then supply chain disruption response management. The final section 2.5 provides reasons for and the impact of pharmaceutical supply chain shortages including economic, regulatory, manufacturing and health system management.

Chapter 3: Describes and develops the research question from the literature review for this research for the specific area of focus. A new theory framework is proposed in this paper which grows from the current research in resilient supply chain strategic management. The lack of the development of the existing knowledge encourages an extended appropriate analytical framework, which motivates this research to bridge the gap with a new paradigm, including the development of the three main research constructs and the nine subsequent propositions which answer the research question posed to give new insights in this field and provide opportunities for further study.

Chapter 4: Provides an overview of the relevant research design and methodology for this study using the onion research plan (Saunders, Lewis and Thornhill, 2007). Each research philosophy is considered and the research approach and relevant research philosophy chosen. This study chose a predominately positivism philosophy which was balanced with a realism perspective. The research approach chosen was through a deductive approach following the hypothetico-deductive model. The theory based research testing strategy was then aligned with the appropriate methodology chosen, which combined quantitative and qualitative procedures to improve the power of the study. The techniques chosen were three main data collection methods; survey, interview, and focus groups, which lend themselves well to the capture of supply chain post disruption data gathering and analysis. The data collected was then analysed by coding through summarisation, reducing substantial amounts of data into similar groups for proposition testing and theory building on post supply chain actions and outcomes. A key element of the research, because of its focus on the public health arena, was ethical approval and considerations, which are set out in the last section of the chapter.

Chapter 5: Presents the data collection and description and background, including the details behind the various stages of data collection and justifications. This includes the desk research, exploratory interviews, survey design, pilot testing, data coding, interview, and focus group research findings.

Chapter 6: Presents the core research data analysis. This is separated into two main elements: the data analysis of the qualitative interviews and focus groups, followed by the data analysis of quantitative findings, including the descriptive findings, cleaning and recoding, the reliability analysis, analysis assumptions, and diagnostic tests. It then presents the quantitative findings and results for each of the propositions tested, including both time dynamics of immediate and post disruption performance. Lastly, it triangulated the data analysis from the research in the cross cutting analysis, bringing together each of the data collection methods analysis findings to balance out any of the potential weaknesses in each data collection method.

Chapter 7: Provides the discussion of the data analysis findings. This meant going back to the literature and grappling with what the research findings mean, including how they fit in with previous work, and the contribution to scholarly academia in the theoretical implications section. This is executed by considering the research question and each of the propositions separately for clear understanding and interpretation. Where the research results differ from others' findings, an explanation is given suggesting why this is. Then the discussion launches into 'bigger picture' issues; the practical real-world implications of the research and giving examples of how this study’s findings could be usefully assimilated into day-to-day operational practice as advice to practitioners and managers, but also reflecting the wider macro implications.

Chapter 8: Presents the conclusions of this study on post disruption supply chains, including what was carried out, the research contributions, and what was learnt to expand current knowledge. It then acknowledges research shortcomings in an evaluation of the study limitations. It then considers future research areas to highlight what remains to be learnt, including research recommendations.

2 Literature Review

2.1 Introduction

Chapter 2 details the literature that has been reviewed as part of this research project. The beginning of this literature review provides an overview of the broad topic of supply chain management, providing context and to demonstrate key works and concepts. This review then focuses more specifically within the extensive areas of the supply chain management literature. By providing a deeper review than just a general description of supply chain management, this review will identify relevant subsections of the extant literature to provide more effective use of the academic body of work. This research review is conducted within the published knowledge of other academic authors, and in doing so allows this research to be located within the context of that work. Furthermore, this review, by defining the appropriate literature subsections within the wider field, enables a focused review of the more relevant work to the topic of interest. It then goes on to explore these subsections in greater detail. Through critical review of the detail of this subdivision, the gaps in the literature are identified to connect this work to that of the current literature to establish an original academic contribution to current understanding and knowledge. As noted by Machi and McEvoy (2009), the literature review is the foundation for identifying a problem that demands original research, and is the basis for the study of a research problem.

The general process followed in the research methodology for refining this review is illustrated below:

1. Define the search terms
2. Identify the databases
3. Determine and apply criteria for inclusion and exclusion
4. Refer to the reference list of the shortlisted articles
5. Ensure that the resulting articles are representative

By following the above steps, it specifies and frames the research topic to enable a thorough review.

The literature review is structured into four sections following the introduction including the initial overview of supply chain management in section 2.2, so that each one can be looked at in detail. This allows the inclusion of both the relevant academic theory with regards to supply chain disruptions and specific industry knowledge considered relevant within the pharmaceutical sector in which this research will be carried out. The subsequent three sections in chapter 2 are pharmaceutical industry supply chain 2.3, supply chain disruptions 2.4. The intersection shown in the grey circle within Figure 1 highlights the context for final section 2.5 of the literature review: supply chain disruptions in the pharmaceutical industry.

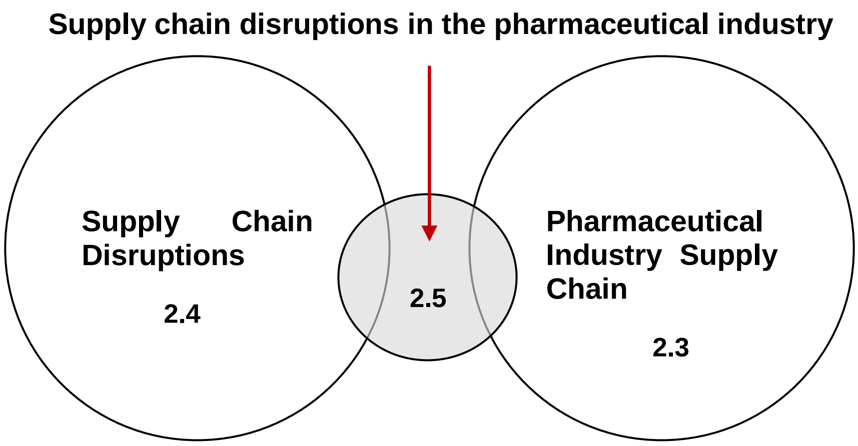


Figure 1. A conceptual outline of the literature review elements describing the overall positioning of this research

The subsections outlined in Figure 1 are to concentrate the review so that the gaps in the current understanding can be highlighted to position and justify this study's research work, and clearly identify the academic contribution. By inclusion of relevant industry-based information, this review avoids the limitations of other reviews solely based on the analyses from the point of view of academics while failing to incorporate the views of practitioners. An academic literature review demands that the review seeks both theoretical and field-based knowledge. The current field-based literature is used to decide the issues, significance, and relevance of the study. The theoretical literature clearly defines the topic and provides the knowledge base for understanding the topic’s breadth and depth (Machi and McEvoy, 2009).

The search terms were defined, and key word searches included supply chain disruptions, risk management, strategic management, strategic resilience management, shortage management, and pharmaceutical supply chain management. Boolean logic was used to frame the database search. These terms were distilled from the initial wider search on the supply chain management research literature as they were more relevant to the chosen topic. The continuous growth of the supply chain risk management literature alone quadrupled between 2003 and 2013, as noted in Ho, Zheng, Yildiz et al. (2015), and so filtration was required so that the review remained focused on the relevant areas of interest. Several criteria were used to filter the articles including resilience, disruptions, risk management methods and research gap identification. Articles were excluded if they did not meet one of the filtration criteria. The shortlisted articles were carefully examined to ensure that an exhaustive search was carried out and that no other articles were omitted from the search. Lastly, the reference list was thoroughly evaluated so that the articles fitted the context of search criteria.

Literature search methods used have been varied, including supply chain and management journals with for example Supply Chain Management: An International Journal, (*SCMIJ),* International Journal of Logistics Management*, (IJLM*), International Journal of Physical Distribution & Logistics Management, (IJPDLM), Journal of Logistics Management, (JLM). These journals were chosen as the most relevant and frequently occurring from the above search criteria. The databases, including ISI Web of Science, Ingenta *(BIDS),* and Science Direct*,* have been utilised. Academic databases were utilised to identify the journal articles, including EBSCOhost, Emerald, IEEExplore, Ingenta, Metapress, Proquest, ScienceDirect, Springer, Scopus, Taylor and Francis and Wiley, have been used for some aspects of the literature searching. In addition to searching for academic articles, a large volume of practice material was gathered from government and non-government organisations, such as Department of Health (PPRS), World Health Organisation (WHO), European Federation of Pharmaceutical Industries and Associations (EFPIA), and corporate publications.

Further to the introduction of the literature review above, the following section outlines the wider topic of supply chain management.

2.2 Supply Chain Management

Supply chain management is not a novel management paradigm as such. Instead, it represents a new focus on how to link organisational units to best serve customer needs and to improve the competitiveness of a supply chain as a whole (Stadtler, 2005). In this endeavour, supply chain management has drawn knowledge and approaches from a number of disciplines like computer science, logistics, marketing, operations research, organisational, theory and many more. To extract, adapt, and combine those approaches that best suit a specific supply chain is the challenge of managing a supply chain successfully (Simchi-Levi, Kaminsky and Simchi-Levi, 2003).

Supply chains are defined by Christopher, McKinnon, Sharp et al. (2002) as the management of upstream and downstream relationships with suppliers and customers in order to create enhanced value in the final marketplace at less cost to the supply chain as a whole. As defined by the Supply Chain Council Report (2002), a supply chain encompasses every effort involved in producing and delivering a final product from the supplier’s supplier to the customer’s customer.

The origin of the supply chain concept has been inspired by many academic fields which Chen and Paulraj (2004) list as:

1. The quality revolution (Dale, Lascelles and Lloyd, 1994)
2. Notions of materials, management, and integrated logistics (Carter and Price, 1993, Forrester, 1961)
3. A growing interest in industrial markets and networks (Ford, 1990, Jarillo, 1993)
4. The notion of increased focus (Porter, 1987, Snow, Miles and Coleman, 1992)
5. Influential industry-specific studies (Womack, Jones and Rood, 1990, Lamming, 1993)

Researchers find themselves inundated with terminology such as 'supply chains', 'demand pipelines' (Farmer and Amstel, 1991), 'value streams' (Womack and Jones, 1994), 'support chains', and many others. The term supply chain management (SCM) was originally introduced by consultants in the early 1980s (Oliver and Webber, 1992) and has subsequently gained tremendous attention (Londe, 1998) where supply chain management (SCM) is the concept of the management of the entire supply chain, or as Drucker (1998) p12. defines in his description of new management paradigms:

> Supply chain management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders.

A typical supply chain, as shown in Figure 2, is a network of materials, information, and services processing links with the characteristics of supply, transformation, and demand. Both suppliers (1) and customers (3) are connected to the internal supply chain (2) which consists of the purchasing, production, and distribution overlapping functions. The term supply chain management has been used to explain the planning and control of materials and information flows as well as the logistics activities, not only internally within a company but also externally between companies (Cooper, Lambert and Pagh, 1997, Fisher, 1997).

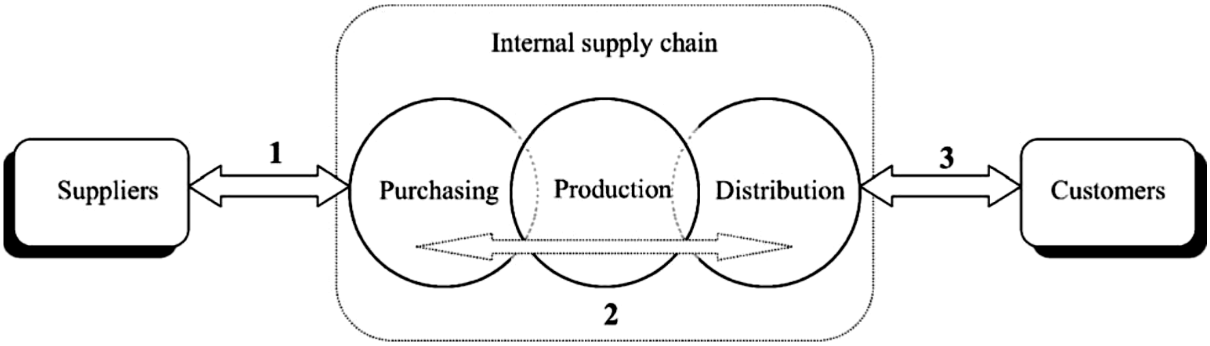


Figure 2. An illustration of a company's supply chain. Adapted from Chen, I.J., Paulraj, A, (2004)

Improving product and process quality have been well established as ways by which organisations can respond to increased global competition. Now, however, the challenges facing organisations go beyond improving quality. Organisations are increasingly faced with the reality that they cannot exist in isolation, but are one piece of a complex chain of business activity. Supply chain management studies support this notion and confirm that all three major components of a supply chain, suppliers, manufacturers, and customers, must be effectively integrated in order to achieve financial and growth objectives (Tan, Kannan, Handfield et al., 1999). Successful management of the supply chain is the key to the long-term success of an organisation. This cannot occur, however, if organisations implement business practices in an arbitrary, uncoordinated manner, or if they direct scarce financial resources to initiatives that are unlikely to yield positive outcomes. With product lifecycles shrinking, firms must unceasingly pursue new markets, modern technologies, and improve cost and delivery performance. Supply chain management provides a framework within which to implement a well-conceived market strategy, but it cannot undo the effects of a poorly conceived one. It is therefore imperative for managers to ensure their quality and procurement implementation strategies, tactics, and measurements are correctly aligned with strategies in the areas of finance, operations, marketing, new product development, and sales. Tan, Kannan, Handfield et al. (1999) noted there is a need to understand how future strategies will unfold and how organisational strategies will merge given different competitive objectives.

The strategies that organisations use to cope with the new supply chain environment are changing. Globalisation and changes demanded by stakeholders have influenced the attitudes of supply chain entities. These entities are becoming more professional, showing ever increasing levels of complexity, and adopting philosophies and management practices with the objective of increasing their levels of competitiveness. Competitiveness is a critical factor in the success of a supply chain. Disturbances increase supply chain challenges and may reduce its performance and competitiveness. It is therefore fundamental for a supply chain to be resilient to disturbances (Barroso, Machado and Cruz-Machado, 2011). Today's supply chains are more complex than they used to be. There are various reasons for supply chain complexity, such as higher levels of R&D and manufacturing outsourcing, supplier–supplier relationships in supplier networks, increased dependence on supplier capabilities, new technologies (e.g., Internet, RFID), regulatory requirements (e.g., post 9/11 security regulations such as C-TPAT, or food safety controls), shorter product lifecycles due to rapidly changing customer preferences, and international market and production expansion (Wagner and Neshat, 2010).

2.2.1 Summary

Section 2.2 & gives an overview of the supply chain literature as an introduction and a contextual overview for the literature review. Section 2.3 reviews the specific industry perspective of the pharmaceutical supply chain, which has a complex international dynamic. Section 2.4 begins by defining and discussing the central concepts of resilience and disruptions within the scope of supply chain management to concentrate the area of academic research focus. Last section 2.5 reviews supply chain disruptions within the context of the highly regulated pharmaceutical supply chain, which has experienced the considerable impact of supply chain disturbances.

2.3 Pharmaceutical Supply Chain

Section 2.3 presents an overview of the pharmaceutical supply chain and, following a brief introduction, begins with section 2.3.1: drivers in the pharmaceutical industry, after which there is a detailed explanation of the two of the main areas of distinction within the pharmaceutical supply chain; section 2.3.2, the primary manufacturing, and

2.3.3, the secondary manufacturing. This is followed by 2.3.4, the pharmaceutical distribution chain and finally the section summary.

Economic and globalisation trends are having a major impact on the pharmaceutical drug manufacturing sector. As multinational drug manufacturers struggle with rising costs, expiration of blockbuster drug patents, and changes in government legislation within their largest markets, Europe and the United States, opportunities are increasing within Asia and South America. These trends have caused manufacturers to re-engineer their supply chain strategies as a consequence. The global pharmaceutical market is expected to reach $1 trillion by 2014 and nearly $1.1 trillion by 2015. Although the United States and Europe have led the world in terms of pharmaceutical sales for many years, according to some estimates, the US share of global pharmaceutical spending is expected to decline from 41% in 2005 to 31% in 2015. As sales slow for both regions, emerging countries are demonstrating strong growth as their markets continue to open up for investments. During the subsequent five years, growth in emerging markets is expected to nearly double to between $285bn and $315bn, compared with spending of $151bn in 2010. There is a cluster of large, research and development-based multinationals with a global presence in branded products, both ethical/prescription and over-the-counter. This group dominates the marketplace and, due to the global nature of the enterprises involved, tends to have the most challenging supply chain problems (Shah, 2004).

In the past, scant attention was paid to supply chains as manufacturers were focused on blockbuster drug sales. The changing government role within the pharmaceutical drug industry, especially in the Europe and United States markets, has meant that manufacturers are now faced with supply chains that are not effective in a sector that is in transformation. With the globalisation of the drug manufacturing sector, manufacturers are targeting emerging markets such as China and Brazil as locations not only to sell to, but also as locations for outsourcing such operations as manufacturing, research and development, and clinical trials. However, an array of issues such as security, intellectual property, and knowledge of government legislation within these emerging markets has presented challenges to drug manufacturers. China is one of the fastest growing markets among the emerging countries (Ni, Zhao, Ung et al., 2017). With China’s share of pharmaceutical industry output augmented nearly seven-fold, from 2.5% in 1995 to 18.3% in 2010, it is expected to become the second-largest pharmaceutical market in the world by 2020 (National Institutes of Health, 2015). This changing trend may also apply to the global healthcare innovation networks as increased sales performance can better support R&D.

China has risen to a worldwide leading position at an accelerated pace in terms of R&D funding, pharmaceutical publications, and patents in recent years (Gautam and Yang, 2014). With the perspective of switching from imitation to innovation, R&D outlay in China's pharmaceutical industry increased from $162.6 million USD in 2000 to $3249.2 million USD in 2011 (Qiu, Chen, Lu et al., 2014).

Figure 3 shows there has been a dramatic rise in research focus in Chinese pharmaceuticals. However, it should be noted that despite the increase in innovation and creation in academic pharmaceutical research, there is still a time lag in patent licensing, The difficulty of patent licensing by universities may imply a considerable gap between academic research and innovative products (National Bureau of Statistics China, 2015).

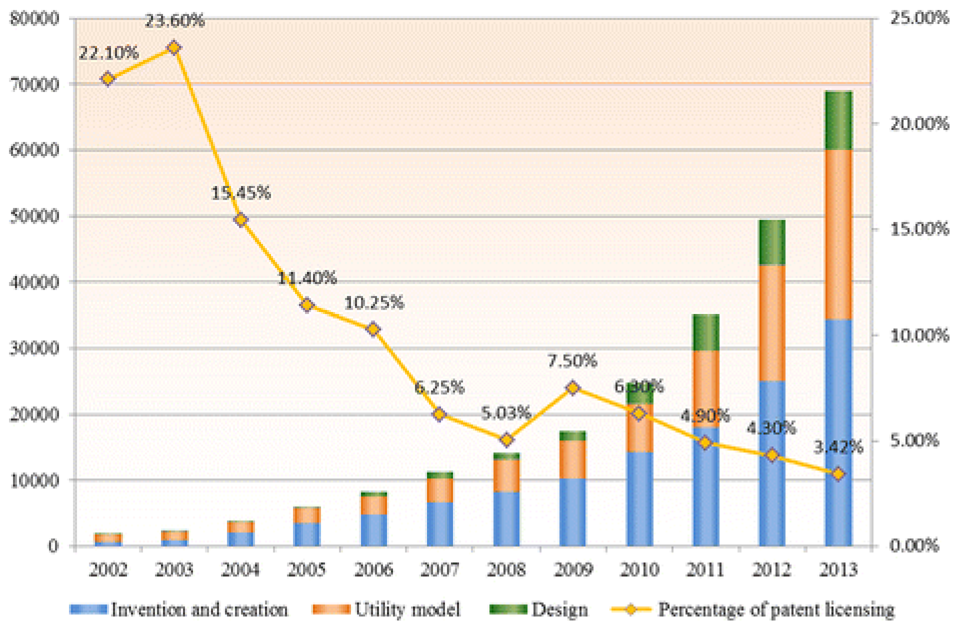


Figure 3. Granted patents and licensing percentage of Chinese universities. Data source: China Universities Statistics Yearbook (2015)

The World Health Organisation (WHO) defines a drug or pharmaceutical preparation as any substance or mixture of substances manufactured, sold, offered for sale or represented for use in the diagnosis, treatment, mitigation, or prevention of disease, abnormal physical state or the symptoms thereof in man or animal; [and for use in] restoring, correcting or modifying organic functions in man or animal. This is a very wide definition, and correspondingly, there are a number of key players in the pharmaceutical industry, as stated by Shah (2004), including:

1. The large, research and development-based multinationals with a global presence in branded products, both ethical/prescription and over-the-counter. They tend to have manufacturing sites in many locations.
2. The large generic manufacturers, who produce out-of-patent ethical products and over-the-counter products.
3. Local manufacturing companies that operate in their home country, producing both generic products and branded products under licence or contract.
4. Contract manufacturers, who do not have their own product portfolio, but produce either key intermediates, active ingredients (AI), or even final products by providing outsourcing services to other companies.
5. Drug discovery and biotechnology companies, often relatively new start-ups with no significant manufacturing capacity.

A supply chain is defined as a system whose constituent parts include material suppliers, production facilities, distribution services, and customers linked together via a feed forward flow of materials and feedback flow of information (Naylor, Naim and Berry, 1999), and includes the flow of resources and cash through the supply chain (Naim, 1997). The pharmaceutical industry is mainly focused on the production or manufacturing part of the supply chain network rather than the end delivery to patients, which is described as a divided structure (Savage, Roberts and Wang, 2006). One of the reasons this may be the case is with nearly $350 billion of pharmaceutical sales in 2005, logistics costs tend to be far lower against revenue than other industries.

According to Booth (1999), the high returns on investment and high turnovers from 'blockbuster' products resulted in the following regime:

1. Good R&D productivity, often creating compounds to treat previously untreatable diseases;
2. Long, effective patent lives of these compounds;
3. Ability of these patents to provide technological barriers to entry;
4. A limited number of product substitutes in a given therapeutic area; and
5. A low-price sensitivity; supported by the separation between

6. Prescribing and paying responsibilities.

The resulting corporate strategy was to ensure high margins by exploiting the price inelasticity and invest a substantial proportion of the resultant profits in R&D (approximately 25% of sales), in order to ensure a healthy product pipeline. The more recent circumstances are much more challenging:

1. R&D productivity (in terms of numbers of new chemical entities (NCE) registered per unit amount of investment) is declining;
2. Effective patent lives are shortening;
3. Even while active, patents provide lower barriers to entry;
4. There are many product substitutes in many therapeutic areas; either alternative compounds ('me-too drugs') or off-patent generics; and
5. The payers of healthcare are exerting strong price pressure and influencing prescribing practices; this means that in order to be approved, new drugs must address new therapeutic areas or have very significant cost or health benefits over existing treatments.

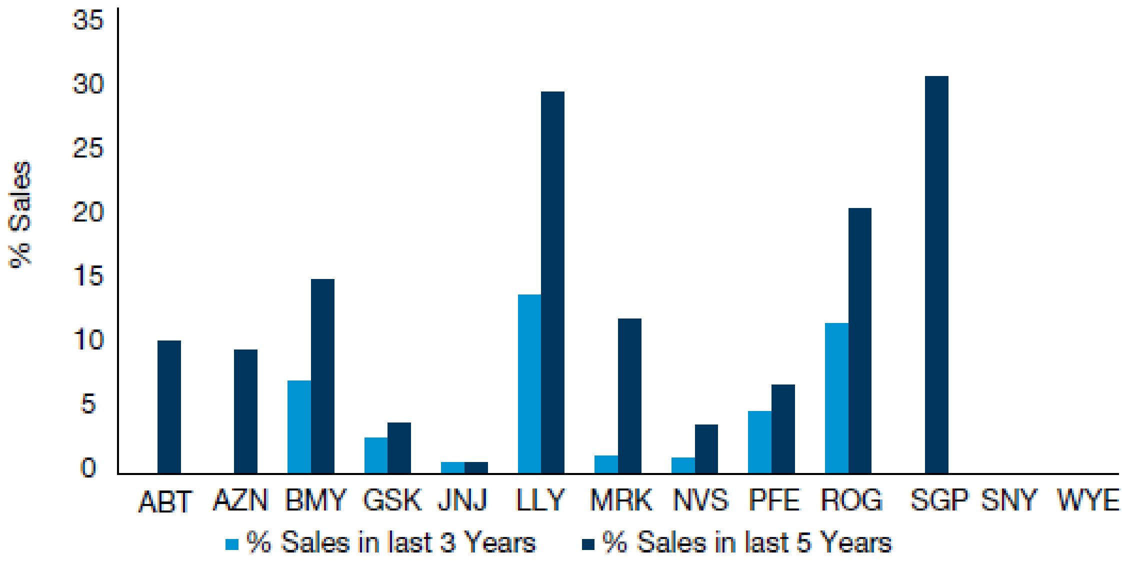
As shown below in Figure 4, the leading pharmaceutical companies will lose between 14% and 41% of their existing revenues because of patent expiries, this squeeze on revenues has focused attention on all costs in the pharmaceutical industry, including the costs and efficiencies in the drug supply chain.

Company	2010		2011		2012		Share of Revenues (%)
AstraZeneca	Arimidex	($2.2bn)*	Seroquel	($4.7bn)	Symbicort	($3.7bn)	38**
BMS			US Plavix Avapro	($4.8bn) ($1.3bn)	Abilify	($2.1bn)	30
GSK	Advair	($3.8bn)			Avandia	($2.5bn)	23
Eli Lilly			Zyprexa	($4.8bn)			22
Merck	Cozaar/ Hyzaar	($3.2bn)			Singulair	($4.5bn)	22
Novartis	Femara	($1.1bn)			Diovan	($6.0bn)	14
Pfizer	Aricept	($800m)	Lipitor Xalatan	($12.1bn) ($1.6bn)	Viagra Detrol Geodon	($1.7bn) ($860m) ($1.1bn)	41
sanofi-aventis	Taxotere	($2bn)	US Plavix Avapro	($3.8bn) ($2.1bn)	Lovenox	($3.1bn)	34

Figure 4. Source AXA (Brand name of Assurances du Groupe de Paris) Framlington in PricewaterhouseCoopers

Notes: *Estimate of global sales in 12 months prior to patent signing
** Value of products losing patent protection as a percentage of total company sales over the next five years

On the one hand, the global marketplace has become more liberalised, exposing products to competition. On the other, governments and other agencies have tended to intervene more as they become concerned at the increasing healthcare costs associated with ageing populations. Measures taken include strict controls on the prices of new drugs, more cost–benefit analysis, and encouragement of the use of generic substitutes or replacements where possible. A further weakness that will hamper the large players in the area is the historical dependence on 'blockbuster' drugs. As shown in Figure 5, only five of the top pharmaceutical companies for example Schering Plough, generate more than 10% of revenues from products that were launched in the last five years (PricewaterhouseCoopers, 2007).



Legend

Pharmaceutical Company Acronym	**Company**
ABT	Abbott
AZN	AstraZeneca
BMY	Bristol Meyers Squibb
GSK	GlaxoSmithKline
JNJ	Johnson & Johnson
LLY	Eli Lily
MRK	Merck
NVS	Novartis
PFE	Pfizer
ROG	Roche
SGP	Schering Plough
SNY	Sanofi
WYE	Wyeth

Figure 5. IMS (Intercontinental Marketing Statistics) Healthcare and PricewaterhouseCoopers Analysis

Patent protection as with other restrictions on the pharmaceutical supply chain can create shortages for the downstream market. As highlighted in the preceding sections, patented blockbuster drugs can mean high price barriers especially in the launch phase of the new effective drug treatment. Governments can place caps on supply or simply not sanction their purchase at inflated prices, for example by the instruction of authorising bodies such as the National Institute of Clinical Excellence (NICE) in the UK. However even when NICE approves product, the Government can still block or ration products to the very sickest, e.g. the patented drug Solvaldi, for treating liver disease which costs £35,000 for a 12 week course (Wapner, 2017).This causes shortages of the drug and alternative treatments sort. In addition, changes to patents by issuing license providers, may reduce the length of the patent, but this may result in changes in manufacturing and location by the producers (Breen, 2008). This in turn can create downstream shortages, as supply maybe coming from offshore outsources as producers push mature or out of patent products which are less profitable to lower cost and potentially lower quality primary production (Huq, Pawar and Rogers, 2016). This has been particularly evident in terms of the manufacture of generic drugs or those coming off patent (Marucheck, Greis, Mena et al., 2011). Patent and license management is a key commercial tool for pharmaceutical suppliers, and by restricting new suppliers in a specific market it can create an artificial shortage through difficult or prohibitive costs in downstream purchasing (Habermann, Blackhurst and Metcalf, 2015). An example was the shortage of HIV medicines to treat the AIDS epidemic in Africa due to the super high pricing by the patent holders. Price campaigners eventually succeeded in enlisting the India company Cipla to make low cost versions of the HIV triple-drug combinations in 2001 that cost $100 per person a year instead of $10,000. Patents normally apply for about 20 years but must be registered in the country where the drug is sold. That stops other companies making rival copies that might compete to push prices down. India had different intellectual property rules at the time, which meant the HIV drugs patent, did not apply there. But the rules have since changed and attempts to make cheap copies of new drugs such as the new Hepatitis C drug have faced long court battles (Boseley, 2017)

2.3.1 Drivers in the pharmaceutical industry

Probably the single most important driver in the pharmaceutical industry is the time-to-market. Companies secure very significant returns in the early life of a successful drug, before any competition. In Figure 6 below the life cycle of typical pharmaceutical products is shown, taking products eight to 12 years to come to market, with only a small percentage of molecules researched actually making it into production launch. The industry itself is separated into the discovery, exploratory, and full development phases of medicine production in a typical 15-year cycle per new product, with the added complication of globalisation and multiple layers of delivery through distributors and wholesalers. The pharmaceutical supply chain typically has four tiers at global and regional levels; from the fourth tier of API manufacturing, tier three, the processing of API into tablet or delivery form, tier two, the packaging stage, and finally the distribution and repackaging phase to final customer. As per Figure 6, production ramps up until approximately year eight, depending on the product, and the company must maximise its profits during this period, as once the product matures and goes towards the generic (GX) production phase, costs are under severe pressure and profitability reduces. The profit reduction also often leads to a reduction in production, affecting the supply of now established drugs on the market.

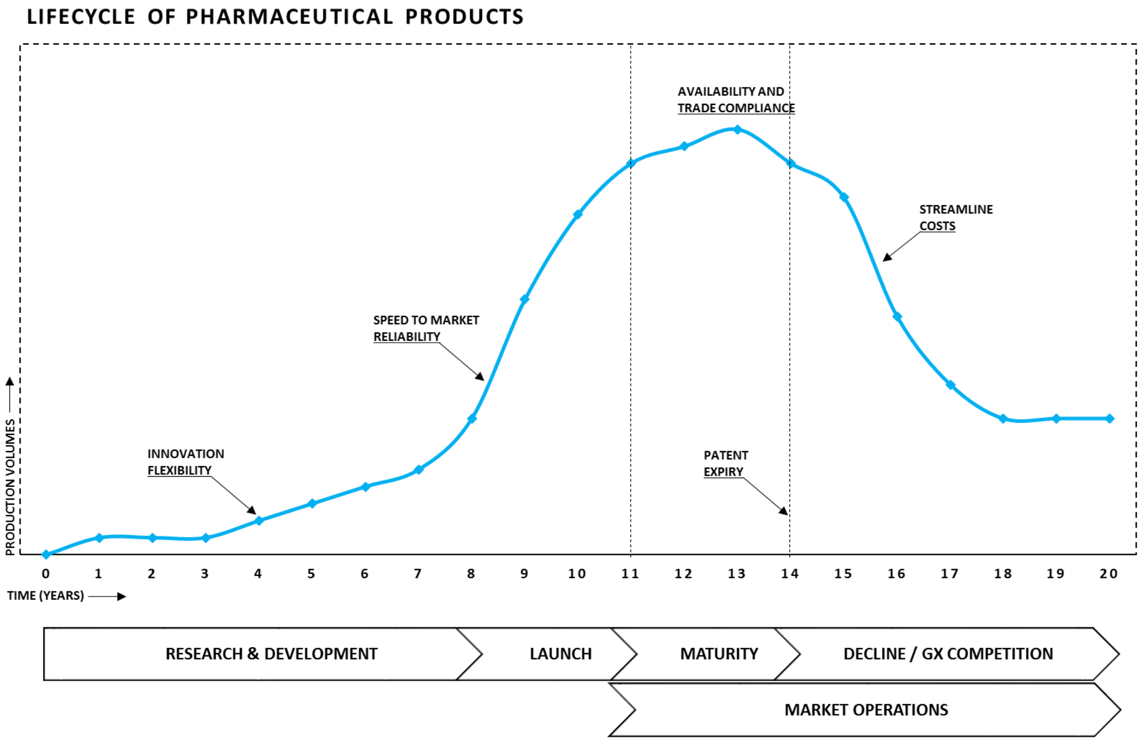


Figure 6. Life cysle of pharmaceutical product

The competition-free early life high-returns period, is, however, shortening, previously averaging five years, whereas now it is between one to two years. Competition in this sense relates to similar (rather than identical) drugs. For example, Bayer's anti-cholesterol drug Baycol was withdrawn in 2001 due to safety concerns, and the two later entrants, Pravachol (from BMS) and Lipitor (from Pfizer), are now the biggest sellers for their companies (Butler, 2002). Given the significant potential for adverse health effects, the industry is subject to very stringent regulation. This starts from the processes used to evaluate the safety and efficacy of the chemical compounds, through to the details of the process and plant design and manufacturing operations. The primary regulator that the companies must satisfy is the US Food and Drug Administration (FDA). It may be the case that the existence of regulatory protocols has hindered innovation in this sector; with companies blaming regulators for their own innate conservatism.

The regulatory process tends to be slow and expensive; both these effects must be borne by the industry. Furthermore, the complex chemical compounds involved have more complex manufacturing processes, and the activities of route investigation, process development, scale-up plant design/retrofit, commissioning and qualification are either increasing in duration or proving stubborn to shorten. It is estimated between £200m to £400m is required to launch a new drug, and an average of eight to 12 years elapses from patent filing to first sale (Grabowski, 1997). Before the medicines even reach this 'supply stage', though they have been through multiple regulatory frameworks, for example, the 2008 Pharmaceutical Price Regulation Scheme (PPRS) and contractual/non-contractual and pricing approvals through government agencies, such as the Commercial Medicines Unit (CMU) and the National Institute for Health and Care Excellence (NICE) in the UK. Each participant in a drug delivery process has their own motivation, access to information, and is regulated and managed in different ways (Breen, 2008).

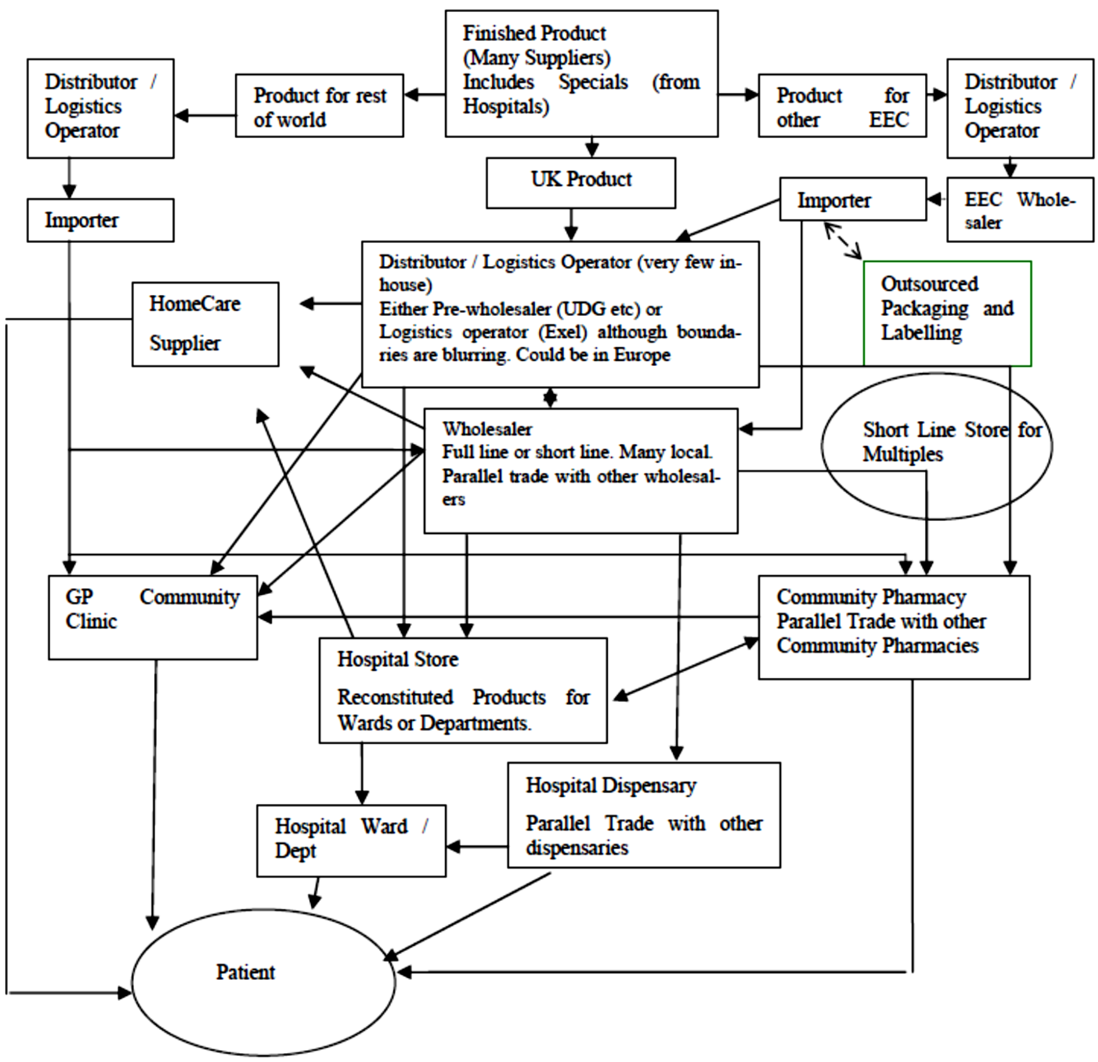


Figure 7. The UK pharmaceutical supply chain map, as identified by the pharmaceutical stakeholder group (Breen, 2005)

Figure 7 shows the UK supply chain map (Breen, 2005), with its multiple layers and actors. This map was summarised from inputs by a range of stakeholders at different levels within the UK pharmaceutical supply chain as part of the aforementioned pharmaceutical supply chain research, looking at the causes of pharmaceutical shortages in the UK National Health Service. The map of the pharmaceutical supply chain describes the manifold of channels the medicines can flow through in the pharmaceutical supply chain. The pharmaceutical supply chain fabric is complex, as shown above in Figure 7, and is regulated and monitored by parties such as the Department of Health (DOH), National Institute for Health and Clinical Effectiveness (NICE), Medicine and Healthcare Products Regulatory Agency (MHRA), Medicines Controls Agency, and the National Health Service Purchasing and Supply Agency (NHS PASA), to name but a few (Breen, 2008). To further understand the pharmaceutical supply chain, it is important to identify the fundamental actors within it. As summarised in Table 1 below, the key stakeholders in the UK pharmaceutical supply chain can be grouped into seven categories as pharmaceutical shareholders:

1. National Health Service (NHS)
2. Pharmaceutical Industry
3. Support Industry
4. Patients Representatives
5. Government Agencies
6. Health Care Professionals
7. Others

National Health Service Organisation	Pharmaceutical Industry	Support Industry
NHS Confederation	Branded Manufacturers (ABPI)	Logistics providers
Acute (Secondary) Trusts (DGH &	Generic Manufacturers (BGMA, EGMA)	Healthcare at Home Providers
Teaching)	Wholesalers (BAPW)	IT Suppliers
Primary Care Trusts	Parallel Importers (BACPD)	Pharmacy System Supplies
Strategic Health Authorities	Shareholders and investors	Automated picking and distributive system suppliers
Purchasing Consortia	Proprietary Association of Great Britain	Processing and Packing Marketing Association
Purchasing Confederations	International Federation of Pharmaceuti	IMS
Supplies Departments	Manufacturers Association	
Clinical Directorates	European Federation of Pharmaceutical	
NHS Direct	Industries and Associations	
Medicines Information		
Formulary Management Systems		
Area Prescribing Committees		
Finance Department		
Audit		

Patients Representatives	Government Agencies	Health Care Professionals	Others
Patient Care Groups	UK	Doctors (Dispensing), BMA	Private Hospitals
Taxpayers	Central Government	Pharmacists (RPSGB, GHP, NPA,PSNC)	Nursing Homes
NGO's (Medicines sans Frontiers	Dept of Health (PPRS)	Nurses (UKCC)	Insurance Companies (BUPA)
Lobbying Groups	Medicines Control Agency (MCA &	Professions Allied to Medicine	Other professional Groups (CIPS)
	CSM)	Dentists	National Office of Animal Health
	National Institute for Clinical Excellence	Other prescribers	Large retail pharmaceutical chains
	Commission for Health Improvement	Prescribing Advisors	
	Prescription Pricing Agency (PPA)		
	Purchasing & Supply Agency (PaSA)		
	NHS Logistics		
	Audit Commission		
	National Patient Safety Agency		
	Office of Fair Trading		
	NHS Information Authority		
	National Prescribing Centre		
	European		
	European Medicines Evaluation Agency		
	Committee for Proprietary Medicinal		
	Products		
	International		
	World Health Organisation		
	Federal Drugs Agency		

Table 1. Key stakeholders in the pharmaceutical supply chain

These stakeholder actor groups overlay the above supply map representing multiple interest groups, each with its own agenda and priorities.

Within each interest group, there are numerous roles that individual managers have that can determine their sphere of influence and the decisions that they make. In the case of secondary care pharmaceutical management within the National Health Service (NHS), previous work on roles was looked at internally using a focus group approach and produced an NHS report (National Health Service, 2005b) looking at NHS processes involved in NHS hospital pharmacy procurement in the area of logistics and supply chain management. This work focused on the key roles of individuals involved in pharmaceutical delivery within the NHS. It highlighted that there was a need to identify a knowledge and skills framework for roles within the pharmaceutical management supply chain. It identified several key observations; discussion at the focus group indicated that a wide variety of work practices existed which would make a detailed analysis difficult to apply to all trusts. A list of work processes was developed for each of the three separate functions; procurement, distribution, and supply chain management. In reality, different managers at different trusts had mixed skills and roles, so that assuming one named role has all or only a set number of skills and knowledge could be misleading in reality.

The complexity in the supply chain of medicines and the difficult decisions that result from drug choice has led to a new discipline being developed to help understand the relevant large data output. Pharmacoeconomics helps in making choices by identifying and weighing up the value of pharmaceutical products and services from multiple perspectives. Pharmacoeconomic research allows decision-makers to characterise and compare alternative treatment options, in terms of primary healthcare outcomes, including: (1) clinical (medical events that occur because of disease or treatment); (2) economic (including direct, indirect, and intangible costs); and (3) humanistic (consequences of the disease or treatment from the patient's perspective, including satisfaction with care, functional status, or quality of life). This expansion in demand for pharmacoeconomic data will be spurred on by greater knowledge or sophistication among healthcare decision-makers over how such information can be used to greater advantage (Thwaites and Townsend, 1998).

The drugs do not flow physically directly from the product manufacturer to the end user, in this case the patient, and there are a number of causes for this, including both regulatory and the market environment. Instead, the routes taken are convoluted in the UK and are similar to pharmaceutical supply chains in other countries and similar issues exist, such as counterfeit medications and product shortages (World Health Organisation, 2006). Research has indicated that in Europe medicines can travel through as many as 20 to 30 pairs of hands before it finally reaches the patient (Haigh, 2004).

There is a general trend for companies to divest excess capacity that came about from having many local manufacturing sites, and move towards a global supply chain (Shah, 2004). This brings with it many complex coordination issues and much tighter capacity constraints. Currently, the logistics cost in the sector is relatively high (Booth, 1999). Research efficiency is declining in the sense that the cost of each new chemical entity is increasing. Although growth in investment in R&D has exceeded inflation over the last 30 years, the global trends are as follows: 844 New Chemical Elements (NCE) were registered in 1961–1970, 665 in 1971–1980 and 506 in 1981–1990 (Ballance, Pogany and Forstner, 1992). This has been one of the main drivers behind the recent series of mergers and acquisitions in the industry, the long-term benefits of which will probably not be felt for some time yet as R&D activities continue to be consolidated. As such, several drug manufacturers have acquired competitors with newer products to fill their own sales gaps. In the last two years, Pfizer paid $68bn for Wyeth, Merck paid $4bn for Schering-Plough, Roche paid $46bn for Genentech, and Sanofi-Aventis paid $20bn for Genzyme (Transport Intelligence, 2011).

Historically, most management attention has been paid to drug discovery and sales and marketing (the extreme ends of the supply chain), but now much more attention is being paid to supply chain optimisation as a means of delivering value. There is a welcome move away from viewing the supply chain as merely having to deliver security of supply at minimum cost, to a recognition of its ability to generate both value for the customer and hence to the shareholder, and restructuring of the supply chain along regional and global lines will require massive reductions in capacity, which was acquired in many cases to propitiate national interest in return for sympathetic pricing (Booth, 1999).

There are several components of the pharmaceutical industry manufacturing and distribution chain. A typical pharmaceutical supply chain will consist of one or more of the following nodes:

1. Primary manufacturing (possibly including contractor sites);
2. secondary manufacturing (possibly including contractor sites);
3. market warehouses/distribution centres;
4. wholesalers;

5. retailers/hospitals.

These five components are explained in more detail in the following three sub sections; section 2.3.2 and 2.3.3, concentrating on the industry manufacturing, and section 2.3.5 commenting on the pharmaceutical distribution chain.

2.3.2 Primary manufacturing

The primary manufacturing site is responsible for the production of the active ingredient (AI or API). This normally involves either several chemical synthesis and separation stages to build up the complex molecules involved, or fermentation and product recovery and purification in the case of biochemical processes. The manufacturing process is characterised by long task processing times, often rounded to multiples of shifts. Where multistage processes are operated, considerable inventories are often held between stages. Furthermore, material from an intermediate stage must often pass some form of quality control check before being approved for use downstream in the process. This can introduce additional delays into the system. The traditional process technology involves batch equipment and flexible pipe work. The relatively low production volumes result in multipurpose plants to spread the capital cost between products. The need to avoid cross-contamination of products and requirements for validated cleaning, plus changeovers, results in long downtimes between products. These have been of the order 4 weeks in the past, but the application of techniques is similar to the single-minute exchange of die (SMED) methods that (Moser, Calderari and Morini, 2000) applied to the car industry have reduced these times somewhat. These downtimes, in turn, imply that long campaigns are the norm; otherwise equipment utilisation is too low. It is not unusual for one year's production of a product to be produced in a single campaign, and the material produced being stored until the next campaign in the following year. Since most complex pharmaceuticals are produced through multistage processes, the same often holds true for the stable intermediates (stage products). This mode of operation does not lend itself well to responsiveness, and contributes significantly to some of the poor supply chain metrics exhibited by this industry. A further source of complexity (and convenience) is the use of contractors to manufacture some, or indeed all, of the active ingredient stages. This process of outsourcing is a growing one, as research-oriented companies concentrate on the discovery and development activities and rely on third parties' manufacturing competence. This gives rise to extended supply chain co-ordination problems.

2.3.3 Secondary manufacturing

This is concerned with taking the active ingredient produced at the primary site and adding 'excipient' inert materials, along with further processing and packaging, to produce the final products, usually in SKU form. For example, a product that is sold in pill form would undergo:

1. Granulation: with addition of all the excipient materials;
2. compression: forming the pills;
3. coating;
4. quality control; and
5. packaging.

The secondary manufacturing locations are often geographically separate from the primary manufacturing locations. This is frequently the outcome of tax and transfer price optimisation within the enterprise. There are often many more secondary manufacturing sites than primary ones, serving local or regional markets. Transportation between sites is of the order of one or two weeks if by ship (usually the default mode), and of the order of one or two days if by air.

2.3.4 Pharmaceutical Distribution Chain

Wholesalers play a significant role in this sector. They tend to be large and few. About 80% of demand flows through this channel in the UK (with three large players accounting for almost all the demand), with the large part of the remainder going to hospitals. In the US, another intermediary is growing; the managed care organisation (MCO), or healthcare maintenance organisation (HMO) (Shah, 2004).
However, as the market shifts towards personalised healthcare, an increasing focus is on a narrower group of individuals. Many of these newer drugs require more complex manufacturing and distribution processes than shelf-stable pills. Also, the push for safety in the supply chain is a factor in requiring backward visibility to manufacturers' suppliers and suppliers' suppliers in a robust and real-time way. Market warehouses and distribution centres, whether run by third party logistic companies or through

dedicated or multi-user distributor, are at the centre of the distribution chain, however, these can be missed out in a direct to market model favoured by some larger pharma companies.

Fluctuation in demand for branded and generic products, and changes in distribution channels, are also driving the continued evolution of supply chain models. For example, the loss of patent protection is impacting the supply chains of both manufacturers and large retailers. For generic drugs, 70% are now delivered direct to retailers in the US, compared with just 10% of brand-name drugs. This volume of generic drugs now sold through the retail channel is leading many large retailers to work directly with manufacturers to integrate products into their own distribution network for less complexity and cost. New direct-to-patient, high-cost specialty therapies are also causing manufacturers to reconsider how they take products to market to better respond to consumer demand. As well as retailers, hospitals themselves are involved in the distribution chain in several ways including supply to other hospitals and groups, and to logistics companies and to and from the parallel trade and, in some cases, urgent specials and reformulations.

Pharmaceutical companies are businesses, not public health agencies; they are not obligated to make certain types of drugs, for example, vaccines. To determine where they should invest research and development (R&D) dollars, pharmaceutical companies evaluate a product's potential to contribute to their bottom line. Among the four large companies that are still making vaccines, these account for less than 1% of the worldwide vaccine industry. None has revenue from vaccines that exceeds 10 percent of total revenue (Offit, 2005).

The growth in emerging markets adds another level of complexity. Global pharmaceutical outsourcing has become increasingly prevalent, but is creating a complex and risky supply chain environment. This global expansion is making it more difficult for pharmaceutical manufacturers to manage their supply chain. The need for a flexible supply chain is great as the industry undergoes changes in product mix, manufacturing routes, and distribution channels for different kinds of products (Transport Intelligence, 2011).

2.3.5 Summary

In summary, section 2.3 introduces the drivers in the pharmaceutical industry, including the primary and secondary manufacturing aspects of the supply chain as it is complex and interlinked, so that a disruption in just one aspect can create downstream havoc. It ends with the distribution chain for pharmaceuticals review, including the remote and widespread outsourcing, and financial factors. Section 2.4 presents a comprehensive understanding of the current knowledge on the topic of supply chain disruptions, including risk management, resilience management, distribution response, and specifically, supply chain disruptions in pharmaceuticals.

2.4 Supply Chain Disruptions

This section outlines the process followed in the literature review of supply chain disruptions, highlights the areas of selected focus, provides the context and background about the current knowledge of the topic, and lays out the argument for further research.

The literature review followed a six step process, as recommended by Machi and McEvoy (2009), from topic selection which then specified and framed an initial search of the literature. The review then explored and catalogued related topics. Next, the review developed the argument to refine the area of interest, and then organised and formed the basis of the literature survey. The review then documented and discovered evidence for the next step, which was the critique of the literature which then advocated and defined the written review. The following topics were selected from the extensive literature in the field of supply chain management, as introduced in section 2, as most relevant from the review process.

The focus of the review of the extant literature considering supply chain disruptions will include the relevant management literature, as well as the following main related topics:

1. Supply Chain Risk Management
2. Supply Chain Resilience Management

3. Supply Chain Disruption Response Management

This is to concentrate the review so that the gaps in the current understanding can be highlighted to position and justify this study's research work and clearly identify the academic contribution.

A review of the extant literature, focusing on supply chain disruptions, revealed a wide range of perspectives have been researched. These include supply chain risk management (Vlachos, Iakovou, Papapanagiotou et al., 2012, Pfohl, Kohler and Thomas, 2010, Wright, 2013), supply chain strategic management (Tang, 2006, Sheffi and Rice, 2005), and strategic resilience management (Teoh and Zadeh, 2013, Jüttner and Maklan, 2011).

The review of supply chain disruptions will examine each of these three perspectives and identify gaps in the research, before looking at them in greater detail.

However, this abundance of research has focused on the antecedents of supply chain disruptions, but the question of what happens after a disruption has received scant attention. This research acknowledges that academic gap, and seeks to build on the Bode et al. (2011) model of organisational responses to supply chain disruptions. This important concept is discussed in more detail in section 2.4.3; supply chain disruption response management, and further developed in the research question in Chapter 3.

The globalisation of economic interchange, rising volatility of markets, trends towards out and single sourcing, as well as just-in-time concepts, are making today’s supply chains ever more complex (Harland, Brenchley and Walker, 2003, Crone, 2006). Flows of goods, information, financial resources, rights, and multiple interfaces have to be integrated, increasing their vulnerability (Peck, 2006). This is exacerbated by numerous events of the previous decade. Supply chains are often triggered by disturbances on the supply and the demand side, e.g., terrorist attacks, natural disasters, changes in consumer behaviour, technological crises, or bankruptcy. The trend to designing lean supply networks that are tightly coupled and operated at minimum levels of time and material’s buffers makes them vulnerable to local disturbances. These can be an existential threat to global or networked supply chains and may have negative effects on costs, quality, flexibility, and reliability on image and, ultimately, the valuation of all the participants in the network. Cross-company supply chain risk management therefore becomes a critical success factor. There has been a fundamental consensus emerging in research, as well as in business practice, that systematic risk management is required to deal with these challenges. However, there are different opinions on the necessary elements of successful supply chain risk management. Research on the process of supply chain risk management implementation has received less focus (Pfohl, Kohler and Thomas, 2010).

2.4.1 Supply Chain Risk Management

A definition of supply chain risk management is applied, as suggested by Kaju"ter (2003) p36:

> Supply chain risk management is a collaborative and structured approach to risk management, embedded in the planning and control processes of the supply chain, to handle risks that might adversely affect the achievement of supply chain goals.

Systemic risks with global geographic scope, cross-industry relevance, uncertainty as to how and when they will occur, and elevated levels of economic and/or social impact have become a major concern for supply chain operators. Building risk management into supply chain governance is essential, but broader measures are also necessary. Through greater public and private sector collaboration, including activities such as the World Economic Forum Supply Chain Risk Initiative, we are deriving a more comprehensive view of supply chain risk and the measures needed to build greater resilience, while increasing both the efficiency and the effectiveness of global supply (Wright, 2013).

The World Economic Forum conducted a detailed survey across Europe, North America, and Asia, via supply chain risk radar; an analytical and self-diagnostic tool developed by the World Economic Forum (WEF). The aim of the survey was to understand how the risk landscape varied across the three regions and how the top risks compared with the top five global risks from 2011. Survey respondents considered global risks and their potential to cause system-wide disruptions in global supply chains. Four of the top five risks (natural disasters, conflict and political unrest, terrorism, and sudden demand shocks) remained unchanged. Extreme weather, however, emerged as a more prevalent concern in 2012, with an overall ranking of number two among the top five global risks.

Processes can either amplify or absorb the effect of risks in the supply chain and refer to the design and implementation of processes within and between the entities in the supply chain. Robust processes are built on a thorough understanding of variability, e.g., in manufacturing or forecasting, supply chain bottlenecks or dependencies on IT systems, and may need to have planned process redundancies or excess capacities where necessary (Mason-Jones and Towill, 1998). For example, the impact of supplier insolvency as a supply risk is either amplified or absorbed by the level of excess capacity held within the chain. Similarly, supply chain control mechanisms, like decision rules and policies regarding order quantities, batch sizes, and safety stocks, can either amplify or absorb risk effects. For example, the effect of a sudden trough in demand is amplified in the presence of inflexible rules regarding order quantities. It is suggested here that a characteristic of supply chain risk sources is that they can be inextricably linked to the supply chain structure.

Supply and demand risk sources are supply chain specific and are likely to affect several interdependent parties in the chain. Moreover, demand and supply risks, as internal supply chain risk sources, imply that any company in the supply chain can be responsible for supply chain risk management implementation and become a source of risk to the supply chain at the same time. Expanding the idea of supply chain risk, it can be argued that a supply chain's risk exposure determines its vulnerability. As argued by Jüttner (2005), supply chain vulnerability is defined as an exposure to serious disturbance arising from supply chain risks, affecting the supply chain’s ability to effectively serve the end customer market. The remit of supply chain risk management as a managerial activity can be defined as the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members to reduce overall supply chain vulnerability. This definition is similar to the one proposed by Lindroth and Norman (2001). However, they take a more restricted view by stating that supply chain risk management deals with risks caused by, or impacting on, logistics-related activities or resources. By contrast, this definition adopts the basic tenet of the overarching concept of supply chain management that logistics is only one of the functions contained in the concept (Guinipero and Brand, 1996, Cooper, Lambert and Pagh, 1997, Ross, 1998, Mentzer, Dewitt, Keebler et al., 2001). Hence, supply chain risk management, like supply chain management, entails the same multiplicity of business functions and processes.

As the supply chain networks keep on expanding geographically in a globalised environment, they are becoming more exposed to risk, even more prone to disruption, and thus more vulnerable (Iakovou, Vlachos and Xanthopoulus, 2007). Increasing product and service complexity, outsourcing, and globalisation have led to the growth of complex, dynamic supply networks, changing risk and its location (Harland, Brenchley and Walker, 2003). Furthermore, business studies confirm that the newly shaped market should take under serious consideration the management of supply chain risk since disruptions could have an impact not only on a company's financial situation, but also on the stock price performance (Hendricks, Singhal and Zhang, 2009).

As a result, researchers try to develop new analysis and optimisation models for demand planning, production scheduling, transportation network design, inventory control, lean initiatives, and other areas along the value chain. This focus on supply chain management aspects inevitably turned the spotlight on the extensive study of supply chain risk management and vice-versa (Vlachos, Iakovou, Papapanagiotou et al., 2012). Either way, the management of risk in supply chains has now become an established element in the fields of supply chain management, corporate strategic management, and enterprise risk management (Zsidisin and Ritchie, 2008). Risk to enterprises research has also incorporated 'time to response' reduction, considering, for example, key factors in cutting response time. Chadist (2012) stated that preparation, partnership, organisation and reserve are all key factors in reducing response time.

The problem is that many companies leave risk management and business continuity to security professionals, business continuity planners, or insurance professionals. However, building a resilient enterprise should be a *strategic* initiative that changes the way a company operates and that increases its competitiveness. Reducing vulnerability means reducing the likelihood of a disruption and increasing resilience, i.e. the ability to bounce back from a disruption (Sheffi and Rice, 2005). Strategic supply chain management is then concerned with planning ahead so that resilience in the supply chain can be built in. Khan, Christopher and Creazza (2012) research in the retail fashion industry investigated the alignment between product design and the supply chain and investigated how this alignment impacts on a firm's supply chain responsiveness and resilience. They considered the alignment of product design and the supply chain, such as expanding and internalising the design process to work closer to procurement teams and other key business functions. Because of this case, an interesting link has been observed between supply chain responsiveness and supply chain resilience in that a number of strategies that were implemented to improve supply chain responsiveness have also reduced the impact of supply chain risk and improved the company's resilience.

Tang (2006) also highlighted the requirement for firms to secure their supply chains through 'robust' supply chain management strategies. Firstly, these strategies should be able to help a firm to reduce cost and/or improve customer satisfaction under normal circumstances. Secondly, the same strategies should enable a firm to sustain its operations during and after a major disruption. The Tang (2006) work identified several robust strategies, as shown below in Table 2, and it is shown how these strategies can help a firm to succeed before, during, and after a major disruption. An established, robust supply chain strategy would enable a firm to deploy the associated contingency plans efficiently and effectively when facing a disruption. Therefore, having a robust supply chain strategy could make a firm become more resilient. Table 2 summarises key features of the nine strategies identified.

Table 2. Robust strategies, Tang (2006)

Table 2 sets out nine supply chain strategies with the main objective for each strategy employed. It also highlights the perceived benefits for each supply chain strategy employed under *normal circumstances*, and the related benefits *after a major* *disruption*. The difference is that while the benefits of strategies employed under normal circumstances look at overall capabilities in a predictable environment, the benefits that ensue after a disruption have a different focus and dynamic. Various strategies and benefits are examined in further detail below.

The postponement strategy, as shown in Table 2, utilises product or process design concepts such as standardisation, commonality, modular design and operations reversal, to delay the point of product differentiation. Strategic stock strategy involves carrying additional 'just in case' safety stock inventories to ensure that the supply chain can continue to function smoothly when facing a disruption in supply. Flexible supply base strategy negates the use of just a single supplier, instead employing multiple suppliers to accommodate regular demand fluctuations but also maintains supply of materials when a major disruption occurs. A make-and-buy strategy allows the production of certain products in-house, while other products are outsourced to outside suppliers. Economic supply incentives strategy uses economic incentives issued by the buyer to cultivate additional suppliers where there is limited number of suppliers in the market. This strategy was used by the US government to mitigate the lack of flu vaccine producers in October 2004. Following a strategy of flexible transportation uses a variety of means to transport product from utilising different modes of transport, routes, and carriers to spread the risk of disruption. Revenue management by dynamic pricing and promotion allows a firm facing a disruption by changing pricing to change customer’s behaviour to mitigate the impact. Assortment planning uses product placement and mix to influence consumer product choice and demand, commonly used, for example, by retailers. Under silent product rollover strategy, new products are 'leaked' slowly into the market without any formal announcement so that key new features on the market do not create unsustainable demand creating a stock-out situation.

The occurrence of supply chain disruptions, which have many downstream effects, including shortages, have prompted the increased academic research focus on supply chain resilience and supply chain disruption management. Resilience engineering is a discipline focused on identifying system capabilities and response to disruption threats, often focused on, for example, safety and security systems (Hollnagel, Woods and Leverson, 2007). Risk analysis, in contrast, concentrates on identifying and understanding existing and evolving threats that challenge operations of complex systems (Lambert, Keisler, Wheeler et al., 2013). Supply chain resilience, however, is a comprehensive view of supply chain robustness and stability. It has a more strategic emphasis on the design of supply chains (Barroso, Machado and Cruz-Machado, 2011).

2.4.2 Supply Chain Resilience Management

Supply chain resilience is currently considered a critical component of supply chain risk management (Ponomarov and Holcomb, 2011), and a relatively new and yet underexplored research area of management as a whole. As Christopher and Peck (2004) state, supply chain resilience is a scientific field of research in its ascendancy. The significance of supply chain resilience in the context of contemporary global supply chains is further validated by Gartner's Supply Chain Top 25 report (2011), in which authors identify resilience as being one of the four major themes for research. The literature review revealed the existence of two discrete approaches on organisational resilience. Some scholars see organisational resilience as simply an ability to rebound from unexpected, stressful, adverse situations and to pick up where they left off, while others visualise organisational resilience beyond restoration to include the development of new capabilities and an expanded ability to keep pace with and even create new opportunities (Lengnick-Hall, Beck and Lengnick-Hall, 2011, Ponis and Kronis, 2012). Lengnick-Hall, Beck and Lengnick-Hall (2011) defines organisational resilience as the firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalise on disruptive surprises that potentially threaten organisation survival

There have been several studies considering the present literature on supply chain resilience in this turbulent disruption-rich world. This literature survey identified 77 studies which were reviewed from the extant supply chain resilience and disruption literature, as per the supply chain disruption resilience table in Appendix 1. As described above, the literature review process involved a search of the extant academic literature using key word Boolean searches. The search defined the investigation terms, identified the databases, then determined and applied criteria for inclusion and exclusion. The references were then catalogued by tabulating under general headings for review. Reference headings were by date, author, title, methodology, perspective, theory, focus, and contribution. The focus content was then further summarised by coding, so that frequency and reoccurring themes could be quickly identified and described. Lastly, a brief critique of each reference included was given so that the limitations of other research could be identified to avoid future mistakes but also to help interpret their findings, identify gaps, and consider the inclusion of variables that may not otherwise have been considered, as suggested by Bryman and Bell (2011). The three key topics identified and focused on were supply chain risk management, supply chain strategic management, and strategic resilience management.

However, most of this research focuses on strategies to mitigate or measure the disruption impact. For example, taking a strategic management perspective argues for increased flexibility to improve resilience (Sheffi and Rice, 2005). Taking a process control perspective, Christopher and Peck (2004) suggests a framework for improved supply chain risk identification, whereas other researchers using a benchmarking approach have endorsed a measurement tool to test proposed resilience (Stephenson, Seville, Vargo et al., 2010). Several researchers have used evaluation measurement either through gaming quantification of mitigating financing (Bakshi and Kleindorfer, 2009), or using graph theory to provide supply chain vulnerability indices for industries (Wagner and Neshat, 2010). Some researchers have drawn on a control theory based approach leading to an optimisation model based framework, (Seferlis, Vlachos, Iakovou et al., 2008), building on earlier work which developed a deterministic EOQ-type inventory control model for a two-stage supply chain that is susceptible to several types of production and demand related disruptions (Xia, Yang, Golany et al., 2004).

Few, except for some notable exceptions (Bode, Wagner, Petersen et al., 2011, Greening and Rutherford, 2011, Primo and Dooley, 2007, Grewal, Johnson and Sarker, 2007), have examined the strategic behaviour of firms in response to the supply chain disruption. While the Greening and Rutherford (2011) research focused mainly on the network structure post disruption rather than specifically on the motivation behind the response. Primo et al's (2007) primary concern was on supplier dissatisfaction by manufacturers. Mishra, Sharma, Kumar et al. (2016) considered buffering and bridging strategies to minimise risk and improve downstream supply chain performance. Their work, however, was based on the classic four firm typology approach of prospectors, defenders, analysers, and reactors (Miles, Snow, Meyer et al., 1978). Grewal et al. (2007) was concerned with the nature of response both location and context. They highlighted two dimensions: response diversity and nature of crisis to give a typology of four response patterns; hedging, cautious, focusing, and maintenance. Pettit, Fiskel and Croxton (2013), in contrast, took a general supply chain research perspective with a focus on supply chain resilience, taking account of both capabilities and disruption response. However, only a single method of focus group was used, based on a single company in the retail vertical. It was conducted over only a short period with strong conceptual bias. The research of Ponis and Kronis (2012), Jüttner and Maklan (2011), Vickers and Kouzmin (2001), Asbjornslett (1999) had both a supply chain resilience and vulnerability aspect included in their work, however, only Jüttner and Maklan (2011) conducted an empirical study; all, however, did have a capability focus. However, Peck (2005) and Greening and Rutherford (2011) focus on both capabilities and distribution response. Ivanov, Sokolov and Dolgui (2014) observed that quantitative analysis tools are rarely applied in practice, and concluded that the ripple effect can be the phenomenon that is able to consolidate research in supply chain disruption management and recovery, similar to the bullwhip effect regarding demand and lead time fluctuations, where the ripple effect describes the impact of a disruption on supply chain performance and disruption-based scope of changes in the supply chain structures and parameters. Following a disruption, its effect ripples through the chain of supply. The scope of the rippling and its impact on economic performance depends both on robustness reserves (e.g., redundancies like inventory or capacity buffers) and speed and scale of recovery measures (Hendricks and Singhal, 2005, Sheffi and Rice, 2005, Tomlin, 2006, Bode, Wagner, Petersen et al., 2011, Kim and Tomlin, 2013). The Ivanov, Sokolov and Dolgui (2014) research, however, was an identification of the challenges and suggested solutions as a summary, rather than an empirical data-based study from the field. Greening and Rutherford (2011) also used a desk-based methodology but conducted an extensive literature review of 485 articles, and rather than empirically-based research, it was looking at the theory of supply chain disruption with a focus on network structure post disruption. Peck (2005) work, in contrast, used an exploratory case study of the military aerospace industry and considered the sources and drivers of supply chain vulnerability, however, the main purpose of the work was to consider the broader 'why' question in supply chain vulnerabilities.

There exists significant research in the extant literature relating to and focusing on mitigating and measuring impact, however, this review found there has been scant attention on strategic responses to disruptions once they have occurred. Section 2.4.3 considers supply chain disruption response management. In particular, this part of the literature review will give insights into the theoretical background and associated findings, articulating the gaps in the literature, and applying findings to the particular context for the research.

2.4.3 Supply Chain Disruption Response Management

Bode et al. (2011) presented the first systematic empirical investigation of organisational responses to supply chain disruptions. Bode et al. (2011) introduced the concept of supply chain disruption orientation, introducing the construct into the supply chain literature, building on earlier organisational orientation works by (Daft and Weick, 1984) investigating active and passive firms. They examined why, how, and under what conditions firms respond to supply chain disruptions. Bode et al. (2011) introduced a model of organisational responses to supply chain disruptions, underpinned by the dual theoretical lenses. These were resource dependency theory (Carroll, 1993) and information processing theory (Galbraithe, 1977, Tushman and Nadler, 1978). Pfeffer and Salancik (1978) state in regard to resource dependency theory that, although organisations depend on their environment to survive, they seek to assert control over the resources they require to minimise their dependence. Galbraith (1973) p150, proposed that uncertainty refers to the "difference between the amount of information required to perform a task and the amount of information already possessed by the organisation". The more environmental uncertainty a firm faces, the more information it needs to gather and process to achieve a given level of performance. The importance of the Bode, Wagner, Petersen et al. (2011) research was that it provided insights into the mechanisms that shape organisational responses to supply chain responses, augmenting resource dependency theory perspective with other lenses, as called for by (Hillman, Withers and Collins, 2009). This research will build on those insights into factors affecting responses by considering their post disruption consequences and extend understanding of the response actions dynamic.

Alternative responses to disruptions and the drivers behind them is a relatively novel area of research compared to that of supply chain risk management. Supply chain risk management is defined as an inter-organisational collaborative endeavour utilising quantitative and qualitative risk management methodologies to identify, evaluate, mitigate, and monitor unexpected macro and micro level events or conditions which might adversely impact any part of the supply chain (Ho, Zheng, Yildiz et al., 2015). Theories that encompass both the striving for stability and the generation of the stability motive to react to disruptions, giving two generic responses: that of bridging and buffering, which can be built off earlier works on the subject (Fennell and Alexander, 1987, Meznar and Nigh, 1995). Buffering actions are attempts to gain stability by establishing safeguards that protect a firm from disturbances that an exchange relationship confers, and bridging actions are attempts to manage uncertainty through employing 'boundary-spanning' and 'boundary-shifting' actions with an exchange partner.

Resource dependency theory focuses on control, power, and vulnerability in firms' external responses, whereas information processing theory focuses on information and smooth internal processes. However, as a supply chain disruption affects both internal processes (information processes) and external processes (exchange partnerships), Bode et al (2011) identified the need for an integrative view to explain why firms respond to these events.

Models of organisational responses to supply chain disruptions have included trust and dependence in the external processes (interfirm) and supply chain orientation and prior experience in the internal processes (intrafirm). Trust is considered to be central to explaining a firm’s interpretation of and behaviour towards its exchange relationships (Morgan and Hunt, 1994). Every firm has learned preferences for the parameters that it uses to determine its response in light of the environmental uncertainty it faces (Huber, 1991), where the experience of such disruptions with an exchange partner establishes the amount of trust between them (Anderson and Narus, 1990). Trust then serves as the condition under which decision choices are formed. Trust is accepted by this research as an important factor in organisational response behaviour and included in Figure 9 below. From a resource dependence perspective, a supply chain disruption requires a response when it entails a dependence relationship (Pfeffer and Salancik, 1978). Dependence on an exchange partner implies that a firm needs to maintain the relationship with the partner to achieve its desired goals (Emerson, 1962). As the degree of dependence increases, so does the likelihood that the firm considers the occurrence of a disruption to be important and reflective of its lack of control (Buchanan, 1992, Daft, Sormunen and Parks, 1988), thereby arousing the stability motive (Green and Welsh, 1988). Dependence is accepted as a key factor in organisational response behaviour and included in Figure 8. Taking an information processing perspective, the occurrence of a supply chain disruption may indicate to a firm that its information processing capabilities and information processing needs are mismatched. Without relevant prior experiences, the firm has difficulty determining the form and the strength of a response that restores fit and, consequently, stability (Sinkula, 1994). Prior experience in a firm means that it has likely developed dedicated rules and routines for dealing with supply chain disruptions (Green and Welsh, 1988). Prior experience is accepted by this research as an important parameter in organisational response behaviour and included in Figure 9.

The interpretative posture and motivation to act determined then the organisational response repertoire (bridging or buffering) to the supply chain disruption, where supply chain disruption orientation is defined by Bode, Wagner, Petersen et al. (2011) p837, as *"*a firm's general awareness and consciousness of, concerns about, seriousness toward, and recognition of opportunity to learn from supply chain disruption*."* Organisational response research findings indicated that a high supply chain disruption orientation makes firms more likely to craft a specific response for reducing the likelihood and impact of future supply chain disruptions (Bode, Wagner, Petersen et al., 2011). Their results are consistent with those of other studies emphasising the importance of firm orientations and cultural traits, enhancing a firm's capability for dealing with adverse events (Edmondson, 1996, Dyck, Frese, Baer et al., 2005, Cheng and Lu, 2017). A firm's ability to effectively respond to adverse events and to accommodate latent problems or changes in its environment can be critical to both its competitiveness and its long-term success (Child, 1972, Alldred, 2006). This is also in line with Li, Wu, Holsapple et al. (2017) who found in a turbulent environment supply chain preparedness, supply chain alertness and supply chain agility all aim at increasing a firm's financial outcomes.

Other researchers have also looked at a firm's orientation affecting their actions, including Autry and Bobbitt (2008) who did look at how a firm was orientated towards risk but there was a focus on disruption from a security perspective, with actors changing their actions accordingly, however, their research was qualitatively based on risk with operational performance. Narver and Slater (1990), in contrast, chose a market perspective to consider the response orientation of a firm, as did Lumpkin and Dess (1996) who examined a firm's orientation through an entrepreneurial lens. The security orientation perspective has also been studied empirically in the US and Italy in a large study (462 firms) considering supply chain security (SCS), classifying practices and differential effects on performance (Lu, Koufteros and Lucianetti, 2017) . They looked at how supply chain security (SCS) breaches (a form of supply chain risk) are distressing supply chains and they have the potential to engender acute pain on the society at large. Although they looked at practices and performance, their results suggested that detection practices are the most efficacious when SCS performance is concerned, however, they were considering action before disruption impact, and detection, for example, would be techniques such as closed-circuit television. Although they suspected that prevention may have a stronger impact than mitigation and response, their conclusion was not statistically supported by the data.

Alternative research perspectives also looked at responses to supplier induced disruptions for example Reiman (2017) on event system theory and presents an in-depth qualitative investigation of 60 response processes following supplier-induced disruptions in Western–Chinese buyer–supplier relationships. An example was defective key components from one of Apple's China-based suppliers that slowed down the release of the Apple Watch (Wakabayshi and Luk, 2015). Event system theory characterizes the strength of an event based on its novelty, impact, and criticality (Morgeson, Mitchell and Liu, 2015). Behavioural research perspectives have also been used to evaluate supply chain disruption response management, as individual's behaviour is a key in understanding response mechanisms. So to better understand the behavior of boundedly rational individuals, behavioral supply management researchers have recently begun to explore the cognitive underpinnings of purchasing managers' decision-making (Carter, Kaufmann and Michel, 2007). In line with this is increasing interest on individual-level based knowledge view in building supply chain risk mitigation competency (Ambulkar, Blackhurst and Cantor, 2016).

Research aimed at improving operational performance in supply chain disruptions have been framed using information processing theory and the complementarity theory suggesting that a combination of external supply chain integration practices with traditional risk management practices is superior in in facing risky environments and improving operational performance (Kauppi, Longoni, Caniato et al., 2016) complementing the work in this area with (Zhao, Huo, Sun et al., 2013, Nooraie and Parast, 2016, Ivanov, Pavlov, Dolgui et al., 2016). Although in the Kauppi, Longoni, Caniato et al. (2016) study, data collection was limited to the exogenous distribution risks. Other orientation based supply chain resilience research in congruence with Bode, Wagner, Petersen et al. (2011) has found orientation important, for example Cheng and Lu (2017) their findings indicated managers of larger firms should consider facilitating trajectory and absorptive capacity to enhance proactive and reactive dimension of supply chain resilience. In contrast to Kauppi, Longoni, Caniato et al. (2016) a resource based theory perspective was adopted by Cheng and Lu (2017). Although as indicated by Nooraie and Parast (2016) increasing supply chain resilience to risks has its own costs. Busse, Meinlschmidt and Foerstl (2017) took a purely information processing perspective and found that in extreme situations though facing the same amount of a certain type of uncertainty, apply the fitting information processing mechanisms with different intensity.

This research will build upon and refine the new construct of supply chain disruption orientation, by building on existing theory and examining it in greater detail through extensive research and rigorous examination. The Bode at al. (2011) model, as shown below in Figure 8, contributes to academic knowledge by normatively explaining the why, how, and under what circumstances firms respond to disruptions, however, their research did not go on to examine the performance implications of the respective bridging or buffering strategic response choices. This is important because to make effective decisions, managers need to be informed (Pfeffer and Salancik, 1978), as per resource dependency theory. Supply chain orientation is a new concept which offers new insights in response behaviours which is important in informing strategic management thinking, however, it requires further development and empirical examination to improve validity and generalisation. The response action outcome information not only comes from prior experience, for example, because the information may have been forgotten, never documented, or the individual manager making that decision could no longer be available. Lack of documentation processes and recording results in large complex organisations, where functions and decisions in a supply chain can be spread over many individuals, has been identified as a threat to performance (Heywood, 2014). As mentioned previously, earlier work on supply chain resilience has attracted optimisation-based framework models using quantitative methodologies (Seferlis, Vlachos, Iakovou et al., 2008, Falasca, Zobel and Cook, 2008, Xia, Yang, Golany et al., 2004). Although Bode at al. (2011) developed the causal links (as shown in Figure 8) between the actions of buffering and bridging as organisational responses to supply chain disruptions, they did not establish the benefits of incorporating dynamic feedback performance that has been examined through optimisation using a quantitative simulation approach.

This research will further consider the dynamic feedback on response disruption decisions and its effect on performance. This area lacks detailed research, with a recent literature survey of more than 200 supply chain researchers presenting three gaps in supply chain risk management, one of which was process gap (inadequate coverage of responses to risk incidents), (Ho, Zheng, Yildiz et al., 2015). To action this, a feedback construct is added to the original model (as shown in Figure 8), to help inform and improve the supply chain orientation of an organisation in a continual process, which is dynamic rather than static. This will be achieved by capturing and understanding the actual outputs of the performance measures used for each behavioural response taken after the supply chain disruption, rather than making normative recommendations. Detailed analysis of past disruptions and successful anticipation, recovery, and adaption efforts will be essential in future research to determine the significant linkages between specific capabilities and inherent vulnerabilities (Pettit, Fiskel and Croxton, 2013).

The learning processes organisations go through have been long considered by researchers, starting with the original concept of organisational learning, which dates back to the 1960s (Fiol and Lyles, 1985). There has been significant growth in the body of knowledge on organisational learning (Crossan and Guatto, 1996), with organisational learning seen as the process and outcomes of changes to organisational level properties such as culture, operational processes, systems, and policies. Organisational learning occurs in all organisations as they inevitably evolve and change, but it is only sometimes seen as such by members of the organisation, or intended by them. There is a common, but not universal, assumption that learning is associated with improved performance (Crossan, Lane, White et al., 1995). However, despite criticisms of organisational learning empirical inquiry and theory, the concept is seen to be valuable. In introducing a compilation of leading texts on the subject, (Cohen and Sproull, 1996) suggest that, using the concept of organisational learning, the texts' authors challenge conventional organisation theory in three fundamental ways:

1. They focus on action, rather than choice
2. They emphasise dynamics, with stability interpreted in that context
3. They explain organisational coherence, rather than assuming it

Learning organisations purposefully construct structures and strategies so that they enhance and maximise organisational learning (Dodgson, 1993). There are arguably two concepts of organisational learning (Easterby-Smith and Araujo, 1997), firstly as a technical process (Huber, 1991), and secondly as a social process (Gherardi, 2000). The technical view assumes that organisational learning is about the effective processing, interpretation of, and response to, information both inside and outside the organisation, whereas the social perspective on organisational learning focuses on the way actors make sense of their experiences at work, where learning emerges from social interaction. This reflects the cognition-behaviour dimension of the learning outcome. A behaviouristic approach underlays reinforcement theory, which says that "behaviour is a function of consequences" (Robbins, Judge and Campbell, 2010) p154. As noted by Huysman (1999), the how, when and why questions present four biases within the literature on organisational learning that were identified. These biases point to an individual learning bias, an active agency bias, a purposeful learning bias and an improvement bias. In the research by Huysman (1999), a case story concerning the learning of old and new routines used by information systems designers is used to demonstrate the alternative approaches to scrutinise organizational learning in different organisations.

The supply chain disruption event can have a variety of possible outcomes on a focal firm, whether directly or indirectly. Every activity that a supply chain conducts has an inherent risk that an unexpected disruption can occur. Disruptions such as the loss of a critical supplier, a major fire at a manufacturing plant, or an act of terrorism, have the potential to adversely affect both revenue and cost (Ponomarov and Holcomb, 2011). Supply chain disruption is captured in this research's model in Figure 9, and the extent of the impact and its relationship with response choices and performance outcome is measured as an independent variable.

Previous research on supply chain disruption did not take account of strategic orientation and environment when considering the concept of supply chain disruption orientation, and were beyond the factors incorporated in their hypothesis. This study will, however, take account of boundary conditions, as argued by Carvalho, Barroso, Virginia et al. (2012), it is expected that specificities related to the industry context, like product type, production process, country, and cultural perspectives can impact on the types of resilience and agile practices employed in the supply chain and in the effect these practices have on supply chain behaviour. Carvalho, Barroso, Virginia et al. (2012) combined agile and resilient approaches developing a new framework to demonstrate their influence on performance and competitiveness, but excluded boundary reality bias of the manager's environment. Differing management decisional roles means their requirements are determined by the manager's role, seniority, and availability of information (Mintzberg, 1973, Mintzberg, 1975, Hales, 1986). Because choices and actions are made by people, who work as part of a team in an organisation that is faced with disruptions, this research will include the role and knowledge of the decision-making manager, making response decisions post disruption to fill this research gap, just as managers are influenced by their roles, knowledge, and the organisation they work within and its environment all have an impact on response decisions. Fennel and Alexander (1987), in their research on organisational boundary spanning in institutionalised environments, found that hospitals in systems are more likely to bridge, probably because of corporate policies intended to centralise functions and minimise costs. System membership was reported by (Fennell and Alexander, 1987) as an important factor in a hospital's selection of bridging or buffering strategies. A hospital that is the sole unit in a hospital trust, as opposed to a hospital in a trust which is made up of several trusts, *may* have a higher tendency, therefore, to bridge within the trust than the sole unit does.

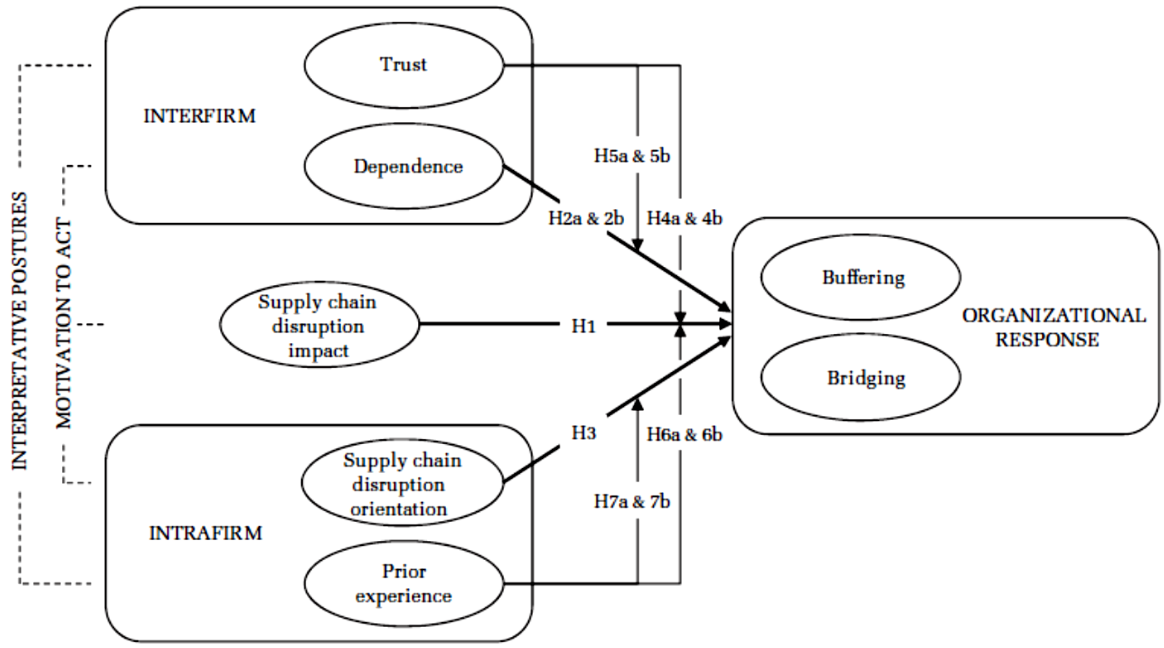


Figure 8. Bode, Wagner, Petersen, Ellram, Academy of Management Journal (2011:853-856) (Vol. 54, No4).

In Figure 8, the conceptual framework was first developed by Bode, Wagner, Petersen et al. (2011), based on the original conceptual model of organisational response to supply chain disruptions; the model is focused on the relationships between the impact of supply chain disruption and intrafirm and interfirm responses. However, in this research, existing knowledge is challenged. Central to this research is the new proposed model, Figure 9, which extends and deepens the focus to concentrate on how those responses affect performance, how the different organisational responses interact (bridging and buffering) and also explores the role of supply chain orientation, both through organisational response and response performance outcomes. This develops the existing conceptual model and provides new insights into the body of work on supply chain disruption management responses. The new model will be further explained in the context of the research question, with a trinity of contructs, examining further the new concept of supply chain disruption orientation, organisational response and performance, and the corresponding propositions directly addressing and testing the underlying theories in Chapter 3.

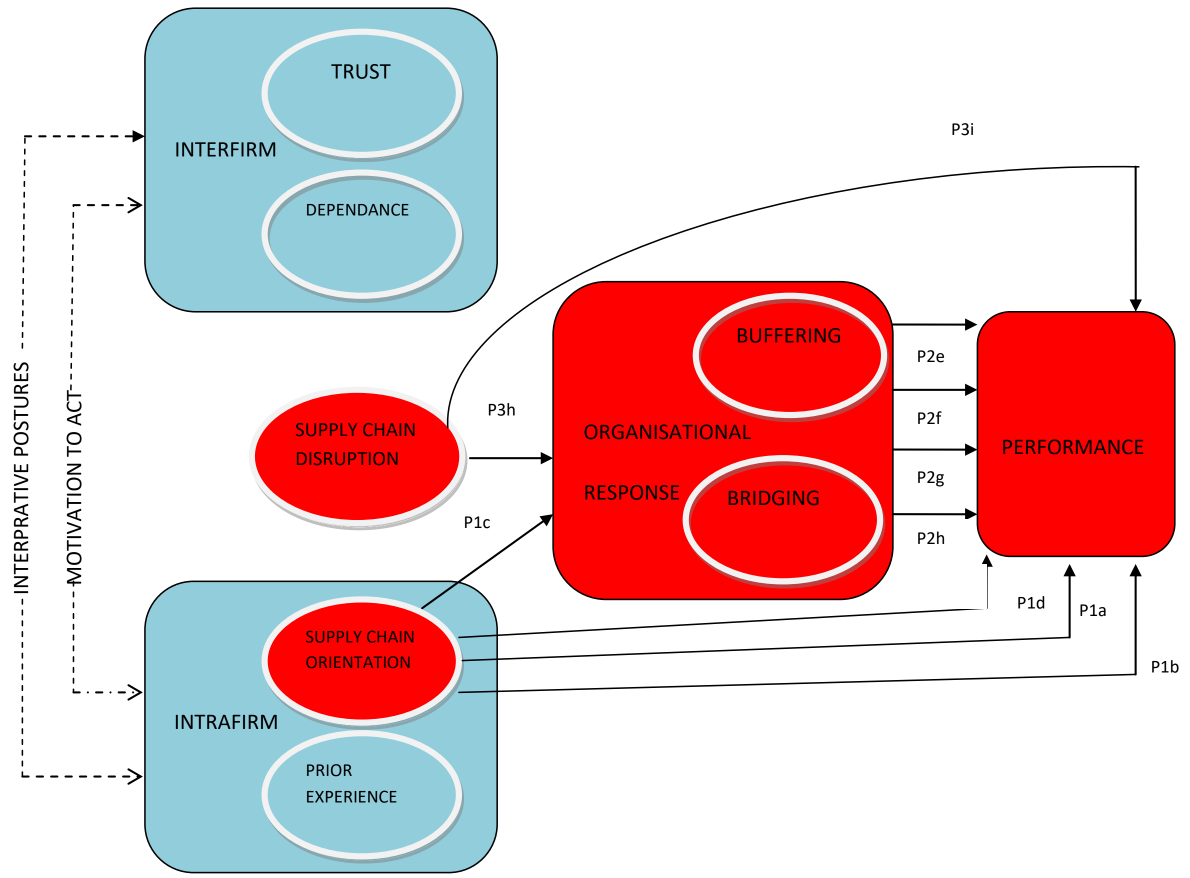


Figure 9. New proposed model of organisational responses to supply chain disruptions integrating response action output performance

Incorporating the boundary rationality bias into the understanding of the manager's decision-making process in response to supply chain disruptions, this research will build on the notion of bounded rationality in managerial decision-making (Simon, 1979, Tiwana, Wang, Keil et al., 2007). Furthermore, as supply chain disruptions affect the environmental certainty in which an organisation must make strategic decisions (Burns and Stalker, 1961, Lawrence and Lorsch, 1967), it is important to consider the actors that are in constant interaction with that environment. It is essential then to take into account managerial roles as the key actors in this interplay (Mintzberg, 1973, Mintzberg, 1975) . Hales (1986) looked in detail at what managers do in reality when they make decisions, and determined they did not act in a vacuum or without reference to their boundaries. Supply chain management is not a linear activity, rather it is a complicated activity and difficult to predict, and these factors need to be accounted for to demonstrate exhaustive research into supply chain disruption response. In so doing, this research returns to examine the original model of Bode et al (2011), which used the combined lenses of organisational information processing (Galbraithe, 1973, Tushman and Nadler, 1978), and resource dependency theory (Pfeffer and Salancik, 1978) to underpin the stability motive and interpretive postures which determine response decisions. It then challenges it with boundary rationality and, in so doing, improves the understanding of the decision-making processes in managerial responses to supply chain disruption. It is important academically because it adds to the body of work on supply chain post disruption response, but also practically for managers actively in decision-making.

Section 2.5 introduces the topic of supply chain disruptions in the industry specific context of the pharmaceutical industry, where disruptions have had a significant impact.

2.5 Supply Chain Disruptions in the Pharmaceutical Industry

This section on supply chain disruptions in the pharmaceutical industry begins with an introduction to the complex area of global drugs supply chain. This, as previously highlighted at the beginning of the literature review (section 2.1, Figure 1), is where the pharmaceutical supply chain intersects with supply chain disruption research. The overall literature review brings together academic literature starting within the supply chain management area and the pharmaceutical industry review. It then narrows to this section, which begins with the introduction in 2.5.1 on the specific topic of supply chain disruptions in the context of the pharmaceutical industry, followed by the description of the causes of these disruptions (section 2.5.2 to 2.5.6), and then the impact these disruptions are having through the supply chain of pharmaceuticals (section 2.5.7). Lastly, the attempts at improvements tried in the pharmaceutical supply chain in response are then explored in sections 2.5.8 to 2.5.13, including best practice guidelines in pharmaceutical distribution and, finally, a summary

2.5.1 Introduction

A shrinking global economy has multiplied failures at home and abroad, threatening supply chain stability. A supply chain breakdown can devastate a company financially and cause extensive reputational damage. The increasing trend by manufacturers to outsource manufacturing of medical products to areas such as India and China have had positive cost benefits for the manufacturers, an important strategic goal for improving overall supply chain efficiencies from a supplier perspective. However, the elongated supply chains and potential for quality impacts has not improved the shortage problem. This is especially important during sustained periods of volatility in the global trade, as described by Christopher and Holweg (2011), where organisations are using supply chain management to gain a competitive edge.

Developing and sustaining competitive advantage for an organisation through supply chain management, as proposed by (Spekman and Kamauff, 1998) in the modern pharmaceutical supply chain, is challenging. Central to their analysis was the belief that collaboration within a supply chain can be achieved to the extent the trading partners share a common 'world view' of supply chain management. With multiple agencies involved in the pharmaceutical supply chain, all with conflicting agendas spread across often emerging economies, collaboration is difficult and product demand is significant compared to the supply, especially with the ongoing disruptions.

For pharmaceutical companies, supply chain breakdown not only brings immediate damage to the affected company, but can also threaten human health and well-being by causing medical supply shortages (PricewaterhouseCoopers, 2009). In an industry study, 75 pharmaceutical companies that reported supply chain failures between 1998 and 2007 were compared by performance with an unaffected peer group. During the two days following a disruption announcement, such as a quality or production problem, the share prices of the affected companies tumbled 7% below the comparison group. One year later, the affected companies stock prices were still underperforming compared to their peers by about 4%. Even after accounting for normal industry and economic effects, the average returns on assets for the disrupted companies was 5% lower, and sales were 3% lower (PricewaterhouseCoopers, 2008).

Supply chain disruptions are more likely in uncertain economic times. As the ripple effects of a shrinking global economy spread through the supply chains of pharmaceutical companies, the potential for cascading failures threatens to disrupt product development. In the US and Europe, many small biotech companies are struggling to continue operations as they find it increasingly difficult to access venture capital and government funding (Wintein, 2009). In China, which is the world's top producer of active pharmaceutical ingredients (APIs), factory cutbacks and closings in export-driven coastal regions are quickly spreading inland (McDonald, 2009). In India, the world's third largest API source, many small and medium sized suppliers with shrinking orders from overseas find themselves on the brink of failure (Heathcote, 2008).

No matter where the supply chain breaks down, when a disruption occurs the public holds the company that owns the brand accountable or the service provider at point of source (for example, the National Health Service in the UK). Supplier management of remote suppliers by pharmaceutical companies is not an easy task to prevent disruptions despite the serious consequences. For example, in March 2008, contaminated batches of an injectable drug (heparin) caused 81 patient deaths and 785 reports of serious injuries associated by the drug use (Powell, 2008). The deaths and severe allergic reactions included difficulty breathing, nausea, vomiting, excessive sweating, and rapidly falling blood pressure that, in some cases, led to life-threatening shock (Gardiner and Bogdonowich, 2008). The US Food and Drug Administration (FDA) traced the contamination to Asian factories that produced the API used in the drug. This incident led to a massive product recall and pointed towards weakness in supply chain monitoring by the industry and its regulators. The episode resulted in negative media attention, public outrage, and numerous lawsuits. The raw material for the recalled heparin batches was processed in China from pig's intestines by the American firm Scientific Protein Laboratories (Powell, 2008).

The review found there has been extensive mapping of relationships, influences and also information and technology in the supply chain healthcare industry, including notably (Whewell, 2010, Savage, Roberts and Wang, 2006, Breen, 2005, Breen, 2008) on the former, and (Ling and Collier, 2000, Siska and Tribble, 2011) on the latter. Whewell (2010) considered the pharmaceutical supply chain from a practical industry based standpoint, which was heavily influenced by the pharmaceutical manufacturer's perspective. His ideas had their antecedents with (Braithwaite, 1993) with a focus on demand management, with attention to the customer before the logistics system. He did, however, promote the importance of information and recommended using a preference share model to understand how to influence sales. Most importantly, he noted, as did other observers, the poor state of the pharmaceutical supply chain, the tendency to overstock product to mitigate against the risk of the supply chain, especially in the launch of new products. Furthermore, there are a number of studies on the safety and errors in the administration of drugs at the practice end of the supply chain, for example, (Armitage, Newell and Wright, 2007), who researched errors in a British acute hospital trust, and (Alldred, 2006), who considered a risk assessment of purchasing safer medicines.

In the review of the literature on supply chain disruptions specifically and the pharmaceutical industry in general, many different geographically based information sources were found. These included predominantly UK, Europe, US and to a lesser extent China based academic reviews as well as industry information and reports. As will be discussed in more detail in the causes and impacts of supply chain disruptions in the pharmaceutical industry in section 2.5.7 drug shortages are a global problem (Gray and Manasse, 2012, Bruhc, 2012). In congruence with other pharmaceutical based research non-industry specific elements (e.g. majority of the disturbance factors) can be applied and extended to other sectors (Huq, Pawar and Rogers, 2016). However, it should be considered that there is no 'one-size-fits-all' strategy, and even for firms in similar sectors supply chain design differs, owing to unique characteristics. For example drug prices vary in each market, in the United States 20mg of Paroxetine (antidepressant) costs $6.83, in Canada $2.98, in the UK and Australia $0.98 and $0.70 in Turkey (Miller, 2018). This could be why 19 million adults in America import medication to save money, i.e. 8% of the population therefore, it is important to note that some of the supply chain configurations presented in this thesis would not be appropriate for particular drug types and that the response actions suggested might in certain cases not be feasible due to regulatory, market issues (The Henry J Kaiser Family Foundation, 2016) . For example in contexts characterized by high power distance, such as China, people accept that power is unequally distributed, and the less powerful supply chain partner therefore accepts its weaker position (Zhao, Huo, Flynn et al., 2008). Power symmetry results in more cooperative interactions Reiman (2017) so that response mitigating strategies can be more effective, for example bridging with suppliers. Drawing information in this review from different regions helps understand the common factors causing the shortage phenomena, and the widespread impacts. However, although there are common factors affecting both patients as the end users, hospitals and healthcare government departments, it should be noted that each country have their own healthcare structures, procurement methods, regulation and policy structures, and caution is required not to believe a solution in one country will automatically be applicable in all. The scope of this review and research study does not provide a fully comprehensive meta-analysis of global policy and delivery structures on a macro level. That said by drawing on sources from different geographies both in the more privately based pharmaceutical supply environment of the US system for example and the largely publicly funded secondary care sector in the UK, allows different perspectives to inform and provide understanding for the research in the general problem area of shortage management. In other supply chain disruption research (Golgeci and Ponomarov, 2013) used a between subjects scenario-based experimental methodology combined with a survey method in US & EU manufacturing. Finding from that research showed common understanding of both positive outcomes of firm innovativeness and drivers of supply chain resilience.

Efforts were made in this systematic review to identify all relevant literature on the review topic so the search would not be limited solely to one geography on a single electronic database (Crumley, Wiebe and Cramer, 2005). Additional search strategies included hand-checking relevant article reference lists and personal communication with experts in the field. Searching the 'grey literature' is of particular importance for pharmacy practice literature reviews because relevant articles written by non-academic pharmacists are often not published in traditional academic journals (Charrois, Durec and Tsuyuki, 2009)

2.5.2 Reasons and impact of pharmaceutical supply chain disruptions

Pharmaceutical supply chain disruptions predominantly manifest themselves further down the pipeline as shortages in medicines for patients. The reasons for drug product shortages are numerous, complex, and interrelated. A shortage is, most fundamentally, a lack of adequate supply of a drug product to meet medical need. Shortage situations most often originate at the manufacturing level and then reverberate throughout the pharmaceutical supply chain and broader healthcare system. Understanding the causes and management of the shortages because of supply chain disruptions can give insights into the management strategies that can be employed as organisational response choices. Recent research on medicine shortage has found a potential link between drug shortages and increasing drug prices. Drug shortages can be associated with an increase in price, even when there are multiple suppliers of a product (Fox and Tyler, 2017). A manufacturer may raise prices for multiple reasons. Where, for instance, manufacturers may pass on additional manufacturing costs when the raw material costs increase or factory upgrades are required. Expenditure could also increase for commercial drive to increase profits. However, the specific root trigger for rises are rarely transparent, similar to reasons for drug shortages.

There are many stakeholders involved, all with their own agenda, some of which may be acting in conflicting directions. They include the producers, distributors, wholesalers, the primary and secondary care health systems, governments, through to the patient's themselves. These differences can be as fundamental as how a pharmaceutical is viewed, either as a high cost-low margin product by the pharmaceutical company to the lifesaving treatment required by the patient. An example of this comes from a recent comment from Stephen Whitehead, Chief Executive of the Association of British Healthcare Industries, ABPI (October 2012) p78, he said:

> It is important we see medicines for what they are, not simply a cost, but an investment. An investment not only in the health of patients, but also an investment that reduces expensive hospital care, promotes medical research and spurs growth in the UK economy.

Yet we could also interpret this statement as a revenue push on behalf of his members from the pharmaceutical industry as 'spend more on our new drug products'. How much push there is by the pharmaceutical industry to reduce shortages of mature or discontinued lines, now outsourced to far-off geographies, using relocated manufacturing equipment is debatable. From a wholesaler perspective, who distributes the medicines once they are received in the local market, they too face difficulties as a result of disruptions to the supply chain. Sawer (2014) stated wholesalers distribute as much product as they possibly can get hold of as quickly as they can, but it's very time consuming for pharmacists to chase drugs. Pharmacists are in the front line. Wholesalers understand that the patient who cannot get hold of a medicine, apart from being a tragedy, is not how the supply chain is supposed to work.

However, some pharmaceutical supply chain stakeholders, in responding to front line complaints of medicine shortages caused either wholly or partly by disruptions, deny there is a problem. The understanding of generic drug shortages, for example, has not been particularly clear. Broeer (2014), chairman of the British Generic Manufacturers Association (BGMA), does not consider shortages to exist. In contrast, although the wholesalers believe they are providing a good service, they do recognise shortages are a real phenomenon. The British Association of Pharmaceutical Wholesalers (BAPW) definition of a shortage is a delay over 24 hours (Sawer, 2014) p128:

> The broader definition of drug shortages used by the UUDIS (University of Utah Drug Information Service) A product shortage occurs when: (Total) supply does not meet demand for a drug on a nationwide or regional basis for a period of time that necessitates changing the practice of treating the patient.

Drug shortages are not a new phenomenon and span the last 10 years, from Charatan (2001) p322, who described "a prescription drug shortage plague*,"* to Mirtallo, Holcombe, Kochevar et al. (2012) p390, who described the *"*crisis in drug shortages*".*

Gray and Manasse (2012) reported the medicines shortage is a complex global problem. They describe how shortages of essential medicines, among them generic injectable chemotherapy agents, are causing increasing concern. Their work revealed the problem is far wider than just one product in one country. It is affecting other classes of medicines, including injectable anaesthetic agents, such as Propofol, intravenous nutrition and electrolyte products, enzyme replacement products, and radiopharmaceuticals.

Medicine shortages are widespread, as Bruhc (2012) p34, described: *"*supply shortages of drugs are a global problem*".* Beerteen and Bonheure (2011) p12, also claimed that the problem is global *"*from Afghanistan to Zimbabwe*"*, listing 21 countries affected by a variety of supply problems. A shortage of the injectable antibiotic streptomycin was reported in 15 countries in Lancet (2010), with 11 more countries predicting their stocks would run out before they could be replenished.

The number of new drug shortages has tripled since 2006. The University of Utah Drug Information Service (UUDIS) and the American Society of Health-System Pharmacists (ASHP) reported 267 shortages in 2011 across multiple product categories, including anaesthesia drugs, oncology products, oral stimulants, antibiotics, electrolyte and fluid-balancing drugs, and others, as shown below in Figure 10. Approximately 80 percent of newly reported shortages were generic injectable products (Healthcare Distribution Management Association, 2012b).

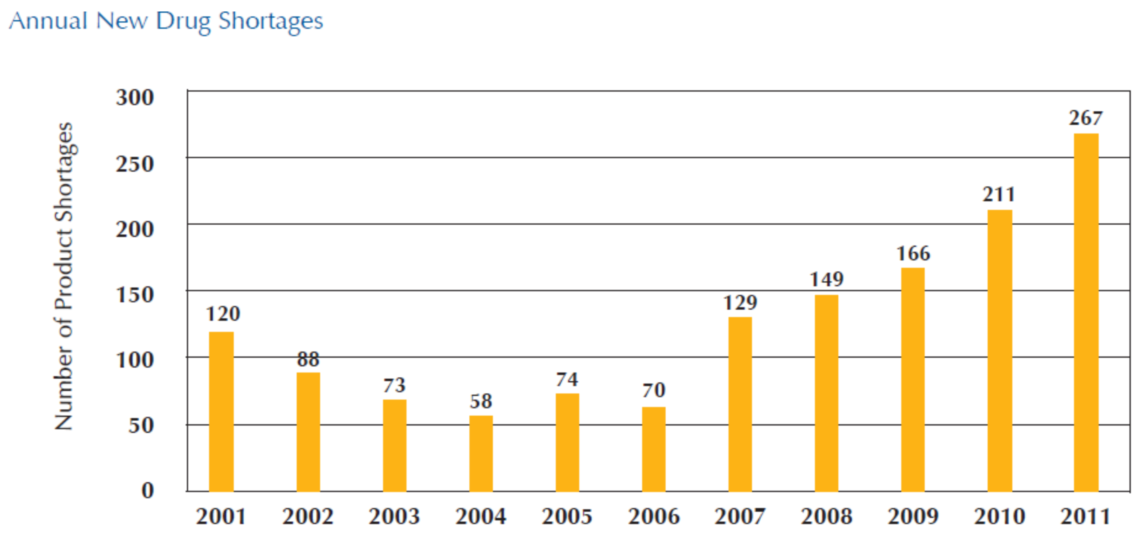


Figure 10. Adapted from HDMA (Healthcare Distribution Management Association) guidelines of report on guidelines for communications for managing product shortages in the healthcare supply chain (2012)

Broadly, the solutions to a product's availability issues will likely depend on the factors that are causing or contributing to the supply disruption problem. A joint working group was set up in the UK to research in more detail the risk factors in product shortages. It brought together a cross section of the stakeholders to rank the causes of shortages. In the research study by (Breen, 2008), a group of 20 stakeholders from the UK pharmaceutical supply chain, including a mixed collection of pharmaceutical manufacturers, wholesalers and National Health Service personnel, was facilitated by pharmaceutical procurement specialists.

Table 3 summarises the results, showing not only the 35 distinct reasons for shortages but also ranks their importance according to the stakeholder group.

Risk	Rating	Risk	Rating
Fragmentation of SC – no single source, multiple channels, no communication, unilateral decisions	10	Too much information	6.5
Lack of visibility of stock	9	Short term SC planning	6.5
Unexpected increase in demand	8.5	Operational in/efficiencies e.g. systems operating properly	6
Demand versus Capacity	8.5	Non standard practice – customised policies per hospital. Lack of common codes etc	6
Information flow or lack of information	8.5	Counterfeiting	6
Lack of forecasting – customer side	8.5	Increase in demand due to NICE approval, patient involvement, press	6
Availability of raw material – true and commercially induced. Regulatory issues – manufacturing licensing/change of standards/drug recalls	8	Rationalisation of range	5.5
Demand/economics – not able to respond to demand	8	Cash flow/cash management – threat associated with small companies and hospitals	5.5
Inadequate buffer stock – JIT/lean	8	Storage/cold chain	5.5
Contracting treated as a commodity – big contracts equals big risk. Drive competitors out of market	8	Reimbursement policies not consistent	5.5
Transportation – unavailability of fuel, congestion, weather, illness	7.5	Response of industry to shortages – communication	5.5
Manufacturer defence tactics	7.5	Loss of expertise – unsophisticated purchasing/practice?	5
Diversion of manufacturing capacity	7.5	Risk of litigation – influence on market	5
External influences – disaster recovery	7.5	Lack of knowledge regarding manufacturing process or source of supply	4.5
Stock holding – more concentrated	7	Procurement Hubs – introduce more complexity	4.5
Exploitation	6.5	Theft	4.5
Dispensing/picking error – medication/packaging, prescription management	6.5	Prioritisation – conflict between patients/profits	4
Decrease in capacity linked to profit	6.5		

Table 3. Product shortage factors adapted from Breen (2008)

The highest ranked factors found in the research (Breen, 2008) for risk factors for supply chain disruptions causing shortages include the fragmented and disparate supply chain, visibility, demand versus capacity, diversion of production by manufacturers, congestion, weather, and lack of adequate information under assessment categories, such as impact, occurrence, and controllability. Although similarities with other industries causal risks were identified, the workshop group established that there are aspects of the product that highlights its uniqueness, for example, criticality.

However, as recently claimed by Blair (2012) referring to drug diversion, although on the increase, is not the only problem involving drugs that hospital officials should be concerned with in the growing drug shortage situation. However, offshore production, counterfeiting, and weaknesses in the drug supply chain in case of a worldwide pandemic are even greater causes for concern. In the UK, manufacturers blamed shortages on parallel trading that forced them to put quota systems in place.

Pharmacies, hospitals, wholesalers, and prescribers pointed to these quotas as the main reason for shortages. They also blamed disruptions in the supply chain caused by the implementation of restricted wholesaler deals. In the case of generics, manufacturing issues was the biggest concern.
As well as shortages in primary care, there is a growing concern about medicines not being delivered on time in secondary care. Hospitals have up to 400 medicines exceeding their expected delivery times, although only a few of these are causing critical shortages (Chemist, 2013).

Breen (2005) case study and questionnaire-based research in the North West of England on improving the pharmaceutical supply chain had earlier argued that improvements in performance could be gained from the introduction of Electronic Data Interchange (EDI) and the implementation and use of e-commerce into purchasing departments in hospital pharmacies. This earlier research, however, took a local practice approach and was based on a national sample basis. Furthermore, it implied that the underlying issue is around information and data transfer to affect quality in performance, addressing the IT agenda rather than the strategic response to supply chain disruptions. They did, however, confirm there was much to learn from alternative industries and to adopt best practices where feasible.

In the research by Breen (2008), disruptions leading to shortages also included commercial factors linked to the profits of manufacturers. There has been a general decline in manufacturers producing vaccines, for example, due to the costs of research and development compared to the relatively small market to generate sales revenue. Offit (2005) describes how during the past fifty years, the number of pharmaceutical companies manufacturing vaccines has decreased dramatically, and those that still make vaccines have reduced resources to make new ones.

2.5.3 The pharmaceutical manufacturing process

Pharmaceutical manufacturing is an inherently complex endeavour. In the US, the Food and Drug Administration cites product quality and other manufacturing-related issues as major reasons for existing shortages (Food and Drug Administration, 2011).

These issues can include, but are not limited to, any of the following:

1. Product quality problems, such as contamination with particulate matter or precipitates (that may result in cessation of or decrease in production and/or recall of existing product);

2. Manufacturing issues, such as equipment failures or scheduled downtime to upgrade facilities;
3. Insufficient manufacturing capacity;
4. Raw material/active pharmaceutical ingredients (API) supply issues, particularly of foreign-sourced material where supply could be interrupted due to geopolitical factors and/or if API is not available from the sole source; and,
5. Disruptions in the supply of drug product components or packaging (labelling, excipients, etc.)

Suppliers cite production-related issues and increased demand as the main reasons for supply chain disruption related shortages, rather than raw material or quality issues, as stated by the Institute of Health Informatics, Institute for Healthcare Informatics (2011). Older, sole, or limited-source injectable products are particularly vulnerable to shortage situations because of limited production capacity, long manufacturing lead times, and the complexity of the manufacturing process.

2.5.4 Economic factors

Arguably the premier reasons for the pharmaceutical manufacturers to end or curtail production are the economic considerations. Panzitta, Ponti, Bruno et al. (2017) developed the concept of manufacturing appraisal, providing a technical overview of upcoming challenges; this is a risk based approach and an economic picture of shortage costs. They developed an overall quality concept, which was not limited to GMP factors but included all elements leading to a robust supply and promoting technical innovation. However, this is of potential relevance to new products manufacturing, but much of the products in short supply are older, difficult to manufacture and not especially profitable. Relevant economic concerns include:

1. Lack of redundancy — fewer firms making multiple products on existing manufacturing lines;
2. Reallocation of manufacturing resources to other products (including new formulations);
3. Unfavourable economies of scale and/or prohibitively high costs to comply with regulatory requirements or inspectional demands; and,
4. Discontinuation by API or other critical component suppliers which may eliminate alternative supply options or cause critical time and resources for manufacturers to find approved alternate sources.
5. Too much money can be squandered in places where less investment would be equally effective.

6. Cutting costs in areas where there is wastage and money is not being used efficiently. There are always areas in any company that are not working as efficiently as they could.

2.5.5 Regulation

The requirements and decisions by regulatory bodies, such as the National Institute for Clinical Excellence (NICE) in the UK or the FDA in the US, can impact product availability. For example, most drugs are subject to regulatory pre-approval of an application. Furthermore, changes to an existing approved application, such as those involving adding new API sources, new equipment, or new manufacturing processes, may also require pre-approval, potentially slowing production if approval is delayed.

Regulatory and enforcement initiatives may also impact product availability, including standards and quotas by authorities around the globe, an increasing issue with global sourcing driven by cost efficiencies by the manufacturers competing in a global market.

2.5.6 Other underlying forces impact pharmaceutical supply chain

Depending on the situation, other factors may result in a short-term disruption, amplification, or unnecessary extension of an existing disruption situation Healthcare Distribution Management Association (2012b).

Although not usually the root cause of any shortage, these dynamics are worth understanding:

1. A domino effect, as increased demand for related or alternative product causes shortages for those products and there is a delay as manufacturers ramp up production to meet sudden increases in demand;
2. Panic buying/hoarding behaviour that exacerbates a potential shortage, creating artificial demand, additional cost and waste in the system if product is unused and returned, as shown in Figure 11 below;
3. Contract awards that produce large demand shifts in a short period of time;
4. Severe inventory demand disruptions which are exponentially greater than predicted normal variation in demand and supply.

Examples could include:

1. An existing product receives regulatory approval to treat a new disease or condition;

2. New product sales significantly exceed expectations;
3. Inaccurate manufacturer demand forecasting;
4. Off-label prescribing;
5. Theft/losses that create temporary 'spot' shortages, and emergency preparedness and response;
6. Natural disasters may disrupt product availability on a local, regional, national or global level;
7. and unusual disease outbreak, pandemic, or other severe public health emergencies may impact product availability due to increased demand.

2.5.7 Impact of pharmaceutical disruptions

The consequences of product shortages have both health and economic implications. In the current economic climate, focus is on costs reduction by governments and industry alike. In contrast, healthcare costs are rising; the World Health Organisation (Guide and Zone, 2017) reported that the UK spent 18% of its GDP on healthcare. Although the consequences of drug shortages may be only a relatively minor part of this rise, it has a significant political impact through real-time media reporting.

The following list gives an overview of the impacts within the secondary healthcare system of acute care medical shortages:

1. Costs of alternatives
2. Time spent on shortages by pharmacists/cost impact efficiency
3. Time spent on shortages by non-pharmacists
4. Additional staff
5. Patient impact (adverse outcomes and clinical incidence)
6. Shortage response path (length of time to get the drug to the patient)
7. Procurement planning, practices, and pricing
8. Stockpiling of medicines in short supply
9. Reduced risk assessment to get into clinical practice

These examples include, for example, direct patient impact, practice management, health system management time and labour resources. Offit (2005) p.623, highlights the many examples within the vaccines group:

> The flu vaccine shortages of 2003–2005 are just one example of what has been a steady, unrelenting series of vaccine shortages. Since 1998, nine of twelve vaccines routinely recommended for young children have been in short supply: specifically, vaccines to prevent measles, mumps, rubella (German measles),

varicella (chickenpox), tetanus, diphtheria, whooping cough (pertussis), influenza, and pneumococcal disease.

These shortages have caused children to miss vaccines that they needed, and some children never caught up when the shortages were over.

It was estimated by Stead (2009) that in the UK, £6 million was tied up in managing shortages through the increased need for management time and resources in managing hospital trusts, sourcing products, and managing staff. Dorsey, Thompson, Dayoub et al. (2009) investigated the September 2007 shortages of generic Selegiline, forcing patients to either switch to more expensive alternatives or forego treatment. They found the societal cost of substituting generic Selegiline with branded capsules was $75,000 over the first four months of the shortage.

Artificial demand is created by panic buying/hoarding behaviour and exacerbates a potential shortage, and causes additional cost and waste in the system if the product is unused and returned, as illustrated in Figure 11.

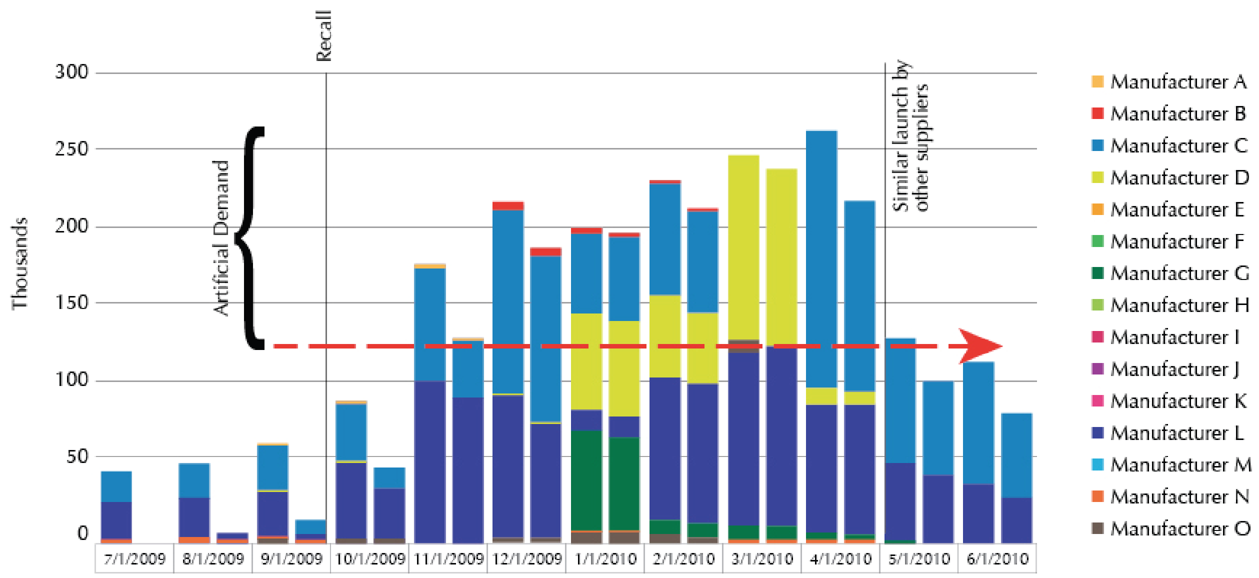


Figure 11. Impact to demand from product recall and supplier backorder, HDMA, (2012)

Figure 11 shows the impact on ordering patterns resulting from a product recall and the domino effect from an anticipated shortage. A product recall of Acyclovir in the Autumn of 2009 triggered an unusually large ordering period lasting more than six months (Healthcare Distribution Management Association, 2012a). Multiple manufacturers received orders for product beyond historical purchase patterns. Once other suppliers launched a similar product, ordering patterns returned closer to previous patterns. In this data from one distributor, all of the orders above the red line resulted from artificial demand. (These reflect orders received, but not necessarily fulfilled.)

Any one of these factors may create or exacerbate a shortage situation that requires consideration of alternative treatments for the patient, whether long-term or short-term. Depending on the patient population undergoing a specific course of treatment, the chronic or acute nature of the medical condition and the therapeutic alternatives available, certain shortages will have a more severe patient impact. From patients to clinicians downstream to raw materials suppliers upstream in the supply chain, the key focus is on the duration of the shortage to make the most informed decisions. As noted by Chadist (2012) both management skill and employee resources are critical to response speed.

As shown below in the Figure 12, which is a high-level diagram showing the upstream and the downstream elements of a pharmaceutical supply chain, there are many elements and levels

Aston University

Illustration removed for copyright restrictions

Figure 12 Pharmaceuticals end to end supply chain map

and actors within those levels. The upstream includes the raw material from different suppliers that make up the finished product the manufacturer produces, and the packaging companies output into the downstream supply chain. The distributors with different channels can use dispensing logistics then to reach further downstream in the supply chain through the hospitals and pharmacies to the patients. The upstream drug supply chain impacts the end sections of downstream hospitals and patients as discussed in section 2.5.2. The upstream problems affecting both the raw materials and the production parts of the end to end supply chain can often be disrupted causing downstream shortages. For example, the Doxycycline shortage of June 2013, where shortages were created by production shortages (Palmer, 2014). The interruptions of production at plants, reduced or halted production of doxycycline by multiple manufacturers because of raw materials shortages. Prices for doxycycline rose dramatically in response with a $5 prescription increasing to $160 and smaller pharmaceutical firms began to produce doxycycline, charging higher prices. With the Centres for Disease Control and Prevention (CDC) recommendation to use Doxycycline only when other interventions were not available. Where the CDC is a public health institute acting as a government agency, and part of the regulatory response in the USA to manage pharmaceutical disruptions.

2.5.8 Managing pharmaceutical disruptions

In the UK, the product shortage crisis has focused the attentions of both the healthcare pharmaceutical participants and the government-run National Health Service (NHS). A variety of groups have been working together to try and understand and mitigate the risks of product shortages in secondary acute care. The NHS has issued guidelines, directives, recommendations and best practice through the European Medicines Agency as well as coordinating through the group of special pharmacists representing the regions across England and the wider pharmacy industry. For example, the 2008 Best Practice Guidance on joint working between the NHS, pharmaceutical industry, and other relevant commercial organisations. The Department of Health and the ABPI have also been working together to develop best practice guidelines. However, as the Chair of the UK National Pharmacy Supply Group, Alldred (2006) notes:

1. Not all pharmaceutical companies are included in the working group
2. Not all pharmaceutical companies in the group follow the best practice guidelines

Drug disruptions in the UK are not always uniformly spread across the regions, however, this may be as much to do with the political geo-economics, such as which medicines to approve and supply by regional hospitals and trusts, rather than a supply chain information issue alone. Government agencies, such as NICE, have recently tried to balance medicines' regional availability using a new scorecard. Stephen Whitehead, Chief Executive of the Association of the British Pharmaceutical Industry, commented (Association of British Healthcare Industries, 2012) that the NHS Innovation Scorecard will be a valuable tool for supporting the use of the latest NICE recommended medicines across England. On regional differences, he further added that there was still a great deal of variation across the country on which treatments patients are able to access and was hopeful the Scorecard will help highlight discrepancies which can then be addressed.

Pharmaceutical companies are businesses, not public health agencies nevertheless and to deal with the problem of drug shortages, a holistic multi-agent approach is required. The challenge has been that relying on a voluntary cooperation between parties with different interests has so far not solved the problems of drug shortages, rather the problem appears to be getting worse, as shown above in Figure 10, with 267 reported drug shortages in 2011 compared to 120 in 2001 in the US alone (Healthcare Distribution Management Association, 2012a).

Governments can legislate through specific policies on the issue of drug shortages, but in the UK the approach has been to focus on the issuing of guidelines and the promotion of working groups, government agencies, and partnership approaches, although the legal threat remains. In contrast, in the US, policy making is already underway to try and prevent shortages occurring in critical drugs. Chabner (2011) records that on October 31, 2011, in response to the shortages, US President Barack Obama issued an executive order in which he broadened reporting requirements for potential shortages and instructed the FDA to accelerate reviews of new applications for marketing of generics and to provide information to the Justice Department about possible collusion or price gouging related to the shortages. This action represents a step forward in addressing this issue. Earlier draft legislation to address the issue of drug shortages has been brought forward in both houses of the United States Congress (2011), leading to the Preserving Access to Life-Saving Medications Act. A similar resource has been developed for Canada. In Europe, France has led the way on regulation in taking action on shortage management through the Health Law of January 2016; France acquired new regulatory tools in order to fight against growing shortages and wanted to target the drugs for which they are the most detrimental: the major therapeutic interest (MTI) drugs (Bocquet, Degrassat-Theas, Peigne et al., 2017).

Gray and Manasse (2012), from a US-based perspective, proposed that a longer-term solution may lie in careful policy-making that avoids winner-takes-all procurement decisions, one that promotes the development of a sustainable local and global pharmaceutical manufacturing capacity, and that identifies and protects particularly fragile markets. While there have been predictable libertarian calls for lifting price controls to encourage investment, governments have a responsibility not only to ensure the quality of medicines and access to essential medicines, but also to create the necessary conditions for a sustainable, productive, and responsible pharmaceutical industry. In this case, *laissez faire* will not suffice.

2.5.9 Improving efficiencies in the pharmaceutical supply chain

To reduce supply chain disruption impacts, proposals and guidelines have been offered through industry journal, such as Pharma IQ (2010), which has focused on improvements to the efficiency of the supply chain:

Cutting out the middle man (wholesaler) or disintermediation
Speed up the distribution process, as the company will be delivering directly to the customer.
Cut costs by cutting out the middle man.
Sell more product; with better prices the companies will be more competitive and outsell competitors.
Improvements in tracking product, to reduce counterfeits and competitors copying product.
Improve technology in the manufacturing process. This will help:
The products to be created quickly and efficiently.
Better technology will help product cost to be reduced and sold at a more competitive price.
Upgrading manufacturing equipment and processes to make manufacturing product more efficient.
Quality control will be increased.
Supply chain analytics should be done...
Examine which suppliers are the best and most efficient: some suppliers are better than others. The more efficient the suppliers are the better, the supply chain will work.
Impaction of varied factors can affect the supply chain. The impact of various elements like weather or the rise and fall of fuel prices on the delivery system will affect cost of supply.
How much inventory to keep for certain products
Examining the purchasing team in the company.
The pharmaceutical industry primary focus and recommendations as private companies are however inevitably driven by the company shareholders. But where cost efficiencies can be combined with practices that result in reduced shortages it can be of benefit.
All participants in the healthcare supply chain play a role. The value of communicating information among all supply chain participants and healthcare providers is required.

Table 4. Supply efficiencies improving the pharma supply chain, adapted from Pharma (2010) p58.

Information normally needed by stakeholders includes:

1. The reason for a shortage;
2. Estimated duration of the shortage;
3. Potential alternate sources;
4. Potential alternate therapies; and,
5. Allocation parameters (including limits and processes from manufacturer and distributor).

If a manufacturer has instituted an allocation plan for distribution to their customers due to a product shortage, how the manufacturer communicates that information to its trading partners is also very important.

Similarly, distributor communication to downstream customers is also important and should be consistent, accurate, and timely. Technology can be a valuable tool in communicating product availability issues. Although manufacturers must consider the potential risk that communications may cause stakeholders downstream to focus on protecting and enhancing inventory position, effective communication can assist in averting panic-buying and/or hoarding, especially of medically necessary products.

The challenge has been that all stakeholders do not cooperate efficiently or equally, causing the quality of the information communicated to reduce its application in some areas of the supply chain and hence a degradation on performance. Frictions exist further down the supply chain between industry groups as pharmaceutical disruptions impact the drugs supply. In a three-month consultation run by the National Pharmacy Association in the UK, over 700 pharmacies expressed their views on the role played by wholesalers in a medicine's supply chain that has been criticised for too often failing to ensure drugs reach pharmacies and patients in a timely manner. The consultation revolved around five issues; fairness, responsiveness, timely communications, efficiency and transparency, allowing NPA members to measure how well wholesalers are performing and to give the NPA a picture of wholesaler performance across the board (Jones, 2014). The British Association of Pharmaceutical Wholesalers reacted to the findings by saying they welcomed all feedback on services. Sawer (2014), executive director of the BAPW, however, commented that BAPW wholesalers and distributors provide a world class, efficient, and resilient service on behalf of two billion different healthcare items per year to all hospitals, pharmacies, and dispensing doctors across the United Kingdom.

The following section illuminate's steps from a manufacturing perspective in managing disruptions that commonly result in product shortages and communication about product availability that have been used in the UK and the US.

2.5.10 Manufacturers Improvements

In the US, the FDA, and in the UK, the Department of Health, works to communicate information about shortages based on information provided by the manufacturers, and will work directly with a manufacturer or manufacturers to take appropriate steps to address the disruption to quality and regulatory barriers that may have caused or contributed to shortage situations. In both geographies, however, this is a voluntary arrangement except in certain circumstances for sole-source and medically necessary products. However, this information is necessary for stakeholders to manage product shortages when disruptions occur and helps determine strategies employed based upon the nature of the shortage and how long it is expected to last.

Pharmaceutical manufacturers can report any information to either drug shortage websites in the UK, this is potentially the University College London Hospital (UCLH) website, or to the Department of Health (DoH), or in the US the FDA, or the Association of British Healthcare Industries (ABHI) websites. In some cases, confidential communications with the DoH or FDA is necessary to protect proprietary information and reduce the risk of panic-buying in cases where medically necessary products may be in short supply until the agency and manufacturer can sort out shortage issues. This delayed communication often causes frustrations at a regional hospital level and tensions exist between the parties involved.

In the UK, these tensions and delayed information communication channels have resulted in the increasing drive for collaboration. The DoH encourages the setting up of working groups where all stakeholders try and work together through cooperation and information sharing. Communication strategies for these products may require special attention to lessen the impact of a shortage on patient care. To help prevent product shortages, manufacturers have been encouraged to focus on accurately forecasting demand and maintaining internal quality assurance and other practices that address product shortages. Demand forecasting requires certain information from a manufacturer's customers, including distributors, purchasing groups, and chain drug and government entities.

In the US, a fee-for-service and inventory management agreement to guide distributors has been set up, providing inventory level information to manufacturers (often through Electronic Data Interchange, or (EDI) so that future manufacturing needs can be met.

Purchasing agreements, according to the UK Commercial Medical Unit, take account of the nature and availability of branded drugs in acute medical care when agreeing contracts with manufacturers. They have also used consultants to investigate the procurement practices and strategies to allow them to rank the suppliers on compliance in their supply of medicines. This has allowed the CMU to negotiate service credits based on supply performance.

The DoH in the UK, and the FDA in the US, have developed other practical distribution disruption strategies to cope with the lack of product. Although this may not address the root cause of the problem, it has been effective in mitigating the impact, and in some cases, reduces the problem.

2.5.11 Product Shortage Allocation

The main consideration in using product allocation programmes (Healthcare Distribution Management Association, 2012a) are as follows:

- The launch of the allocation programme for the finished goods inventory as close as possible to the communication of a shortage to trading partners (i.e. the sharing of the limited supply amongst Trusts and Institution by critical need)
- To consider the potential benefits of maintaining a central pool of inventory:
- Also, to ensure allocation programmes are user-friendly, fair and adequately communicated to all stakeholders.

2.5.12 Health systems or hospital pharmacy

By defining the guideline, as proposed by Fox, Birt, James et al. (2009) for the decision-making procedure, the response of the healthcare system can try and diminish the supply chain disruption impact, as shown in Figure 13. These guidelines come from the American Society of Health System Pharmacists (ASHP), the UK has a similar best practice guide from the Association of British Healthcare Industries (ABHI).

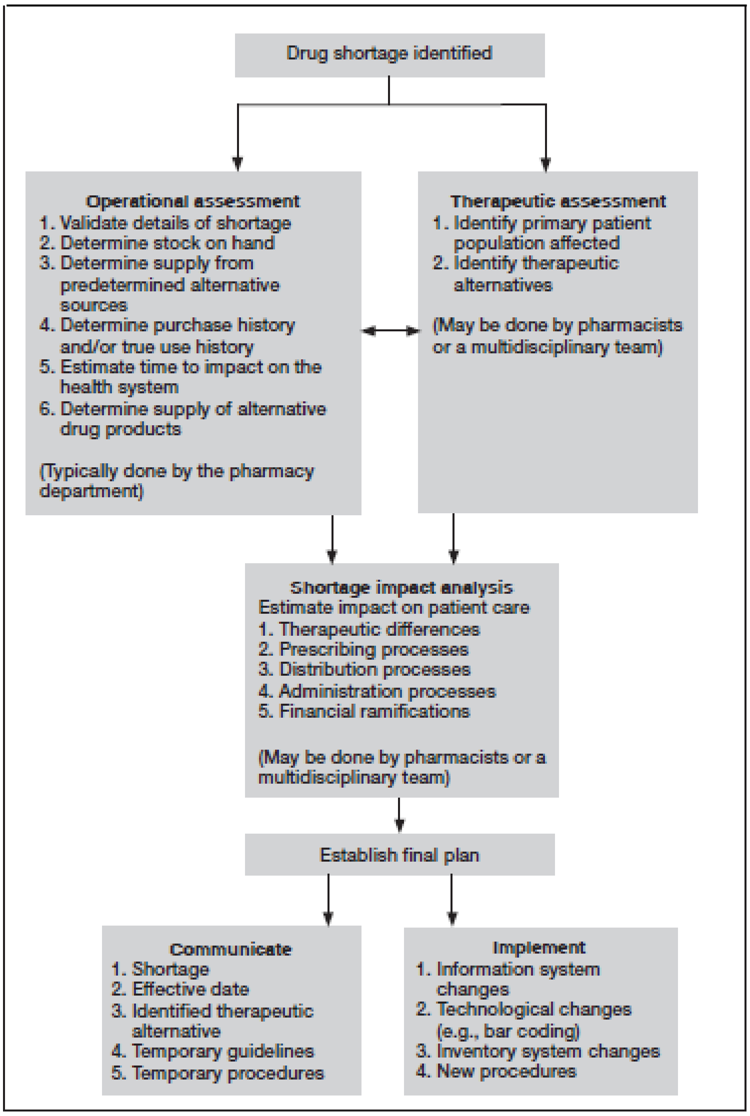


Figure 13. Adapted from ASPH (American Society of Health System Pharmacists) Guidelines for drug disruption management in hospitals and healthcare systems (2009:61)

The ASPH (2009) guidelines recommend that hospital pharmacy staff, which are generally a multidisciplinary team of both pharmacy and non-pharmacy staff depending on the size of the institution, will take the following actions:

1. An operational assessment, typically done by the pharmacy department, will examine shortage details, determine remaining stock, identify alternative sources of the product in shortage, analyse purchase and use history, estimate time until impact, and identify supply of alternative drug products;
2. A therapeutic assessment performed concurrently with the operational assessment will determine the primary affected patient population and identify any therapeutic alternatives;

3. After collecting necessary operational and therapeutic information, the team will conduct an impact analysis by examining therapeutic differences, prescribing, distribution and administration processes and financial ramifications to estimate the impact of the shortage on patient care;
4. Using the collected information, staff will create a final plan that addresses operational, therapeutic, and ethical issues while meeting the institution's patient care standards. This plan is approved by the Pharmacy and Therapeutics Committee when the shortage represents a significant impact on patient care (e.g., alternative therapies are less effective than the drug in shortage);
5. Sustained communication throughout the health system is necessary for the duration of the shortage. The shortage team uses the most effective means available to inform all affected staff of the shortage, the date of impact, identified therapeutic alternatives, and any temporary guidelines and procedures necessary for maintaining patient safety and quality of care. Communication means may include email, order-entry and decision support systems, staff meetings, or other established internal communication routes; and,
6. Once informed, staff members will ensure that the plan is implemented. This includes information technology system changes, technological changes (e.g., bar coding), inventory system changes, and new procedures.

Section 4.4.13 summarises the pharmaceutical supply chain disruption topic, including management strategy.

2.5.13 Medicine supply chain disruption discussion

The causes of medicine supply chain disruptions are disputed depending on which stakeholders are engaged in discussion, but can be categorised under supply chain disruption as a result of economic, manufacturing, and regulatory factors. There are usually several factors occurring at the same time, combined with a global dynamic. The consequences can be catastrophic at a patient level and the problem is growing year on year. A variety of preventative measures and approaches have been used in different geographies, both at a macro and micro level.

In some cases, however, because of the nature and structure of the pharmaceutical chain, legislative measures designed to improve the drug supply can in fact worsen the situation. For example, as described in research looking at the critical challenges for generic medicines by Chabner (2011), it was observed that in the US, the problem for cancer treatment stems from a confluence of factors: consolidation of generic drug production in the hands of a few manufacturers (Teva, Bedford, APP Pharmaceuticals, Hospira), who in turn have experienced both increased demand for drugs and production 'problems'. In general, generic drugs are sold for very limited profit, as fixed in the US, for example, by Medicare legislation, and therefore are produced as inexpensively as possible, using older and less efficient production facilities, and with limited inventories to reduce carrying costs for the company. Once these factors were combined with the closure of several key plants, i.e. Bedford and Hospira, due to contamination of commercial drug vials with particulate or biologic matter, the problem becomes critical. Also, legislation to change the behaviour of profit-making organisations can have unpredictable consequences, and each country has their own laws and interpretations. Countries with low cost legislation for critical drugs can find supplies reducing as pharmaceutical companies, or resellers, divert products to more profitable markets, therefore disrupting the supply.

At a country level, the implementation of voluntary communication guidelines and examination of other practices could help the healthcare industry mitigate the impact of supply chain disruptions and consequential product shortages and, to an extent, improve communications when disruptions occur, and encourage coordinated recovery from product shortage situations between trading partners. Due to the unique nature of each product shortage and the complexities of the underlying causes, it will take strong relationships between trading partners, open channels of communication, and controlled discipline among supply chain partners to mitigate their effects. Regardless of the root cause(s) of any shortage, it is a shared responsibility among all supply chain partners to manage available inventory to meet patient need to the fullest extent possible and to recover from the shortage in the most expedient manner possible.

On a wider perspective, (Boscheck, 1996), looking at comprehensive healthcare reform and the restricting of the pharmaceutical industry, stated that market transparency and the independence of information is the essence of managed care.

As previously mentioned, management strategy to combat the consequences of pharmaceutical supply chain disruptions has offered up a variety of ‘options’ for organisations. Those organisations:

> that have been hugely successful…are great not because they were focused on cost or flexibility or speed, but because they have the ability to manage

> transitions, changing market [and environmental] conditions, evolving technology, and different requirements as a product moves through its life cycle

(Enyinda and Szmerekovsky, 2008) p98.

Organisations that can adapt are the ones that will be here for the long-term (Beth, Burt, Copacino et al., 2003). Possibly, smart supply chains can create customer or shareholder value through their abilities to sense and respond to changes in environmental conditions and threats in order to meet customers' value expectations. It has been argued that transforming the pharmaceutical industry supply chain through sense and response supply chain models will become a matter of adapt or perish. Adaptability invokes the ability of organisations to sense early (anticipate) and quickly respond to sudden changes in environmental conditions (Haeckel, 1999, Heinrich and Betts, 2003). For the pharmaceutical firms, it is the ability to sense and respond swiftly to changing business environments that will be required for firms to survive in the 21st century global economy and to gain a competitive advantage. Just like other industries, the pharmaceutical firms can leverage a sense and respond supply chain model to defend against counterfeiting and diversion of legitimate drugs. Every adaptive system survives by making sense its internal and external environments and responding with appropriate pre-emptive actions. The sense and respond supply chain model, with an adaptive value chain network depicted below in Figure 14, presents how pharmaceutical firms can mitigate disruptions by sensing what is taking place in its environment. Adaptive supply chain networks are communities of customer-centric organisations that must first sense what is going on in its environment, share knowledge, rapidly seize new business opportunities, and responding to them while judiciously adjusting to changing business conditions (Haeckel, 1999). The ability to rapidly adapt to uncertain environmental changes is arguably hinged upon sense and respond supply chain technologies such as RFID. Possibly, RFID enabled sense and respond supply chains can provide near perfect real-world awareness of information regarding environmental changes.

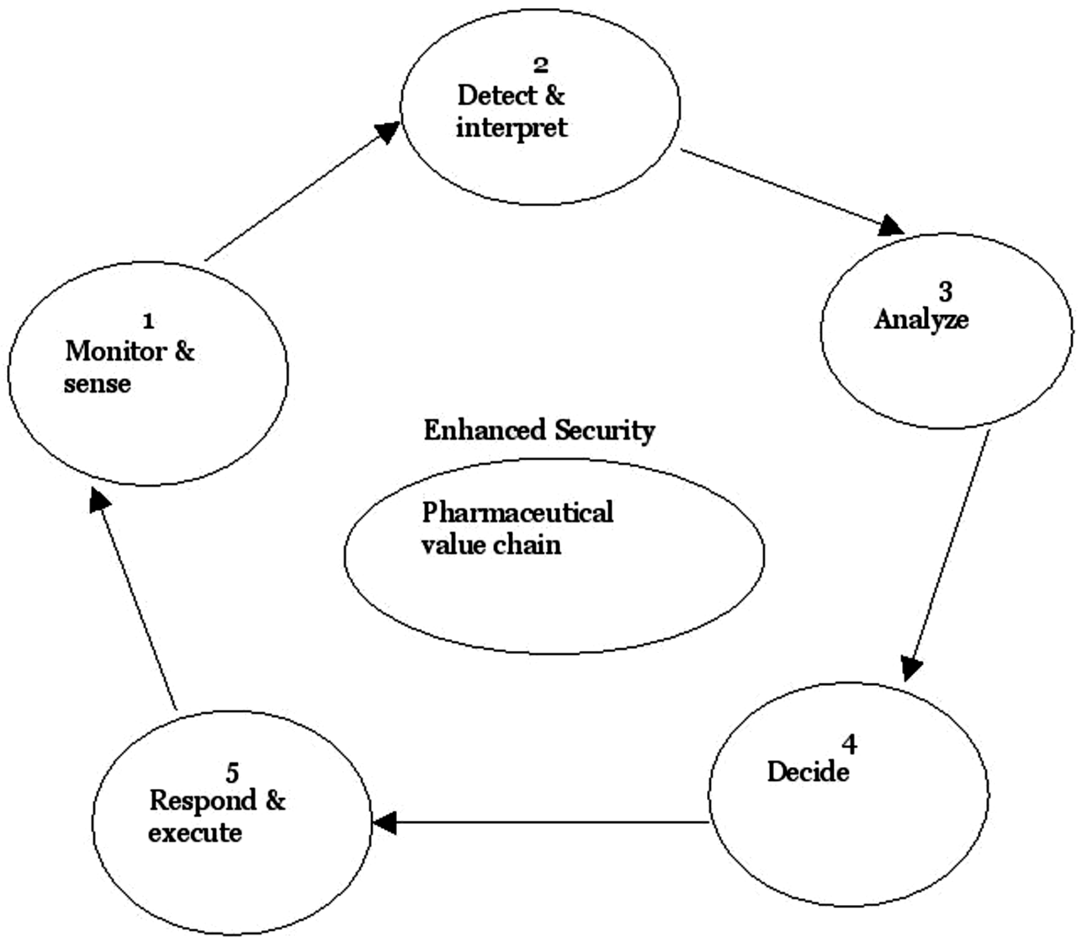


Figure 14. Sense and respond supply chain with an adaptive value chain network, adapted (and modified) from IBM (2005). Transforming the Military through Sense and Respond. IBM Consulting Services (Lin and Luby, 2005).

As described above in Figure 14, RFID adaptive supply chain networks can develop beneficial capabilities, including, 1) monitor and sense, 2) detect and interpret, 3) analyse, 4) decide, and 5) respond and execute (Lin and Luby, 2005). Fisher (1997) p.110, asserted that: “never has so much technology and brainpower been applied to improving supply chain performance,” as is the case with RFID technology. Essentially, the ability to sense unexpected vulnerabilities and provide near real-time information can adapt supply chain processes to respond in the most efficient and/or timely fashion, which is imperative (Ferrari, 2006). Increasingly, because the pharmaceutical firms can no longer meet today’s challenges with their current mitigating strategies, there are alternative/additional options to look toward developing sense and respond supply chain capabilities. With RFID-based send and respond supply chains, firms can achieve real-time visibility on the status of products within and across enterprises. For example, according to an FDA report, the pharmaceutical industry has been subjected to serious consequences because of the current level of counterfeiting that is estimated at 7% to 10% of the total market and growing annually. To reverse this trend, the pharmaceutical industry must evolve its supply chains into adaptive networks of supply chain partners that use technology to sense and respond in a coordinated fashion to changes in their operational environment (Radjou, Orlov and Nakashima, 2002).

Not only are firms' transitions to sense and respond supply chains evolutionary, but it is also more urgent than ever if firms want to be less vulnerable, less massive, more robust, and more effective. This indicates that firms must evolve along two premier trajectories; becoming more collaborative and adaptive (Castano-Pardo, et al., 2006). However, this technology-based strategy relies on the easy adoption of RFID, which has not been the case in the pharmaceutical industry because of multiple barriers. Yao, Chu and Li (2010) showed that most care providers indicated RFID to be functional and useful in asset tracking and patient identification. Nevertheless, major barriers were also identified to RFID adoption in healthcare, including prohibitive costs, technological limitations, and privacy concerns. Other barriers to RFID adoption include the lack of organisational support, trust issues, and security concerns. Further agreement on universal standards and protocols globally is far from resolved. It can possibly assist in identifying counterfeiting and diversion of products, but for disruptions caused by production interruption at the manufacturing level, something that is common (Breen, 2005), there may also be no product to track. In emerging markets, such as Africa, an m-pedigree method has been piloted using mobile phone technology to verify the validity of pharmaceutical packs where no other technology is prevalent and available. Though tracking and authenticating drug packs may improve security, reduce waste (Paik, Chen and Subramanian, 2009), and so reduce supply chain disruptions due to counterfeiting, it does not offer an effective management strategy for responding to the disruption once it occurs.

Eliminating waste and thus fat from the supply chain does cut costs, but with it also comes risks: it makes the supply chain increasingly vulnerable to disruptions and unpredictable events as there is no slack to fall back on. In the car industry, which may not be such a problem, all it means is the customer will just have to wait a little bit longer until the car is ready. Patients, on the other hand, must take their medication immediately; sometimes their life depends on having the product available day to day. We have the moral obligation to guarantee the best possible treatment to the patients and, consequently, securing the supply of medication (Pharma, 2011).

Pharma Trade Journal (2011) p89, predicts:

> In 10 years' time, risk management will not only take place on a strategic level, but it will have penetrated day-to-day supply chain operations. We will see a comeback of operations research, not to cut costs, but to calculate and balance the likelihood and impact of risks against the cost of mitigation. Agility will become a feature of the industry, and the organisations that succeed in implementing this most successfully are best equipped for survival in an uncertain 21st century.

Resilience, in turn, can be achieved by either creating redundancy or increasing flexibility. Redundancy is the familiar concept of keeping some resources in reserve to be used in case of a disruption. The most common forms of redundancy are safety stock, the deliberate use of multiple suppliers even when the secondary suppliers have higher costs, and deliberately low capacity utilisation rates. It can be argued that significantly more leverage, not to mention operational advantages, can be achieved by making supply chains flexible and dynamic. Flexibility requires building in organic capabilities that can sense threats and respond to them quickly. Adding a dynamic aspect to shortage disruption management response actions can improve flexibility and actions can be fluid and combined to potentially improve shortage management performance. These findings from the literature review will be crystallised in the development of the research question in Chapter 3.

2.5.14 Summary

In summary, this section considered the current knowledge and literature on supply chain disruptions, including risk management, response management in general and in the distinctive context of the drug industry environment. It described and critiqued the current research, including a detailed and focused examination of 77 supply chain resilience articles to inform and highlight the gaps in the research to further develop the extant research which underpin the development of the research question this study will address in Chapter 3.

3 Development of Research Question and Propositions

3.1 Introduction

The following sections describe the development of the research question for this study. The research question is crucial as it guides multiple aspects of the research study, from research design, data collection and analysis and focuses the direction of how, what, and why the research is conducted (Bryman and Bell, 2011). The research development chapter is divided into four sections, firstly introducing the overarching research question (3.2). It then elucidates the three constructs: Supply Chain Disruption Orientation, Supply Chain Disruption Performance, and Organisational Response and each section are followed by their relevant propositions.

The research question section will refer specifically to the new conceptual model that this research will examine in detail. The original and new models are both described and contrasted in the literature review in section 2.4.3, supply chain disruption response management. In particular, the research question is built from the supply chain response management post disruption gaps identified in the literature review.

A single research question was chosen because, following the in-depth literature review, it focuses on the key area of unexplored research extending the previous academic work by (Bode, Wagner, Petersen et al., 2011) on understanding responses to supply chain disruptions: insights from information processing theory (Galbraithe, 1973, Tushman and Nadler, 1978) and resource dependence perspectives (Pfeffer and Salancik, 1978). That is the interactions of supply chain response alternatives of buffering and bridging post disruption event, considering the performance aspect not explicitly considered previously in studies and set in the critical and challenging new context of the real-world phenomenon of shortage management. As explained in the review, buffering actions are attempts to gain stability by establishing safeguards that protect a firm from disturbances that an exchange relationship confers, and bridging actions are attempts to manage uncertainty through employing 'boundary-spanning' and 'boundary-shifting' actions with an exchange partner (Fennell and Alexander, 1987, Meznar and Nigh, 1995). The critical challenge of shortage management is, most fundamentally, a lack of adequate supply of a particular drug product to meet medical need (Charatan, 2001, Mirtallo, Holcombe, Kochevar et al., 2012). Performance measures are used in supply chains by management to determine the efficiency or effectiveness of a specified supply chain (Swaminathan, Smith and Sadeh, 1998).

The measures to be used in this research are taken from the relevant academic and practitioner literature, and this research highlights the measurement and the analysis of causal relationships between the variables which are developed. The use of performance measurement is a novel approach to supply chain disruption response decisions. Items included are validated measures used in previous studies on supply chain performance (Gruen and Corsten, 2003, Baumer, 2004) and are described and justified in detail in the technique and procedures (section 4.6) of the research design. The three key constructs explained below were developed to succinctly answer the research question and each was defined by the key research areas that are not presently explored in-depth in the extant literature on supply chain disruption response, as identified in this research's literature review and evidenced in the focused 77 articles review in Appendix 1. These constructs extend the previous work on post disruption events management strategy, i.e. supply chain disruption orientation, supply chain performance, and organisational response, as highlighted in red in the below Figure 15. The first two constructs, as shown in Figure 15, are drawn from the existing model of organisational responses to supply chain disruptions introduced by Bode, Wagner, Petersen et al. (2011), and the third construct of performance extends the original model. Each of the constructs was further developed into a series of relevant propositions which were expanded so that each element of the construct can be measured, examined, and defined. The three constructs are highlighted and put into context of the overall study in the research design and strategy discussion in Chapter 4, as shown in Figure 22: the research problem flowchart. This flowchart links the research question, constructs, and propositions. Although a research question can never fully be answered in completeness, it does allow the generation of fresh insights into the subject under examination to contribute to existing and future research.

As identified in the research literature review (Section 2.4.3), understanding a firm's responses to supply chain disruptions *after* the event and constructing a holistic theory to explain these issues is still developing. This research gap has informed the research design of this study which will lead on from the principles of theory-orientated research following a deductive approach by testing the below propositions. The objective of theory-orientated research is to contribute to the development of theory (Dul and Hak, 2007). The research question below was formed by the need to build on and give further insights into post-disruption management strategy theory, as highlighted in this study's review of the extant literature. It will be explored in the subsequent propositions introduced with each construct, which will then be tested by this research to contribute to academic theory development.

3.2 Research Question

How do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management?

The specific research question is formulated to define the area of interest and what it is the research wants to know. This is to prevent the risk of open-ended research which can lead to the collection of too much data, which lacks focus. As noted by Bryman and Bell (2011), without the focus of a specific research question the researcher is unsure what the research is about and the reason the data is being collected. A series of propositions (P1-P3) were designed based on the existing research theory of information processing theory (Galbraithe, 1977) and resource dependence theory (Pfeffer and Salancik, 1978). However, this research will also include other perspectives of organisational learning literature and organisational response (Crossan, Lane, White et al., 1995, Crossan and Guatto, 1996, Dodgson, 1993, Cohen and Sproull, 1996) incorporating the concept of dynamic resilience (Grewal, Johnson and Sarker, 2007, Peck, 2006, Huber, 1991, Edmondson, 1996, Ponomarov and Holcomb, 2011) as discussed in the literature review (Section 2.4.3). For each of the underlying theory constructs, as shown below in the new proposed model, these constructs, highlighted red in Figure 15, were developed and extended from the original Bode et al. (2011) model of organisational responses to disruptions, which will be tested by examining the propositions using a survey tool and triangulated with interviews, focus groups and secondary data described and justified in the research design section.

The following section outlines each construct this research will examine to answer the above research question. Each construct is firstly defined from its basis in the extant literature and then each subsequent proposition (P1-P3) to be tested by this research is developed and explained.

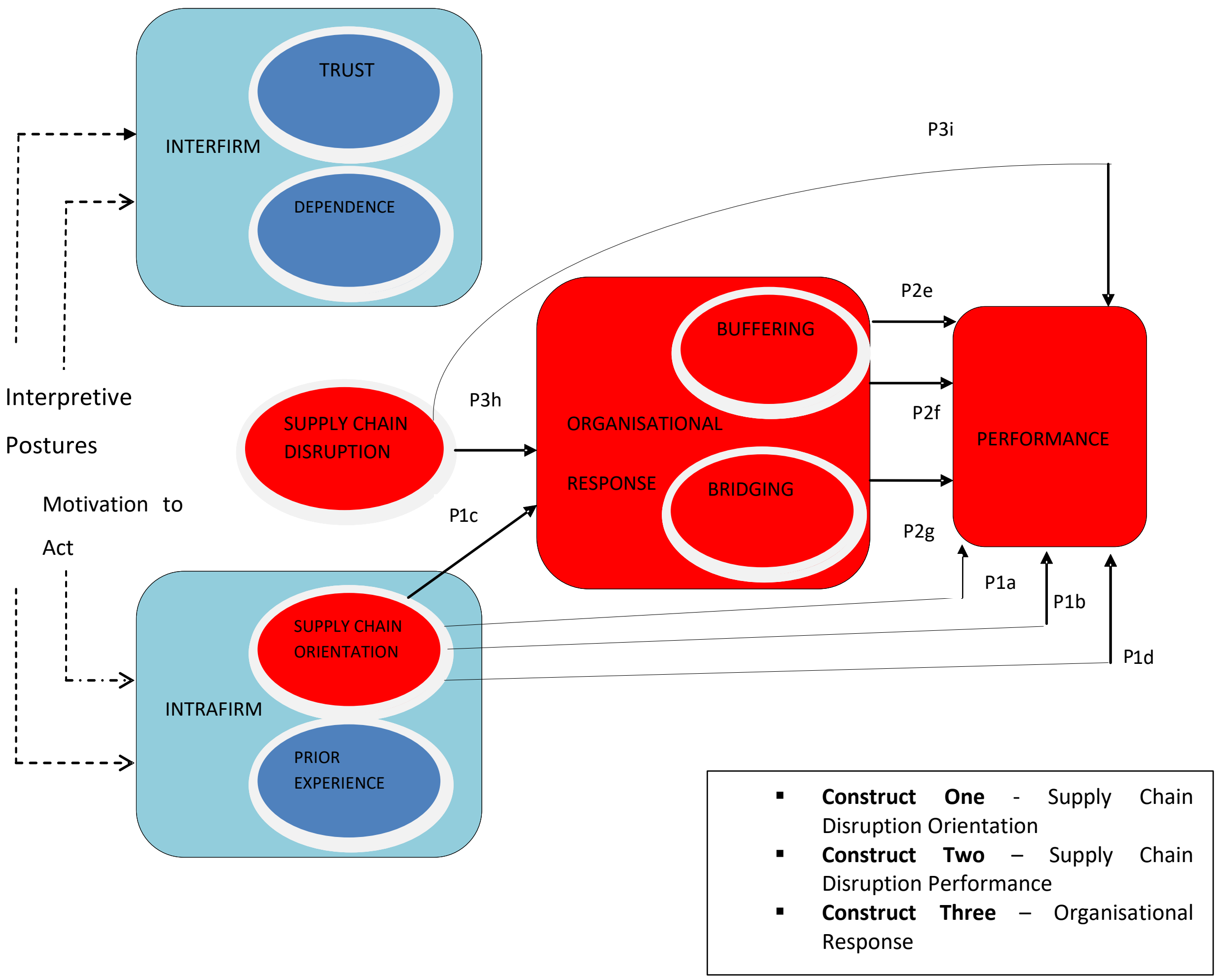


Figure 15. New proposed model of organisational responses to supply chain disruptions, integrating response action and output performance

3.3 Supply Chain Disruption Orientation Construct

The first construct that this research will refine and expand to augment understanding of supply chain disruption management knowledge is *supply chain disruption* *orientation,* which was first introduced into the supply chain management literature by Bode et al. (2011) to fill the gap in the research, as identified in the literature review.

Supply chain disruption orientation is a new concept and was defined by Bode et al. (2011) as an organisation's general awareness, consciousness of, concerns about, seriousness toward, and recognition of the opportunity to learn from supply chain disruptions. The stronger the firm's supply chain disruption orientation, the more importance it attaches to the issue of supply chain disruptions and the more pronounced its need for stability is. The supply chain orientation concept built on previous work in the supply chain risk management literature (Autry and Bobbitt, 2008, Christopher and Peck, 2004, Sheffi and Rice, 2005). Autry and Bobbitt (2008) did look at how a firm was orientated towards risk but there was an emphasis on the security element, with respondents blending their responses to this purely qualitative research on security risk with operational performance. The supply chain security (SCS) has since developed from the risk management literature with an emphasis on an orientation to damage limitation and performance (Lu, Koufteros and Lucianetti, 2017), identifying practice against performance in the wake of incidents, such as the 9/11 attacks, to thwart breaches and restore operations. Supply chain security has an emphasis on prevention rather than concentrating on the reasons due to interpretation and motivation to act by examining mitigation and response actions. Supply chain disruption orientation, in contrast, builds on a firm's market orientation (Narver and Slater, 1990) and entrepreneurial orientation (Lumpkin and Dess, 1996). Supply chain disruption orientation draws on Daft and Weick (1984) work which explained how a firm's behaviour was categorised either as active or passive. Whether a firm is active or passive then determines their actions as both proactive and assertive, or to accept the environment as a given and being reluctant to change, therefore making them slower to respond to environmental events.

This argument indicates that if a firm is an active firm with high awareness of disruptions that they would have a strong motivation to act as per resource dependency theory (Pfeffer and Salancik, 1978). As examined in the literature review (Section 2.3), resource dependency theory states that firms seek to assert control over the resources they require to minimise their dependence. So, where a supply chain disruption entails a dependence relationship, it requires action. Furthermore, when a disruption event occurs there can often be a mismatch between the amounts of information available to a firm and its information processing capacity (Huber and Daft, 1987). As per information processing theory (Galbraithe, 1973) , the greater the uncertainty a firm faces, the more information it needs to gather and process to achieve a given level of performance. Organisations may be more active in using information to try and influence their environmental stability, and use information proactively. In this way, organisations would be high performing in response to a disruption event causing shortages by using information more effectively. As informed by the literature review, and addressing the first construct of supply chain disruption orientation, the below proposition P1a is developed, where the unit is defined as a pharmaceutical dispensing operation managed by a pharmaceutical lead within an acute secondary care hospital (as described in detail in the Section 6.10 of the research design section). The proposition to be tested is:

Proposition 1a. The stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management.

The original concept of supply chain orientation did not take account of boundary conditions in which a firm makes response decisions. Looking at supply chain redesign for resilience, Carvalho, Barroso, Virginia et al. (2012) stated it is expected that specificities related to the industry context like product type, production process, country and cultural perspectives can impact on the types of resilience and agile practices employed in the supply chain and the effect these practices have on supply chain behaviour; so the decision-making response to disruption is affected by the environment the firm operates in. Simon (1979) originally developed the concept of boundary rationality and considered rational decision-making in business organisations. Bounded rationality refers to the limits experienced by managers in their ability to process and interpret a large volume of pertinent information in their decision-making activities (Simon, 1979). Boundary rationality bias in managerial valuation of real options was considered by (Tiwana, Wang, Keil et al., 2007); they noted that real options theory unequivocally suggests that uncertainty increases options value. Furthermore, the more knowledge supply chain members possess, the greater their awareness that additional knowledge can ultimately enhance outcomes (Hult, Ketchen and Slater, 2004). Mintzberg (1973, 1975) considered decisional roles of managers. He described how decision-making choices and their requirements are determined by the manager’s role, seniority, and availability of information. Bounded rationality thus describes the process of how managers arrive at their assessments (Simon, 1979). Bounded rationality encompasses two central concepts: search and satisfying. Search refers to how extensively a decision maker searches for information to guide decision-making, its perceived organisational benefits, and the technical and business uncertainties that might affect its likelihood for successful completion. The search scope is capped by what Simon describes as an aspiration level that defines at the outset of the search process what constitutes a good enough solution. As soon as this aspiration level is reached, individuals terminate the search process and reach a tentative conclusion. Search is guided by heuristics that are tacitly held but consistently used to simplify the cognitive decision-making process (Simon, 1979, Tiwana, Wang, Keil et al., 2007, Hammond, Keeney and Raiffa, 1998).

Managers cope with the potentially large volume of contextual information by focusing on a few salient cues in forming heuristic-driven judgments under uncertainty (Kahneman, 2003, Simon and Houghton, 2003). Individuals then reach a preliminary conclusion after assessing a salient subset of the available information that they see as being most informative and terminate their search (Miller and Chen, 2004, Hilary and Menly, 2006). Management strategy in response to post disruption has to then take into account other factors than explained by resource dependency theory. Having control over a firm's resources in traditional strategic management decisions (Child, 1972) is only one aspect of the contingency approach to organisational behaviour (Buchanan and Huczynski, 2004). Taking account of the alternative perspectives using the determinists approach to contingency, for example, (Burns and Stalker, 1961, Lawrence and Lorsch, 1967) describe 'contextual' factors, such as size, ownership, technology or environment, imposing constraints on managers' choices as also necessary. The environment in which managerial decisions are made in response to disruptions affects the decisions made and so influences the outcomes. The extent of the disruption, the role, and knowledge of the manager making the decisions will influence the response choice and therefore the performance. The next proposition is informed by the gap identified in literature review, where the original supply chain disruption orientation concept excluded boundary rationality, to test how the contextual factors through the role of the actor influence outcome:

Proposition 1b. The lower the role of the actor responsible for making supply chain disruption action decisions, the lesser the shortage management performance

Boundary spanning activities (Thompson, 1967) can either link organisations to other organisations or buffer them from environmental disturbances, as noted by Fennell and Alexander (1987). Given the problem of hierarchical clustering or multiple levels of organisation (Freeman, 1978), organisations can be defined as either independent units or members of larger organisational systems. Fennel and Alexander (1987), in their research on organisational boundary spanning in institutionalised environments, found that hospitals in systems are more likely to bridge, probably as a result of corporate policies intended to centralise functions and minimise costs. System membership was reported by Fennell and Alexander (1987) as an important factor in a hospital's selection of bridging or buffering. A hospital which is the sole unit in a hospital trust, as opposed to a hospital in a trust which is made up of a number of trusts, *may* have a higher tendency therefore to bridge within the trust than the sole unit does. The concept of supply chain disruption orientation is a novel concept in supply chain management research, as discussed in the literature review (Section 2.4.3), and this research aims to give further insights into this concept to fill this academic gap. To develop the concept of supply chain disruption orientation, it is important to identify the response spectrum, taking account of the system, a unit is in (i.e. whether the pharmaceutical dispensing unit in the acute care hospital has opportunity to bridge with other hospitals which are part of the trust or not). The next proposition therefore is:

Proposition 1c. The larger the number of hospitals in a trust, the stronger the supply chain disruption orientation of a unit

Organisational performance in response to disruptions they encounter is not uniform (Hendricks and Singhal, 2005). Hendricks and Singhal (2005) analysed disruptions, including announced shipping delays and other supply chain disruptions reported in the *Wall Street Journal* during the 1990s and showed, based on matched sample comparisons, that companies experiencing such disruptions under-perform their peers significantly in stock performance as well as in operating performance, as reflected in costs, sales, and profits. Firms with a highly developed supply chain orientation should therefore not only out perform their contemporaries but also make better response decisions when the worst of the disruptions occur. The last proposition to examine this construct is:

Proposition 1d. The higher the severity of the disruption, the better the managers with higher supply chain disruption orientation perform

The first construct was concerned with the development of the new concept of supply chain disruption orientation; the second construct further develops supply chain disruption understanding by considering the performance aspect. Performance implications, as debated in the literature review (Section 2.4.3), were not considered in previous research on disruption orientation, specifically Bode, Wagner, Petersen et al. (2011) did not go on to examine the performance repercussions of the respective bridging or buffering strategic response choices.

3.4 Supply Chain Disruption Performance Construct

Supply chain management, observed Seferlis, Vlachos, Iakovou et al. (2008), involves a number of decisions to be taken at every time period to meet end-customer requirements. The overall supply chain performance is multi-dimensional and directly or indirectly affected by several factors, such as service quality and overall operating costs. Provided that these factors are generally battling with each other, trade-off and compromise choices are necessary to achieve the best performance. Inventories at the nodes of the network serve as safety stock to handle the stochastic variation of demand, anticipate for lead time in ordered quantities, and compensate for abrupt shocks (e.g., damaged products during transportation, bad storage conditions, and delays in lead times) that would otherwise disrupt the smooth supply of products. However, making disruption response decisions that give either a positive or sub optimal performance are ‘of the moment’ unless the managers and organisations can learn from that performance (Peck, 2006). As highlighted by Daft and Weick (1984), overlapping with extant organisational information processing models, gathering, processing, and acting on data from the environment is a firm's main task**.** Taking an information processing perspective, it is critical to supply chain success (Bowersox, Closs and Stank, 1999, Busse, Meinlschmidt and Foerstl, 2017).

The supply chain disruption performance construct has its grounding in the information processing perspective, as did Bode et al. (2011), in developing the organisational response framework, as shown in Figure 14, but also draws on the organisational learning research, as discussed in the literature review. Two assumptions underpin much research on learning in the organisational context; that learning is intended, conscious, or purposeful and that ‘successful’ learning leads to better performance. To influence employees, as noted by Sims and Lorenzi (1992), successful managers require an understanding of a contingency of reinforcements, also called the behavioural contingency. The link between learning and performance is explicitly addressed in several reviews. Many organisational learning researchers assume a link between learning and performance (Huysman, 1999, Crossan, Lane, White et al., 1995, Dodgson, 1993). As noted, however, by Huysman (1999), is the learning just a new rather than old routine, or is it an ‘active’ agency. Huber (1991) p1001, defined learning: *“an entity learns if, through its processing of information, the range of potential behaviours is changed”.* Also as per reinforcement theory noted by Robbins, Judge and Campbell (2010), any consequences that, when immediately following responses, increase the chances that the behaviour will be repeated. The results of Bode et al. (2011) points towards the moderating effect of prior experience making a strong case for organisational learning from supply chain disruptions. Hedberg (1981) also raised the question of whether firms forget what they have learned from prior supply chain disruptions. In encapsulating the literature, Huber (1991) identified four key learning elements: knowledge acquisition, information distribution, information interpretation, and organisational memory. In a strategic supply chain, memory encourages more acquisition knowledge (Hult, Ketchen and Slater, 2004).

Members of chains that possess significant memory are aware that knowledge coordination across nodes reduces duplication, waste, and redundancy (Handfield and Nichols, 2002). To make effective response decisions to disruptions which lead to, for example, stock-out situations, outcome performance information needs a feedback loop mechanism. In this way, management making strategic response decisions can make informed response choices, with dynamic capabilities drawing a response dependence perspective (Pfeffer and Salancik, 1978, Daft and Weick, 1984). Actors making independent response decisions may hold diverse views whose interpretation may overlap without reaching consensus on meaning (Gioia and Thomas, 1996). But diverse interpretations are often a hindrance in the supply chain context (Hult, Ketchen and Slater, 2004). Diverse views of concepts can be resolved so that effort can be focused on necessary activities. By including the assistance of empirical performance data from prior response decisions, strategic supply chains can benefit and individual participants learn to think alike. There is a distinction, as discussed in the literature review between managerial ‘work’ as a set of actual behaviours and as a set of desired (either by managers or others) outcomes (Hales, 1986). The following proposition is developed to fill the gap left by previous research by considering the role of feedback and supply chain disruption:

Proposition 2e. There is a positive relationship between the performance feedback given after a supply chain disruption event and higher performance in shortage management.

The analysis of buffering and bridging strategies in response to supply chain disruptions requires further investigation, leading on from the initial works by Bode et al. (2011). An examination of the interplay of buffering and bridging is needed. Buffering involves trying to keep the environment from interfering with internal operations and trying to influence the external environment (for example, building safety stock). Bridging occurs as firms seek to adapt organisational activities so that they conform to external expectations (for example, developing new supply sources). This response could be a response strategy due to a supply factor risk, for example, as a result of having too small a supply base, supplier dependency, inflexibility, or single sourcing (Wagner and Neshat, 2010, Ho, Zheng, Yildiz et al., 2015, Tummala and Schoenherr, 2011). However, as identified by previous research (Meznar and Nigh, 1995, Bode, Wagner, Petersen et al., 2011), the interaction of the different strategies are still not fully understood. In particular, there exists a research gap for deeper analysis of their comparative efficiency and effectiveness. Buffering and bridging choices are not mutually exclusive, as shown in prior work (Meznar and Nigh, 1995, Fennell and Alexander, 1987, Bode, Wagner, Petersen et al., 2011). Although the Bode et al. (2011) study (based on integrating perspectives; information processing and resource dependency theory) did not find significant correlation between the two strategies, they did find that there may be a temporal ordering wherein a focal firm progresses from less to more intense responses. This dynamic nature of organisational responses to supply chain disruptions and their relative efficiency and effectiveness will be tested by the following proposition:

Proposition 2f. Pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management

The dynamic and evolving nature of supply chain risks means that no supply chain strategy is ever likely to be risk-free, and no system, however well managed, is invulnerable. Therefore, as noted by Peck (2005), it seems that there is slack in the system, whether in the form of inventory, capacity, capability, and even time. Mitigating strategies and buffering and bridging have been positively related in risk management research to consider risk reduction and its relation to improved downstream supply chain performance overall, by Mishra, Sharma, Kumar et al. (2016) based on the Miles, Snow, Meyer et al. (1978) four firm typology, although constant awareness and vigilance are needed if supply chains are to become, and remain, truly resilient. The previous two propositions consider whether the use of a combined strategic approach of buffering and bridging will deliver improved shortage management performance in response to a disruption. According to resource dependency theory, responses can be different on the basis of whether they are internal or external to a current relationship (Carroll, 1993). Buffering actions are predominately internal (for example, controlling stock an organisation already has on hand or ordered), whereas bridging actions are predominately external (for example, sourcing new suppliers or a new organisational network). The last proposition to examine supply chain disruption performance is:

Proposition 2g. Buffering actions in response to supply chain disruption are more effective than bridging actions in shortage management performance

The third construct, following on from supply chain disruption performance, is organisational response.

3.5 Organisational Response Construct

The final construct extends the examination of post supply chain disruption strategic management, as highlighted in the literature review (Section 2.4.3), giving new insights by considering dynamic response and its effect on performance. Strategic management and responses do not operate in a vacuum and at a single point in time, instead they change and adapt to the environment they operate in. As described in constructs one and two above, organisations can learn from post disruption decisions and their performance can vary with the response spectrum.

The organisational response construct incorporates prior work on organisational responses to adverse environmental events. These have been investigated in various settings and through many theoretical lenses (Chattopadhyay, Glick and Huber, 2001, Ford and Baucus, 1987, Meyer, 1982, Grewal, Johnson and Sarker, 2007, Primo and Dooley, 2007), and by Bode et al. (2011), who explicitly examined these issues across the boundaries of firms and at the dyad level. Taking an information processing perspective (Galbraithe, 1977) and resource dependency perspective (Pfeffer and Salancik, 1978), the Bode et al. (2011) research developed the organisational response construct to encompass the repertoire of disruption response. These include the dual strategies of buffering and bridging, building on earlier generic response alternatives developed by (Fennell and Alexander, 1987, Meznar and Nigh, 1995). This research will build on this construct and will further consider the dynamic nature of disruption response management, as previously identified. In the supply chain disruption performance construct section, the performance feedback is considered, taking into account the effect of organisational learning. But, if an outcome of learning might be the potential to act, the opportunity to deploy this new capability in practice might not arise immediately. Furthermore, if the opportunity did arise, one might expect a short-term loss of performance as competence in new skills would take time to develop. In addition, changes to organisational routines and culture may have an enduring detrimental effect on organisational performance (Crossan, Lane, White et al., 1995). So, any association between learning and performance could be discernible or not; positive or negative; temporarily proximate or distant; clear or equivocal. Whilst we may recognise that interest in learning relates to interest in performance, we should not assume a simple static relationship exists between them. Many publications about organisational learning and learning organisations are not based on robust empirical evidence (Easterby-Smith and Araujo, 1997). This research will consider the time dynamic of organisational learning in post disruption decision-making integrating concepts from organisational management and supply chain management. The diversity of disciplines in the research will benefit from the plurality of perspectives.

Supply chain processes are often measured against time (e.g., on time deliveries, picking rates, etc.), as opposed to some other physical dimension or quantity (e.g., picking accuracy, product tolerances, etc.) as noted by Christopher and Peck (2004). Applying a dynamic management approach to enhance performance in strategic disruption response where a shift, stabilise, and resynchronise response is varied over time offers supply chain resilience. However, as Tang (2006) pointed out, a robust strategy is useless unless a firm can execute the strategy in a proactive manner. Resilience, as defined by Christopher and Peck (2004), is the ability of a system to return to its original (or desired) state after being disturbed. In the context of supply chain disruptions, a resilient supply chain must also be adaptable, as the desired state may be different from the original. 'Robust' processes may be strong but they are not, by definition, adaptable, hence a supply chain of robust processes is not necessarily going to be resilient. The dynamic management approach to managing disruptions proactively is concerned with adjusting the response alternatives over time according to the situation presented, and it has been used in resilience optimisation from other perspectives, for example, industrial and systems engineering (Ng and Sy, 2014). From an information processing theory perspective, a bridge forestalls uncertainty by facilitating access to reliable and timely information about looming supply chain disruptions and their consequences (Grewal, Johnson and Sarker, 2007). In addition, bridging may be associated with investments in collaborative structures or initiatives, such as joint risk management systems, or with scanning approaches such as monitoring or intensifying information exchanges (Flynn and Flynn, 1999, Pfeffer and

Salancik, 1978). These proactive responses, as opposed to static passive reaction, will result in strategic action changes post disruption and yield improved performance. The second construct supply chain disruption performance, examined through propositions P2e-P2g; the interaction of effectiveness of pursuing the alternative strategic responses of buffering and bridging. The following propositions, P3h-P3i, offer further new insights to contribute to the supply chain management literature by examining the dynamic aspect of supply chain resilience through the perspective of dynamic organisation response, as explored in the literature review (Chapter 4). Specifically, how response decisions to disruptions can vary over time and the subsequent effect of those dynamic decision choices on performance. This is a novel research area and builds on and expands the previous research of (Bode, Wagner, Petersen et al., 2011).

Proposition 3h. Varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management

The original supply chain disruption model did not focus on the specific interplay between the buffering and bridging alternative response actions to supply chain disruptions. The literature review identified this gap, and to address the aims of this research study, as described in Section 1.3, the next proposition is therefore to examine not only the differing impacts of each action, but how those actions and outcomes unfold or play out over the post action period. It uniquely empirically tests this dynamic interchange, which stretches the existing description of supply chain organisational resilience as identified in the literature review; for example, of Lengnick-Hall, Beck and Lengnick-Hall (2011) of situation specific responses to examine the blends, suites and chemistry of post responses over time from initial impact. Therefore, the last proposition is:

Proposition 3i. The impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact

3.6 Summary

Chapter 5 developed the research question and propositions for this study, which will be answered by the research design and methodology laid out in the following Chapter 6. The study has a single research question and subsequent nine propositions, which are organised into three specific constructs, as highlighted in the new proposed framework model shown in Figure 15, to extend and give further insights to current knowledge. By launching a new study which includes performance, boundary rationality, feedback and dynamics new perspectives will augment the existing supply chain management body of work and underlying theory, as described in the literature review, to tackle the gaps identified in current research, by extending the existing disruption response model (Bode, Wagner, Petersen et al., 2011) based on information processing and resource dependency. Considerable amounts of the literature are focused on the mitigation of risk, implicitly assuming that sources of risk can be identified, and centres mitigation strategies on organisational preparedness (Greening and Rutherford, 2011). However, to deal with the nature of disruptions which often have significant impact and result in discontinuities, further understanding is required as to the post disruption response mechanisms, and by testing the new conceptual disruption framework it allows the incorporation of additional dimensions, including actual outcome affects rather than nominal conjecture.

4 Research Design and Methodology

4.1 Introduction

Chapter 4 introduces the approach taken to the overall research design. It sets out and defines the considerations of the research and then goes on to provide an overview of the methodology. A methodology needs to be chosen in order to outline the activities that are needed to answer the research questions (Blaikie, 2000). The research design is the general plan of how to go about answering the research question. This research used the ‘onion’ research plan (Saunders, Lewis and Thornhill, 2003) as a way of depicting issues underlying the choice of data collection methods, philosophies, and approaches. The way research questions are answered is influenced by the research philosophy and approach to theory. As shown in Figure 16, which is based on Saunders, Lewis and Thornhill (2003), the philosophical stance (layer 1) and research approach (layer 2) will subsequently influence the inner research layers. Those inner layers being the research strategy (layer 3), method choices and time horizons (layers 4 and 5) and techniques and procedures, including data collection and data analysis (layer 6).

This research as described and explained in the following section, sets out the research design process followed for this research using the research onion as a reference roadmap. These five research headings relate to the research onion used in this research:

1. Philosophical Stance (4.2)
2. Research Approach (4.3)
3. Research Strategy (4.4)
4. Research Methodology (4.5)
5. Techniques and Procedures (4.6)

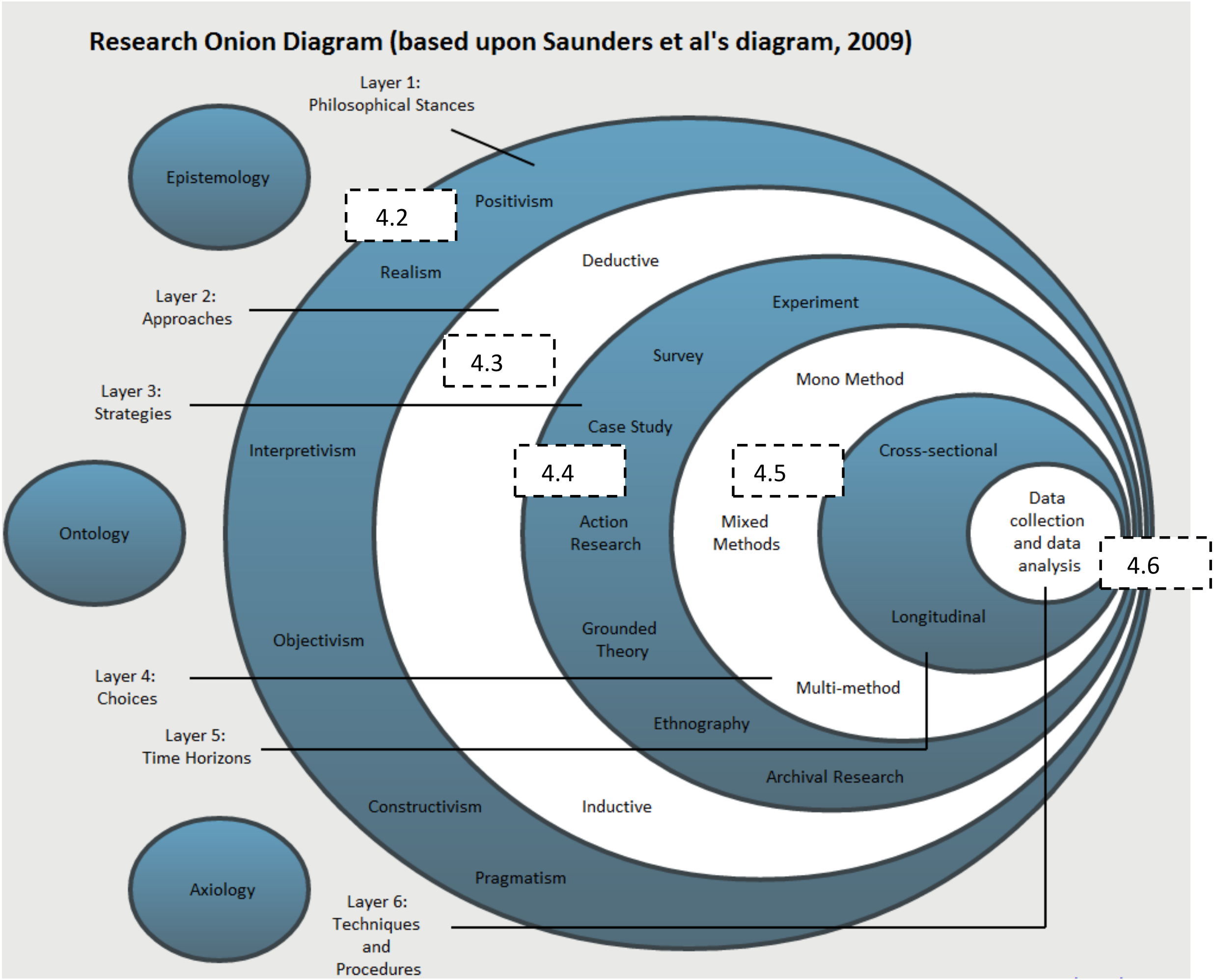


Figure 16. Research Onion: adapted from original source (Saunders, Lewis, and Thornhill, 2011: 160).

Each section will be separated into two parts, the first part setting out the general explanation of the research considerations, and the second part setting out the proposed choice for this research.

The original research onion diagram, created by Saunders, Lewis and Thornhill (2003), included the possible philosophical stance choices of positivism, realism, interpretivism, and pragmatism. The model, as shown in Figure 16, excludes the three philosophies of Ontology, Epistemology and Axiology from the research onion for simplicity, as these are broader terms which include several philosophical approaches. Understanding and choosing a philosophy is a key step in planning and carrying out research, and these approaches have been included as three additional elements outside of the main onion in Figure 15 for clarity.

4.2 Philosophical Research Considerations

Layer 1 of the research onion, as shown in Figure 16, contains the philosophical stances associated with the philosophies. Each of the possible choices at this level require careful thought as they provide structure, guidance, and possible limitations to following decisions and, ultimately, the way a researcher can collect and analyse data to create valid findings

Ontological philosophy is concerned with the nature of reality. It requires researchers to ask themselves how they think the world operates, how society is constructed, and how this influences everything around us. Ontology talks about the difference between reality, our perception of reality, and how this influences people's behaviour.

There are three philosophical positions commonly agreed to work under an ontological worldview. These are objectivism, constructivism, and pragmatism (Phillimore and Goodson, 2004).

Epistemology is concerned with addressing the facts by asking what the acceptable knowledge is. It asks you to define what acceptable knowledge about your field of research is and what information is known to be true after rigorous testing, and thereafter is treated as fact. This philosophy is most commonly used in scientific research as it searches for facts and information that can be proven without doubt, rather than changeable situations and opinions. The epistemology philosophy is about understanding the nature of knowledge and how it is acquired. Therefore, it entails the most relevant ways of enquiring into the nature of the world (Easterby-Smith, Thorpe and Jackson, 2008) and focuses on the data collection processes (research methods). The further philosophical positions associated with epistemology are positivism, critical realism, and interpretivism (Norris, 2005).

The different combinations of ontological and epistemological philosophies determine the methodological perspectives (paradigms) for the investigation of theory and data. According to Blaikie (2007) p.79:

> The methodological perspectives are defined in terms of their ontology and epistemology, and include reference to the logic of theory construction, what counts as data, explanations and theory, criteria of validity, and views on the particular nature of social reality and the relationship between the natural and social sciences.

According to Bryman and Bell (Bryman and Bell, 2011) p.102, a paradigm is *"a cluster of beliefs and dictates which for scientists in a particular discipline influence what should be studied, how research should be done, and how results should be interpreted"*. There is no collective agreement regarding the terms for these paradigms to be used and it is common for different names to be used to describe apparently similar paradigms. However, three main paradigms that can be identified in the literature are namely positivism, critical realism (realism or post positivism), and interpretivism (anti-positivism or constructivism) (Boll, 2009, Bryman and Bell, 2011, Creswell and Plano Clark, 2011, Denzin and Lincoln, 2000, Easterby-Smith, Thorpe and Lowe, 2004).

In Figure 17, these three paradigms can be identified. Positivism supports that the real world exists independent of our knowledge (objective ontology) and the knowledge about this world obtained in an objective way (objective epistemology). Objectivism recognises that social phenomena and their meanings exist separately to social actors. An example of social phenomena could be heavy rain and social actors are people wanting to have a picnic outside. The rain exists, it is real and would be acknowledged by everyone to exist and is, therefore, independent to the people who have had their day out ruined by it. On the other hand, interpretivism and critical realism believe that knowledge is socially constructed (subjective epistemology). Concerning ontology, interpretivism takes the stance of subjective ontology and qualitative data is mostly used, whereas critical realism accepts the objective ontology as positivism does. However, positivism can be described as a 'flat' ontology': one reality exists and that reality can be observed. Critical realism supports that it is impossible to observe everything. In the following section, these paradigms will be explained in detail.

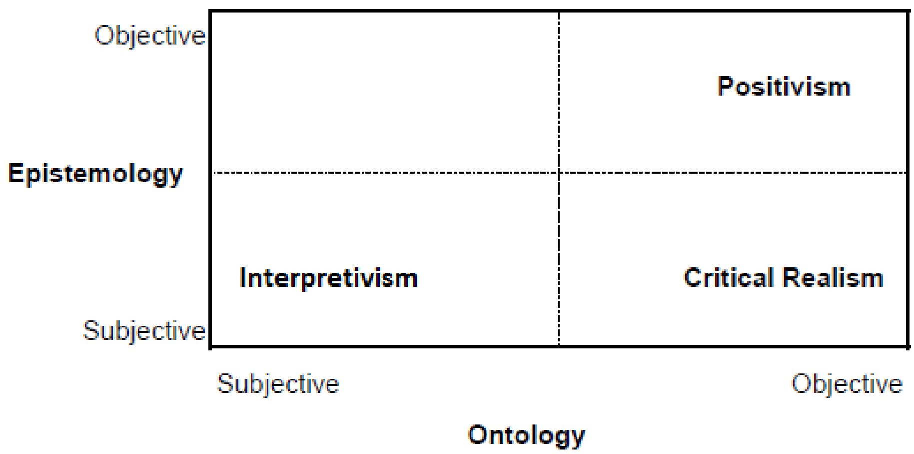


Figure 17. Positioning the paradigms Positivism, Constructivism and Critical Realism (adapted from Bol, 2011:16)

4.2.1 Positivism

Positivism generates hypotheses (or research questions) that can be tested and allows explanations that are measured against accepted knowledge of the world we live in. These could be the laws of gravity applied to an apple falling from a tree. This position creates a body of research that can be replicated by other researchers to generate the same results. The emphasis is on quantifiable results that lend themselves to statistical analysis. Logical positivism is one of the central strands of the fabric of twentieth century thought and was entwined with some of the most important scientific developments, including the growth and propagation of Einstein's theory of relativity (Friedman, 1999).

The first positivist research examples are the work of (Pugh, Hickson, Hinings et al., 1963) at Aston University when researching into organisational structure that used highly structured interviews and questionnaires over a large sample. Thus, the focus is on quantitative data, and includes research methods such as simulation, mathematical modelling, and structured questionnaires (Bryman and Bell, 2011, Easterby-Smith, Thorpe and Jackson, 2008). The positivist position believes that there are 'absolute truths' about the real world and the researcher is separated from the observed phenomena (ontology). Quantitative research searches for general laws and such research highlights the measurement and the analysis of causal relationships between variables. The positivism paradigm usually tests a set of hypotheses developed from existing theory (deductive logic). The theoretical models developed from the positivist stance are generalisable and can describe cause and effect relationships (Easterby-Smith et al., 2008). The main strengths of positivism are that its methods can be fast and economical. However, they are inflexible, artificial, and not effective in understanding processes or the significance that people attach to actions (Easterby-Smith, Thorpe and Jackson, 2008). According to Habermas, positivism reaches the ideal knowledge and ignores the moral choices, values and judgments researchers make (Cohen, Manion and Morrison, 2007)

4.2.2 Interpretivism

Interpretivism refers to approaches emphasising the meaningful nature of people's participation in social and cultural life. Researchers working within this tradition analyse the meanings people confer upon their own and others' actions and take the view that cultural existence and change can be understood by studying what people think about, their ideas, and the meanings that are important to them. This position is described differently in research such as constructivism, or by (Hatch and Cunliffe, 2006) as anti-positivist, and by (Blaikie, 2007) as post-positivist. Constructivism argues the opposite beliefs as objectivism; it is a standpoint that believes social phenomena are actually constructed by social actors. So, if you had a constructive ontological world view, you would believe that, for example, a new law is the product of the behaviour of the group of people it now has an impact on.

Interpretivist approach starts from data and views reality subjectively (a researcher's knowledge on a specific topic relies on the perceptions of the participants). Interpretivism considers the differences between people (Bryman, 2001) and the researcher is trying to understand the interpretations of social actors (what they are thinking, feeling, et cetera), and the world from their point of view, which is highly contextual and hence is not widely generalisable (Easterby-Smith, Thorpe and Jackson, 2008, Saunders, Lewis and Thornhill, 2007). Interpretivist researchers look at organisations in-depth by using qualitative methods, such as interviews, observations, and secondary data analysis in order to overcome generalisability critiques (Bryman and Bell, 2011, Easterby-Smith, Thorpe and Lowe, 2004, Eriksson and Kovalainen, 2008). Constructivism is based on inductive reasoning, where data is collected first and then the theory is developed (Saunders, Lewis and Thornhill, 2007). At the centre of this paradigm is that all knowledge is socially constructed. One of the limitations to interpretive research is that it does not verify the results and thus cannot be generalised to other situations (Mack, 2010). Another limitation of this paradigm is the subjective nature of it (Mack, 2010).

4.2.3 Realism

Realism is similar to positivism in its processes and belief that social reality and the researcher are independent of each other and so will not create biased results. However, where they differ is that realism thinks that scientific methods are not perfect. It believes that all theory can be revised and that our ability to know for certain what reality is may not exist without continually researching and leaving our minds open to using new methods of research. Realism may, therefore, use several types of research methods to triangulate results in its search for a more reliable outcome.

Critical realism offers an alternative position to positivism and interpretivism. It is a combination of positivist conceptions of an external world with the recognition of interpretive understanding. Thus, the critical realist paradigm combines the strengths and avoids the limitations of positivist and interpretivist paradigms (Easterby-Smith, Thorpe and Lowe, 2004). The major advantage of this paradigm is the multiple sources of data and perspectives (Easterby-Smith, Thorpe and Lowe, 2004). Events, experiences, structures and mechanisms can be interpreted by using qualitative and quantitative methods (Sobh and Perry, 2006). Critical realism uses the research strategy of 'retroduction', which means describing the mechanism that has resulted in the current situation (Bhaskar, 1997). According to (Sayer, 1992) p263, retroduction is a: "mode of inference in which events are explained by postulating (and identifying) mechanisms which are capable of producing them". The critical realist entails the notion of stratified ontology, which distinguishes between the real domain, the actual domain and the empirical domain (Bhaskar, 1978). The real is whatever exists, and it consists of objects, structures, and powers (mechanisms). These mechanisms may exist unexercised. The activation of these mechanisms and its implications belongs to the actual domain. Finally, the empirical refers to the events that entail our experiences and perceptions. Realism believes that events are not predetermined to take place, but they depend on contingent conditions. However, the same mechanism can lead to different outcomes based on the context and spatio-temporal relations with other objects (Sayer, 2000).

Table 5 summarises the main differences seen in positivist, interpretivist, and critical realist paradigms regarding their ontology and epistemology. There seems to be a stronger polarisation between positivist and interpretivist paradigms, whereas the critical realist paradigm appears to be taking a middle view.

Elements	**Positivism**	**Critical Realism**	**Interpretivism**
Ontology	Reality is real and apprehensible	Reality is real but only imperfectly	Multiple local and constructed realities
Epistemology	Findings are true	Findings are probably true	Created findings based on the interpretations of the researcher
Aims	Discovery	Exposure	Invention
Starting Points	Formulation of hypotheses	Propositions/Research Questions	Research Questions
Designs	Experiment, survey	Triangulation (case study, survey)	Observation, interviews
Methodology	Outcome and verification oriented	Discovery oriented	Observation oriented
Techniques	Measurement	Survey	Conversation
Sample Size	Large	Small	Small
Interview Questions	Closed with limited probing	Open with probing	Very open

Table 5. Research Paradigms (Bryman and Bell, 2011; Easterby-Smith et al., 2004; Sobh and Perry, 2006)

Axiology, in contrast, allows the researcher to understand and recognise the role their values and opinions play in the collection and analysis of the research, as opposed to eliminating or trying to balance the influence of them. For example, if the researcher is a vegetarian and they are researching the availability and range of vegetarian food in hotels, this must be declared in their research. How this shapes your investigation of the issue and how you analyse the results will need to be detailed and analysed in different ways according to the approach you choose. The problems and issues axiology investigates have been with us from the moment man began to reflect upon conditions of his life, the structure of reality, the order of nature, and man's place in it (Hart, 1971). Pragmatism argues the alternative, that both constructivism and objectivism are valid ways to approach research. Pragmatism allows a researcher to view the topic from either or both points-of-view regarding the influence or role of social actors and uses these to create a practical approach to research. This may be used to find solutions to problems (May, 2011).

4.2.4 Philosophical Stance Chosen

This research considered the range of philosophical stances available. In particular, it considered critical realism which lends itself to a multi-method research approach (Sayer, 1992, Mingers, 2004). Critical realism paradigm includes in-depth interviews, focus group methodologies, and case studies (interview protocol, questions), and relatively quantitative methodology such as survey and modelling (Healy and Perry, 2000). Figure 18 below, illustrates that critical realism is a 'middle-ground' approach in terms of the methodology, the roles of the individual and of context, and the modified objectivist epistemological position. Critical realism's combination of quantitative and qualitative methodologies complements the provision of an elaborated view of issues and establishes the validity of findings. Qualitative, naturalistic approaches provide richness, depth, density, and the contextual embedding of data. Quantitative approaches, including those utilising certain forms of statistical analysis, allow for the assessment of the capacity for the broader applicability of observed patterns in data. Critical realist research may be initially qualitative and inductive, enabling issues, propositions, and models to be developed, clarified, and modified, then followed by the hypothetico-deductive approach (most commonly used in quantitative accounting research) to unearth knowledge concerning broader mechanisms and tendencies. This research will use a predominantly positivist paradigm, however, includes the realism perspective to complement and balance the research approach.

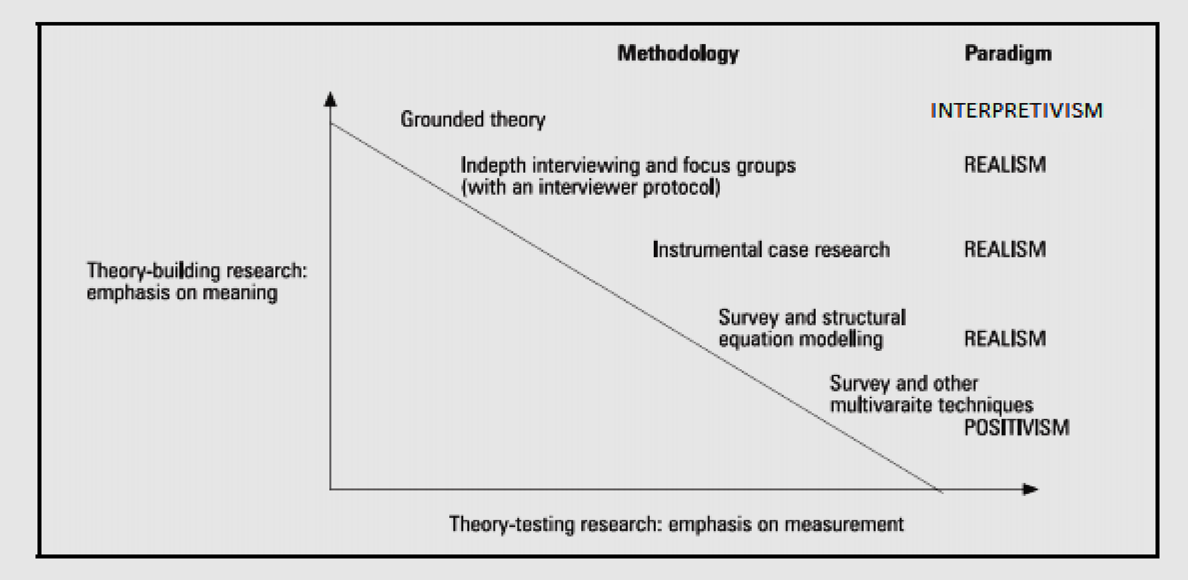


Figure 18. A range of methodologies and their related paradigms, adapted from Healy and Perry (2000:121)

The research paradigm(s) that a researcher adopts will influence the research method chosen (Healy and Perry, 2000), and the research approach is the next step in the research design to select the range of dimensions of the research process (Bryman and Bell, 2011). Section 4.3, explains the research approach considerations, referred to as layer 2 in the research onion (Figure 16) based on Saunders, Lewis and Thornhill (2007), and then explains and justifies the research approach chosen for this research.

4.3 Research Approach Considerations

The research onion in Figure 15 contains the terms deductive and inductive, which are forms of logical inference. A decision on this level may be strongly indicated by the decisions made at the previous level, or may need to further assess the research aim, or limitations and subjective opinions to decide which method will work best for the research. A deductive approach means that you start with a statement or question and your research sets out to answer it. The aim would be to conclude with a yes or no response to the question. Questions may be statements or informed speculation about the topic that the researcher believes can be answered.

The thought process of deduction moves from theory, to the research question, to data collection, findings, to a rejection or confirmation of the research question. This should lead onto a revision of the theory and often starts the process over again. Inductive means that you are researching to create a theory. The process moves in the opposite direction to the deductive approach, taking its focus from the working title of the research rather than the existing theory. This means the research goes from research question, to observation and description, to analysis, and finally theory. Therefore, if little research exists on a topic then an inductive approach may be the best way to proceed (Saunders, Lewis and Thornhill, 2007).

Critical realism contends that there are four modes of inference and these have different possibilities and limitations in terms of knowledge discovery. These modes are deduction, induction, abduction, and retroduction (Blaikie, 2007). The deductive reasoning includes conclusions made logically from things already known. That is, it is about going from the general to the particular, or applying a general knowledge to a particular situation, whereas inductive reasoning can be seen as a process in which the outcome, for example, the general rule (or conclusion) is based on individual ideas (or facts). In this case, it is about going from the particular to the general, or building a general knowledge from particular situations. Furthermore, there is the question of abduction and retroduction.

Deduction is generally taken to be the opposite of induction in that it takes its starting point from the conclusion of induction, namely a universal or general law. Deduction can thus be used to deduce a particular, from a universal law. The key point to make is that while deduction and induction are very effective at investigating the empirical level of reality, critical realism is also concerned with understanding the generative powers and mechanisms which cannot be directly observed at the domain of the empirical (Blaikie, 2007).

A decisive difference between deduction and abduction is that deduction proves something must be in a certain way, while abduction shows how something might be (Habermas, 1972). Critical realism criticises empiricism for its reduction of reality to the observable because it claims there is a distinction between a real world and a conceptual one, between our description and the factual reality. Comprehending deeper structures and generative mechanisms requires the use of abductive and retroductive inference. It is for this reason that the study described in this thesis cannot be conceptualised as a strictly inductive study. Critical realism would argue that induction:

> Gives no guidance as to how, from something observable, we can reach knowledge of underlying structures and mechanisms; it is limited to conclusions of empirical generalisations and regularities.

(Danermark, Ekstrom, Jakobsen et al., 2002) p70. Critical realism's notion is that the objects of science are not primarily empirical regularities, but structures and mechanisms.

Abductive research has entered numerous streams of research in disciplines such as learning, logic, neural networks, and artificial intelligence. More recently, there have been pleas for it to be used in SCM in order to break out of the positivist bias which has resulted in "a paucity of discussing different research approaches in logistics journals" (Kovács and Spens, 2005). The abductive approach stems from the insight that most great advances in science follow the pattern of neither pure deduction nor pure induction. Creativity in research is necessary to break out of the limitations of deduction and induction, as advances in sciences often come from intuitive leaps that emerge as a whole and are commonly called abductive reasoning (Kovács and Spens, 2005, Danermark, Ekstrom, Jakobsen et al., 2002). The introduction of intuition, creativity, and imagination into research is what differentiates abduction from the dominant research methods. Abduction involves the ability to see something in a different context, to 'see something as something else', so to speak. It involves not only description but re-description. Re-description is not seen as necessarily providing a better description of the object of study; rather, in abductive reasoning, the case presents a plausible but not logically necessary conclusion. Therefore, abductive conclusions in social science are seldom capable of deciding if something is ultimately true or false (Danermark, Ekstrom, Jakobsen et al., 2002).

The severe limitations of abduction raise the question about why it should be used in SCM research. The first point is that abduction seeks to generate new insights by examining matters from fresh perspectives and, similarly, SCM is a multidisciplinary field, drawing on many perspectives. Secondly, SCM involves investigating social issues. Social scientists are not in the business of discovering new events previously unknown to anyone; rather, what they discover is connections and relationships that are not directly observable. The modes of inference available through abduction will assist social research. Finally, abduction is very useful in developing theory in emerging fields, such as SCM, and can lay a platform for subsequent inductive and deductive research (Kovács and Spens, 2005).

Retroduction differs from deduction, induction and abduction in that it is not a formalised mode of inference. What it does have in common with these other modes of inference is thought operation, whereby it is possible to move one thing to knowledge of something else. The core of retroduction is transcendental argumentation. This argumentation seeks to clarify the basic prerequisites or conditions for social relationships, people’s actions, reasoning, and knowledge. In this context, conditions mean the circumstances without which something cannot exist. As intentionality is taken as a universal condition for all human activity, retroduction encourages investigators to ask questions as to what would happen to social structures if intentionality changed. An obvious example in SCM would be what would happen if intentionality around the often-cited constructs of trust and collaboration were removed. This approach has been severely criticised for being outside what we spontaneously experience or observe. Critical realism repudiates such a view on the grounds it reduces knowledge to that which is directly given or observable. Retroduction has been widely used in social science by researchers who side with and against critical realism (Danermark, Ekstrom, Jakobsen et al., 2002). Since it has been established that we are dealing with research into open systems, and the more open the system the more the complexity around the mechanisms which are cooperating to maintain that system, retroduction is well suited to assisting the exploration and possible detection of tendencies which maintain the system within a specific context.

While some researchers treat these interchangeably (two concepts overarching each other), others claim the opposite. According to the former type of definition scholars, such as abductive or retroductive, reasoning is a process in which explanatory hypotheses are formed and tested to give an explanation for a particular situation (Paloniemi, 2010). In critical realism, some researchers present the abductive logic together with retroduction, while some other scholars (e.g. Blaikie, 2007) want to differentiate the latter from the former.

“The retroductive research strategy involves the building of models in order to explain observed regularities.” (Lisle, 2000) p121. The retroductive strategy encompasses induction, deduction, and abduction, as well as building and testing models to explain the phenomenon (Lisle, 2000). Critical realism is well connected with retroduction (Mingers, 2004), which means that mechanisms are proposed that may lead to a specific phenomenon (to be investigated) if the mechanism existed.

Section 4.3.1 explains the specific research approach chosen for this research.

4.3.1 Research Approach Chosen

This research considered various perspectives and approaches prior to choosing the research approach, and took into account the relationship between the data and the theory as recommended good practice (Easterby-Smith, Thorpe and Jackson, 2008).

The deductive approach, as discussed above, moves towards hypothesis testing, after which the principle is confirmed, refuted, or modified. These hypotheses present an assertion about two or more concepts that attempt to explain the relationship between them. Concepts themselves are abstract ideas that form the building blocks of hypotheses and theories. The first stage, therefore, is the elaboration of a set of principles or allied ideas that are then tested through empirical observation or experimentation.

This study will follow a predominately positivist paradigm in combination with a realism paradigm through a deductive approach following the hypothetico-deductive model (Lee and Lings, 2008). The researcher will reduce phenomena to their simplest elements, focus on facts and formulate propositions, and then test them, (Easterby-Smith, Thorpe and Jackson, 2008). The deductive approach, moves towards proposition testing, after which the principle is confirmed, refuted, or modified. The main research method will use quantitative research through a survey. However, qualitative research will also be used in both the initial and final phases of the research, using both interviews and focus groups so that multiple sources of data and perspectives can be included. This is to make the research study more rigorous, as referenced when discussing the considerations of philosophical stances in Section 4.2 from Easterby-Smith, Thorpe and Lowe (2004).

Table 5 summarises the main differences seen in positivist, interpretivist, and critical realist paradigms regarding their ontology and epistemology. Taking account of the data required to be measured in this research and that it will be collected from a large population, a predominately positivist paradigm is followed. It is important that the research design provides a framework for the collection and analysis of data and importance should be attached to expressing causal connections between variables, and so both factors were built into the research design (Bryman and Bell, 2011). Furthermore, three of the most prominent criteria for the evaluation of management research are reliability, replication, and validity. Both reliability and measurement validity are essentially concerned with the adequacy of measures, which are most obviously a concern of quantitative research. Internal validity is concerned with the soundness of findings that specify a causal connection, an issue that is most commonly of concern to quantitative research (Bryman and Bell, 2011). This research aims to discover causal connections to give new insights into how performance is affected by strategic choices in supply chain disruptions.

However, to address ecological validity, which is concerned with the question of whether or not social scientific findings are applicable to what happens in people's everyday lives, e.g., their relevance (Bryman and Bell, 2011, Hammersley, 1992), interviews will also be used by this research. Using qualitative research methods will help to explain the relationships between variables, in addition to strengthening the research to withstand criticism. When a single qualitative research method is used, the problem of generality would occur, for example, critics of qualitative research state that there is a tendency for findings to be presented in an anecdotal fashion (Bryman and Bell, 2011).

Following a stepwise approach to research design selection, as outlined by (Dul and Hak, 2007):

1. First defining the research topic
2. General research objective
3. Determining the specific research objective
4. Choosing the research strategy
5. Select instances
6. Conduct measurement
7. Conduct data analysis
8. Discuss results
9. Report the research

This research will use a theory-testing research design. Theory-testing research is aimed at the testing of formulated propositions (Dul and Hak, 2007), and a type of theory-orientated research, as explained by Figures 19 and 20 (Flowcharts 1A and 2A respectively).

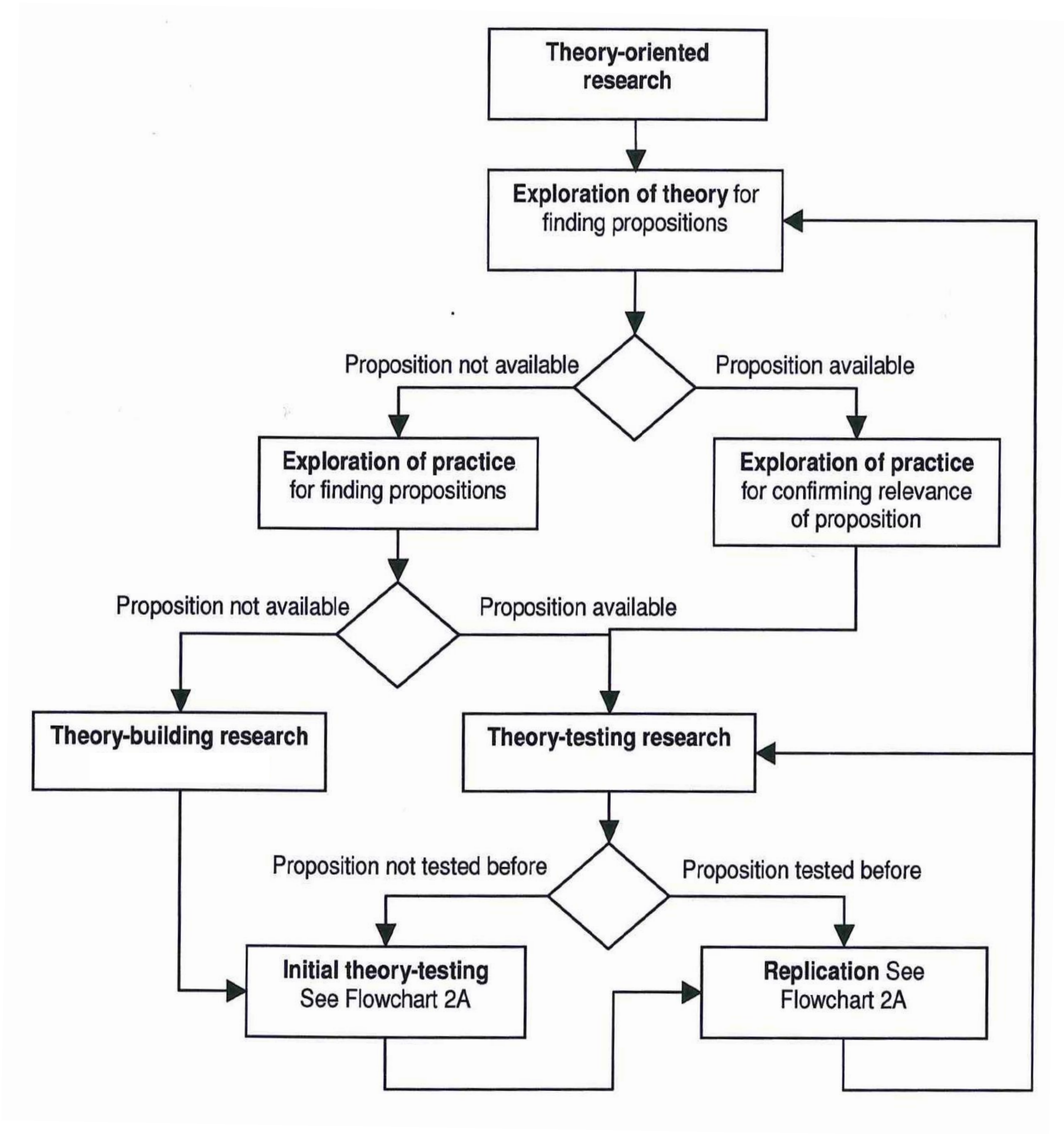


Figure 19. Flowchart 1A - Deciding on the type of theory-orientated research, adapted from Dul and Hak (2007:252).

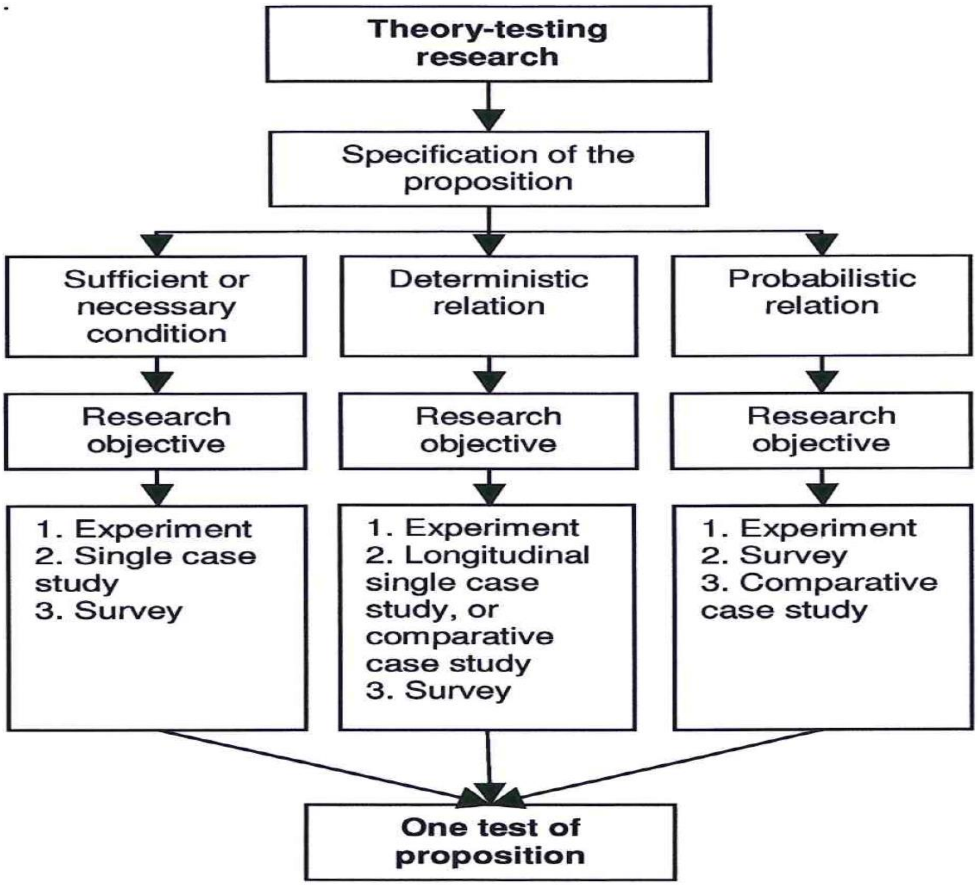


Figure 20. Flow chart 2A - Theory-testing research (initial theory-testing), adapted from Dul and Hak (2007: 254).

This research, following the principles as highlighted by the pathways in Flowchart 1A, confirmed following the exploration of theory that related propositions did exist but it needs refining and extending, thus the study chooses an initial theory testing approach (Flowchart 2A).The first phase involved a detailed and focused literature review, which led to the development of the conceptual supply chain disruptions theory framework that explains different supply chain responses to disruptions. After the examination of the theory and refining of the propositions, the specification of the propositions was of a probabilistic proposition; a probabilistic proposition is defined as a proposition which expresses a probabilistic relation (Dul and Hak, 2007). A probabilistic relation is a relation between an independent concept or variable and a dependent concept or variable in which their values, on average, increase or decrease at the same time (positive relation) or in which the value of one, on average, increases as the other decreases (negative relation). The survey instrument was selected as an appropriate method to test these relationships between concepts and variables. Analytical surveys are highly structured and place an emphasis on the careful random selection of samples, so that the results can be generalised to other situations or contexts (Gray, 2013). Analytic surveys emphasise:

1. A deductive approach
2. The identification of the research population
3. The drawing of a representative sample from the population
4. Control of variables
5. The generation of both qualitative and quantitative data
6. Generalisability of results

This research will not use experiments because they are usually used where variables can be controlled. Experiments are commonly used methods in physical sciences but are not so valuable in management research (Beech, 2005). Participant observation, ethnography, or discourse analyses are commonly conducted over a long period of time (longitudinal). Action research cannot be employed due to time, economic, and accessibility constraints. Grounded theory and ethnography were excluded as they are purely qualitative. Grounded theory uses inductive methods to predict and explain behaviour to build theory, whereas this study aims to use a theory testing approach (Dul and Hak, 2007).

There are then multiple competing paradigms and associated research approaches that can be selected to conduct research to address the research question that the investigator is interested in (Bryman and Bell, 2011). Sections 4.4 and 4.5 explain the strategy and research method considerations, which are also reflected in Figure 16 (Saunders, Lewis and Thornhill, 2007).

4.4 Research Strategy Considerations

Strategy choices refer to the research style that is used to collect and analyse data, such as grounded theory. Each one has its benefits and limitations. This needs to be thought through, explained, and balanced throughout the research. Choices may be more commonly associated with different philosophies and philosophical standpoints, as shown in the research onion (Figure 16). Experimental designs are more rigid and scientific in their structure to enable the research to be replicated. These designs test the causal effects of phenomena on a group compared to a control group who are not subjected to any phenomena. The causal effect is the independent variable on the dependent variable. Experimental strategies generate data that can be statistically analysed. A survey strategy is often associated with a deductive approach. It offers the researcher a highly economical way of collecting large amounts of data to address the who, what, where, when, and how of any given topic or issue. This strategy can generate both rich and statistical data (Somekh, 2006).

Grounded theory uses inductive methods to predict and explain behaviour to build theory. This starts with data being collected from observation and theory. Predictions are generated from that data and those predictions are then tested. This strategy, although generating new theory, is still grounded by existing theory and literature on the topic (Strauss, 1998, Wertz, 2011). Ethnography is rooted in anthropology, which is the study of others from a detached point-of-view. However, ethnography requires the researcher to be a part of the community or situation they are researching. This may be time consuming for the researcher to achieve full integration into a social scene to experience and document long-term changes in actions and opinions (Crang and Cook, 2007). Archival research strategy centres its data collection on existing data sets or archive documents. This allows for exploratory, explanatory, or descriptive analysis of changes tracked over a long period of time. However, the accuracy and breadth of information available may be an issue for a researcher relying solely on this type of secondary data.

4.4.1 Research Strategy Chosen

This study is seeking to explain how the actions of buffering and bridging in response to supply chain disruptions events affect the performance of shortage management, and is seeking detailed explanation of the constructs and propositions summarised in the Research Question (section 3.2) based on constructs that were developed and extended from the original constructs of Bode, Wagner, Petersen et al. (2011). A theory testing emphasis approach will be most appropriate (Rao and Perry, 2003), as shown in Table 6. Table 6 contrasts the different strategies best employed to approach different research problems. As this research addresses the theory testing emphasis, a survey strategy choice is appropriate. This research will use a survey strategy which will be conducted after the initial interviews, where the aim will be to test the propositions and thus give further novel insights on supply chain response management.

	Theory building emphasis	**Theory testing emphasis**
Research Problem	What kind of strategies are implemented?	What impact do these strategies have on performance?
Literature Review	Exploratory	Explanatory: constructs have been measured before
Paradigm	Interpretive	Positivist
Methodology	Case study	Survey

Table 6. Research Approaches (Rao and Perry, 2003)

The overall research strategy is outlined below in Figure 21, which describes the research work flow plan from the initial in-depth literature review (both academic and industry based), the identification and development of the theory framework (as described in the research question, section 3.2), through to the desk research and UCLH mining and initial descriptive analysis, followed by interviews and the main survey design to test the theory based propositions. The outputs of this are analysed, and feedback and further interviews and focus groups are conducted, the results of which are critically collated, theory refined, and conclusions and limitations drawn. The work flow, which is outlined in Figure 21, follows the theory testing plan (Dul and Hak, 2007) explained in Flowchart 2A and in the research approach chosen section (4.3.1).

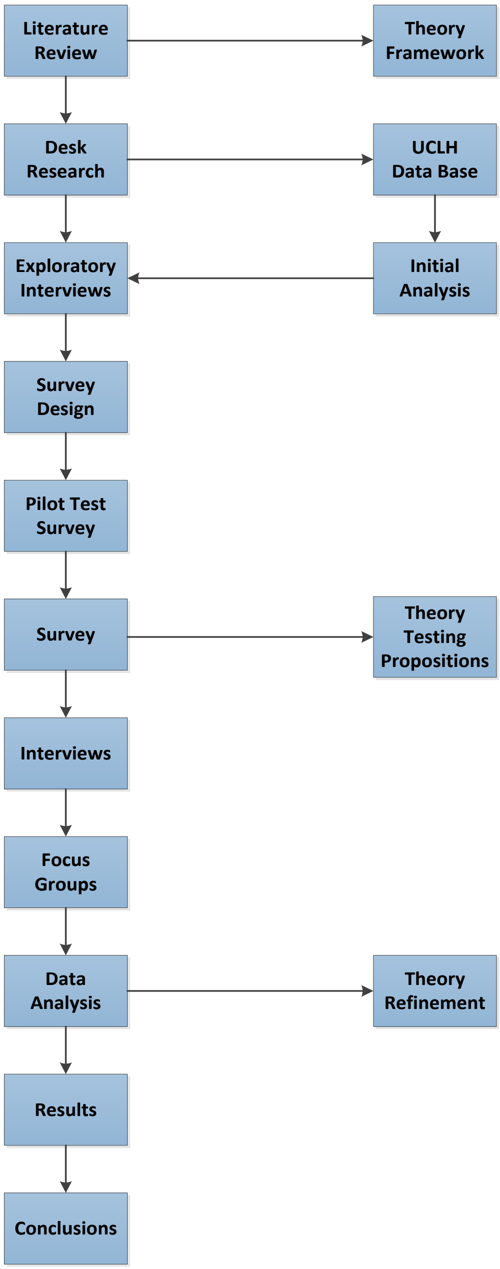


Figure 21. Research High Level Design Flow Chart

Figure 21 outlines the research high level design flowchart followed by this research. The initial literature review composed three main elements; supply chain management, an industry review of the pharmaceutical supply chain, and a literature review of supply chain reductions.

This provided the supply chain post disruption theory framework for the research. The initial secondary research included desk research which revealed and facilitated the data mining of the University College London Hospital (UCLH) shortage management historic database. This and other secondary research provided informed background for the exploratory interviews after the initial analysis. The exploratory interviews guided the survey tool design, and later provided expert advice in the pilot testing of the survey to facilitate a robust final survey online tool. The survey tool was used to test the theory propositions extending the existing theory framework. The interviews were then conducted after ethical approval was granted. The last data collection method used was the focus group, which comprised of three focus groups reflecting the spectrum of the target population. The data analysis of each of the data collection methods was then carried out, refining and informing the new theory framework understanding so the research data analysis findings could be presented and the research conclusions drawn and explained.

Section 4.5 is separated into two parts. The first illustrates the research methodology considerations, including the time horizons, and then the second part specifies the research methodology selected for this research.

4.5 Research Methodology Considerations

Layer 4 in the research onion diagram is where the researcher defines how to use quantitative and qualitative methods in research. Methods are the ways in which a researcher will actually design and collect data. Each choice at this stage has a framework of methods and tools. Mono-method research is when either quantitative or qualitative data is collected, rather than a combination of both. This may be due to the demands of the philosophy, philosophical choices, and strategies employed. It could also be used to research an opposing view to existing mono-method research. Mixed-method research is when the researcher uses quantitative and qualitative research methods in the process of their study, data collection, and analysis. It can be argued that by combining both types of research, the limitations of each individual method can be offset and gaps of data can be filled or predicted (Sandelowski, 2000). A multi method is where the researcher uses both quantitative and qualitative data, but the researcher’s outlook is rooted in only one of them. So, both types of data are analysed from only one point-of-view.

In layer 5 of the research onion, there are only two-time horizon choices for the research. These are cross-sectional, which is a short-term study, and longitudinal, which is research carried out over a longer period of time. Cross-sectional designs can use qualitative and quantitative research, and they measure an aspect or behaviour of many groups or individuals at a single point in time. Longitudinal designs can also use qualitative and quantitative research but they study events and behaviours using concentrated samples over a longer period. As noted by Collins, Joseph and Bielaczyc (2004), certain design research methodology faces other serious challenges, including the following:

• Difficulties arising from the complexity of real-world situations and their resistance to experimental control
• Large amounts of data arising from a need to combine ethnographic and quantitative analysis
• Comparing across designs

Different aspects of reality lend themselves to different methods of inquiry, so that before choosing a research methodology, the problem, the research question and the subjects and situations must be considered (Wolfer, 1993, Creswell and Plano Clark, 2011). Is a combination of methods, rather than a single method, possible to strengthen results, and if so is the typology of a mixed method approach going to be emergent or fixed? The researcher has the choice to start off with one method, and then add in other methods if the first is deemed insufficient; the challenge here is reliability, can the study be replicated by others to corroborate findings. One of the key drivers that must be considered is if the methodology chosen is achievable and practical, this can be both from a time and resource perspective but also from a data availability aspect. In addition, is the method under consideration appropriate for the environment to be conducted, certain fields have very high barriers of ethical or security control to prevent smaller scale research projects with impractically brief time spans. Lastly, have previous methods in the same general problem area been challenged due to limitations of the research? An example of this is using an action research methodology in certain settings (Ritchie, 2002). In that research, it was noted that having a research assistant embedded in the environment may have affected the validity of results with researcher bias. Staff found this type of working relationship confusing, and it was observed that if the research had been less action based, potentially more analysis could have been performed but actions may not have been initiated, as they were researcher driven, pointing towards possible researcher bias. Section 4.5.1 describes the research methodology chosen for this study.

4.5.1 Research Methodology Chosen

A combination of qualitative and quantitative methods will be used in this research. Mixed-method research is a dynamic option for expanding the scope and improving the analytic power of studies. When done well, mixed-method studies dramatize the artfulness and versatility of research design (Sandelowski, 2000). A qualitative research method is used to answer questions about the nature of phenomena, with the purpose of understanding them from the participants' points-of-view. Quantitative approach assisted in testing the theory as it involves variables analysed with statistical procedures in order to test if generalisations of the theory hold true (Creswell, 2003). This study will use both qualitative and quantitative research methods as complementary methods rather than competitive. Yin (2003) argues that quantitative and qualitative approaches can be used to complement each other to provide methodological triangulation and enhance reliability of the study

Quantitative and qualitative research methods do not have a layer of their own in the research onion diagram (Saunders, Lewis and Thornhill, 2007) as they should be continually considered as the researcher travels through to the centre. Quantitative research involves numbers. It is concerned with quantity and measurements. Qualitative research is concerned with rich data, such as personal accounts, opinions, and description.

The initial dialogue with the target participants and desk research identified multiple sources of data, both in the form of an information database and willing key participants from the pharmaceutical suppliers and buyers, including NHS hospital trust lead pharmacies, NHS regional procurement specialists, and the Department of Health.

The methodological approach taken in this research is mixed-methodology, with an emphasis on quantitative data. Mixed-method research focuses on collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies (Creswell and Plano Clark, 2011). Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone. Easterby-Smith, Thorpe and Jackson (2008) refers to data triangulation as the collecting of data over different times or from different sources. This approach is typical of cross-sectional designs. Methodological triangulation is also possible, with the use of a combination of methods, such as interviews, surveys, and secondary data. All methods have their strengths and weaknesses, so not only does the use of multiple methods assist in data triangulation, it helps to balance out any of the potential weaknesses in each data collection method (Gray, 2013). Careful measurements, generalisable samples, experimental control, and statistical tools of good quantitative studies are precious assets. When they are combined with the up-close, deep, credible understanding of complex real-world contexts that characterise good qualitative studies, it produces a powerful mix (Miles, Huberman and Saldana, 2014).

This research will use qualitative techniques in an exploratory phase to uncover hidden practices as recommended by Bryman and Hardy (2006), and is explained in more detail in Section 6.6. However, the majority of the data will be collected using a quantitative self-report questionnaire. Survey research (or 'the survey') is research in which (1) a single population in the real life context is selected and (2) scores obtained from this population are analysed in a quantitative manner (Dul and Hak, 2007). A predominately quantitative research methodology was selected using survey research that employs a cross-sectional research design. Quantitative survey research has previously been successfully used in researching supply chain disruptions and resilience (Stephenson, Seville, Vargo et al., 2010, Wagner and Neshat, 2010, Jüttner and Maklan, 2011). The cross-sectional design will be used as it is necessary to have a systematic and standardised method for gauging variation in order to establish variation between cases (and then to examine associations between variables), (Bryman, 2012).

The closing section of the research design chapter describes the techniques and procedures considerations, and then finally the techniques and procedures chosen for this research. It presents how the research survey design is linked to the research question, constructs, and propositions which were first set out in Chapter 3.

4.6 Techniques and Procedures Considerations

The last layer of the research onion moves the research design further into the practicalities of data collection and analysis. This is where the researcher needs to decide from all the previous decisions made what data collection methods will work best and what type of analysis to employ to create the results to answer the research question. Data collection and analysis includes decisions on sample groups, questionnaire content, and questions to be asked in interviews. All of the decisions and tools employed at this final stage must fit in with the philosophies, philosophical stances, strategies, choices, and time horizons already fixed upon if valid results are to be created and withstand criticism (Brace, 2008). It is important, however, to be aware that all research methods have limitations. As noted by Bryman and Bell (2011), quantitative research, for example, teaches us that it is rarely the case that we find perfect association between variables. We should not be surprised, therefore, that the practice of business research similarly lacks absolute determinism.

Utilising secondary analysis offers numerous benefits to researchers, including saving both cost and time and providing high quality data obtained using rigorous sampling procedures. This ensures the data is representative, and it often offers national samples covering the UK (Bryman and Bell, 2011). By including secondary analysis in conjunction with other forms of data collection, this research will avoid the pitfalls of relying solely on a single source of data collection (Yin, 2003).

4.6.1 Techniques and Procedures Chosen

This section firstly describes the overall research problem flowchart in order to put the subsequent techniques and procedures into context, and to enable each proposition to be linked to the construct it addresses to answer the research question. Processes used can be justified and the research will output relevant deliverables which will address the research question. Next, the survey research design is outlined, followed by the data collection and data analysis subsections, which describe in detail the instruments selected and analysis of data to be used in this research study.

The following flowchart, Figure 22, unpacks the path followed within the high-level research design to address the research problem, as identified in the research question in Chapter 3. In Section 3.2, the research problem was described in the research question***: how do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management*?** Three constructs were developed as a way of bringing the theory down to earth, and helping to explain the different components of theories, as well as to measure and observe their behaviour. Constructs are the building blocks of theories, helping to explain how and why certain phenomena behave the way that they do (Rioux, 1997). The three constructs; supply chain disruption orientation, supply chain disruption performance, and organisational response based on the new theory framework (Figure 15, Section 3.2), were then translated into nine propositions, P1a to P3i, to be tested so that the relationships they describe can be examined to give new insights into post disruption response management. As explained by Rioux (1997), constructs must be translated from the abstract to the concrete (for instance, measurable or testable in the form of variables). This requires the re-stating of constructs as variables, with variables also having their own attributes. The role of the operational definition is to exactly describe how to measure the characteristics of a construct. Characteristics are the abstractions/ideas within constructs that are ultimately measurable in the form of variables and their attributes. It is these variables and their attributes that are measured.

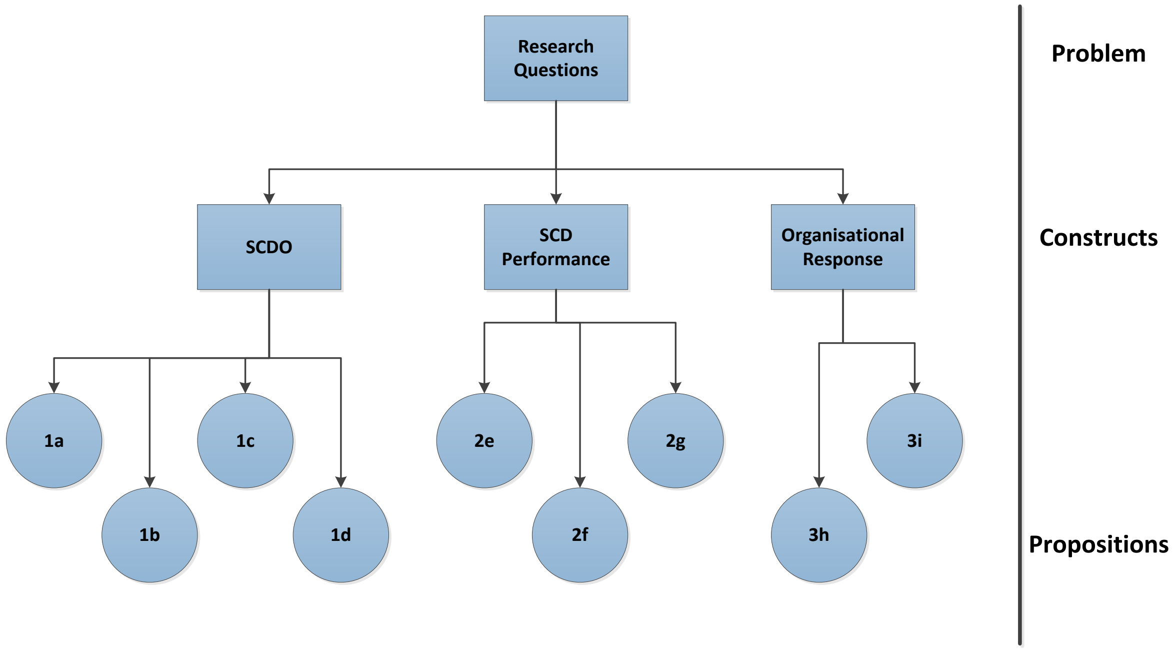


Figure 22. Research Problem Flowchart

In order to address the research problem and answer the research question, the three constructs and the nine propositions that test them are categorised in Figure 22, and the survey questions that will directly answer them are described below in the broader research survey design. It is then followed by the techniques and procedures sections, and lastly the ethical considerations.

4.6.2 Desk Research & Exploratory Interviews

This research will use desk research as the initial technique following on from the literature review. Desk research comprises searching for information using existing resources, such as the press, the internet, analytical reports, and statistical publications. This is then followed by cross-referencing and the collation of data. Desk research, or secondary research, can serve as a standalone research technique or as the initial stage of a project and a precursor to primary research (PMR, 2016). Desk research uses secondary analysis, which is the analysis of data that has been collected by other organisations in the course of their business (Bryman and Bell, 2011).

Interviews were conducted at two stages within the research process, highlighted in the high-level research design flowchart (Figure 21).

An initial exploratory set of semi-structured interviews was conducted on a limited pool to include a relevant range of managers involved in the buyer side of the acute secondary care pharmaceutical supply chain including:

1. Pharmacy lead procurement technicians, or hospital pharmacy managers
2. Regional pharmacist specialists
3. Commercial Medicines Unit (CMU)
4. Department of Health (DoH)

The sample pool of exploratory interviews was drawn from two of each of the above role types using a purposive sampling technique. Purposive sampling is a non-probability form of sampling, as participants are not sought on a random basis. The goal of purposive sampling is to sample cases/participants in a strategic way so that those sampled are relevant to the research question being posed (Bryman and Bell, 2011). In acute secondary care, the above four categories of teams are involved in the procurement side of the pharmaceutical supply chain, representing distinct levels and stages, i.e. operational (pharmaceutical leads and specialists), contractual (CMU) and policy (DoH). It is recognised as a limitation of this research that using a non-probability sampling approach whilst employing a purposive approach does not allow the researcher to generalise to a population. However, the reason for these initial interviews was to deepen the immersion of the interviewer in the topic under consideration to discover and guide the later research.

The exploratory phase was carried out in order to ensure that the measures being used in the quantitative survey would be as applicable to the situation as possible. It is also designed to give contextual information as to the general issues of supply chain disruptions, decision response actions being taken and subsequent performance consequences. Research using a combined methodology with an in-depth focus on the pharmaceutical supply chain from a buyer perspective is novel in the supply chain disruption research area and will provide contextual insights as to the phenomena under consideration. In particular, it considers the multi-layered nature of buffering and bridging decision-making and its effect on shortage performance in secondary care acute hospitals.

The exploratory interviews allowed the researcher to gather deeper insights into the challenging working environment the operational managers had to face on a day-to-day basis in managing shortages in response to supply chain disruptions. As this research was focusing on the decision-making actions, their interplay, and outcomes, it was important to gain industry verification of the proposed quantitative survey instrument. For this purpose and to help maximise the research support and exposure, including the ethical considerations, an informal research steering committee was set up. This consisted of two experienced participants from the exploratory interviews on the operational side, i.e. one regional specialist pharmacist and one lead procurement pharmacist technician.

The pharmacy lead procurement technician and regional pharmacist specialist were asked to review and pilot the survey questions and validate the medicines in the shortage frequency sample, as identified in the initial desk research analysis of the UCLH database. The survey questions were then piloted before the questionnaire content and schedule was finalised, as recommended by Bryman and Bell (2011) for conducting a self-completion questionnaire for a social survey. A self-completion questionnaire was chosen rather than a structured interview because of the wide geographic scope of the respondents, therefore making it cheaper and easier to administer. There would also be no interviewer effects, no interviewer variability, as well as being convenient for very busy hospital pharmacy leads. It further allowed the whole population of acute care hospitals to be targeted and included in the research rather than a limited representative sample. However, all methods have limitations and it is recognised that there may be a discrepancy between what participants do and what they say they do, and what observers see participants doing is generally considered a more accurate reflection of reality than self-report (Sandelowski, 2000).

Following on from the desk research and initial interview phase, the research survey will be conducted.

4.6.3 Research Survey Design

A survey strategy is often associated with a deductive approach. It offers the researcher a highly economical way of collecting large amounts of data to address the who, what, where, when, and how of any given topic or issue. This strategy can generate both rich and statistical data. This research used a survey that was designed so that the overall research question would be directly addressed by examining the constructs through the refined propositions. As detailed in Table 7, each proposition is addressed by a series of questions in the survey instrument (Appendix 2).

Research Question	Do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management?								
Construct	SCDO	Performance	Organisational Response	Performance	Organisational Response	Performance & SCDO	Organisational Response	SCDO	SCDO
Propositions	1a	2e	3h	2f	3i	1d	2g	1c	1b
Survey Questions	Section A & B	Section A & B	Section A & B	Section B	Section B	Section A & B	Section A & B	Section A & B	Section A & B
Questions	B.24 to 64	B.24-64	B.24-64	B.24-64	B.24-64	B.24-64	B.24-64	B24-64	B.24-64
	A11-23	A18-19	A20-21			A11,13-23		A12	A9

Table 7. Research Survey Design

The online questionnaire was created following on from the initial exploratory interviews. A feasibility enquiry and pilot testing of the research questions and measures were carried out within a pharmacy region, previously known as Strategic Health Authority areas or SHAs, using the steering committee to ensure that the questions were able to be answered by the target audiences, and that the interviewees were able to easily understand the measures requested. To ensure content validity, a group of practitioners acting as a steering committee were invited to pre-test the interview questionnaire. Specifically, they needed to evaluate the appropriateness, clarity, and accuracy of questions and their evaluation involved changing the wording of some of the questions to comply with these three requirements. Lead pharmacists were targeted who were identified by the initial interviews and steering committee to have key roles in making operational response decisions to supply chain disruptions causing drug shortages. Any discrepancies between their interpretations and researcher's expectations were discussed beforehand and based on their feedback, the initial questionnaire was modified. The design of the survey was rigorously developed using good procedures of scale development via the general approach adapted from DeVellis (2003) and Creswell and Plano Clark (2011).

1. Determine what you want to measure, and ground yourself in theory and in the constructs to be addressed (as well as in the qualitative findings).

2. Generate an item pool using short items, an appropriate reading level, and questions that ask a single question (based on participant language when possible).
3. Determine the scale of measurement for the items and the physical construction of the instrument.
4. Have the item pool reviewed by experts.
5. Consider the inclusion of validated items from other scales or instruments.
6. Administer the instrument to a sample for validation.
7. Evaluate the items (e.g., item-scale correlations, item variance, and reliability).
8. Optimise scale length based on item performance and reliability checks.

4.7 Validity and Reliability

The choice of the design reflects the research interests and objectives pursued. The goal was to develop and validate a generic instrument that would have reasonable predictive power, and can be used to predict individual's behaviour in relation to real life. When constructing a scale or using an existing one, it is good practice to analyse the data for reliability and dimensionality (Bryman and Bell, 2011).

Internal consistency reliability was considered as part of the individual scale item analysis. Where internal consistency reliability reflects the degree to which each item is intercorrelated with other items in the pool, thus it indicates how well the items fit together conceptually (Parsian and Dunning, 2009). The Cronbach's alpha is one of the most commonly used procedures for measuring internal consistency reliability (Bryman and Cramer, 1999) and this was used in the analysis of this research, detailed in Chapter 6. According to Gliem and Gliem (2003), the Cronbach's alpha is a reliability test technique that requires only a single test administration to provide a unique estimate of the reliability for a given test. Cronbach's alpha is the average value of the reliability coefficients one would obtain for every possible combination of items when split into two half-tests. In this way, Cronbach's alpha was intended to remove 'garbage' items which displayed low levels of internal consistency reliability (Churchill, 1979). The Cronbach's alpha will be calculated based on both all and standardised items. A computed alpha coefficient will vary between 1 (denoting perfect internal reliability) and 0 (denoting no internal reliability). As noted by Bryman and Bell (2011), the figure 0.8 is typically employed as a rule of thumb to denote an acceptable level of internal reliability, though many writers accept a slightly lower figure. For example, in the case of the Burnout scale replicated in Schutte, Arbour, Lorenz et al. (2000), the alpha was 0.7, which they suggested was a rule of thumb which is considered to be efficient**.** Although reliability and validity are analytically distinguishable, they are related because validity presumes reliability.

The survey design included procedural remedies to prevent common method variance (Podsakoff, MacKenzie, Lee et al., 2003). Although the survey gave an outline in the participants' information sheets of the general objectives of the study, no clues were given as to the specific relationships under investigation. The respondents were given anonymity to reduce chances of influencing the outcomes, for example, by answering in a way the respondents believed the researcher desired*.* The participants were also asked to base their responses on a specific medical shortage situation to improve the design of the research instrument (Doty and Glick, 1998). Specifically, they were asked to base their answers on the experience of five specific medical lines, or cases, that were subject to disruption causing a shortage event which occurred in the previous 12 months prior to the data collection. The reported instances from the UCLH shortage database included supply chain disruptions prompted by quality issues with the manufacturing process, batch failure to pass quality control, raw materials issues, cargo issues, labelling or packaging problems, short shelf life, regulatory changes, and product changes. The selection procedures of the resultant shortages that were presented in the survey instrument are detailed below in the survey sampling strategy.

The disruption's severity was also captured with the exact month in which the disruption occurred. This is to ensure that when asking a reflective question about historic events, the recency effect, a potential threat to validity, is limited. This is particularly important, as validity is the extent to which a research procedure can be considered to meaningfully capture its aims (Dul and Hak, 2007). For all cases in the survey data set, objective secondary data for the variables' unit size and performance was sorted through NHS website, all of which is in the public domain.

4.8 The scaling method

The survey instrument used a combination of question approaches to allow for both a clear and understandable presentation to the participants, whilst at the same time maximising the response rate. It gave clear instructions on how to respond and kept answers and questions together. The online survey also used response sets of closed questions, allowing for pre-coding to expedite computer analysis. Response sets used a Likert scale as this is the most appropriate choice for studies exploring attitude patterning (Oppenheim, 1992). It uses fixed-choice response formats and measures the strength and intensity of attitudes (Rattray and Jones, 2007). In this project, I asked subjects to give numerical indication on their degree of preference of the statement by selecting from a numerical score range. For example, a score of five equals the most favourable attitude, and a score of one equals the least favourable attitude, with three as the middle point for an undecided or neutral opinion. The benefit of having a neutral point is that it allows respondents to be honest about their choice rather than being forced to choose either extreme (Cox and Isham, 1980).

The survey pilot and retesting of subject matter experts from the steering committee helped refine the questions so that the response set and answers were likely to provide a valid assessment for the participating individual.

4.9 Survey sampling strategy

The survey instrument is the main data collection method for this research. However, the discovery and development of the UCLH database of drug shortages provided evidence over an uninterrupted time period of six years, reported by hospital pharmacists across the country. (Patton, 1990) p201, argues that: "Sample size depends on what you want to know, the purpose of the inquiry, what will be useful, what will have credibility, and what can be done with available time and resources." Two key decisions were required to select the components of the sampling strategy; the target population to be surveyed and the drugs in shortage as a result of supply chain disruption.

4.9.1 Drugs in shortage as a result of supply chain disruption

The first key decision in the sampling strategy of this research was to choose the drugs in shortage as a result of supply chain disruption to be presented to the target population via the survey instrument, questioning their decision responses post disruption and subsequent performance. Note that although the participants were presented with five specific known shortages cases, they were also offered the option of selecting 'other' and detailing their specific shortage.

The UCLH data provided a ready source of drug shortage data which gives credibility to the inclusion of a selection from a total list of 2008 different medicines nationally reported to have a disruption in the pharmaceutical supply chain. As this data is still in a raw state, initial analysis of this research focused on aggregating the records and summarising the data.

A typology of medicines in shortage for sample selection was prepared:

1. Readily recognised as in shortage over the last seven years
2. Frequency of occurrence
3. Severity of impact (meaning there was no substitute readily available)

The high frequency drugs selected from the UCLH drug shortage database were further refined in accordance with this typology and additionally verified by the steering committee. Typologies provide tools that help researchers design their studies and by focusing our attention on the points of interface it facilitates good research design (Guest, 2013). Of the UCLH medicine shortages, the following medicines were recognised as meeting the above typology criteria by the steering committee and selected for inclusion in the research survey instrument as a supply chain disruption case from the original item pool of 10, as shown in Figure 23:

1. Lidocaine Injection
2. Aciclovir Infusion Solution and Powder
3. Glycopyrronium Bromide Injection
4. Ketamine Injection
5. Lorazepam Injection

The original pool of 10 drugs in shortage were selected from the UCLH shortage database and ranked by frequency of incidence to distil to a pool of 10, with the other drug shortage medicines discarded. The steering committee then distilled it further using the specified typology, keeping three of the original 10, discarding the rest, and adding two additional new medicines in shortage: Ketamine and Lorazepam.

Rank	Generic Name and Preparation	Drug Disruption Frequency		
1	Lidocaine Injection	12		
2	Metformin Tablets	11		
3	Metronidazole Tablets	11		
4	Aciclovir Infusion Solution	10		
5	Amiodarone Tablets	10		
6	Anusol Cream/Suppository	10		
7	Cytarabine Injection	10		
8	Flucloxacillin Capsules	10		
9	Glycopyrronium Bromide Injection	10		
10	Ibuprofen Tablets	10		

Figure 23. Pharmaceutical shortages identified by occurrence rank from the UCLH shortage database

4.9.2 Target population to be surveyed

The target population selected was the largest available within the nations where the research was based to take account of the time and resources available to the research. This comprised of all the NHS trust and acute care hospitals in England, Wales, Northern Ireland, as well as the acute care and general hospitals in the Republic of Ireland. Targeting the entire population enabled this research to avoid sampling bias, improving the validity of the research method. As noted by Bryman and Bell (2011), the researcher needs to ensure that steps are taken to keep bias to an absolute minimum.

The survey was aimed at the key individuals responsible for managing shortages in the secondary care hospitals, which normally have a dedicated or semi-dedicated manager responsible for managing shortages, usually the lead pharmacist. However, as was seen from the response from the survey and subsequent interviews, there are a range of roles within the pharmacy work environment that share responsibility in managing the medicine shortages.

The total population of 261 acute care hospitals and trusts in the UK, excluding Scotland, and 57 hospitals in the Republic of Ireland, gives a total population of 318. The population pool excludes ambulance trusts, mental health trusts, and district and community hospitals and clinics. This reduction in the total population pool was because initial interviews with senior hospital pharmacists and health departments had indicated the high impacts and occurrence of drug shortages were in secondary care acute hospitals and trusts. This research recognised that drug shortages also occur on a regular basis in primary, community and mental health hospitals, however, as noted by the experts and steering committee that provided expert advice for this research, the critical nature of the illnesses in acute secondary care means that shortages often cause immediate actions to be taken, which is the focus of this research. As noted by respondents in the interviews, for example, patients in hospital can be quickly affected by a drug shortage given their urgent need for treatment, and this treatment will have to be stopped if an alternative cannot be found. Furthermore, the main issues in drugs in shortage in secondary care are hospital-only medicines, as drugs that are regularly used in primary care are not ordered in large quantities by the secondary care sector, meaning they are less in demand.

There is, however, scope for further research in primary care and this will be discussed in more detail in the closing chapter under limitations and further research sections.

4.9.3 Generating the pool of preliminary items

Once the overall sampling strategy was defined and a prior dimensional structure postulated in the propositions of Chapter 3, it was necessary to generate a pool of items that measure each dimension. Within the scaling literature, such dimensions are referred to as factors (DeVellis, 2003, Netemeyer, Bearden and Sharma, 2003). In order to operationalise factors, items are required to ‘tap’ or ‘cover’ the domain of the construct (Netemeyer, Bearden and Sharma, 2003).

Before experimentation can take place, underlying concepts must be operationalised (made measurable) in such a way that they can be observed to confirm that they have occurred. Hence, measures and indicators are created (Gray, 2013). The process of quantitative research is frequently depicted as one in which theory is employed in order to deduce hypotheses which are then submitted to empirical scrutiny (Bryman and Hardy, 2006). Within the hypothesis will be two or more concepts that will require translation into empirical indicators. These indicators are frequently referred to as variables and represent the fundamental focus of all quantitative research.

4.10 Survey Measures

Measures constitute direct quantitative assessment of variables (Bryman and Hardy, 2006). In order to determine the measures to be used in the survey research, an extensive review was carried out of the extant academic and practitioner literature and exploratory qualitative interviews with pharmaceutical purchasing managers and regional pharmaceutical specialist managers. In addition to pre-testing, an in-person pilot study was conducted to purify the measurements used. Following the multi-item measure approach developed by the scale development, summarised by Creswell and Plano Clark (2011), each construct was based on multiple item scales for the quantitative tests. Section 4.11-13 outlines all the measures and items used and presents the information in table form using the multi-scale measurement scale in Table 15, Chapter 6 data analysis. A unit is defined as a pharmaceutical dispensing operation, managed by a pharmaceutical lead within an acute secondary care hospital.

The items for each measure used were consistent throughout, depending on the construct under consideration. However, to test the propositions and thereby answer the research question, the variables did vary from independent, dependent, or moderator. Section 4.11-13 explains all the variables used.

4.11 Independent variables

To measure supply chain disruption orientation construct, a scale was developed in congruence with prior research using the five scale developed by Bode, Wagner, Petersen et al. (2011). Roles within the pharmaceutical hospital environment were also allocated a five scale listing the job titles that were refined from the extant literature (Ritchie, 2002), and from prior management practice work on roles carried out in the National Health Service (2005a). Hospital numbers representing the number of hospitals in a given trust was defined by adopting a four point scale based on desk research of the current NHS publicly available hospital data, prior research (Baumer, 2004), and from pilot testing and review from the research steering committee. Disruption severity, which encapsulates the extent to which a disruption had an effect (positive or negative) on a hospital unit, was measured by using a five-point scale, in congruence with the approach of prior research (Chadist, 2012, Ponis and Kronis, 2012). Feedback is key in establishing learning from past events in disruptions, as in the case for urgent shortages during events, as noted by (Hales, 1986, Chadist, 2012). A five-point scale was developed to capture both intra-regional and inter-regional management feedback, as the public health service environment in which this research was conducted is structured into hospitals, trusts, and health boards within regions, and the regions within each nation.

This research measured buffering and bridging as actions taken post supply chain disruption causing a medicine shortage by the focal unit. These activities were drawn from the extant literature on supply chain risk management and exploratory interviews, which were then further adapted and refined in a novel approach by breaking down each action into time periods past the disruption. For example, buffering immediately after the supply chain disruption causing a shortage was up to eight weeks afterwards, with buffering (post) actions taken eight to 16 weeks after the disruption. This subdivision allowed the dynamic nature of post disruption actions in real world operations to be captured. Being able to adapt actions during events in a dynamic way builds on the work on dynamic management by Grewal, Johnson and Sarker (2007) and extends and further investigates the initial work on supply chain disruption resilience (Bode, Wagner, Petersen et al., 2011). The analysis of the time-critical supply chains requires application of dynamic methods (Ivanov and Sokolov, 2013, Ivanov, Sokolov, Solovyeva et al., 2016) and the ability to adapt during the course of a disruption (Xu, Wang and Zhao, 2014).This is due to the dynamic nature of the disruption fall out and need to respond to the specific and changing circumstances including for example the severity (Ponomarov and Holcomb, 2011). In pharmaceutical shortage management due to the criticality of the supply chain (high patient demand and life-threatening circumstances) hospital pharmacists and clinicians need to respond to the immediate impact of the disruption causing the shortage, but those response action(s) can change after a number of weeks. This can be due to the nature of the illness being treated, line inventory levels, alternatives medicine available, prescribing protocols, new suppliers (at home and abroad), preparation of the product for example, and the expert steering committee recommended that a typical response change time division post disruption impact was up to 8 weeks after the shortage started, and then from 8 weeks to 16 weeks.

Six item scales were developed for both buffering and bridging for immediately after the disruption event and actions taken eight to 16 weeks after the event. These were based on prior research on pharmaceutical practice item scales and adapted from Baumer (2004).

The extant academic literature on supply chain risk management, supply chain resilience management, and boundary spanning organisational behaviours management describe the generic strategic responses of bridging and buffering (Fennell and Alexander, 1987, Meznar and Nigh, 1995). However, as pointed out by Peck (2006) p130, "No one person manages a whole supply chain", and there is a need to understand the multi-layered nature of organisational response. Further responses are a process and not an end in itself, so in congruence with the literature, the items for buffering and bridging have been extended from Bode, Wagner, Petersen et al. (2011) to include information gathered from qualitative pre-testing and items validated from earlier studies (Baumer, 2004). These include resources, policies and boundary spanning items of inter and intra-organisational relations. The bridging and buffering new constructs both included the concept of time from disruption occurrence, recognising the dynamic nature of response decisions, and the process nature of supply chain risk management. As Aitken (1998) noted, the term 'supply chain' is a flow of material and information from suppliers to end users; it is not a static process that can be understood by one decision immediately after one disruption.

A five point scale was derived from the supply chain resilience literature and the exploratory interviews for the dynamic variable reflecting during event adaption (Christopher and Peck, 2004, Tang, 2006) These were further broken down into both internal business needs and length of time from the disruption to further examine the dynamic nature of the post disruption management behaviour.

4.12 Dependent variables

Performance measures are used in supply chains by management to determine the efficiency or effectiveness of a specified supply chain, (Swaminathan, Smith and Sadeh, 1998). The performance measures are taken from the relevant academic and practitioner literature and pre-test qualitative interviews and steering group pilot study review. The use of performance measurement variables is a novel approach to post supply chain disruption response decisions. Items reviewed included those validated measures used in previous studies on supply chain performance:

1. Fraction of time an item is out of stock, which is similar to out-of-stock used in the retail industry (Gruen and Corsten, 2003)
2. Line fill rate
3. Time to fulfil order
4. Proportion of orders fulfilled

From these items, the line fill rate was selected into an item scale. One was for immediately after the disruption, and one was for eight to 16 weeks after the disruption for each measure, to capture the performance of the focal unit for analysis. The fill rate was selected as the most recognisable and the most relevant to the shortages captured on an ongoing basis via the pharmacist management systems, as identified by the expert steering committee.

Further measures reflected previous industry context studies, such as Baumer (2004), to ensure relevance and impact and from initial qualitative interview feedback:

1. Procedure change
2. Patient impact
3. Suboptimal treatment
4. Health consequence

Supply chain disruption orientation was also used as the dependent variable to test the proposition P1c in further exploring the new concept initially developed by Bode, Wagner, Petersen et al. (2011), and extended with regards to the system membership aspect based on the extant boundary spanning organisational literature (Fennell and Alexander, 1987).

4.13 Control Variables

The control variables in the analysis phase are set to the context of the dyad but included the variable beds for which a four item scale was developed based on previous research (Baumer, 2004) as this may affect organisational actions and inertia (Chattopadhyay, Glick and Huber, 2001).

Having collected the completed questionnaire responses, and after cleaning data entry errors, the data was input and coded using SPSS. After collating the information, a simple check was carried out on the response data for obvious errors such as entries falling outside the defined question responses. The data was further visually inspected and a descriptive analysis conducted using mean and standard deviation and variation in responses to determine general trends in the data prior to the data analysis phase, as described in Chapter 6.

The next section describes the interviews that were conducted and the process followed, including the initial descriptive statistics from the survey. The interviews were then followed up by conducting three separate focus groups, as described in 6.17. The reason for conducting several contrasting qualitative procedures, in addition to the data collected by the quantitative tool of the online survey, was to triangulate the results and to enable the better interpretation of the results and the 'why' question. The original post supply chain disruption model was built by Bode, Wagner, Petersen et al. (2011); Bode, Wagner, Petersen et al. (2011) almost exclusively used a survey quantitative methodology, with limited exploratory interviews and secondary data. By applying a combination of methods approach, as noted by Sandelowski (2000) p251, "Mixed-method research is a dynamic option for expanding the scope and improving the analytic power of studies." Interviews not only allow the investigator to clarify questions for the participant, but also probe responses and seek deeper insights in meaning, focusing on the research question. For example, not only finding out what management actions were taken but why those actions were taken, and often examples may be given to further illuminate the issue under consideration and to add empirical first-hand information to corroborate the participant information of the subject under discussion. However, there is a downside to every method, and interviewees can go off the point and start discussing their own experience or answer non-related questions of their own; for example, the ethical considerations in treatment decisions, although this does give the investigator a wider perspective of the environment, the decision-making takes place by their research participants.

4.14 Interviews

The interviews were conducted following on from the self-completed questionnaire in order to give meaning to the data collected and to verify and develop the findings. The processes followed and the initial outputs of the interviews are described below. The full data analysis of the interviews is included in Chapter 6.

The main preoccupations of quantitative research are described by Bryman and Bell (2011) in terms of four features: measurement, causality, generalisation, and replication. The triangulation of this information with the rich source of research data through in-depth semi-structured qualitative interviews with a cross section sample of the survey participants provided detailed answers to make sense of and challenge the quantitative findings. Qualitative interviewing allowed the interviewee to depart from the scheduled and quickly coded answers to accommodate flexibility (Bryman and Bell, 2011), whilst at the same time focusing on the outlined topic.

4.15 Interview Sampling Strategy

The interviews were conducted on participants drawn from the survey instrument. Due to the strict ethical considerations within the public health system ethics procedures, highlighted below in Section 4.19, and the approved ethical protocol, the participants in the survey were given participant information and consent requests. These included indicating whether they would participate in the follow-up interviews.

4.16 Validity and reliability

The application of rules in content analysis is important as it means the analysis is done in a consistent manner in order to eliminate bias. The rules can be a reflection of the researcher's concerns and interest and these might be subject to bias. The main issue for reliability, however, is that once designed and documented they can be followed without the intrusion of bias. The eight step process, known as the Weber Protocol (Weber, 1990), was followed in formulating the coding scheme, so that the process and outputs of the content analysis could be replicated without bias:

1. Definition of the recording units
2. Definition of the coding categories
3. Test of the coding sample of text
4. Assessment of the accuracy and reliability of the sample coding
5. Revision of the coding rules
6. Return to step three until sufficient reliability is achieved
7. Coding of all the text
8. Assessment of the achieved reliability or accuracy

4.17 Focus group

Following on from the online questionnaire and interviews, three group interviews were organised in the form of a focus group. The focus group offers the researcher the opportunity to study the ways in which individuals collectively make sense of a phenomena and construct meaning around it. It is a central tenant of theoretical positions like symbolic interaction that the process of understanding social phenomena is not undertaken by individuals in isolation from each other. Instead, it is something that occurs in interaction and discussion with others (Bryman and Bell, 2011). Focus groups reflect the processes through which meaning is constructed in everyday life and to that extent can be regarded as more naturalistic than individual interviews (Wilkinson, 1998).

However, as with all research methods, the focus group approach has limitations. As well as the practical challenges of group organisation and the large amount of information they quickly generate, there are the potential problems of group effects or 'groupthink'. These include reticence to contribute, the tendency, in some cases, for agreements rather than disagreements, and the expression of culturally expected views in contrast to individual interviews (Janis, 1982, Krueger, 1998). To overcome and reduce these phenomena, the groups were given active encouragement to contribute, with the interviewer expressing that there were no right or wrong answers and that each interviewee's opinion was valid.

4.18 Focus group selection

The focus group has been subject to criticism in a marketing research context, with critics stating that a group of 10 or so interviewees, usually chosen haphazardly at a single location, cannot be expected to reflect the views of the whole population. However, this research is not considering a product in a marketing context and the focus groups were conducted for the entire population of regional specialist pharmacist managers in England and Wales, with a separate focus group for each. Because focus groups are useful for assessing complex concepts, they are ideal for researchers who wish to systematically research and include concepts via survey or experimental work (Cyr, 2016). This research also conducted a focus group with a senior cohort group from the buyer side of the pharmaceutical acute care secondary supply chain, derived from the same teams involved in the exploratory interviews for consistency and wider understanding, namely the Commercial Medicines Unit (CMU), and the Department of Health (DoH) Supplies Team, who focus on shortages.

These groups did not consist of randomly selected managers with limited knowledge of supply chain disruptions and shortages in medicines, rather they were the key targeted groups of operational experts involved in the operational management, policy, and contracting of the buyer side of the pharmaceutical supply chain in acute secondary care. Selecting focus group participants from natural groups of experts in a field has been successfully used in other management research, such as Kiely (1998). One of the potential criticisms of using natural groups is that the participants can often already know each other and take it for granted that topic knowledge is high and this can be difficult if a hired moderator is involved to control the group discussion. To counter this issue, and for ethical and resource constraints, the focus groups were conducted by the researcher and did not include a hired moderator.

After conducting three separate focus groups in different locations across England and Wales, the information and data collected was substantial and varied, however, repeated themes were identified. Due to the time, finance, and resource constraints of this research and the saturation of the data outcomes, a further focus group to be conducted in the Republic of Ireland was deemed beyond this research study and not critical to the data integrity due to the repeated theme outputs from the existing focus groups, in addition to reducing the complexity of the research overall (Schlesinger, Dobash and Weaver, 1992). The focus group sample size was then not predetermined, but rather dictated by theoretical saturation; that is, data collection was stopped, when no additional concepts or relationships among the concepts emerged, a technique used in other qualitative research in disruptions and crisis management by Grewal, Johnson and Sarker (2007). The data generated by qualitative methods are voluminous, and the sheer quantity of raw data needs to be organised and managed. As part of this process, the recognition of ‘sensemaking’ and a goal approach has, at its roots, pragmatism (Brinkman, 2014). Livingstone and Lunt (1994) note on this point of theoretical saturation that the criteria for selecting the number of focus groups is determined by continuing until comments and patterns began to repeat and little new material is generated.

Fern (2001) has argued that the generalisability of focus group findings, as with other research methods, depends on the scale of the sample. What the focus group does allow the researcher to do is to drill down into the details of an issue, with a group of experts’ collective knowledge producing a clearer and fuller picture, especially in a topic-based approach.

All the focus groups were recorded and transcribed, as were all the individual interviews, as it has the following advantages, as described by Heritage (1987):

1. It helps correct the natural limit of our memories
2. It allows more thorough examination of what people say
3. It permits repeated examination of the respondent answers
4. It opens up the data to public scrutiny
5. It therefore counters accusations of bias by researcher influence
6. It allows the data to be reused in other ways

The focus groups were included in the ethical approval process, along with the individual interviews, and focus group protocol guides, including anonymity and data integrity, participation information sheets, and consent forms were all approved, issued, and collected as part of the focus group research. Each group interview was held for approximately one-and-a-half hours, with all participants meeting the criteria for participation. The participants were told the session would be audibly recorded and subsequently transcribed by the researcher. The same focus group guide was used for each of the groups.

Each focus group followed a six step topic agenda relating back to the research question and consequent propositions in order to concentrate on the explanation of the subject under consideration:

1. Current shortage challenges
2. Supply chain disruption orientation
3. Buffering and bridging actions
4. Feedback and dynamics
5. Size and role
6. Shortage management performance

These topics not only reflected the requirement to answer the research question, but were also a distillation of the main themes identified by the collective interview results. The transcriptions from the focus groups were also uploaded into the NVivo software programme. This was to allow the management of the substantial amounts of data generated by the focus groups' transcriptions, facilitate easy extraction of quotations in the display screen, and to identify the main themes using the Word Cloud function. However, the focus group transcripts were not fragmented into nodes and categories to allow for wider participant perspectives across the group and to facilitate moving from findings to actions from the group-based discussions and interactions, as recommended by Bloomberg and Volpe (2015).

The next section refers to the ethical considerations for this research, prior to data collection and analysis.

4.19 Ethical Considerations

When conducting research, the researcher needs to maximise benefits and minimise harm, therefore, the researcher must consider the impact of his or her actions before conducting them (Barrar, 2002) and so, as with all research conducted, consideration had to be given to the ethical and moral implications of the research methodology applied. To maximise the validity of the research findings, a number of research methods were triangulated, e.g., there was no one area of the research where the researcher did not employ more than one method of data collation. This mixed method approach meant the research had the potential for ethical repercussions, and so a robust action plan was put in place in accordance with the ethical rules of both the university and the National Health Service, the latter of which ethical staff involvement was required from both organisations.

Having developed an appropriate and relevant questionnaire, interview and focus group participation information sheets and consent forms (as part of the risk assessment and gaining the relevant external and internal ethical approvals), the data was then collected. The data collection tools for the questionnaire were administered to the inter-organisational actors by internet link to protect the identity of the recipient, which is important from an ethical aspect but also as this is a self-reporting tool to encourage objective participation. The survey was issued with a participant information letter outlining the purpose of the research and an individual consent form confirming that the research is for academic purposes only and that it has been approved by the ethical committee of the university, who will act as sponsors for the research, as were the interviews and the focus groups. In parallel to the Research Ethics Committee (REC) review, NHS permissions were sought and granted by the appropriate NHS Ethics Committee representative. This research did not involve collecting data direct from patients but through interviews and surveys of NHS pharmacy staff in aggregate. No sensitive personal data (Data Protection Act, 1998) or commercially sensitive data

(Freedom of Information Act, 2000) will be gathered or examined. Research protocols were developed, reviewed, and approved prior to any data being collected, including a relevant risk assessment.

4.20 Summary

In Chapter 4, the research design and methodology plan was initially described following the five-step research plan. The first steps of the research plan are the philosophical stance and research approach, and considerable attention was given in this part of the research plan as this influences the way in which all other elements of the later elements of the research plan, i.e., strategy, methodology and techniques and procedures, are constructed. It is recognised by this research that there are multiple philosophical stances and research approaches available to the researcher in any study (Healy and Perry, 2000). However, by using comprehensive criteria, the relative merits of each stance and methodical design has to be aligned to an appropriate paradigm, in this case positivism, given the theory testing nature of the research. This section also included the high-level research flow chart, research problem, constructs and propositions flowchart and the research survey design summary table to explain how the research question will be answered. The proposed techniques and procedures for this research are outlined above, before being described in detail in the next data collection sections of Chapter 5.

Chapter 5 is the final layer 6 in the research plan, as described in the Saunders, Lewis and Thornhill (2007) research onion in Figure 15. It presents the actual data collection process followed using a step by step approach, to clearly set out the method(s) used to allow verification and replication (Marczyk, DeMatteo and Festinger, 2005).

5 <u>Data Collection and Descriptive Presentation</u>

5.1 Introduction

This chapter describes the data collection process in detail and presents the descriptive statistics and outputs of the initial results. The data collection instruments, as described below, follow the strategy path outlined in the research high level design flowchart: Chapter 4.4.1, Figure 20.

5.2 Desk Research

The initial dialogue with the target participants and desk research identified multiple sources of data, both in the form of an information database and willing key participants from pharmacists representing each of the NHS areas in England, tracking the 10 SHA regions, NHS Wales and Health Service Executive (HSE) Hospital Groups in Ireland. Each region includes trusts or regions of cooperation, which themselves have varying numbers of acute care hospitals, where a lead pharmacist will be responsible for the operational delivery of pharmaceuticals to patients.

The desk research identified the UCLH national drug shortage database as a relevant and available source to be investigated by this research.

5.3 Drug Shortage Database

The drug shortage database was developed by the University College London Hospital NHS Trust (UCLH) in 2001. The site was initially cultivated in-house to provide details of manufacturing problems of medical products for departments within the trust.

The idea proved a success within UCLH, and interest became so great that its availability was gradually expanded to hospitals on a national basis via e-mail, fax and post. The data is uploaded either directly to the site or on a manual basis by the in-house team, which also administers and supports the site. It became a valuable and unique source of drug shortage information in England in the medicine supply chain final mile for practitioners and stakeholders alike. The site progressed to become the Solutions website, a valuable resource to its users in the communication and management of pharmaceutical supply problems. The site is designed for NHS healthcare professionals, and to access and use the site a mandatory account must be set up using a username and password. Applicants are first reviewed internally by the ULCH solutions website staff.

The raw data includes information relating to over 2,000 medicines that have been in shortage in the United Kingdom's secondary care supply chain, reported as so by a variety of sources. Specifically, the data includes the shortage medicines' generic name and preparation, strength, pack size, brand-name, manufacturer, a target date for the shortage resolution, the reason for the shortage, and alternative drug source information. The 'Product Shortage Information' section is updated daily and has a search function available. The most significant pharmaceutical supply shortages are readily identifiable at a glance in the 'Critical Drugs' section, which also offers advice on how to deal with the problem.

Figure 24 shows there is a frequent incidence of injectable drug shortages from various manufacturers, with the top five from four different suppliers. Summary description of the data identified the most frequent causes of pharmaceutical shortages are due to 'macro' disruption issues, with the manufacture of the drugs upstream in the pharmaceutical supply chain. Note that there are 2008 types and preparation of generic drugs recorded in shortage not taking into account pack size, which introduces the scale of the complexity involved in managing inventory of shortages. Figure 24 displays several drugs in shortage, all due to supply chain disruption, over a six-year period (2009-2015) summarised by frequency of occurrence.

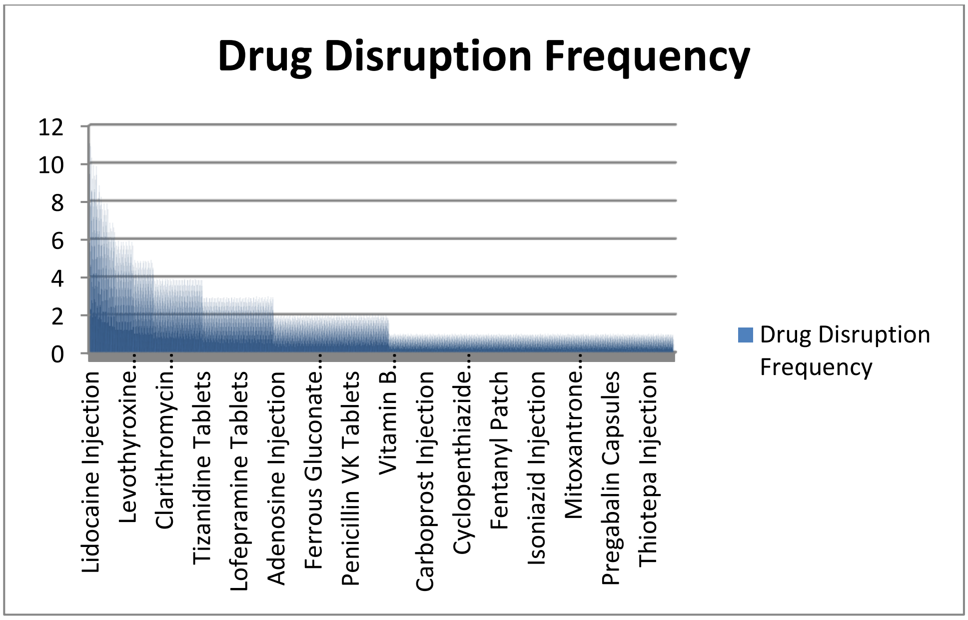


Figure 24. Frequency of pharmaceuticals in shortage incidence by medicine from the UCLH shortage database.

Following on from the desk research and initial analysis of the UCLH drug shortage database, exploratory interviews were conducted to give further meaning to the initial quantitative data found. The interviews also assisted in guiding and selecting the survey design and to help define the survey sampling strategy, including the medicines in shortage to be included, so that they are relevant and valid. The need to sample is one that is almost invariably encountered in quantitative research (Bryman and Bell, 2011).

5.4 Exploratory Interviews

The exploratory interviews conducted identified that disruption response actions and the mechanisms that underlie them vary between organisations and responsible managers. Initial discussions also indicated that, currently, the pharmaceutical supply chain in acute care is underperforming in shortage management, with the ongoing disruptions affecting the supply of drugs becoming the norm rather than the exception.

The preliminary discussions with the range of professionals helped to further illuminate the pharmacy supply chain field. The professionals were all aware of shortages in medicines, and noted that this was not a new phenomenon. The occurrence of shortages was seen as a routine part of the pharmaceutical supply chain. It was also seen as getting worse with every passing year, and whilst 95% of secondary care drugs were readily available, the challenge lay with the remaining 5%; patients require

100% care availability at the point of use. Pressure was evident from the interviewee's feedback to improve this performance to 100%. The focus, however, was local disruption to the supply chain, albeit with an awareness of the global supply chain network. The initial discussions with research participants, desk research and literature review all identified the ongoing performance issues in shortage management with regards to pharmaceutical supply chain disruptions. For example, when discussing with a lead procurement technician at one hospital trust regarding medicine line samples that had been in shortage over the last 12 months, there were multiple examples readily given, including injectables such as insulin. A widespread problem identified was medicine contracting and the non-adherence to contracts, for example, prematurely pulling out of contracts that were seen as not economically viable. The quality and availability of data, such as forecasts, and supply chain flexibility were also cited as important.

In addition to contractual adjustments and risk assessment strategy, Stead's (2009) work was referred to by two of the interviewees, specifically *A Framework for Managing Medicines Shortages and Product Discontinuations*, which involved a multi-agency approach[1] . There was a recognition at an early stage of the need for both wider and local bridging actions to complement the local buffering actions. This work was a follow-on from the earlier NHS 'Improving pharmaceutical supply chain performance: pilot programme'. The thickening of the supply chain for a wide range of elevated risk medicines (buffer stocks) and the public healthcare ownership of emergency stock was mentioned. Also, the selection criteria of suppliers were not solely price focused, but this conflicts with the 'value based pricing' current government directive, economic climate, and the fact that all secondary care regional pharmacy managers have costs reduction targets.

Access to information and having the right information in the right place at the right time was a common theme coming from the interviewees. This included a variety of information flows and methods, but it was identified that there was no automatic direct real-time flow of data. Pharmacy data was uploaded monthly and held by the CMU. Manufacturing companies affected can give inventory forecasts twice weekly as required, plus a two-way process of manual alerts. Other drug companies send weekly lists. Data and the availability of information to hospital pharmacies is centred around the CMU as a gatekeeper. The interviewees stated that the conflicts existing between the multiple systems that were in use throughout the process negatively impacted the

[1] Agencies included ABPI,BAPW and BGMA

efficient use of the data. They identified that a single integrated IT system would benefit the supply chain process enormously. The interviewees coded, however, that improvements had recently been made. For example, most hospital trusts are now using EDI to transfer data, improving the flow of information.

The preliminary interviews identified that within the NHS system, these are the key strategic decision-making areas for supply chain response to disruptions. It was mentioned that roles at each hospital trust have different focuses, but often those with responsibility for dealing with shortage issues caused by disruptions have multiple responsibilities. For example, the pharmacy director or head of pharmacy has focus on the overall budget and wider service level agreements to the customer and board notifications but also takes a strategic role in responding to shortages. This exploratory phase involved face-to-face interviews or telephone interviews (in order of preference) depending on the commitments of those taking part. Using pre-existing, readily accessible resources and permissions for interviews on a large population is useful (Bell and Bryman, 2007) after the typology of the sample is considered (Patton, 1990, Miles and Huberman, 1994). However, it is important to note that these exploratory interviews were not a convenience sample being simply available by chance; in contrast, they were selected with the study's research question in mind.

5.5 Survey Response

The overall response rate was 125 respondent hospitals, 109 from the UK, excluding Scotland, from a possible 261, meaning 42% of the possible population responded, and 16 from the Republic of Ireland, from a possible 57, meaning 28% of the possible population responded. This gives a strong overall response rate of 39% from the entire population of 261 hospitals. There was a limited amount of missing data in the survey responses, amounting to 146 data points from a possible 7,875, totaling less than 2%.

5.6 Interview Response

Those in the subsequent candidate pool of consenting interview participants were then contacted to request participation in a follow-up interview. An interview candidate list was drawn up and from all those contacted with follow-ups, an interview schedule was drawn up and conducted. No filtering of the consenting participants was conducted and the total number of interviews conducted was 18, 14% of the available survey respondent’s population, which itself was drawn from all the secondary care acute hospitals in the UK, excluding Scotland and including the Republic of Ireland. There were no missing data items as all questions were answered by each participant during the interviews. The interview format allowed participants to clarify questions and the examples given by the interviewer were necessary to illuminate the questions posed. The pre-testing of the interview's semi-structured protocols by the steering committee meant that many of the questions were easily understood by the candidates.

The data analysis of the interviews was based on the technique of quantitative content analysis. This is an approach to the analysis of documents and texts that seeks to quantify content in terms of predetermined categories. The approach to content analysis is based on categories designed to capture the dominant themes present in the text (Franzosi, 1995). Data analysis, or coding, of each of the first two participants, before continuing with subsequent interviews, was carried out, as recommended by (Saldana, 2013). This ensured the quality of the interviewing process by identifying possible leading comments and/or incomplete participant responses. This pause in conducting interviews allowed greater confidence that the interviews were conducted completely and accurately. A comprehensive definition of 'code' is given by (Saldana, 2009) p129, he states:

> A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data.

In analysing qualitative data, it is essential to keep an open mind, remembering that qualitative research is all about discovery (Bloomberg and Volpe, 2015). Although content analysis has the advantages of being flexible and transparent, it is recognised that inter-coder reliability can never be perfect and it is almost impossible to devise a coding manual that does not involve some interpretation on the part of the coders through everyday knowledge (Cicourel, 1964).

The interviews were analysed by using the NVivo software. This programme had already been applied in the literature review of this research for analysing content; codes are created by the researcher, which facilitates the process of analysis.

The interviews were all audio-taped, transcribed and entered into the NVivo software programme. The researcher also imported field notes from observations, and other secondary data collected; for example, standard operating procedures to verify and add depth to the meaning of the interviewer's comments. Documents from each case were stored together in order to make individual case analysis easier and more efficient (Heritage, 1987). The software was used during initial coding and to develop coding categories for each case.

The NVivo software tool helped organise and manage the large volume of data collected in the research process. If data are to be thoroughly analysed, they must be well organised (Bloomberg and Volpe, 2015). Although there is still an ongoing debate within the field about the utility of CAQDAS (computer-aided software programmes for data analysis), they do enable selective monitor display of data and codes in configurations to allow the researcher review and apply analytic thinking to the research material and their meanings (Miles, Huberman and Saldana, 2014). The justification for the interviews and subsequent focus groups to be transcribed by the researcher was to allow total immersion in the data, to improve familiarisation, and to become familiar with it. The NVivo software allows the storage and organisation of raw data in multiple forms, for instance Word and PDF, and so allows a common platform for organising the research results and analysing them.

Although the qualitative and quantitative parts of this research project were conducted separately and analysed in different ways, the overall reporting of findings means that data from both sources are seamlessly woven together to provide an overall integrated and holistic presentation, as recommended by (Bloomberg and Volpe, 2015). After the transcripts were entered case-by-case into the NVivo software, they were profiled into themes by allocating variables to each theme.

To facilitate the refinement process and ensure a reliable process was documented, a two-stage process of coding was followed.

5.7 First round coding

First round coding was completed in NVivo using nodes. A node is defined in the latest release as, "a collection of references about a specific theme, place, person or other area of interest" (Bryman and Bell, 2011) p598. Coding was carried out by applying nodes to segments of text. Each theme or variable is allocated a node. This profiling method enables the development of coherent descriptions of what and how things happen across a number of cases (Miles, Huberman and Saldana, 2014). Next, each case, or interview, from the complete collection of 18 interviews was reviewed line by line in the NVivo display to allocate first coding by phrase or word most relevant to each of the nodes.

In addition, while first coding by theme, individual quotations were retained by using memos, which were saved separately by theme. This facilitated a bank of salient quotations against each theme, which could be referred to and compared and accumulated against other quotes by different cases on the same theme on an ongoing and iterative process. This meant large amounts of data could be distilled and refined, allowing the successful linking of case-orientated with a variable-orientated approach, which gains conceptual power that cut across variables can bring (Miles, Huberman and Saldana, 2014). As the interviews were semi-structured, they were purposely chosen to answer the research question by addressing the relationships posed by the research propositions. The coding schedule, shown in Table 8, is in the form into which of all the data relating to an item was subsequently entered. Each of the Roman numerals in Table 8 relate to a specific dimension that was being coded. The coding schedule helps the researcher simplify the principals involved in the process of content analysis, and is the first step in funnelling the large amounts of data prior to categorisation through the coding manual, as noted by (Bryman and Bell, 2011). This technique has been used successfully in prior research, including management decision-making and behaviour (Harris, 2001).

Information about the actor	Actions, response	Performance	Advice
(i) Role	(x) Response Action	(xv) Performance shortages	(xvii) Shortage Management Advice
(ii) Length of service	(xi) Response Reason	(xvi) Performance patient	
(iii) Size	(xii) Response Dynamic		
(iv) Region	(xiii) Dynamic Reason Description		
(v) Job Function	(xiv) Effective response action		
(vi) Knowledge			
(vii) Information Access			
(viii) Feedback			
(ix) Shortage Frequency			

Table 8. Coding schedule

After this process was completed, the cross-case themes could be viewed in groups of strips of the relevant text taken from the transcript of each case. The process was refined and tested before progressing onto the next stage of the coding drawn from the condensed information in the NVivo software repository, where the transcripts were uploaded and nodes defined from the content of the interviews.

5.8 Second round coding

The second-round coding was done by distilling the contents of the 17 nodes, each consisting of a theme derived from the interview transcripts. This further distillation was done to dive deeper into the data by classifying it in a consistent manner using a coding manual, shown in Table 8. The coding manual, sometimes referred to as the content analysis dictionary, is a statement of instruction to coders specifying the categories that will be used to classify text based on a set of written rules that will define how the text will be classified (Bryman and Bell, 2011). This enables replication to enhance reliability, ensuring that the process could be carried out again by another researcher and get the same results.

Information about the actor	Actions, response	Performance	Advice
i. **Role** (1) Specialist Pharmacist(2) Head of Pharmacy (3) Purchasing Manager (4) Clinical Pharmacy Manager (5) Medicines Information Manager (6) Pharmacy Procurement (7) Pharmacy Technician	x. **Response Action** (1) Buffer (2) Bridge (3) Both Buffer & Bridge (4) Neither	xv. **Performance shortages** (1) 5 (2) 6 (3) 7 (4) 8 (5) 9 (6) Missing	**xvii. Shortage Management Advice** (1) Communication (2) Information (3) Knowledge (4) Relationship (5) Vigilant orientation (6) Feedback
ii. **Length of service** (1) Upto 1 year (2) One upto three years (3) Three upto five years (4)Five upto ten years (5) Ten years and more	xi. **Response Reason** (1) Continuity of supply to patient (2) Efficently manage existing stock (3) Estimated Shortage Time length (4) Nature of medicine (5)Plan future stock	xvi. **Performance patient** (1) 5 (2) 6 (3) 7 (4) 8 (5) 9	
iii. **Size** (1) Standalone (2) Two to three hospitals (3) Four to five hospitals (4) Six or more hospitals	xii **Response Dynamic** (1) Always dynamic (2) Regularly dynamic (3) Occassionally Dynamic (4) Never Dynamic		
iv **Region** (1) North (2) South (3) Middle & East of England (4) London (5) Other	xiii. **Dynamic Reason Description** (1) Duration of shortage (2) Nature of medicine (3) Shortage Cause (4) Alternatives availability (5) Not Dynamic		
v. **Job Function** (1) Procurement/Sourcing (2) Inventory Management (3)Team Management (4) IT Management (5) Contract Management	xiv. **Effective response action** (1) Speed of action (2) Close supplier engagement (3) Team dynamic & orientation (4)Single point of contact (5) Defined Process (6) Information Gathering (7) Feedback (8) Shortage Champion		
vi **Knowledge** (1) Extremely knowledgable (2) Good knowledge (3) Average knowledge (4) Some knowledge (5) Not knowledgable			
vii. **Information Access** (1) Multiple source easy access (2) Easy access (3) Limited Access (4) No access			
viii. **Feedback** (1) Really good feedback (2) Useful feedback (3) Limited Feedback (4) No feedback			
ix. **Shortage Frequency** (1) Very frequently (2) Frequently (3) Occassionally (4) Rarely (5) Never			

Table 9. Coding manual

The above coding manual in Table 9 indicates the detail by category to be recorded, for example, under action response, (xiv): Effective response action has eight possibilities in the coding manual, from (1) speed of action through to (8) shortage champion. From these options, the frequency of response by the interviewees can be collected in a relevant way to ultimately answer the research question, but importantly the method is confirmed in the manual for replication in future research.

Following on from the coding manual, the contents of the 17 individual nodes were analysed using the NVivo query tool, and allows viewing the Word Cloud grouping at the exact match to the generalisations level. This produces an image of the most frequent 1,000 words which allowed the researcher to pick out the highest frequency words relevant to the theme.

The Word Clouds drawn from each of the nodes were then reviewed along with the actual relevant text, to specify the categories within each theme. Then for each case, using the NVivo software, their corresponding node content was reviewed and used to categorise each node reference content, according to their strip salient words for that case. These case categorisations were then accumulated in the contents summary matrix, shown in Table 10.

Information about the actor	Actions, response	Performance	Advice
i. **Role** Specialist Pharmacist(2) Head of Pharmacy (4) Purchasing Manager (3) Clinical Pharmacy Manager (2) Medicines Information Manager (1) Pharmacy Procurement (4) Pharmacy Technician (2)	x. **Response Action** Buffer (5) Bridge (4) Both Buffer & Bridge (9) Neither (0)	xv. **Performance shortages** 6 (3) 7 (7) 8 (7)	**xvii. Shortage Management Advice** Communication (4) Information (4) Knowledge (1) Relationship (0) Vigilant orientation (6) Feedback (3)
ii. **Length of service** Upto 1 year (3) One upto three years (5) Three upto five years (2)Five upto ten years (0) Ten years and more (10)	xi. **Response Reason** Continuity of supply to patient (12) Efficently manage existing stock (3) Estimated Shortage Time length (2) Nature of medicine (1)Plan future stock (0)	xvi. **Performance patient** 6 (2) 7 (10) 8 (4) 9 (2)	
iii. **Size** Standalone (5) Two to three hospitals (4) Four to five hospitals (5) Six or more hospitals (4)	xii **Response Dynamic** Always dynamic (2) Regularly dynamic (10) Occassionally Dynamic (5) Never Dynamic (1)		
iv **Region** North (4) South (3) Middle & East of England (5) London (1) Other (5)	xiii. **Dynamic Reason Description** Duration of shortage (6) Nature of medicine (5) Shortage Cause (3) Alternatives availability (2) Not dynamic (2)		
v. **Job Function** Procurement/Sourcing (10) Inventory Management (1)Team Management (4) IT Management (1) Contract Management (2)	xiv. **Effective response action** Speed of action (2) Close supplier engagement (3) Team dynamic & orientation (3)Single point of contact (1) Defined Process (1) Information Gathering (1) Feedback (1) Shortage Champion (6)		
vi **Knowledge** Extremely knowledgable (2) Good knowledge (14) Average knowledge (0) Some knowledge (2) Not knowledgable (0)			
vii. **Information Access** Multiple source easy access (5) Easy access (6) Limited Access (6) No access (1)			
viii. **Feedback** Really good feedback (11) Useful feedback (4) Limited Feedback (2) No feedback (1)			
ix. **Shortage Frequency** Very frequently (7) Frequently (9) Occassionally (2) Rarely (0) Never (0)			

Table 10. Contents matrix summary

Table 10 displays the categories by theme and allows the researcher to review, in summary form, the results of the content analysis. It was separated by four overall summary sections:

1. Information about the actor
2. Actions (Response)
3. Performance
4. Advice

Table 10 shows the typology of the role theme, and displayed that the two most frequent roles were head of pharmacy and pharmacy procurement. The length of service of the participants was most frequently over 10 years, with 10 out of the 18 interviewees holding their role for at least this length of time. There was an even spread of the hospital numbers within the trusts. The job function of the roles was mainly procurement, again with 10 out of the 18 interviewees having this job function, with predominately good knowledge, with 14 out of the 18 interviewees meeting this standard.

By reviewing the results in the content summary matrix in these four subdivisions, the most frequent categories of each theme can be easily identified, allowing the researcher to become further immersed in the data.

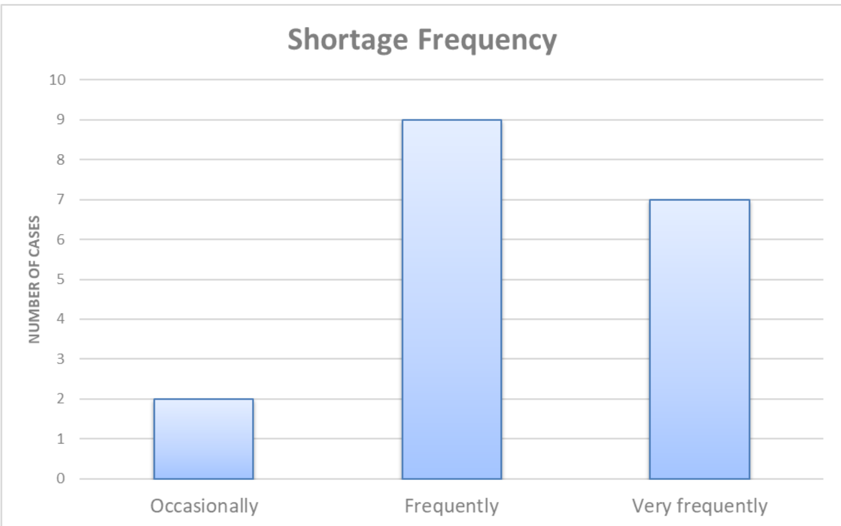


Figure 25. Medicine shortages frequency of the interview responses

Shortages experienced by the interviewees showed a pattern of 'frequently', shown in Figure 25. All the interviewees had experienced shortages of at least occasional frequency.

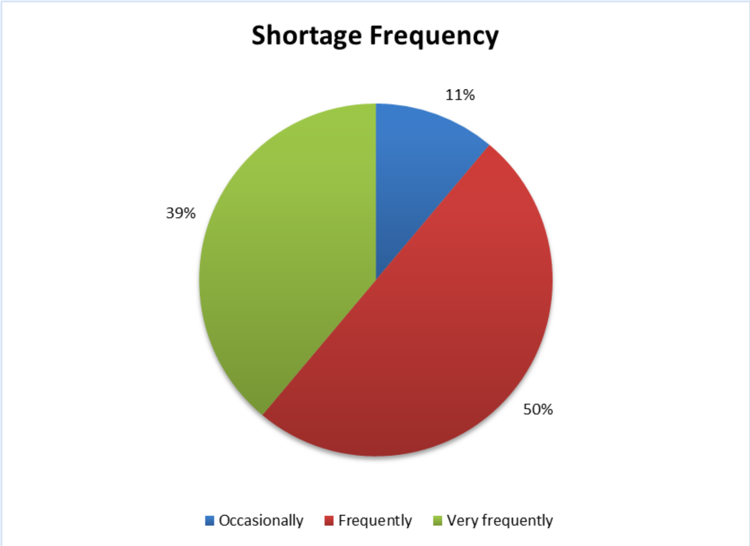


Figure 26. Shortages as a percentage of the interview responses

As shown in Figure 26, all the interviewees had experienced shortages of at least occasional frequency.

In the 18 cases interviewed, only two (11%) interviewees reported an occasional shortage frequency. There were nine (50%) interviewees that frequently have a shortage, and seven (39%) interviewees having a shortage very frequently. This frequency distribution is described in Figure 26.

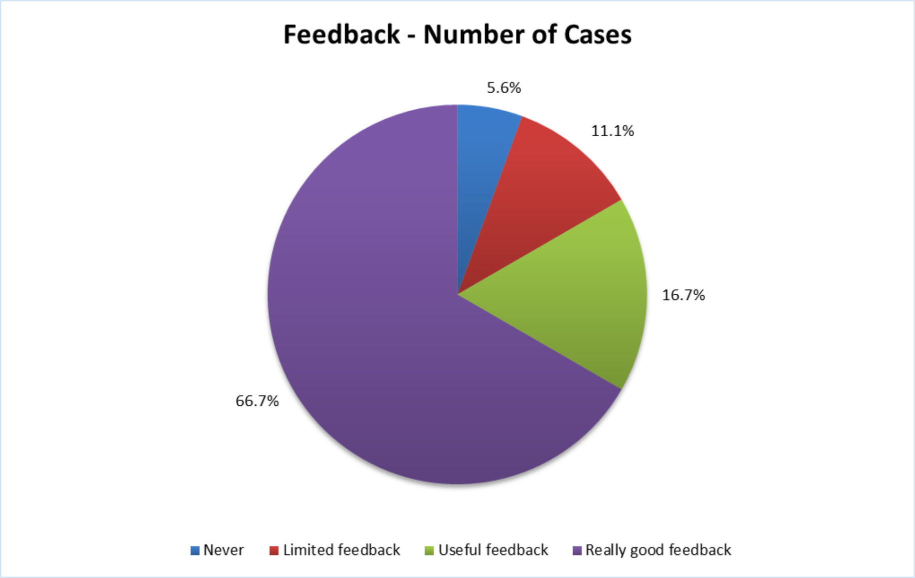


Figure 27. Feedback by case

The feedback by case was captured and summarised, with 11 out of the 18 interviewees (66.7%) stating they had 'really good' feedback, as shown in Figure 27.

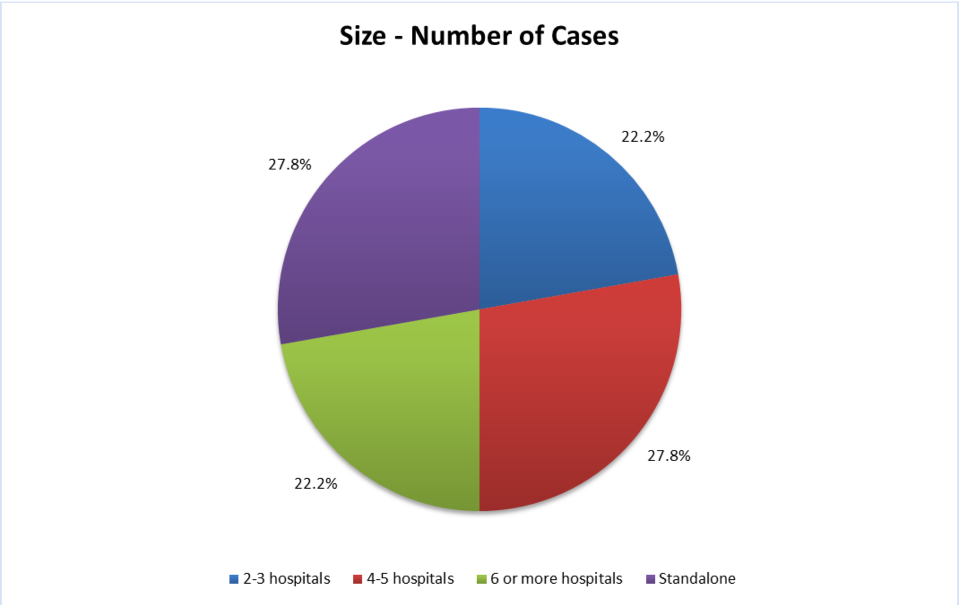


Figure 28. Size of trusts or regional hospital groups

The size of the hospitals was evenly spread across those interviewed (Figure 28). As shown in Figure 28, the standalone hospitals were 27.8%, and between 4 and 5 hospitals 27.8% was the most frequent number of cases.

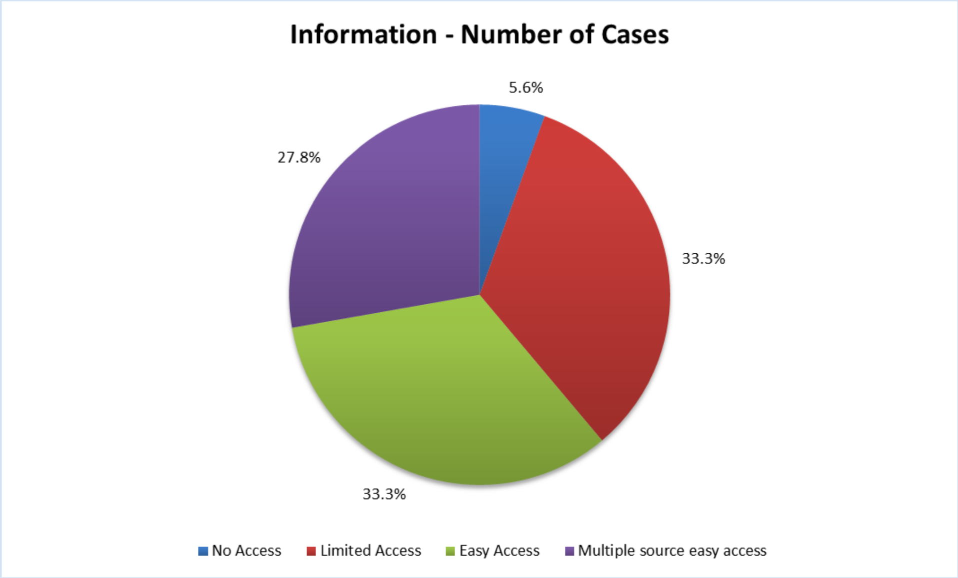


Figure 29. Sources of shortages information

There was an even spread of interviewees who had either limited access to information and easy access to multiple sources of information, each comprising 33.3% of the total interviewees (Figure 29). This suggests that those charged with managing shortages do not have a uniformed standard when it comes to accessing information. However, 27% of those interviewed did have multiple sources of information, which could potentially explain why there was some variation in the level of shortage performance. As per information processing capacity (Huber and Daft, 1987), when a disruption occurs there can often be a mismatch between the amounts of information available to a unit.

Both buffering and bridging together was the predominant choice as was maintaining continuity of supply for the response reason. In the dynamic response, most were regularly dynamic with a spread of reasons given. Effective response was using a shortage champion (6 of the whole group) and team dynamic and orientation, with performance for shortages and patients both scoring highly generally. Vigilant orientation was the dominant advice category shown, with 6 of the interviewees choosing this category. Although the overall intent is not to quantify qualitative data, tallies and frequencies in qualitative research are essentially a supplement to the narrative (Bloomberg and Volpe, 2015).

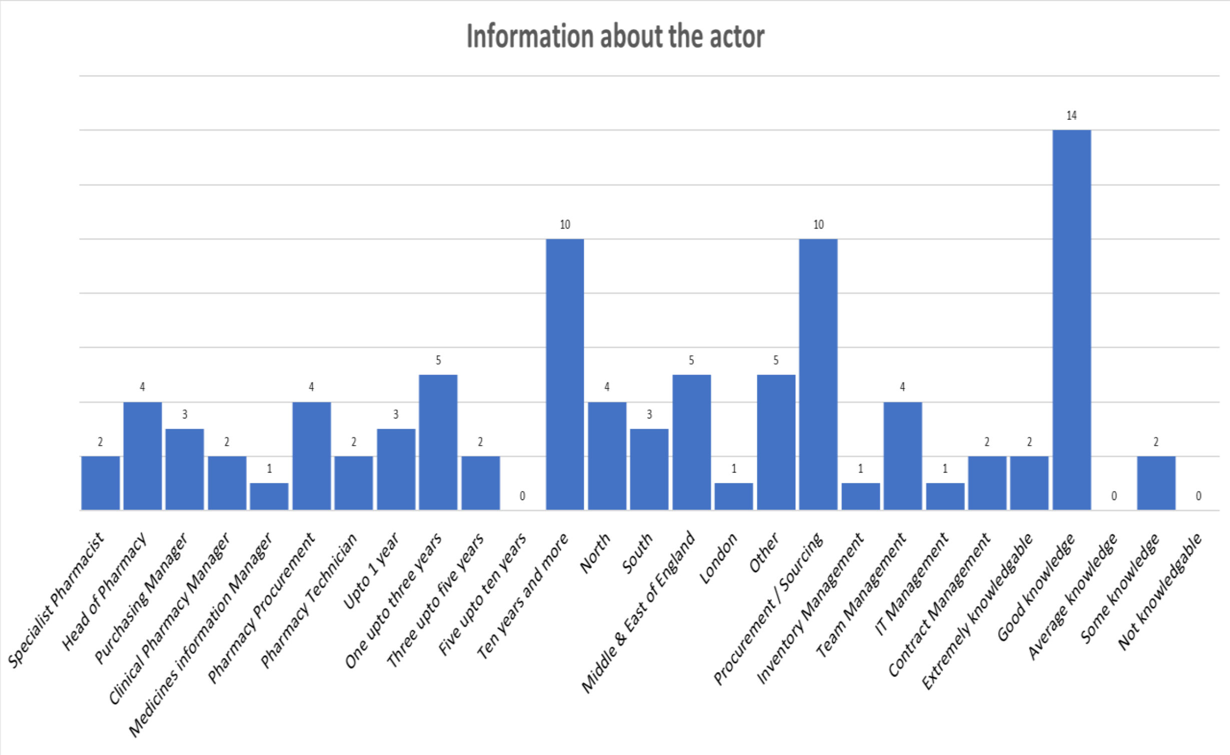


Figure 30. Information about the actor

Figure 30 sets out the descriptive response findings in one view to give the background of the interview respondents. As can be seen in the chart, there is an even spread of role titles and a good mix of experience by time in the position. With most of the respondents having strong experience, albeit as sometimes explained by the respondents that their role has evolved to include wider responsibilities and cross functional activities given the limited resources and increased activities of growing shortage management due to disruptions. There is an even spread of regions served and role function, with the predominant function being in sourcing and procurement which was anticipated prior to the findings being obtained. Lastly, the knowledge level reported by the interview respondents was overwhelmingly good on shortage management which, given the average length of service on the ongoing shortages they were experiencing, is consistent with expectations.

The results are further evaluated in the data analysis in Chapter 8, where the data from the contents summary matrix is transposed into a case and variable by variable matrix. Interrelationship is one of the foundation principles for methods of explaining change and explaining causation. As noted by (Miles, Huberman and Saldana, 2014), a variable by variable matrix first explores the interaction and interplay between multiple pairs of variables to see whether they apply to particular cases. However, it is appreciated by this researcher that good explanations need to link the explanations given by the people we are studying with explanations we develop as researchers, as recommended by (Miles, Huberman and Saldana, 2014). It is recognised that this is not a straightforward process and, as (Morrison, 2009) advises, researchers should consider carefully the nuanced differences between a cause, a reason, and a motive, and to keep the primary focus on people's intentions, choices, objectives, values, perspectives, expectations, needs, desires, and agency within their particular contexts and circumstances.

The findings from the three focus groups were consolidated under the above six topics. As recommended by (Wolcott, 1994), the researcher typically moves through a series of analyses episodes that condense more and more data into more and more coherent understanding of *what*, therefore building a solid foundation for later analysing *how* and *why*.

The next section describes the findings of the focus groups.

5.9 Findings from the focus groups

The findings from the three focus groups are consolidated throughout this section under the six topics raised in the focus group sessions, which relate back to the research question and propositions. There were common outputs across all the focus groups, which are extracted in the below narrative. There was a richness of perspectives, including the policy and contracting from the CMU and DoH groups, however, as the majority of these managers also had either worked directly in the pharmacy environment or had deep knowledge of it, there was a common experience and knowledge base.

To first highlight the findings of the three focus groups, a Word Cloud was generated using the NVivo programme query selecting the three internal focus groups' transcripts, shown in Figure 31. A Word Cloud is a special visualisation of text in which the more frequently used words are effectively highlighted by occupying more prominence in the representation. Grammatical words and non-frequent words are hidden so that the resultant representation cleanly shows the most frequently occurring words of importance (McNaught and Lam, 2010). Word clouds, also called tag clouds or a weighted list, are a visual depiction of the frequency tabulation of the words in any selected written material. Advantages of word clouds include their flexibility and capability to create a simple visual image from copious amounts of written material, and by highlighting the most frequently used words, allows focus. Disadvantages of word clouds are due to their prioritization of words by frequency, so key concepts may be excluded because the words used to describe a concept appear irregularly (Miley and Read, 2012). Despite the noted limitations this research uses word clouds for the focus groups in combination with the narrative themes. As noted by DeNoyelles and Reyes-Foster (2015) it fosters critical thinking and is an ideal way to encourage open exploration of a concept or topic without being hindered by a large amount of text.

An initial content analysis can be supported using word clouds to analyse the responses to researchers questioning to consider certain words and phrases employed. It has been previously used successfully by Sweeney, Grant and Managan (2018) in supply chain management research for example in supply chain management in practice, where they considered supply chain management particularly at a strategic level, through an investigation of the four perspectives taxonomy of the relationship between logistics and supply chain management. Word clouds were used in particular to furnish some insights into how respondents define the terms logistics and supply chain management. Other researchers have used word clouds to analyse themes associated with time in operations management research.Klassen and Hajmohammad (2017) for example used words clouds in their research in operations management looking at how humans and organizations experience time, termed process-time, which was chronicled by events and stages of change. Klassen and Hajmohammad (2017) p1609, used the word cloud as a way of offering research findings as a "perception of a central tendency, rather than a precise position". As noted by Gottron (2009) and Tidy, Wang and Hall (2016) word clouds are a relatively recent way of visualizing the content of documents to make decisions about relevance and emphasis. A word cloud does not necessarily illustrate a trend but by preference provides an overall visual impression through identification of the most frequently used words in a piece of text (Santos, Ma and Judd, 2011), in this way it complements the existing narrative and helps explain it rather than replacing it entirely. Results from research by Kuo, Hentrich, Good et al. (2007) further indicate that word clouds are effective to give an impression of what information is present in a query result set. They draw the conclusion that word clouds are a good visualization technique to communicate an 'overall picture' of the text contents. However, it is noted that this technology and its use in research is still developing, and improvements are continually being suggested for example by Heimerl, Lohman, Lange et al. (2014) whose study indicated that word clouds are indeed an effective tool for text analysis if equipped with further information and sophisticated interaction techniques.

One of the key first observations for the shortage management of medicines post supply chain disruption is the largest item of ‘change’. This was not a surprise to the researcher as; having conducted both the exploratory and individual interviews, managing the supply chain after disruption is dynamic and not static. As noted in previous research (Slack, Chambers, Harland et al., 2001, Ritchie, 2002), the pharmaceutical supply chain is different to other organisational supply chains due to the scale of the operation and the volume/variety mix of its products. A hospital pharmacy buys approximately 4,000 lines of stock from pharmaceutical wholesalers, and this is only a part of the range held by these operations. This indicates that the range of stock held and the volume of lines processed per day are extremely high in the downstream supply chain.

Figure 31. Word Cloud from all the focus groups

Change, clearly, is a constant for the pharmaceutical supply operations manager, and the disruptions that the focus groups reported were frequent, or as one participant noted from the Wales focus group, *"beyond frequent".* Some of the other key and most frequently mentioned outputs from the focus groups were ‘act’ and ‘actions’, and ongoing actions noted from the cloud included both 'bridging' and 'buffering'. Some of the significant other factors mentioned in the Word Cloud include communication, information, suppliers and management. Managing the supply chain can be difficult due to the volume and diversity of products involved, resources, technology, and complexity of networks (Lamming, Johnsen, Zheng et al., 2000). Large, complex supply networks bring problems to the fore, such as managing information flow which is essential to the success of efficient supply chains, potentially leading to investments in data capture technology, or information technology for coordinating material and information flows (Ritchie, 2002). This also underpins (Bode, Wagner, Petersen et al., 2011), based on the motivation to act post supply chain disruption, drawing on both information theory (Galbraithe, 1977, Tushman and Nadler, 1978) and resource dependency theory (Pfeffer and Salancik, 1978).

The six discussion topics for the focus groups were formulated to address the research propositions and, ultimately, the research question to closely examine the interrelationships between buffering and bridging that affect performance in shortage management post disruption.

The findings for each of the topics are summarised by topic heading, taking in all the focus groups' comments and observations. The common themes for each topic are encapsulated with appropriate salient points and corroborated with participant quotations. In this qualitative part of the research, the emphasis is on understanding. One is not seeking to determine any single causal explanation, to predict, or to generalise. The aim, as advocated by Bloomberg and Volpe (2015), is to tell a richly detailed story that takes into account and respects a context and that connects participants, events, processes, activities, and experiences to larger issues or phenomena. With this aim in mind, the focus group findings are presented in a narrative form rather than template or thematic chart or by coding. This later analytical approach was rejected by the researcher for this section of the data collected, not only because of the problem of losing the context of what was said, but also so that the narrative flow of what people say is not lost (Coffey and Atkinson, 1996). The emphasis in this section is to let the participants speak for themselves with short commentary by way of a thick description (Denzin, 2001). Further scrutiny will be continued in Chapter 6 throughout the data analysis.

5.9.1 Current shortage challenges in pharmaceutical supply

The focus groups identified multiple challenges in medicines shortages in the current environment. These included regulatory, supplier, quality, policy, and in some cases of conflicting policy pulling supply chain management of shortages from disruption in different directions. For example, participants commented:

> *"From a policy perspective, it is also worth pointing out that we have got things such as the Carter Report which was published early in this year* [2016]*, and there is a direct recommendation in there for hospitals to reduce their stock holdings to around 15 days. Now, of course, that means they are going to have less stock available before they run out if there is an issue further up the supply chain. So, you have got that one particular policy directive on the one hand where hospitals are being asked to reduce their stock holding, and on the other hand you have got another policy which, where we have the emergencies buffer stock pile, which, of course, seeks to hold stocks in the event of any sort of pandemic event or emergency; so, you almost have two different policies driving different aspects by hospitals having to keep less stock. On the other hand, you have got a policy that advocates the holding of buffer stocks."* (Participant A1)

> *"Increasing is sort of big regulatory global issues, I am not sure if that we have better infrastructure in place with the regulatory or if we just have a better relationship with the regulator now, so that what is happening increasingly is that an inspector will go into a factory in sort of China, India, Europe, anywhere in the world and find an issue and it is not necessarily a UK inspector, because we have something called mutual recognition agreements across the EU, and to some extent with the FDA and other global regulatory authorities, and they will find something wrong with a factory that may manufacture several hundred medicines for this country and for Europe and it will shut the factory down."* (Participant C1)

In addition, the current state of the pharmaceutical market, a participant commented that contracting of medicines that the department has pointed out that where we procure medicines in secondary care or generics, they are procured on the basis of a commercial perspective, that is to say, for example, paracetamol tablets, there is recognition that there will be a hundred different suppliers of paracetamol tablets. Whereas participants noted:

> *"Market failure description, where you have many suppliers of a given product in a market (e.g. paracetamol), whereas the same cannot be said of injectable medicines which are difficult to manufacture, you are going to have a very limited number of manufacturing facilities. In some cases, you are going to have a wholly dedicated facility for things like oncology medicines, where you can't just manufacture other product lines for risk of cross contamination, and in those incidences, we seek to adopt a more strategic view. We would take a more strategic view on the procurement of medicines in that we would seek to award to more than one supplier in the market and that is done in recognition that if one supplier has an issue or supply disruption, you have at least two or*

> *three other suppliers who might be able to help out, so we would not always seek to award to the cheapest supplier*." (Participant A1)

The type of medicine and how it affected the severity and the length of impact and the subsequent post disruption management response was a predominant theme, although there were limited comments that shortages exist across the board. The management impact and response was less difficult due to the possibility of alternatives.

Other challenges highlighted included poor supplier engagement, minimum stock availability, and pharmaceutical suppliers' processes that were geared towards their own commercial considerations rather than the impact of possible disruptions potentially causing shortages. Participants expressed the disconnect in the following ways:

> *"One of our big challenges is the combination of people* [suppliers] *not telling us that they are going to have problems, to companies not giving us advanced warning or not giving us enough warning, so that the shortage has already happened and so there is not much that can be done in an effective manner. So, there is an element about things that go wrong in the supply chain that you cannot really be prepared for, there is a kind of, not talking across the board, but there is a kind of efficiency challenge with companies themselves where they are not holding months' worth of stock, where there is this almost 'just in time' manufacturing process, where orders are placed months in advance, and so orders arrive that is just enough for the UK. There does not seem to be a lot of in-house buffering that is around*." (Participant B1)

A variety of specific examples were given to corroborate the focus groups' participants' comments on the supplier issues, including medicine type, for example:

> *"We had a shortage recently of an oncology drug, Bleomycin, that was ordered. Whenever it did arrive in the UK, one of the potency tests just wasn't coming up to what it should have been according to the product licence, so they had to do more testing which was another three or four weeks, and there was just nothing the company could do to help. They had only just ordered enough for the UK supply and then the manufacture in Japan had a three to four month lead time, so I think there is a big combination of things going wrong and there is not a lot we can do to respond to it quickly. There is also just a combination of companies just not telling us when things are going to go wrong; they are not giving us enough notice, so that is one of our big challenges."* (Participant B1)

Many of the participants noted that the shortages caused by the disruptions resulted in a lot of extra resources, work, and time:

> *"It causes a huge amount of unnecessary activity in the day to day workload."* (Participant C2)

"Within every trust, there is someone who is almost full-time sorting out shortages and making stock available, usually the lead pharmacist." (Participant A2)

On top of the additional drain on resources, a common theme throughout was the escalating number of shortage incidences, as well as broader product scope across the board from disruptions, which has resulted in both buffering and bridging actions to cope:

"I think the number of shortages we have seen over the last 12 months is significantly more than we have seen in the previous decade." (Participant A3)

"For example, dermatological treatments and ointments, that does not seem to be a problem in the past, a lot of those we have had problems with in the last 12 months. We have had to change what we are actually supplying." (Participant C3)

After the introduction topic of supply chain shortages as a whole, the next topic considered was the concept of supply chain disruption orientation to try and understand the practitioner's perspective and to give further insights.

5.9.2 Supply chain disruption orientation

There was an indication from the groups that each hospital did not react in the same way to supply chain disruptions of medicines so an acknowledgement of the supply chain disruption orientation concept, one participant mentioned:

"There are definitely in-house mechanisms that hospitals have built up themselves that seem to work really well. Yes, I think hospitals are different in the way they respond to it." (Participant B1)

However, it was not simply that different hospitals were following different written procedures, as one participant noted:

"You can kind of tell during a big shortage because some regions we will get a lot of noise from and other regions you won't hear a thing and you know it's not because that region has got more product than the other because there is none, so I think it is safe to assume that some are managing the situation better or they have the infrastructure in place to know what to do when there isn't product available." (Participant C1)

So, the actual management of the shortage by hospital units was important in the outcome; it was not solely down to something physically available. As another contributor commented:

> *"*[Every shortage] *has individual circumstances and that's why it's really difficult to fix because they are all different and they all have different causes, they have different effects, and therefore they have different answers, so you can't generalise the response. You have to react."* (Participant A2)

It's that response reaction which is the essence of the supply chain disruption orientation concept. Bode, Wagner, Petersen et al. (2011) explained that supply chain disruption orientation is the zeal to learn and dynamic awareness, these sentiments were echoed by some of the focus groups' participants', with one commenting on coping post disruption:

> *"…become quite good at it, in terms of learning in becoming agile and learning and where to go to ask for help, they will bend over backwards to do it."* (Participant F2)

It was also then managers with high supply chain disruption orientation who had knowledge of where to go for the 'right' information. There was an observation of the seriousness towards disruption management and the recognition of the opportunity to learn:

> *"They do think now that a way to potentially manage it is to share the problem with their colleagues within their region and include the regional pharmacy specialist in their region to see if we have any more information than they currently have. And that has been a learning curve process, that is more mature in some regions than it is in others."* (Participant C2)

There was a consensus throughout the focus that not everyone was performing to the same level. The question was raised in the deliberation with regards to their disruption orientation. This lead on to discussion about whether supply chain disruption orientation affects performance and there was a recognition that it did. This led to further tangent discussion as to whether it was a particular individual that was responsible or a whole team or organisation:

> *"I think there are particularly good individuals but I don't think it's an organisational thing, I think it's an individual thing."* (Participant C2)

Units that use information to influence their environment and that behave proactively and assertively so are active rather than passive, as described by Daft and Weick (1984), and show a stronger supply chain disruption orientation. This was confirmed in the focus groups, with one participant stating:

> “[The] *key thing for me is the communication, once we are aware of what that shortage is, what is that initial pathway, and take some leadership on it.”* (Participant E3)

Again, this points back to the Word Cloud, figure 30 where communication was a dominant theme, further supported by participant comments supporting a propensity to take quick command of the situation and then act. The different actions taken by the actors in hospitals and trusts post disruption were discussed in the next section topic: buffering and bridging actions.

5.9.3 Buffering and bridging actions

The focus group participants understood and were acquainted with the different response actions of buffering and bridging. The reasons why they made those decisions was also evident in some of their responses. Information and change were key factors mentioned, as highlighted in the Word Cloud, and one contributor mentioned:

> *“We do use information and data to base a lot of our decisions on but it does carry a risk in that the changing environment in which medicines are moved around the supply chain does put that at risk to some extent. Certainly, it is recognised that there has to be some sort of consistency in terms of the IT systems which are used, but the difficulty is you have got so many different stakeholders in the system. You have got the DH, you have got CMU, you have got the NHS, you have got individual suppliers, you have got third party outsource providers all having different IT systems to somehow bring and consolidate all of this together to allow information to flow more freely, which is what everybody is wanting, but it is just a matter of getting everybody around the table, therein lies the biggest challenge of all.”* (Participant A1)

So, although decisions were based on information, that information was not uniform or consistent, with stakeholder dynamics being an influence. The changing environment leading to communication difficulties hampering decisions was also highlighted:

> *“Communication issues with a supplier, so you will be told one thing by one part of the company and another by another. The other thing that we find, because of the way the market works at the moment, is that suppliers are constantly changing names or they are merging their divesting products. There seems to be a lot of changes within companies, you lost the sort of corporate knowledge and contacts, and it is only when there is an issue that you re-establish those relationships then it's almost too late.”* (Participant A3)

It was pointed out by the focus groups that there was a commercial and cost element to the supply decision dynamic to add to the regulatory and organisational challenges for the purchasing units:

"For those medicines which have a framework agreement within England, if a hospital cannot procure a medicine within 14 days sitting on their shelves, they have recourse to source that product from elsewhere from an alternative supplier, potentially at list price and then the awarded supplier will have to reimburse the difference between the contracted price and the list price of the competitor products. So, an individual supplier can stand to lose a substantial amount of product within a given amount of time. Now that punitive measure can vary from one market to another, but it is the case in the UK that if a contracted supplier cannot supply within 14 days of a hospital placing an order, they can seek compensation if they have to source an alternative supplier, so it can be both a carrot and a stick." (Participant A1)

Buffering actions were well used, however, there was not a straightforward rationale:

"We all have strategies to build up extra products." (Participant B4)

However, even if a buffering response was put in place, some hospitals have limited physical space. Participant B1 gave one example of the consequences:

"You had difficulties at St. Thomas' [Hospital]*, you had some stock at which you had built up, but the problem is people don't understand the number of lines a hospital pharmacy can hold, so it's much higher; it's typically 2,000, 3,000 lines, so if you run down one of those it can become critical as soon as you can't get it."* (Participant B1)

So there exists a restriction to the response action on buffering in the pharmaceutical supply chain, which has an effect on the decision post disruption, and as such to an extent, the interplay potentially between the buffering and bridging decision. However, the bridging decision itself also has restrictions at the local level:

"Bridging is difficult because the personnel within the organisation changes so rapidly, so there is a little bit of that, the Department of Health have asked that there be somebody in each company [supplier] *who is responsible for shortages, and they have that named person, and really that's it and that just shows how ridiculous it was before."* (Participant B1)

So, neither the buffering nor the bridging options for a response decision is an easy one, it was evident from the focus groups, and there are restrictions and challenges with both. However, all groups recognised, as stated previously, that both of these actions were taken, whether that was separately, together, or in changing combinations.

There was also a conflict between which choice to take from a macro policy perspective, for example, the Carter Report. There were also seasonal elements to take into consideration:

> *"So, what's happening is this dichotomy situation where we are taught to manage our stocks to a minimum but that doesn't support having extra stock just in case."* (Participant B3)

> *"There is a bit of an artificial effect at Christmas when we buffer, when we tend to hold more."* (Participant B10)

> *"And if you use French* [suppliers], *August."* (Participant B10)

Buffering actions were used in both a hedging response to buy time to see if the medicine in shortage would come back into supply but also as an emergency response reflex, as Participant C2 commented regarding drawing back stock from wards:

> *"Particularly where there's more than one indication for a medication, there's a critical indication that you keep the medication for that indication, so it does get used so you don't lose a patient or if you were desperate."* (Participant C2)

The dynamic nature of decision-making post disruption in shortage management was evident throughout the focus groups with regards to buffering and bridging, as the below extract highlights:

> *"They do change their actions depending on how long it goes on for. Only so much that, I mean quite often we would look to specialist pharmaceutical industries to supply an unlicensed version of the product* [that] *can be sourced from abroad, where there is no other licensed alternative available in the country, and feedback from them is that in many shortage situations they won't get any queries from trusts, or get any interest in using the unlicensed product. Which suggests trusts are managing with stocks they have, whether that be from a stockpile or from across the region; they are sharing but then every shortage sort of goes on. If it is prolonged, they then try to dip into the unlicensed source, yes. We then hear we are getting a lot of demand for finished stock. That is the type of action which is dynamic, which is anecdotal from the suppliers."* (Participant A3)

Unlicensed products are only allowed to be used in secondary acute care when the licensed product is not available, both actions are buffering by either stockpiling or by reaching out for alternatives, but the decisions are taken at different times subject to the circumstances that are changing over time.

Having both the technical expertise but also the awareness of the urgency of the situation is crucial:

> *"Each hospital will have different degrees of resilience in how they deal with disruptions and supply issues, just to supply a bit of context to all of this. It certainly is important that whoever deals in shortages has some appreciation for medicines as a commodity and the criticality of what the medicine does."* (Participant A1)

Again, there was an acknowledgement of the variation of performance and attributes of each hospital and trust throughout the focus groups. Considering the effects that performance has and the time element in the dynamic action process, the next topic looks at Feedback and Dynamics.

5.9.4 Feedback and Dynamics

There was consistent input from the groups on feedback and dynamics in the management decision processes, with a constant back and forth between the frontline pharmacy leads procuring and supplying, and the clinical staff prescribing and administering.

Changing actions over time and an agility to do that was a consistent theme:

> *"I think the forecasted length of the shortage and what that's going to be tends to change very quickly. So initially you might be told that it's only going to last a week but then that stretches to a month and that carries on, so you have to adjust your behaviours and actions to that."* (Participant B5)

> *"We have already said that people are very good at this, that every shortage is different and if every shortage is different then it always morphs over time as well. For example, you might be bridging then that product goes out of stock and you get a ripple effect where successive products go out of stock so you have to keep changing your strategy."* (Participant B2)

The dynamic actions translate both at a unit level and a national level, according to participants:

> *"We do have examples where, because we know the shortage of a particular drug, that it is going to be an ongoing lengthy problem we come up with criteria as to the order of which patient's medicines should be kept up. So, we look at the different indications that the medicines can be used for and tend to rank these as to which patient to provide for, and we have had examples where we have had to micromanage the supply chain. For example, trusts with cardiac surgery, patients will be issued a specific medicine because the other indications can be treated with other products, so it's almost like keeping the limited resource to the most critical patients so we have had examples of having had to do that. And that would be done nationally in collaboration with the drug companies."* (Participant B3)

> *"But it is also done locally. Trusts can do a similar thing."* (Participant B10)

Interestingly, as per the attributes of supply chain disruption orientation, there was an appreciation by the groups of the self-learning process on shortage management actions:

> *"You might do that slowly at first, but if that product becomes short again the next time round you would have learnt from that process and can intervene much earlier."* (Participant B4)

"So, you're learning from yourself." (Participant B10)

Regular and ongoing feedback from the clinicians was a key driver to the decision-making process. The constant understanding at any one time of how the patient was doing and what was needed to treat them motivated action to perform to a higher standard. As one contributor said:

> *"*[The] *feedback you get is pretty black and white, and if you do not do a good job then you get the negative feedback."* (Participant B2)

High in the minds of the actors procuring the medicines was the feedback:

> *"Could the patient be treated or not treated."* (Participant B3 and others)

The form of the feedback that drove the reaction and led to the highest performance was as follows:

> *"The most effective feedback is only from the end users* [clinicians], *whether they are happy or not."* (Participant C1)
>
> *"At the end of the day, we get feedback from the end user, and it will be negative feedback if we don't supply that drug."* (Participant C3)
>
> *"You may get initial feedback, 'Thanks for providing an alternative.'"* (Participant C6)

So, the 'ward' feedback was the predominant driver and source of pressure, be it mainly negative if the drugs weren't available but also positive if the drug shortage was relieved, either by an alternative or by the availability of the drug delivered exactly as prescribed. What the pharmacy procurement and supply actors were looking to avoid was not being able to supply a critical drug and that having a negative patient outcome, which would result in them having to complete an incidence report in the software system, for example, Datex. That report would then have to be investigated and hopefully closed. Certain cases would have to be reported nationally, for example, if the incidence resulted in the death of a patient and would be reported in the National Report and Learning System (NRLS).

The next topic discussed with the three focus groups was the size of the trust, specifically the number of hospitals, and the role of the actor making the post disruption decisions.

5.9.5 Size and role

There was a mixed reaction from the focus groups of the topics of size and role with regards to post disruption actions by managers, with some seeing a connection but others not. However, there was an appreciation of speed of action when competing for a limited resource as a crucial factor:

> *"First come first serve really, if you are at the front of the queue and if you are the last one."* (Participant C2)

> *"But I haven't had experience of biggest and loudest will always get what they need."* (Participant C1)

However, as per the above comment by Participant C1, the highest performance in the management of a particular shortage was not simply a case of the law of the jungle. There were other factors involved, such as resources and aptitude:

> *"It might be a case of resource, so larger organisations may have a resource dedicated to shortage management."* (Participant B5)

> *"On the flip side, smaller organisations can be a bit more agile in their response. In terms of their role, sometimes you have to involve different roles to adjust choices of drug, depending on what shortage there is."* (Participant B5)

Clearly, it was not merely the level of the role of the actor involved but also a requirement that a combination of actors might be required if a team approach was necessary. This team or group involvement, rather than size, was similarly echoed by Participant B4:

> *"I don't think it is particularly related to size though, because I see examples of large trusts where they don't really do anything around, like, chase end products and a similarly sized trust that gives you regular updates on* [the shortage]*. It could be varied in terms of people and management, and some people just put a lot more effort into it."* (Participant B4)

The recent development of a roles matrix highlighted the cross functionality of many roles, with a diversity of titles and functions often masking the true nature of the work the individual was tasked to do beyond their job description (see Appendix 3; NHS pharmacist roles matrix). This matrix shows 12 separate roles, with 12 different grades, with six main skillset categories with 20 class levels.

The local management and the awareness of the disruption impacts can vary depending on the size of the trust and number of hospitals in it. However, larger trusts are not necessarily always positive regarding shortages:

> *"I was at St. Thomas' and one of the senior guys wanted to scrap our chasing orders guys to redeploy them to another hospital, and it was colossal the amount of orders they were chasing. It was thousands even that they were having to intervene on. And it was just a management lack of understanding that this was a critical service, I think that's how they view it. Some trusts can view it differently. But like in a small trust you can walk down the corridor and speak to M.I.* [Medicines Information], *'Can we just use this product?' And down*

> *the corridor to Q.A.* [Quality Assessment], *get it assessed really quickly, compared to it would take you two or three weeks in St Guy's."* (Participant B6)

Issues on size and role were debated but no consistent answers were given, with many participants giving both sides of the argument:

> *"If you work in a hospital trust and you've just got more experience in those types of things, it does afford that you are going to be more flexible and nimble in your approach in dealing with a supply issue. Whereas if you are part of a much larger institution made up by a number of hospital trusts, there is a possibility that it could be more cumbersome in reaching consensus between a group with a greater number of stakeholders within your hospital little patch or region to get a feel of which direction one should take in managing a shortage, i.e., what sort of clinical alternative might be appropriate. So, you might end up with a lot more feedback but it may not always be consistent, with a lot of clinicians all telling you different things, whereas if you are in a standalone hospital you may just have a single clinician, and you can act upon the single advice they have given. It could work both ways, to be honest."* (Participant A1)

However, the larger hospitals may be more likely to bridge due to corporate policies, as described in the research by Fennell and Alexander (1987).

On the role, the discussions were predominately around the level of knowledge of pharmaceuticals, as in hospitals the supply of medicines also sometimes involves non-pharmaceutically trained staff, the inference being that without an awareness of the impact of the shortage on the actual patient, incorrect/poor decision actions would be taken. It was cited by one participant that the role does have an impact on the shortage management performance, which may only be evident after that particular person had left the hospital:

> *"There is a teaching hospital close to here, a lady called Sue and she was a very experienced pharmacist and contributed all sorts of things to procurement, but she has never really been replaced and is one of the ones that contacts me and says, 'What do I do?'"* (Participant B2)

The regional specialists that interacted with each of the trusts and hospitals in their region described how they could monitor the reaction of each of the managers responsible for the shortages in their hospitals by their interaction with them, for example, when they were receiving a lot of potentially unnecessary requests on an uninformed nature, it gave them insights into how the hospital or trusts were likely to perform.

The last topic for discussion by the focus groups was the shortage management performance of the actors responsible for taking post disruption decisions.

5.9.6 Shortage management performance

The focus groups highlighted a number of factors around the performance in shortage management, and, as brought to the fore later in the data analysis section 6.1.2, word cloud in Figure 41, information and by extension how you interpret and use that information is an important factor. Where the level of movement away from the acceptable level of drug supply to patient is a deviation from what the unit deems as acceptable, they will act appropriately as described in the information processing theory (Daft and Weick, 1984, Kiesler and Sproull, 1982). As highlighted by one participant, the information that is received is not always consistent, and so having the correct orientation and aptitude in deciphering helps in performance management:

> *"If we get regular information from suppliers and they might tell us there is a potential we might have an issue six months down the line, that is all well and good, the difficulty is how do we use that information to help me to gauge a disruption, knowing that disruptions are a movable feast. It is not unheard of where we get told by suppliers that they are not going to get any stock for the next six months and only three months later for a shedload of stock to arrive. And it is how do you use that information to help mitigate these issues."* (Participant A1)

Additionally, the reliance of accurate and good quality information was noted as a limiting component on performance:

> *"I think our performance is very determined* [and] *driven by the information we are able to get hold of from the suppliers. We do share information, both on contract and non-contract lines, with some of the other devolved administrations but we are very reliant on the information we get out from the company that has the shortage, and as colleagues have said, the estimated time of arrival of stock on a lot of occasions lose, to put it bluntly. So, it is very hard then to manage that shortage again with clinical colleagues in making short-term decisions and longer term decisions on how you are going to manage that population patient group that is exposed to that shortage if you are not confident on the robustness of the information you're receiving."* (Participant C1)

Constructive and cooperation were two of the key words picked out by the Word Cloud. Suppliers, as part of the bridging strategies used, have an influence on shortage performance, with one participant stating:

> *"So, the mood music that we like to give out when we hold out our olive branch to suppliers, we want to work with them in order to mitigate a supply issue."* (Participant A2)

What was apparent from the focus groups was that there were a lot of shortages happening and that generated a lot of information and communication. To quantify that, an example was given:

> *"We did a tally count and we were getting in the region of 500 different notifications* [of shortages] *every other week, so every roughly two weeks, and it was roughly 500 different notifications of different products that there is a supply issue with."* (Participant A3)

Despite this recognition of high shortage incidence, there was not a definite process of measuring how different units perform nationally. This was due to many factors, not least of which was how to define the shortage, and also the sheer scale of the task to get agreement of the required metric or set of metrics. As one group member mentioned:

> *"So, we don't have a formalised process or metric to measure would be the best statement for that."* (Participant B3)

There were discussions, however, on this subject, previously including a measure of frequency on the contracted medicines:

> *"We were hoping that the contract log, every time you intervened regardless of whether you claimed or not, could be used as a measure."* (Participant B5)

Other comments on the measurements to monitor shortages included:

> *"We don't even have a system of grading how severe a shortage is because we can't define it, so we can't even say its red, amber, green."* (Participant B3)

> *"Because what might be a red for you, two trusts along the road is a green because they use a different wholesaler. Also, it depends whether it's being managed regionally, nationally, who's involved, how it was discovered. There are an awful lot of variables and we haven't defined them as a single metric and haven't got the time to do it."* (Participant B5)

What was clear from the focus groups was that it was easier to see what was actually in shortage, for example, than why it was in shortage. One participant commented regarding the IT system they were using to manage the stock:

> *"In terms of managing shortages and managing our own performance, it is more subjective than objective really. But, as it is showing 'out of stock', you haven't been able to supply something. Therefore, the item is 'to follow'. It could be down to our poor procurement or the wholesaler's failure to supply, it can be quite difficult to identify what's causing the shortage."* (Participant C3)

The learning curve that the shortage management environment forces onto the units did give the managers in the focus groups insights into the best way to manage the shortages but this was not a documented process. As previously described by research into supply chain management by Peck (2006), unless managers do learn from experience then performance can be suboptimal.

5.10 Summary

In summary, Chapter 5 provides the data collection and presents the desk research and the response rates for both the qualitative and quantitative techniques and procedures used, including the first and second round coding of the interviews and the findings from the focus groups conducted. Chapter 6 takes the next step in the research process, moving on from the data collection and descriptive phase, into the analysis and interpretation of the findings.

6 Data Analysis

The purpose of this chapter is to analyse, interpret, and synthesise findings from this research. The research used different methods of enquiry to collect both quantitative data using a survey instrument and qualitative data by conducting in-depth interviews and focus group discussions. To explain the data analysis and, following on from the descriptive data collection and presentation in the previous chapter, Chapter 6 is separated into two main subsections. The first, 6.1, is the qualitative data analysis, including the interviews and focus groups research. The second subsection, 6.2 onwards, is the quantitative data analysis. Appendices 4 and 5 include the summary of the quantitative analysis (Table 37) and the condensed list of the diagnostic test tables, respectively.

Section 6.1 analyses the data from the qualitative enquiry, and 6.2 onwards analyses the data from the quantitative enquiry, and the last section 6.7 includes the cross-cutting analysis, bringing together both the qualitative and quantitative analyses proposition by proposition to synthesise and triangulate the analysis, leading to further and more in-depth discussion in Chapter 7.

6.1 Data Analysis of the Qualitative

6.1.1 Interviews

The qualitative descriptions of the enquiries used to collect the data are shown in Chapter 5, which were respectively the semi-structured interviews and the focus groups. To look at the interrelationships between the variables, the content matrix was further transposed into a case by case variable matrix, as shown in Table 11.

Cases	Role	Service	Size	Region	Job Function	Knowledge	Information	Feedback
C1	Pharmacy technician	Ten years or more	Standalone	South	Inventory Management	Good Knowledge	Easy Access	Never
C2	Specialist Pharmacist	Upto one year	Standalone	Other	Procurement/Sourcing	Extremely Knowledgable	Multiple source easy access	Really good feedback
C3	Purchasing Manager	Ten years or more	4-5 hospitals	Other	Procurement/Sourcing	Good Knowledge	Limited Access	Useful feedback
C4	Purchasing Manager	Ten years or more	2-3 hospitals	North	Procurement/Sourcing	Good Knowledge	Limited Access	Limited feedback
C5	Pharmacy procurement	Ten years or more	2-3 hospitals	Middle and	Procurement/Sourcing	Good Knowledge	Easy Access	Limited feedback
C6	Head of Pharmacy	Upto one year	4-5 hospitals	Middle and	Procurement/Sourcing	Good Knowledge	Multiple source easy access	Really good feedback
C7	Head of Pharmacy	Ten years or more	6 or more hospitals	Other	Team Management	Good Knowledge	Multiple source easy access	Really good feedback
C8	Specialist Pharmacist	Upto one year	2-3 hospitals	North	Procurement/Sourcing	Some Knowledge	Multiple source easy access	Really good feedback
C9	Clinical pharmacy manager	One to three years	Standalone	South	Team Management	Good Knowledge	Easy Access	Really good feedback
C10	Medicines Information Manager	One to three years	4-5 hospitals	North	Procurement/Sourcing	Extremely Knowledgable	Limited Access	Useful feedback
C11	Head of Pharmacy	Ten years or more	6 or more hospitals	Middle and	Contract Management	Good Knowledge	No Access	Really good feedback
C12	Pharmacy procurement	One to three years	2-3 hospitals	South	Procurement/Sourcing	Good Knowledge	Easy Access	Really good feedback
C13	Pharmacy procurement	Ten years or more	Standalone	Middle and	Team Management	Good Knowledge	Easy Access	Really good feedback
C14	Head of Pharmacy	One to three years	6 or more hospitals	Other	Contract Management	Some Knowledge	Limited Access	Really good feedback
C15	Purchasing Manager	One to three years	4-5 hospitals	North	IT Management	Good Knowledge	Multiple source easy access	Really good feedback
C16	Pharmacy procurement	Ten years or more	6 or more hospitals	London	Procurement/Sourcing	Good Knowledge	Limited Access	Really good feedback
C17	Pharmacy technician	Three to five years	4-5 hospitals	Middle and	Team Management	Good Knowledge	Limited Access	Useful feedback
C18	Clinical pharmacy manager	Three to five years	Standalone	Other	Procurement/Sourcing	Good Knowledge	Easy Access	Really good feedback

Cases	Shortage Freque	Response Action	Response reason	Dynamic response	Dynamic reason	Effective response	Performance shortage	Performance patient	Advice
C1	Frequently	Buffer	Continuity of supply to patient	Never dynamic	Not dynamic	Close supplier engagement	5	5	Communication
C2	Frequently	Bridge	Continuity of supply to patient	Regular dynamic	Duration of shortage	Feedback	8	9	Vigilant orientation
C3	Occasionally	Bridge	Continuity of supply to patient	Regular dynamic	Duration of shortage	Shortage champion	7	7	Information
C4	Very frequently	Buffer	Estimated shortage time length	Occasionally dynamic	Duration of shortage	Speed of action	5	6	Information
C5	Very frequently	Buffer	Estimated shortage time length	Never dynamic	Alternatives availability	Team dynamic and orientation	5	5	Knowledge
C6	Very frequently	Buffer	Continuity of supply to patient	Regular dynamic	Nature of medicine	Team dynamic and orientation	9	9	Information
C7	Frequently	Both Buffer & Bridge	Continuity of supply to patient	Regular dynamic	Not dynamic	Shortage champion	9	9	Communication
C8	Very frequently	Both Buffer & Bridge	Efficiently manage existing stock	Regular dynamic	Shortage cause	Single point of contact	9	8	Vigilant orientation
C9	Very frequently	Both Buffer & Bridge	Continuity of supply to patient	Regular dynamic	Shortage cause	Close supplier engagement	8	9	Vigilant orientation
C10	Frequently	Both Buffer & Bridge	Continuity of supply to patient	Occasionally dynamic	Duration of shortage	Shortage champion	8	8	Vigilant orientation
C11	Very frequently	Both Buffer & Bridge	Efficiently manage existing stock	Regular dynamic	Shortage cause	Defined process	8	7	Communication
C12	Very frequently	Both Buffer & Bridge	Continuity of supply to patient	Occasionally dynamic	Nature of medicine	Shortage champion	8	9	Feedback
C13	Frequently	Both Buffer & Bridge	Continuity of supply to patient	Occasionally dynamic	Nature of medicine	Shortage champion	7	7	Feedback
C14	Frequently	Both Buffer & Bridge	Continuity of supply to patient	Regular dynamic	Duration of shortage	Speed of action	9	8	Information
C15	Frequently	Bridge	Efficiently manage existing stock	Regular dynamic	Nature of medicine	Close supplier engagement	8	8	Vigilant orientation
C16	Occasionally	Bridge	Nature of medicine	Always dynamic	Alternatives availability	Shortage champion	8	8	Communication
C17	Frequently	Buffer	Continuity of supply to patient	Occasionally dynamic	Duration of shortage	Information gathering	7	7	Vigilant orientation
C18	Frequently	Both Buffer & Bridge	Continuity of supply to patient	Regular dynamic	Nature of medicine	Team dynamic and orientation	8	7	Feedback

Table 11. Case by case variable matrix

This matrix allows the researcher to examine each case against the variable, and then examine the variables against each other. A variable by variable matrix by case enables the exploration of the interaction and interplay between multiple pairs and sets of variables to see whether they apply to selected cases and then to groups of cases. It is descriptive ordering, exploratory, and explanatory. As noted by Miles, Huberman and Saldana (2014), it matches cases with several variables to encourage the researcher to explain why the interrelationship is suggested in the matrix. This presentation method was used as it gives a clear path from one variable set to another and to assist the navigation through the depth of the data. Miles (1979) has described qualitative data as an 'attractive nuisance' because of the attractiveness of its richness but the difficulty of finding analytic paths through that richness.

From the variable by variable matrix, it was feasible to draw the possible interrelationships and relate them back to the propositions in the research to evaluate them. The values in Table 11 were placed from the variable matrix into a pivot table, ordering each case by value, before being compared and considered in relation to the research's propositions.

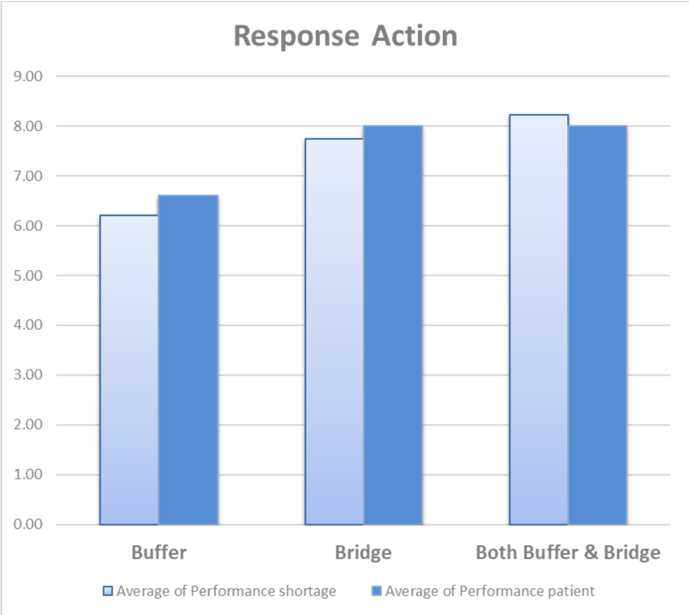


Figure 32. Buffering and bridging response action against performance

Figure 32 displays the interaction between buffering and bridging actions (from the response action column) against the performance of the cases.

It shows the average of the performance score in shortage management in general and also by performance against patient impact. As can be seen in Figure 18 where actions of buffering and bridging were both taken in response to a shortage, the response action was most effective, the next best response action was for bridging action alone and, lastly, the buffering alone had the lowest response action. In summary, both buffering and bridging averaged 8.2 for performance (from a possible score of 10) for shortage management and 8.0 for performance patient, with 50% of the cases having a combined buffering and bridging response action.

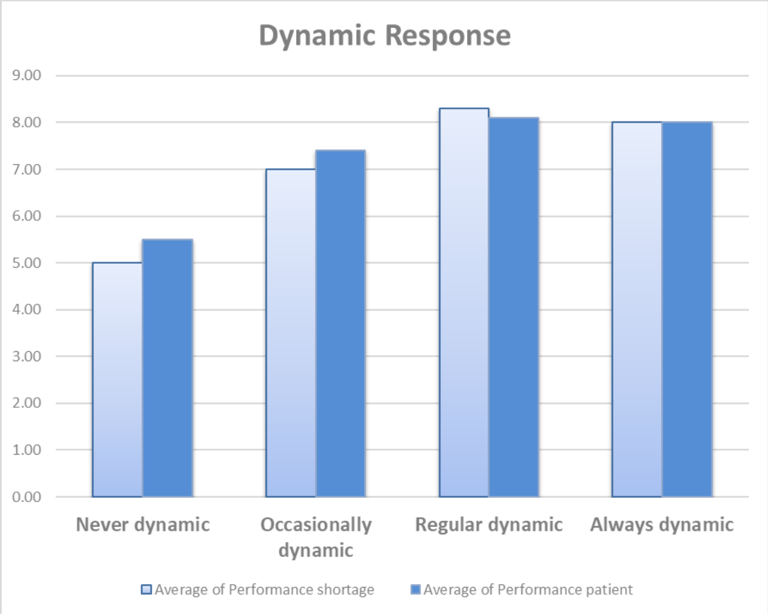


Figure 33. Dynamic response action against performance

Figure 33 displays the dynamic response and performance of the variables. The average of 'regular dynamic' and 'always dynamic' was 8.3 for performance shortage management and 8.1 for performance patient, with 55.6% of the cases having the regular dynamic response action.

After considering the dynamic response and performance interrelationship shown in Figure 33, the next relationship analysed was that between the summary of the advice on shortage management given by the interviewees and the performance achieved. This was to try and understand which response path could potentially be the most positive.

Figure 34. Advice and performance on shortages

Figure 34 shows that vigilant orientation averaged 8.0 out of 10 for performance shortage and 8.2 for performance patient. Knowledge scored poorest of the advice given, whereas feedback, information, and communication all scored an average of 7.0 out of 10 against performance.

Analysing performance in shortage management further, Figure 35 looks at feedback against performance.

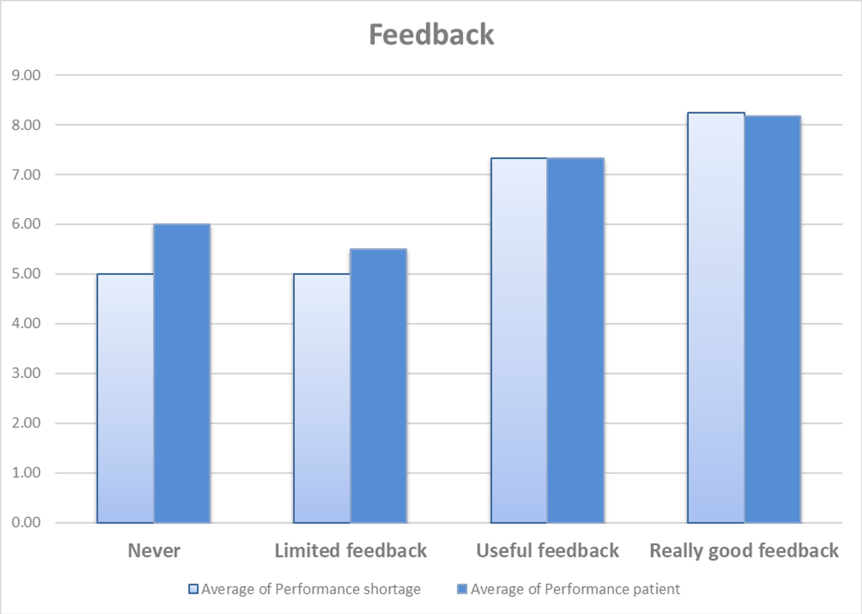


Figure 35. Feedback against performance in shortage management

Over half of the cases, 66.7%, gave really good feedback that averaged 8.3 for performance shortage and 8.2 for performance patient. From the interviews conducted, it shows a very strong relationship between good feedback and performance and, conversely, poorer performance for limited or no feedback actions.

The variable of the role against shortage performance is interpreted in Figure 36.

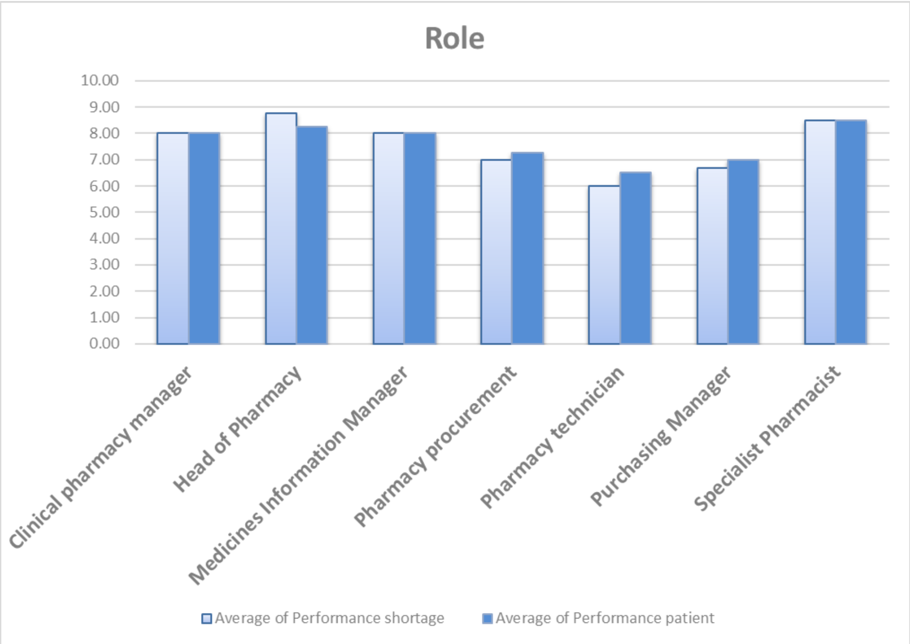


Figure 36. Role against performance in shortage management

The head of pharmacy achieved scores of 8.8 out of 10 for performance shortage and 8.3 for performance patient. This senior role, however, is contrasted by the less qualified role of pharmacy technician, which respectively was the lowest scorer, achieving 6.00 for both performance shortage and performance patient.

6.1.2 Focus groups

Section 6.1.2 gives a summary of the focus group findings, which are then examined in a deeper analysis proposition by proposition in the cross-cutting analysis in Section 6.6.

The focus groups produced a considerable amount of information for the research and were devised to reflect the extension of the framework theory (Bode, Wagner, Petersen et al., 2011), which itself was underpinned by two theories; the information processing theory (Galbraithe, 1977) and the resource dependency theory (Pfeffer and Salancik, 1978). This research study used three main constructs: supply chain disruption orientation, supply chain disruption performance, and organisational response. Under these three themes, a further nine propositions were produced to answer the research question. The focus groups' six topics were designed to contribute to this challenge.

Firstly, to consider the context of the broader phenomena, the current shortage challenges in medicine shortage management post disruption incident were discussed with every group. Each of the focus groups had their own different perspectives on the current shortage situations, but all were in general agreement as to the growth and the real practical problems it presented to them and their respective teams on a daily basis. Figure 37 is a word cloud generated by the NVivo software and drawn from all the responses to the first topic in the focus groups: current shortage challenges. It is from all the groups based on the 100 most frequent words used. As well as the central phrase ‘just stock shortage’ which sums up the current situation as outlined by the groups, supplier issues, manufacturing, market, regulatory, and policy challenges are all recurring themes.

Figure 37. Current shortage challenges

The focus groups identified and articulated many of the causes of disruptions in concert with those identified in the literature review, including regulatory, policy, quality, commercial manufacturing, and elongated global supply chains and just in time practices.

Just in time (JIT) practices, it was observed by the groups, have exacerbated an already overextended pharmaceutical supply chain. Bridging actions have been used to alleviate some of these challenges in response to disruptions, which are not new to supply chain practice and theory. Kelle and Miller (1998) also suggest that during the transition from a traditional to JIT purchasing system, the purchaser tries to co-operate with the vendor with the goal of receiving smaller, more frequent deliveries on time that are received with the quality and quantity required. The other side of the coin, however, was observed by the focus groups and highlights the problems associated with just in time purchasing. As Ansari and Modarress (1986) suggest, the major problems of JIT sourcing include: lack of support from suppliers, top management and carrier companies, low product quality, and lack of communication. Some of these issues were evident in the comments by the focus groups. There were, according to the groups, communication issues evident in both the supplier organisations and within the pharmacies themselves.

So, whilst the practices are becoming more aligned with JIT principles, the outputs are not as productive as potentially anticipated in the face of ongoing disruption environments. Although other benefits have been identified within the research literature, such as improved relationships with suppliers and improved customer service (Yasin and Wafa, 1996), this paradigm was challenged by the focus group research commentary.

The supply chain disruption orientation topic attracted considerable comment, with the main thrust of the contributions being that each hospital, trust, and region has its own profile, and hence orientation would affect its performance in the management of shortages. This topic addressed directly propositions P1a, 1Pc, and P1d under the supply chain disruption orientation construct. However, considerable restrictions to the management options existed internally and externally. Information and communication were both identified as key factors in levels of supply chain orientation from the focus groups responses. As shown in the below Figure 38, drawn from topic two, supply chain disruption orientation for all the focus groups.

Figure 38. Supply chain disruption orientation

In Figure 38, the word cloud generated from the NVivo software, based on word frequency of the top 100 words displays a frequency on individual, unit, actions and regions, as well as organisations, knowledge and process. There was an acknowledgement by all focus groups that differences did exist in the orientation to supply chain disruptions. This was not an abstract concept but a real-life management phenomenon; a crucial factor and one that influenced success in disruption management.

Change is a dominant theme in the above word cloud, communications was also shown in the top 100 words used although less common than change and further to the periphery of the word cloud. Both were response choices of the shortage managers post disruption with regards to whether to buffer or to bridge, which addressed propositions P2f and P2g. Many group commentators confirmed that both were used in a dynamic way. Again, both action paths had challenges, both at internal and external levels. For example, conflicting health policy directives pulling actors in different directions. Although these phenomena could also be reflected in a private company, it's important to understand the context of this research was conducted in a public health environment where the pressures of public scrutiny were evident. For example, where communication across various levels of the health service were restricted to reduce the possibility of not only internal panic buying, but so as not to overly concern the public where necessary. This was highlighted by the focus group discussion in the example of the critical Diamorphine shortage in December 2015:

> *"One of the problems we have in managing shortages, and one of the reasons the Department of Health doesn't pass everything on to the trusts immediately, not only in commercial and in confidence nature of the issue, but unfortunately some buyers, in their enthusiasm to protect patients locally, will buy up what little stock there is left in the system and make the shortage even more acute."* (Participant B4)

So, in the focus groups, not only were conflicting policy issues discussed that had an effect on the choice spectrum, but the buffering and bridging choices they did make would have to be carefully considered to prevent knock-on effects, such as panic buying. So, decisions made at a local level could translate to a regional and national level and vice versa.

In Figure 38, the query generated in NVivo software produced the following word cloud displaying the 100 most frequent words.

Figure 39. Buffering and Bridging

The word cloud in Figure 39 shows focus on individual changes of both bridging and buffering within units at an organisational and regional level, and highlights the challenges of ‘right’ communication. It also highlights the importance of information, organisational knowledge, and the interaction of buffering and bridging actions in response to events.

These challenges in free flow communication, however, bring with them the loss of fast and direct communication across departments, regions internally, and supplier externally. As noted in earlier research, such communication is a critical capability in developing and deploying possible mitigating solutions to disruptions (Chadist, 2012). Delay in cascading information through various levels of organisations can lead to potential miscommunication inherent in relayed communication, causing confusion and consequential performance.

The next topic was feedback and dynamic, which focused on proposition P2e under the supply chain disruption performance construct, which is further explored in Figure 40, the word cloud query.

Figure 40. Feedback and Dynamic

The predominant words, excluding generalisations picked out by the Word Cloud query, are ‘change’ and ‘shortage’. Common to all focus groups was an agreement that the actions taken by post disruption managers were dynamic in nature, not static but rather constantly changing to the situation over time. By varying response actions over time, the consensus from the group discussions was that this would be the most effective approach, rather than choosing an action and sticking to it, irrespective of a change in circumstances.

The feedback communication was also mentioned as a constant presence in the critical management of shortages from disruptions, with every focus group showing a high awareness of this. The team dynamic of this was important, with a successful team dynamic being described as having valuable feedback interaction from the clinical team prescribing the drugs for the patients on the hospital wards.

Following on from the dynamic and feedback topic, the next topic considered by the focus groups was size and role. Under the supply chain disruption orientation construct, these topics were reflecting the questions in propositions P1c and P1b, respectively. This attracted a varied response from all the groups, with arguments given for the possible relationship between role, performance, and size (the number of hospitals per trust).

The one consistent throughout every focus group was that although both size and role did have an influence on the performance of post disruption shortage management, the strength and possible causation of that relationship and the direction was not simple to quantify. An independent, larger stream of research on cognitive biases in managerial decision-making has consistently demonstrated that managers are boundedly rational, not perfectly rational (Simon, 1979, Hammond, Keeney and Raiffa, 1998). They cope with decision-making complexity by using only a subset of the available information, leading to biases in a variety of decision-making contexts (Miller and Chen, 2004, Hilary and Menly, 2006, Smith and Winkler, 2006).

Some participants noted that smaller institutions could be more agile, but it was dependent on the individual managers. Others pointed towards a team dynamic as a key factor, also the city versus provincial location of the trust affected the orientation of the team and its development. When presented with a selection of information on which to base decisions, it could be limited by the level of the role, however, managers made choices that they perceived were in the best interest of the patient at that given time according to their reading of the situation. This type of behaviour was also previously observed in an investigation of management belief structure, and it was highlighted that actors making decisions often demonstrate selectivity and selective perception when processing information (Walsh, 1988).
The final topic of shortage management performance helped illuminate factors and influences on many of the propositions and constructs under examination in this research, and the focus groups' inputs were centred on the best response actions to mitigate the shortage impact on the patients in their hospital wards.

The groups observed that their relationship with upstream and downstream actors is, by definition, one of the key control points in the medicine supply chain. The management of each external relationship during the response to a disruptive event takes on new priority, and new mechanisms may be established in the context of these relationships. The challenge from a contractual perspective, however, was to:

> *"Maintain a competitive market and also to maintain continuity of supply of medicines at the same time*." (Participant A1)

This balancing act was itself a high ideal but the reality on the ground (as outlined in the focus groups) would often lead to disruptions as individual pharmaceutical vendor companies either could not or would not supply an in-demand product, thereby causing a resultant disruption in supply and having a detrimental effect on the supply chain performance possibilities, despite the pharmacy procurement team's best efforts.

> *"So, you look at Pfizer, if you look at their innovative new medicines, they would kill their own grandmother before there was any supply chain disruption because in patents they are making a fortune. But in their legacy products, which are low value to them, they are not so interested. But you also get huge differences from company to company. Other companies like Glaxo* [GlaxoSmithKline]*, for example, have invested a lot of time and money into their supply chain and generally."* (Participant B2)

> *"But you do get companies, particularly generic companies where the margins are very low, so they do not invest in their supply chain at all, they will sell it when they have got it, when they haven't got it they don't see a moral separation.*" (Participant B3)

The commercial interests of the pharmaceutical companies were an underlying theme of the focus groups' commentary, and informed the supply chain environment in which they were making decisions in response to disruptions. As highlighted by Lee (2004), cost efficiency comes with a huge hidden cost should a major disruption occur, and one must balance the notion of cost efficiency with agility, adaptability, and alignment. When considering response mitigation actions, the actors in the procurement of the medicines in the secondary care hospitals would be pushed potentially to buffer (through search for alternative suppliers) and then bridge (to work with the existing reliable suppliers) in a dynamic push-pull fashion to get the best outcome for the patients at that time.

From the query run in the NVivo software, as shown in Figure 40, a word cloud was generated from the focus groups' responses to the topic of shortage management performance.

Figure 41. Shortage management performance

From the word cloud output, as above in Figure 41, shortage and stock information from suppliers was described by all the focus groups as key. Despite the public health service environment, the pharmaceutical suppliers are commercial concerns, and the availability and accuracy of the data itself had an influence on management responses. The main themes from the word cloud query, as shown in Figure 41, in successfully managing the disruption response performance were feedback and response time, as well as systems management and contracts.

Competitors who may play an adversarial role during routine business procedures can play a very different role in the risk response, where the event affects multiple supply chains and can put either the entire industry or downstream customers under stress. The nature of the relationship with competitors has both tactical (event response) and strategic (market-shaping) aspects in the events under study. Parallel to the shift from normal organisational design to crisis response within the organisation, the focus groups observed that most hospital pharmacies were in a permanent state of crisis response to disruptions. This is possibly not unique to the pharmacy environment but was observed in this research throughout the focus group discussions. This research finding echoes another recent drug shortage survey pointing to weaknesses in the pharma industry supply chain management. In January 2017, the Pew Agency for Charitable Trusts and the International Society for Pharmaceutical Engineers (ISPE) released results of a 10-company survey on the reason for drug shortages. Surveyed pharmaceutical companies identified gaps within their supply chains, and many respondents said they did not implement best practices in supply chain management, such as maintaining back up supplies, sourcing from multiple suppliers, or increasing manufacturing shifts, in any standardised or consistent manner (PharmTech, 2017).

6.2 Data Analysis of the Quantitative Survey

The following sections lay out the data analysis of the quantitative survey, beginning with the data cleaning and recoding introduction, and then going on to give the descriptive statistics analysis for the main variables used in the analysis (6.2.1 to 6.2.3); relevant contextual variables are then presented. This is followed by the normality tests used 6.2.5. Then the summary of the variables used in the analysis 6.3 and the reliability analysis are presented.

In addition, 6.4 lays out the justification and explanation of the analysis tests used which include the assumptions. Section 6.5 presents the findings and interpretations of the variable model tests used in the quantitative survey analysis.

For clearer understanding of the variables and their summary descriptors used in the statistical analysis tables, the summary table of the variables in Table 15 explains the variable, dimension, question text and response categories.

The data file was checked for data entry errors by running the range for each variable and checking that values were not outside the range of valid response categories. Missing values were defined in SPSS for each variable. Imputation was considered unnecessary due to the low level of missing data, which is shown in the tables of descriptive statistics for independent and dependent variables.

6.2.1 Dependent variable

The measures of performance used were the fill rate both immediate, up to 8 weeks after the disruption, and post, between 8-16 weeks after the disruption. This was ‘lines fulfilled immediately' (PERF1) and ‘lines fulfilled post’ (PERFPOST 1), and both of these are used as dependent variables in all of the regression analyses presented. Just under half of respondents (45%) had between 75%-100% of lines fulfilled immediately (as shown in Figures 42 and 43) Looking at 'post' in Figure 43, the proportion who have 0-25% of lines fulfilled had increased (from 3% to 35%) and the proportion who have 51-75% of lines fulfilled had decreased from 36% to 8%. The analysis did not further investigate the types of medicines by performance as this was not the main focus of this study, but this could be included in future research.

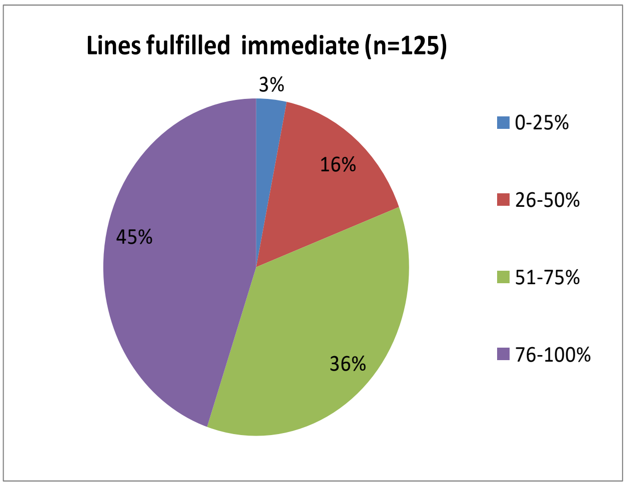


Figure 42. Performance (lines fulfilled immediate)

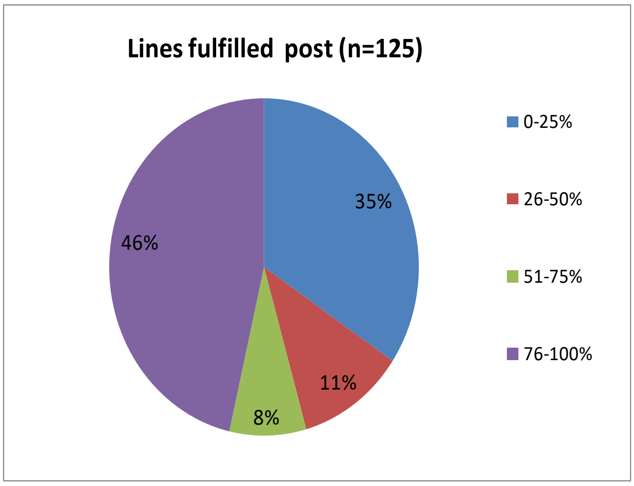


Figure 43. Performance (lines fulfilled post)

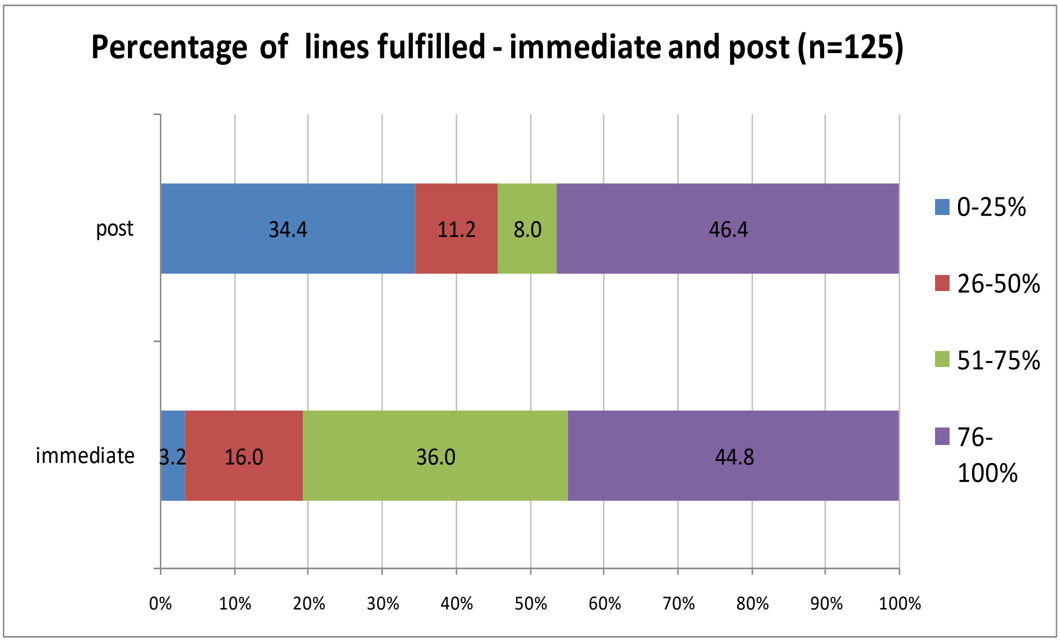


Figure 44. Percentage of lines fulfilled – immediate and post (n=125)

Figure 44 clearly summarises the differences between the immediate and post line fill rates, and further justifies the selection of both immediate and post measures rather than just one of the measures, as differences do exist.

Supply chain disruption orientation (SCDO) average was the dependent variable in one query and an independent variable in other queries; the descriptive statistics for SCDO average are shown in Section 6.5.1

6.2.2 Independent variables (nominal and ordinal)

Bed numbers were used as a control variable in all of the regression analysis presented. Table 12 shows the descriptive variables in the analysis. Table 12 also includes whether the hospital was in a collaborative hub or federation, as well as the patient medication budget. Both elements are included for descriptive purposes only.

		What is the number of staffed beds you serve?	Is your hospital a standalone institute or one of several in a Trust?	What is your current position title?	What was the severity of the disruption?	Is your hospital in a collaborative hub or federation?	What is your in-patient medication budget (£ million)?
N	Valid	125	125	117	116	114	115
	Missing	0	0	8	9	11	10
Median		2.0000	2.00	4.00	4.00	2.00	4.00
Mode		2.00	1	5	4	2	4
Variance		.749	.759	1.951	.614	.252	1.033
Range		3.00	3	4	4	1	3
Minimum		1.00	1	1	1	1	1
Maximum		4.00	4	5	5	2	4

Table 12. Descriptive statistics for variables in the analysis (categorical)

6.2.3 Independent variables

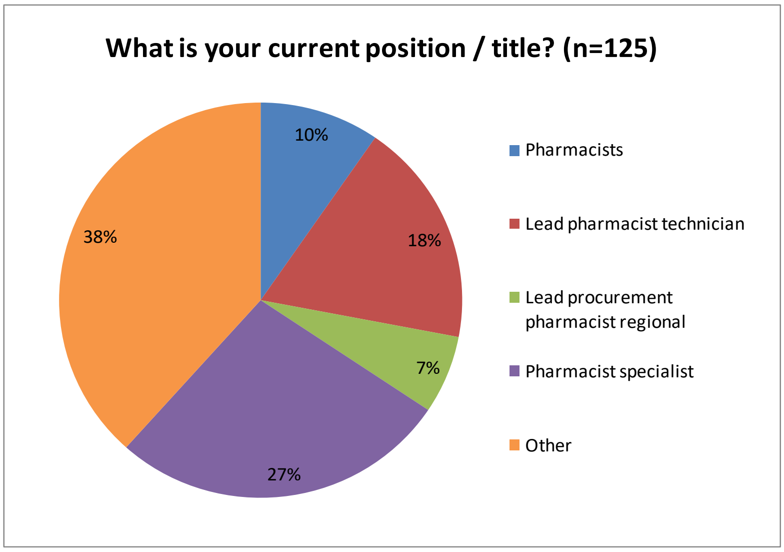


Figure 45. Role of respondents

The largest category in role of respondents was ‘other’ (38%) followed by pharmacist specialist (27%); lead pharmacist/technical (18%) as shown in Figure 45.

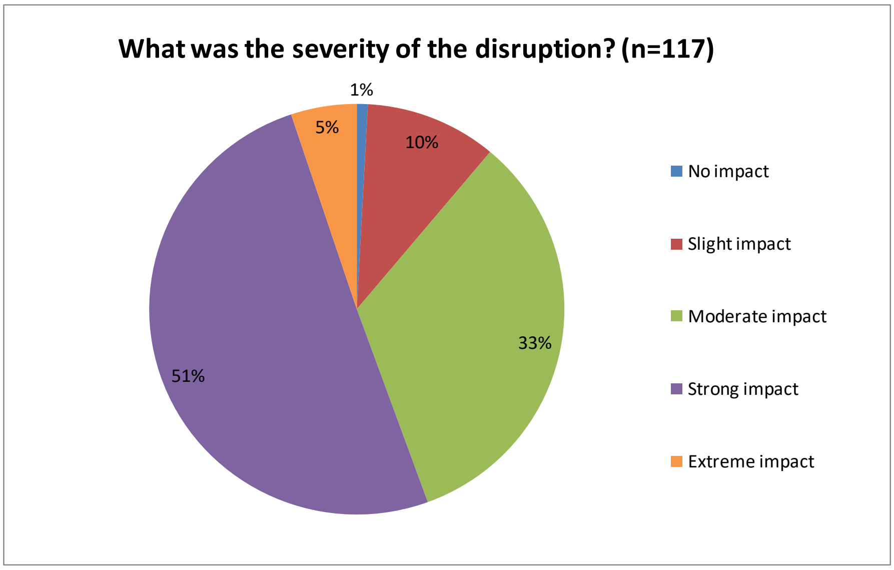


Figure 46. Disruption severity

For the disruption severity, only 5% of respondents said that the impact had been 'extreme', as shown in Figure 46. However, more than half of respondents said that the disruption had had a strong impact highlighting its importance.

Control variable

The number of staffed beds served (bed numbers) was used as the control variable in the ordinal regression. The number of staffed beds is a key demographic used by both global organisations for example OECD (Boscheck, 1996) and local healthcare societies and national governments (Siska and Tribble, 2011). It has been used in previous shortage impact research in acute care hospitals (Baumer, 2004). In that study more, time was spent tracking shortages in hospitals with larger bed numbers for example, and more money was spent by larger bed hospitals than smaller bed number hospitals on obtaining alternative products of the same therapeutic class. The purpose of a control variable in regression is to hold constant the effect of some variable which is thought to affect the dependent variable and therefore to 'control for' the effect of that variable, making it easier to detect the effect of other independent variable, or variables, on the dependent variable.

The majority of respondents were in hospitals with 100-299 staffed beds as shown in Figure 47.

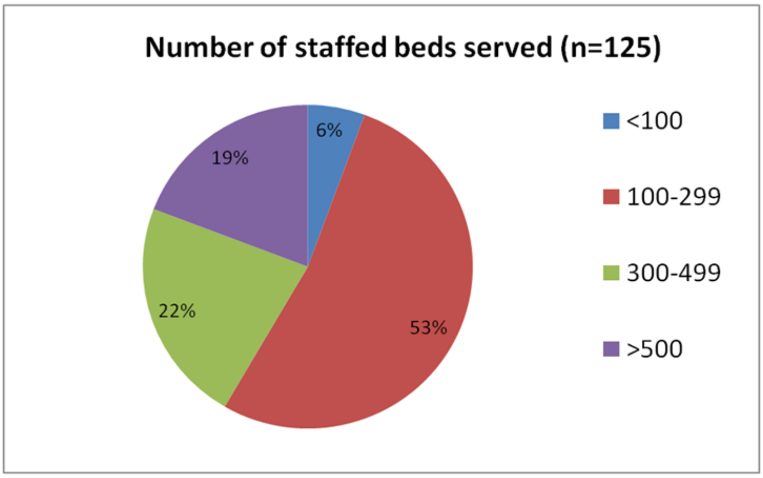


Figure 47. Number of staffed beds in respondents’ hospitals

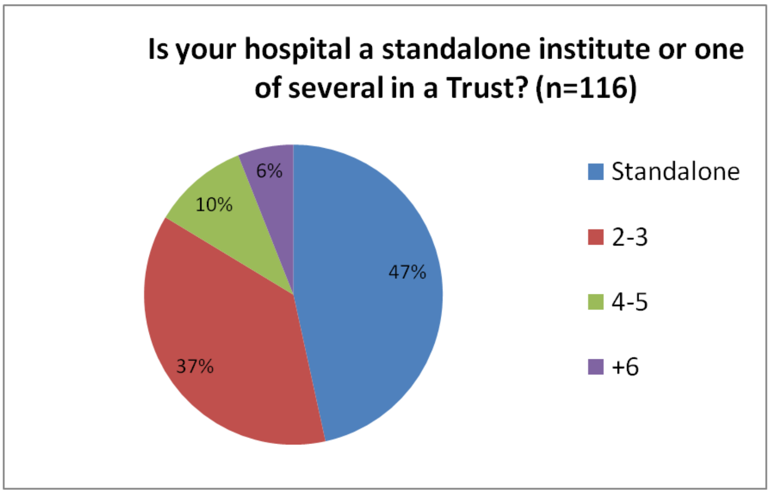


Figure 48. Stand alone or part of a trust

Just under half of respondents (47%) were from standalone hospitals, as shown in Figure 48, which along with 2-3 hospitals, formed the majority of the participants.

6.2.4 Other contextual variables

Figures 49 and 50 show whether the hospital is a hub or federation, and their hospital's medication budget for descriptive contextual purposes.

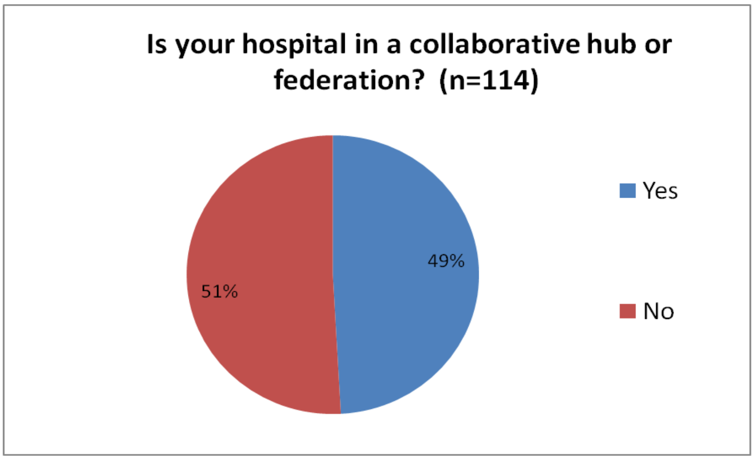


Figure 49. Hospital group

As shown in Figure 49, respondents' hospitals were almost evenly split between those who were in collaborative hubs or federations and those who were not.

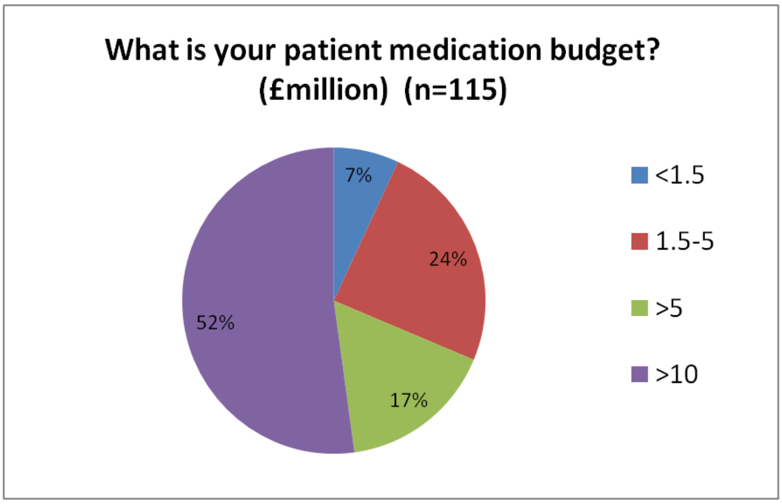


Figure 50. Patient budget

Just over half of respondents were in hospitals with a patient medication budget exceeding £10m as shown in Figure 50.

Independent variables - continuous

Descriptive statistics for continuous independent variables are presented in Table 13. All items were measured on five-point Likert scales, where a higher score represented a more positive attitude to the statement. All the items (apart from 'vary response internally' and 'vary response time') represent the mean of several items for a particular dimension. Means tended to be average or low (around or just above the mid-point of the scale: 2.5). Means were notably higher for ‘vary response internally’ and ‘vary response time’. The two items with lowest means were ‘BUFPOST average’ and ‘BRI 1 to 7 average’. Standard deviations were low for most items (below a value of 1) suggesting low dispersion around the mean. The range was quite small on many items (between 2 and 4), again, suggesting that responses were not widely dispersed.

Statistics										
		SCDO_AVG_NEW (5 point scale) [b]	FEEDBACK_REGMGR_NEW	FEEDBACK_REGOTHER_NEW	BUF1to6_average)	BUFPOST 1to6_average	BRI1to7_AVG	BRIPOST1to7_AVG	Varyrespintern_NEW	Varyresptime_NEW
N	Valid	125	119	122	125	125	124	125	125	125
	Missing	0	6	3	0	0	1	0	0	0
Mean		3.1744	2.9748	3.1475	3.556	2.3659	2.2798	2.901	4.032	3.984
Std. Error of Mean		0.03808	0.1208	0.10961	0.02833	0.06227	0.06796	0.08368	0.07615	0.07001
Median		3.1	3	3	3.6667	2.3333	2.1548	3	4	4
Mode		3	2.00[a]	3	3.67	2.33	2	3.57	4	4
Std. Deviation		0.42576	1.31782	1.21064	0.31675	0.69622	0.75677	0.93552	0.85134	0.78272
Variance		0.181	1.737	1.466	0.1	0.485	0.573	0.875	0.725	0.613
Skewness		-0.087	0.047	-0.089	-2.228	0.549	0.478	-0.463	-1.177	-0.792
Std. Error of Skewness		0.217	0.222	0.219	0.217	0.217	0.217	0.217	0.217	0.217
Kurtosis		-0.079	-1.122	-0.893	5.662	0.097	-0.314	-0.598	2.031	1.277
Std. Error of Kurtosis		0.43	0.44	0.435	0.43	0.43	0.431	0.43	0.43	0.43
Range		2	4	4	2	3.33	3.14	3.71	4	4
Minimum		2	1	1	2.17	1	1	1	1	1
Maximum		4	5	5	4.17	4.33	4.14	4.71	5	5

a. Multiple modes exist. The smallest value is shown

b. This is the dependent variable in one query but otherwise all are independent variables only

Table 13. Descriptive statistics for variables in the analysis (continuous)

6.2.5 Normality tests

Normality tests showed, as presented in Table 14, that none of the continuous independent variables had a normal distribution (p<.05 on both Kolmogorov-Smirnov and Shapiro-Wilk tests). For most queries, this was not a limitation as ordinal regression does not require a normal distribution in the independent variable or dependent variable (Norusis, 2016). However, for one query, SCDO average was the dependent variable and, as it was not normally distributed, this meant that non–parametric tests had to be used. The Kolmogorov-Smirnov test was selected for the test of normality with the Lilliefors correction for the fact that the mean and variance of the distribution are being estimated rather than being known. Normality is not a requirement for ordinal regression but it was needed to decide if parametric / non-parametric tests could be used with SCDO average. It is also a standard descriptive statistic to provide as it helps us to be aware of what tests might be valid for any analysis involving these variables.

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SCDO_AVERAGE_NEW	.089	118	.022	.976	118	.031
FEEDBACK_REGMGR_NEW	.165	118	.000	.906	118	.000
FEEDBACK_REGOTHER_NEW	.158	118	.000	.913	118	.000
BUF1to6_average	.423	118	.000	.614	118	.000
BUFPOST1to6_average	.128	118	.000	.970	118	.010
BRI1to7_average	.108	118	.002	.969	118	.008
BRIPOST1to7_AVG	.100	118	.006	.952	118	.000
Varyrespintern_NEW	.330	118	.000	.788	118	.000
Varyresptime_NEW	.305	118	.000	.817	118	.000
a. Lilliefors Significance Correction						

Table 14. Normality tests for variables in the analysis (continuous)

In Table 14 the Lilliefors significance correction was used. This 'correction' is used to adjust the calculation of normality where no specific population mean or standard deviation is available (this applies in most cases as we usually do not know what the mean or SD of the population we are interested in, i.e. what we are comparing our sample to, and so we must use the mean and SD of the sample but this tends to overstate the normality of the distribution). If the Lilliefors correction was not applied, the calculation of normality would tend to be too 'lenient' and some distributions would be classified as normal when they were not normal (Internation Business Machines, 2018).

6.3 Summary of variables in the analysis

The variables shown in Table 15 are the main variables used in the analysis, (table continues over next 3 pages)

Dimension	Variable name	Question text	Response categories
Performance (immediate)	PERF1	Q51. Of the medicine affected by the disruption, what was the percentage of the lines fulfilled during the period up to 8 weeks after the disruption first occurred?	0-25% (1) 26-50% (2) 51-75% (3) 76-100% (4)
Performance (post)	PERFPOST 1	Q52. What was the percentage of the lines fulfilled during the period 8 weeks to 16 weeks after the disruption first occurred?	0-25% (1) 26-50% (2) 51-75% (3) 76-100% (4)
Supply chain disruption orientation	SCDO_AVERAGE_NEW	Mean of SCDO 1 to 5 (see below)	
Supply chain disruption orientation	SCDO1	Q11. We feel the need to be alert for possible supply chain disruptions at all times.	Strongly Disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4) Strongly agree (5)
Supply chain disruption orientation	SCDO 2	Q12. Supply chain disruptions show us where we can improve.	As above
Supply chain disruption orientation	SCDO 3	Q13. We recognise that supply chain disruptions are always looming.	As above
Supply chain disruption orientation	SCDO 4	Q14. We think a lot about how a supply chain disruption could have been avoided.	As above
Supply chain disruption orientation	SCDO 5	Q15. After a supply chain disruption has occurred, it is analysed thoroughly.	As above
Feedback average		Mean of Feedbackremgr new + Feedbackre other new (see below)	
Feedback	Feedback remgr new	Q16. We feedback performance data on the alternative response taken to our region.	Strongly Disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4) Strongly agree (5)
Feedback	Feedback re other new	Q17. We feedback performance data on the response alternative taken to all other SHA regions.	Strongly Disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4) Strongly agree (5)
Bridging (immediate) average	BRI1to7_average	Mean of BRI 1 to 7 (see below)	
Bridging (immediate)	BRI 1	Q37. Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	Never (1) Seldom (2) Sometimes (3) Often (4) Almost always (5)
Bridging (immediate)	BRI 2	Q.38. Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	As above
Bridging (immediate)	BRI 3	Q39. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	As above
Bridging (immediate)	BRI 4	Q40. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following	As above

Dimension	Variable name	Question text	Response categories
		activities?	
Bridging (immediate)	BRI 5	Q41. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	As above
Bridging (immediate)	BRI 6	Q42. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	As above
Bridging (immediate)	BRI 7	Q43. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities?	As above
Bridging (post)	BRIPOST1to7_AVG	Mean of BRIPOST 1 to 7 (see below)	
Bridging (post)	BRIPOST 1	Q44. Actions (8-16 weeks after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities? Establish a closer relationship with this supplier in order to collaborate better in case of supply chain	Never (1) Seldom (2) Sometimes (3) Often (4) Almost always (5)
Bridging (post)	BRIPOST 2	Q45. Tighten the control mechanisms on this supplier (e.g., more monitoring).	As above
Bridging (post)	BRIPOST 3	Q46. Cooperate more intensively with this supplier.	As above
Bridging (post)	BRIPOST 4	Q47. Improve information exchange with this supplier.	As above
Bridging (post)	BRIPOST 5	Q48. Engage in risk management activities with this supplier (e.g. development of joint contingency plans).	As above
Bridging (post)	BRIPOST 6	Q49. Developed inter-organisational relations within your SHA regional area	As above
Bridging (post)	BRIPOST 7	Q50. Developed inter-organisational relations outside your SHA regional area activities?	As above
Buffering (immediate)	BUF1to6_average	Mean of BUF 1 to 6 (below)	
Buffering (immediate)	BUF 1	Q25. Actions (Immediately after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities? *Make us more independent of this supplier or the purchased item.*	Never (1) Seldom (2) Sometimes (3) Often (4) Almost always (5)
Buffering (immediate)	BUF 2	Q26. Increase our protective barriers against disturbances in the supply of the purchased item.	As above
Buffering (immediate)	BUF 3	Q27. Search for or develop one or more alternative supplier(s) for the purchased item.	As above
Buffering (immediate)	BUF 4	Q28. Taken on extra staff or resources to cope with such disruptions.	As above
Buffering (immediate)	BUF 5	Q29 Modified/developed policies (care plans/guidelines)	As above
Buffering (immediate)	BUF 6	Q30. Purchased compounded replacement pharmaceuticals.	As above

Dimension	Variable name	Question text	Response categories
Buffering (post)	BUFPOST1to6 _average	Mean of BUFPOST 1 to 6 (see below)	
Buffering (post)	BUFPOST 1	Q31. Actions (8-16 weeks after the disruption) Since the disruption, to what extent has your business unit pursued, or made plans to pursue the following activities? Make us more independent of this supplier or the purchased item.	Never (1) Seldom (2) Sometimes (3) Often (4) Almost always (5)
Buffering (post)	BUFPOST 2	Q32. Increase our protective barriers against disturbances in the supply of the purchased item.	As above
Buffering (post)	BUFPOST 3	Q33. Search for or develop one or more alternative supplier(s) for the purchased item.	As above
Buffering (post)	BUFPOST 4	Q34. Taken on extra staff or resources to cope with such disruptions.	As above
Buffering (post)	BUFPOST 5	Q35. Modified/developed policies (care plans/guidelines)	As above
Buffering (post)	BUFPOST 6	Q36. Purchased compounded replacement pharmaceuticals.	As above
Response time	Varyresponseintern	Q18. We vary our response to disruptions depending on our business unit needs.	Strongly Disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4) Strongly agree (5)
Response time	Vary responsetime	Q19. We vary our response to disruptions depending on the length of time from initial occurrence.	Strongly Disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4) Strongly agree (5)
Hospital numbers	Hospital numbers	Q10. Is your hospital a standalone institute or one of several in a trust?	Standalone (1) 2 to 3 (2) 4 to 5 (3) 6+ (4)
Disruption severity	Disruption severity	Q23. What was the severity of the disruption?	No impact (1) Slight impact (2) Moderate impact (3) Strong impact (4) Extreme impact (5)
Staffed bed numbers	Bed numbers	Q3. What is the number of staffed beds you serve?	No impact (1) Slight impact (2) Moderate impact (3) Strong impact (4) Extreme impact (5)
Role/job title of respondent	Role	Q9. What is your current position title?	Pharmacist Technician (1) Lead Pharmacist Technician (2) Lead Procurement Pharmacist Regional (3) Pharmacist Specialist (4) Other (please specify) (5)

Table 15. Summary of variables used in hypothesis testing

6.3.1 Reliability analysis

Cronbach's alpha is a widely used measure of scale reliability (National Centre for Research Methods, 2016). Specifically, it is a measure of how closely related a set of items are as a group (i.e., internal consistency). A value for Alpha of 0.7 or above is widely considered as the 'acceptable' level. The internal consistency of a group of related items is particularly important where items are being aggregated or averaged, as they are in this analysis, so that the aggregated variable is a reasonable reflection of the components of which it is made.

6.3.2 Cronbach's alpha

Alpha was at acceptable levels for all averaged variables except for SCDO 1 to 5 vary response, and BUF 1 to 6, where alpha was lower than the commonly accepted threshold of 0.7; see Table 16 for value summary. It was not possible to improve alpha for SCDO 1 to 5 or vary response. There were no variables which, if deleted, would lead to a higher value of alpha. The alpha of BUF 1 to 6 could have been significantly improved to .704 by dropping BUF1, but it was considered more important to retain the item BUF1 ('actions immediate independent of supplier/item').

Variables	**Cronbach's alpha**
SCDO 1 to 5	.585
BUF 1 to 6	.528
BUFPOST 1 to 6	.704
BRI 1 to 7	.769
BRIPOST 1 to 7	.869
FEEDBACKREMGR and FEEDBACKRE OTHER	.747
VARYRESP + VARYRESPONSEINTERN	.594

Table 16. Summary of Cronbach's alpha values

6.4 Analysis

Ordinal regression (also known as ordered logistic regression) was determined to be the most appropriate procedure for all but one of the hypotheses. This was because the aim was to look at the effect of a number of independent variables (both categorical, ordinal and continuous) on a dependent variable which, in all cases apart from one, was ordinal with four levels (Lines fulfilled Immediate - PERF1 in the data file, taken as a measure of performance). Multiple linear regression would not have been appropriate as this requires the dependent variables to be continuous (interval or ratio). Multinomial logistic regression would have been an option but this would have been less appropriate as it would not be sensitive to the ‘ordered’ nature of the dependent variable and so would have less chance of detecting a relationship between the independent variables and the dependent variable. For hypothesis number three where the dependent variable was continuous (SCDO average) and the independent variable (hospital numbers) was ordinal, it was decided to use one-way ANOVA, however, the assumptions of this parametric test were not met, so a non-parametric alternative (Kruskal Wallis test) was used instead.

6.4.1 Assumptions of ordinal regression and associated diagnostic tests

Independent variables in ordinal regression can be either categorical or continuous or a combination of both. The dependent variable must be ordinal; it consists of two or more categories which can be meaningfully placed in a hierarchy. Ordinal regression is non-parametric and does not assume a normal distribution of the dependent variable, the independent variables, or multivariate normality.

6.4.2 Assumption of proportional odds

The key assumption in ordinal regression is that the effects of independent variables are consistent or proportional across the different thresholds, hence the term 'assumption of proportional odds' (National Centre for Research Methods, 2016). This assumption follows from a more basic assumption that, there is a latent continuous outcome variable and that the observed ordinal outcome arises from discretising the underlying continuum into J-ordered groups (Norusis, 2016).

Whether these assumptions are met in SPSS or not can be determined through the test of parallel lines where the null hypothesis states that the location parameters (slope coefficients) are the same across response categories (i.e., that the assumption of proportional odds is met). Therefore, *p*>.05, the test of parallel lines, retains this null hypothesis and signifies that the assumption of proportional odds has been met.

The test of parallel lines is considered to be 'anti-conservative' (NCRM 2016), meaning that it tends to reject the null hypothesis too readily. It is sensitive to empty cells which are very likely to occur when using continuous variables (covariates) in the model. If the test is failed (i.e., *p*<.05), then alternative forms of regression with less restrictive assumptions can be considered (e.g., multinomial logistic regression) but for reasons stated previously, this is not ideal as multinomial logistic regression is not sensitive to the ordered effect in the dependent variable (UCLA, 2016).

6.4.3 Goodness of fit

Ordinal regression assumes that there is goodness of fit, namely Whether the observed data are consistent with the fitted model (NCRM 2016). SPSS provides a goodness of fit test consisting of Pearson's chi-square statistic for the model and a second chi-square statistic based on the deviance. The null hypothesis for the goodness of fit test is that the fit is good and, therefore, a non-significant result (*p*>.05) indicates that the null hypothesis can be accepted and there is a good fit. However, NCRM advise that the goodness of fit test is unreliable in models with a large number of categorical independent variables or with continuous independent variables because both of these scenarios often result in many empty cells in the analysis. NCRM (2016) suggest that, in such cases, one should refer to other indicators of whether the model is valid, such as a Pseudo R^2 statistic (e.g., Nagelkerke).

6.4.4 Assessing the effect of independent variables on the dependent variable

Ordinal regression provides a parameter estimate for each independent variable in the model. Ordinal regression parameter estimates refer to 2 Log-likelihood of an increase of one level in the dependent variable for a one unit increase in the independent variable (for continuous variables) or compared to the reference category (for categorical variables). Taking the exponential of the estimate (which is in logits), allows an estimate of the actual increase or decrease in the probability of an increase of one level in the dependent variable for a one unit increase in the independent variable (for continuous variables), or compared to the reference category (for categorical variables) when all other independent variables in the model are held constant. This probability is known as the cumulative odds.

6.5 Findings and Interpretation of the survey data analysis

This section of the quantitative analysis, presents the tests used for each of the nine propositions as first described in chapter 5. It begins with an overview of the range of the model tests outputs.

Overview

In this section, we present an overview of the various models which have been used in the analysis and identify which models appear to have the greatest predictive power for each of the dependent variables (performance immediate and performance post).

There was a very considerable range of explanatory power amongst the models (see Appendix 4 for a detailed overview in the summary quantitative analysis table) both within each dependent variable (performance immediate and performance post) but the best models achieved quite impressive levels of Pseudo R^2. For performance immediate (PERF1) the best models in terms of Pseudo R^2 were model number 4 (43%), model 2 (39.4%), and model 1 (36.6%). There is then a large drop in Pseudo R^2 to reach the next best model, model 5 with 25%, followed by model 8 with 12.6%, and model 6 with 10.2%. The remaining two models, 9 and 7, have Pseudo R^2 of 8% and 3.7% respectively. The significant independent variable in models 1 and 2 is SCDO independent variables are good predictors of performance immediate (PERF1). It is worth noting that while model 4 does show some improvement in Pseudo R^2 over models 1 and 2, it is not a great amount and one might conclude, therefore, that SCDO

With regards to performance post (PERFPOST 1), there is a similar range of Pseudo R^2 amongst the models, with the highest being models 8, 7, and 5 with Pseudo R^2 of 48.4%, 44%, and 41.4%, respectively. There is then a large gap to the next best model, model 6 with 34% Pseudo R^2, and then a further large gap to model 4 with 17.4% Pseudo R^2, followed by models 2, 1, and 9. This suggests that buffering, bridging, and feedback are key to predicting performance post (PERFPOST 1).

It is very notable that the best models for predicting performance immediate tend to be very poor for predicting performance post and vice versa, suggesting that very different variables are important in understanding each of these types of performance. In summary, a number of models for each dependent variable have been identified which have high levels of Pseudo R^2 and are statistically significant.

6.5.1 Supply chain disruption orientation and performance (1)

Rationale for the analysis

The aim was to investigate proposition P1a; whether the stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management, as described in Chapter 3 under the supply chain disruption orientation construct.

Descriptive statistics

Descriptive statistics (comparison of means) shows that there is considerable variation in the mean of SCDO average according to the categories of the dependent variable (performance – lines fulfilled immediate), and that the relationship seems to be positive (SCDO means increase through the levels of performance) suggesting that there may be some relationship between these variables, as shown in Table 17.

SCDO_AVERAGE_NEW			
Lines fulfilled Immediate	Mean	N	Std. Deviation
0-25%	2.5500	4	.50000
26-50%	2.7850	20	.36314
51-75%	3.1467	45	.31809
76-100%	3.3804	56	.37582
Total	3.1744	125	.42576

Table 17. SCDO means by category of performance (immediate)

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone).

The results of the standard diagnostic test for ordinal regression are presented below.

Goodness of fit

Since *p*>.05, we retain the null hypothesis that the model has goodness of fit, Table 18.

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	112.498	140	.958
Deviance	102.228	140	.993

Table 18. Goodness of fit (1)

Parallel lines

The test of parallel lines shows *p*>.05 and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable, Table 19.

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	147.517			
General	145.289[b]	2.229[c]	8	.973

Table 19. Parallel lines (2)

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall (*p*<.001). Therefore, the null hypothesis is rejected and the alternate hypothesis is accepted, Table 20.

Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	197.135			
Final	147.517	49.618	4	.000
Link function: Logit.				

Table 20. Significance (1)

The various Pseudo R-Squared statistics attempt to emulate the function of R square in multiple linear regression but are not exactly equivalent, hence the term ‘Pseudo’.

The function is to estimate the amount of variance in the dependent variable which is explained by the model (i.e., the independent variables collectively). There is not complete consensus on which Pseudo R-Squared (PRS) statistic is the most valid and hence SPSS presents all three options, but it is known that the Cox and Snell statistic does not give a value of 1, even with a perfect model, and many researchers choose the Nagelkerke statistic which is what we shall use in this analysis (Norusis, 2016).

In logistic or ordinal regression (which share an underlying logic), there is no R^2 value per se as there is in multiple regression. However, an assessment of the explanatory power of the model can be made by looking at the amount of variance which is unaccounted for by the model (the lower the unaccounted-for variance, the higher the explanatory power of the model and hence higher Pseudo R^2 (Hu, Shao and Palta, 2006).

There are three estimates of Pseudo R^2 (Cox Snell, Nagelkerke, Mc Fadden) provided by SPSS. There is also the Hosmer-Lemeshow but SPSS treats this is a test of goodness of fit rather than an attempt to provide a Pseudo r square. Nagelkerke is based on the same formula as Cox and Snell but rescaled to give a value between 0 and 1.

This is probably why Nagelkerke is most widely used, because it produces a result from 0 to 1 and so emulates the Pseudo R^2 found in multiple linear regression (which is more familiar to most quantitative researchers than is ordinal regression which tends to be used relatively infrequently).

Mc Fadden uses a slightly different formula (comparing a model with no predictors to the model with all the predictors in) and while it can in theory produce a zero value for R^2 it can never produce a value of 1. It is argued by some that Mc Fadden is more accurate and that it would tend to give lower values than Negelkerke but there is no consensus amongst researchers about which form of pseudo r square is best (Alison, 2013). As Laerd (2013) notes the three measures (Cox and Snell, Nagelkerke and McFadden) are the three most common measures of R^2. Conceptually they are somewhat the same, so in terms of interpretation they can be seen as similar to the R^2 in linear regression in that they provide a gauge of the substantive significance of the model (Field, 2009).

The Nagelkerke value in this model is .366, suggesting that the model has good explanatory power, accounting for 36.6% of the variance in the dependent variable (performance), Table 21.

Pseudo R-Squared	
Cox and Snell	.328
Nagelkerke	.366
McFadden	.176
Link function: Logit.	

Table 21. PRS (1)

Ordinal regression coefficients

Table 22 shows that the independent variable ‘SCDO average’ was statistically significant. The exponential of the logits, which are shown in the estimate column, gives us the cumulative odds (CO) which shows that, for a one unit increase in SCDO average, the probability of going up one level in the dependent variable (performance) increases by a factor of 25.48. Hospitals with smaller numbers of beds had an increased probability of being at a higher level of performance than the reference category (over 500 beds), but not to a statistically significant extent.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERF1 = 1]	6.344	1.624	15.254	1	0	3.16	9.528		
	[PERF1 = 2]	8.794	1.665	27.911	1	0	5.532	12.057		
	[PERF1 = 3]	11.017	1.776	38.496	1	0	7.537	14.497		
Location	SCDO_AVERAGE_NEW	3.238	0.534	36.796	1	0	2.192	4.284	25.478	SCDO
	[Beds=1.00]	1.477	0.855	2.986	1	0.084	-0.198	3.153	4.381	B1 (under 100)
	[Beds=2.00]	0.237	0.474	0.25	1	0.617	-0.692	1.166	1.267	B2 (100 to 299)
	[Beds=3.00]	0.936	0.576	2.645	1	0.104	-0.192	2.065	2.55	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 22. Ordinal regression coefficients

6.5.2 Supply chain disruption orientation and performance (1x)

The following analysis refers to the same variables as in section 6.5.1, but with PERFPOST1 (8 to 16 weeks) rather than PERF1 (first 8 weeks) as the dependent variable.

Rationale for the analysis

The aim was to investigate proposition P1a; whether the stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management, as described in Chapter 3 in the supply chain disruption orientation construct section.

Descriptive statistics

Descriptive statistics (comparison of means) shows, as below in Table 23, that there is little variation in the mean of SCDO average according to the categories of the dependent variable (performance – lines fulfilled post).

Report			
SCDO_AVERAGE_NEW			
Lines fulfilled Post	Mean	N	Std. Deviation
0-25%	3.1209	43	.36681
26-50%	3.1571	14	.44326
51-75%	3.0600	10	.46476
76-100%	3.2379	58	.45570
Total	3.1744	125	.42576

Table 23. SCDO means by category of performance (POST)

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone).

The results of the standard diagnostic test for ordinal regression are presented in the diagnostic test summary in Appendix 5. Since $p>.05$, we retain the null hypothesis that the model has goodness of fit.

The test of parallel lines shows $p>.05$ and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall ($p<.05$) but at p=.043 it is only just below the threshold for statistical significance, Table 24. However, the null hypothesis is rejected and the alternate hypothesis is accepted.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	198.602			
Final	188.743	9.860	4	.043

Table 24. Significance (1x)

The Nagelkerke value in this model is .084, Table 25, suggesting that the model has low explanatory power, accounting for just 8.4% of the variance in the dependent variable (performance).

Pseudo R-Squared	
Cox and Snell	.076
Nagelkerke	.084
McFadden	.034

Table 25. PRS (1x)

Ordinal regression coefficients

Table 26 shows that no independent variables were statistically significant. The exponent of the estimate tells us that for a one unit increase in SCDO average, the probability of going up one level in the dependent variable (performance - lines filled post) increases by a factor of 1.78, but this was not statistically significant. Hospitals with smaller numbers of beds had an increased probability of being at a higher level of performance than the reference category (over 500 beds) but not to a statistically significant extent. The fact that no independent variables were statistically significant is not surprising given the very low level of Pseudo R^2 and the fact that the model overall was statistically significant at a very low level.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/ category name
Threshold	[PERF POST1 = 1]	1.066	1.358	.616	1	.432	-1.595	3.728		
	[PERF POST1 = 2]	1.567	1.361	1.325	1	.250	-1.101	4.236		
	[PERF POST1 = 3]	1.915	1.365	1.969	1	.161	-.760	4.591		
Location	SCDO_ AVERAG E_ NEW	.577	.412	1.960	1	.162	-.231	1.384	1.780	SCDO average
	[Beds=1.0 0]	-.603	.810	.555	1	.456	-2.190	.984	0.547	B1 (under 100)
	[Beds=2.0 0]	-.397	.448	.783	1	.376	-1.275	.482	0.673	B2 (100 to 299)
	[Beds=3.0 0]	.823	.554	2.209	1	.137	-.262	1.908	2.277	B3 (300-499)
	[Beds=4.0 0]	0[a]			0				reference category	B4 (over 500)

Table 26. Ordinal regression coefficients

6.5.3 Role, supply chain disruption orientation, and performance (2)

Rationale for the analysis

The aim was to investigate proposition 1b; whether the lower the role of the actor responsible for making supply chain disruption action decisions, the lesser the shortage management performance, as described in Chapter 3 in the supply chain disruption orientation construct section.

Hypothesis/Proposition

The null hypothesis is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The results of the standard diagnostic test for ordinal regression are presented in the diagnostic test summary in Appendix 5. Since p>.05, we retain the null hypothesis that the model has goodness of fit.

The test of parallel lines shows $p>.05$ and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model is statistically significant overall ($p<.001$), Table 27 and, therefore, the null hypothesis is accepted and the alternate hypothesis is rejected.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	247.510			
Final	193.022	54.487	8	.000

Table 27. Significance (2)

The model has good explanatory power (Nagelkerke =.394), Table 28, suggesting that the model explains 39.4% of the variance in the dependent variable (performance immediate).

Pseudo R-Squared	
Cox and Snell	.353
Nagelkerke	.394
McFadden	.193
Link function: Logit.	

Table 28. PRS (2)

Ordinal regression coefficients

The independent variable SCDO average is statistically significant ($p<.001$, CO 31.5). This indicates that an increase of one unit in SCDO average leads to a 31.5 greater probability of going up one level in the dependent variable (performance/lines fulfilled immediate), as shown in Table 29. Role has 5 category names included in the analysis: pharmacist, lead pharmacy technician, lead procurement, and other, which is the reference category that the rest of the categories are compared to, it is the benchmark, the baseline which the other categories are interpreted. There are no statistically significant effects associated with role or bed numbers, although the category ‘under 100 beds’ comes close to being statistically significant compared to the reference category (over 500 beds, *p*=.063 CO 5.455) as does the category 300-499 beds (*p*=.061 CO 3.023).

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval		Cumulative Odds (CO)	Variable/ category name
							Lower Bound	Upper Bound		
Threshold	[PERF1 = 1]	7.215	1.721	17.577	1	.000	3.842	10.588		
	[PERF1 = 2]	9.727	1.771	30.162	1	.000	6.256	13.198		
	[PERF1 = 3]	12.013	1.890	40.401	1	.000	8.309	15.718		
Location	SCDO_ AVERAGE _NEW	3.450	.555	38.611	1	.000	2.362	4.538	31.500	SCDO average
	[Beds=1.00]	1.697	.912	3.462	1	.063	-.091	3.484	5.455	B1 (under 100)
	[Beds=2.00]	.390	.488	.638	1	.424	-.566	1.346	1.477	B2 (100 to 299)
	[Beds=3.00]	1.106	.590	3.514	1	.061	-.050	2.263	3.023	B3 (300-499)
	[Beds=4.00]	0[a]			0					B4 (over 500)
	[Role=1]	-.168	.650	.067	1	.795	-1.442	1.105	0.845	Pharmacists
	[Role=2]	.832	.529	2.468	1	.116	-.206	1.869	2.297	Lead pharmacist technician
	[Role=3]	-.782	.786	.989	1	.320	-2.323	.759	0.458	Lead procurement pharmacist regional
	[Role=4]	.367	.470	.612	1	.434	-.553	1.287	1.444	Pharmacist specialist
	[Role=5]	0[a]			0				Reference category.	Other

Table 29. Results of ordinal regression

6.5.4 Role, supply chain disruption orientation, and performance (2x)

The following analysis refers to the same variables as in section 6.5.3, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for the analysis

The aim was to investigate proposition P1b; whether the lower the role of the actor responsible for making supply chain disruption action decisions, the lesser the shortage management performance, as described in Chapter 3 in the supply chain disruption orientation construct section.

Hypothesis/Proposition

The null hypothesis is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis). The results of the standard diagnostic test for ordinal regression are presented in the diagnostic test summary in Appendix 5. Since $p>.05$, we retain the null hypothesis that the model has goodness of fit.

The test of parallel lines shows $p>.05$ and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model is not statistically significant overall ($p>.05$), Table 30 and, therefore, the null hypothesis is retained and the alternate hypothesis is rejected.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	253.865			
Final	240.540	13.325	8	.101

Table 30. Significance (2x)

The model has low explanatory power (Nagelkerke=.112), Table 31, suggesting that the model explains 11.2% of the variance in the dependent variable (performance post).

Pseudo R-Squared	
Cox and Snell	.101
Nagelkerke	.112
McFadden	.046

Table 31. PRS (2x)

Ordinal regression coefficients

None of the independent variables were statistically significant (*p*>.05). An increase of one unit in SCDO average leads to a 1.817 greater probability of going up one level in the dependent variable (performance/lines fulfilled POST) but was not statistically significant, as shown in Table 32. There are no statistically significant effects associated with role or bed numbers.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/ category name
Thres Hold	[PERF POST1 = 1]	1.345	1.411	.907	1	.341	-1.422	4.111		
	[PERF POST1 = 2]	1.855	1.416	1.718	1	.190	-.919	4.630		
	[PERF POST1 = 3]	2.212	1.420	2.427	1	.119	-.571	4.994		
Loca Tion	SCDO_ AVERAGE_ NEW	.597	.421	2.015	1	.156	-.228	1.422	1.817	SCDO average
	[Beds=1.00]	-.404	.847	.228	1	.633	-2.064	1.256	0.668	B1 (under 100)
	[Beds=2.00]	-.366	.461	.629	1	.428	-1.269	.538	0.694	B2 (100 to 299)
	[Beds=3.00]	.803	.564	2.025	1	.155	-.303	1.909	2.232	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)
	[Role=1]	.161	.640	.063	1	.801	-1.094	1.416	1.175	Pharmacists
	[Role=2]	.154	.483	.101	1	.751	-.793	1.100	1.166	Lead pharmacist technician
	[Role=3]	-.470	.766	.376	1	.540	-1.970	1.031	0.625	Lead procurement pharmacist regional
	[Role=4]	.716	.443	2.618	1	.106	-.151	1.583	2.046	Pharmacist specialist
	[Role=5]	0[a]			0				reference category	Other

Table 32. Results of ordinal regression

6.5.5 Number of hospitals in the trust and SCDO (3)

Rationale for the analysis

The aim was to investigate proposition 1c; whether the larger the number of hospitals in a trust, the stronger the supply chain disruption orientation of a unit, as described in Chapter 3 in the supply chain disruption orientation construct section.

Hypothesis /Proposition

The hypothesis is that there will be statistically significant differences between the means of the groups (levels) within the variable 'hospital numbers', the null hypothesis is that there will not be statistically significant differences between the means of the group within hospital numbers.

Rationale for test

In this analysis, there are two variables: independent variable, hospital numbers (ordinal), and dependent variable, SCDO (continuous/interval). So again, ANOVA would be the obvious choice (if assumptions were met). SCDO is not normal, as discussed in the normality tests in Section 6.3.1. Transformations and removal of outliers did not improve normality. However, the histogram suggests an approximation of normality and as one way ANOVA had considerable robustness, it was decided to use that (and also back up with a Kruskal Wallis test).

ANOVA

Levene's test *p*>.05. showed that there was homogeneity of variance (an assumption of ANOVA). The ANOVA was not significant (F=.839, 3,1112, p=.475) showing that there was not a statistically significant difference between the means of the categories in hospital numbers in respect of the dependent variable, SCDO, Table 33. Therefore, the null hypothesis was accepted and the alternate hypothesis was rejected.

Test of Homogeneity of Variances

SCDO_AVERAGE_NEW

Levene Statistic	df1	df2	Sig.
1.229	3	112	.303

ANOVA

SCDO_AVERAGE_NEW

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.384	3	.128	.839	.475
Within Groups	17.100	112	.153		
Total	17.484	115			

Table 33. Significance (3)

Kruskal-Wallis test

As the dependent variable was not normally distributed, thus violating one of the assumptions of ANOVA, it was decided to also test the hypothesis with a non-parametric test (Kruskal-Wallis). This gave a similar result (p=.432) and, again, the null hypothesis was accepted and the alternate hypothesis rejected.

6.5.6 Disruption severity, disruption orientation, and performance (4)

Rationale for analysis

The aim was to investigate proposition 1d; whether the higher the severity of the disruption, the better the managers with higher supply chain disruption orientation perform, as described in Chapter 3 under the supply chain disruption orientation construct.

Hypothesis/Proposition

The null hypothesis in ordinal regression (as in most other forms of regression) is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis). The results of the standard diagnostic test for ordinal regression are presented in the summary of diagnostic tests in Appendix 5. Since p>.05, we retain the null hypothesis that the model has goodness of fit.

The test of parallel lines shows p<.05 and, therefore, we reject the null hypothesis that the slope coefficients are the same across response categories of the dependent variable. The assumption of parallel lines is not met.

However, as the goodness of fit test was passed and the Pseudo R Squared is high, it was decided to retain the model. Although clearly there must be a degree of uncertainty in the findings, given that the parallel lines test is not passed.

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall (p<.001), Table 34. Therefore, the null hypothesis is rejected and the alternate hypothesis is accepted.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	230.442			
Final	173.389	57.053	8	.000

Table 34. Significance (4)

The model has very good explanatory power of model (Nagelkerke =.430), Table 35, meaning that the model explains 43% of the variance in the dependent variable (performance immediate).

Pseudo R-Squared	
Cox and Snell	.386
Nagelkerke	.430
McFadden	.213

Table 35. PRS (4)

Ordinal regression coefficients

The statistically significant independent variables are SCDO average (p<.001, CO 31.668) and disruption severity levels 2, 3, and 4 (slight, moderate, and strong impact with p =.044, .014, and .041 respectively and CO of 8.031, 8.755, and 5.637 respectively). This indicates that a one unit increase in SCDO average is associated with a 31.668 times greater probability of going up one category on the dependent variable (performance) and that categories 2, 3, and 4 of disruption severity are associated with increased probability (ranging from 5.637 to 8.755) of going up one level on the dependent variable compared to the reference category (extreme impact), as in Table 36. Although the categories relating to smaller numbers of beds showed increased probability of going up one level on the dependent variable (performance) compared to the reference category (over 500 beds), the effect was not statistically significant.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval		Cumulative Odds (CO)	Variable/category name
							Lower Bound	Upper Bound		
Threshold	[PERF1 = 1]	8.629	1.959	19.400	1	.000	4.789	12.469		
	[PERF1 = 2]	11.120	2.006	30.715	1	.000	7.187	15.052		
	[PERF1 = 3]	13.699	2.166	40.012	1	.000	9.454	17.943		
Location	SCDO_AVERAGE_NEW	3.455	.578	35.748	1	.000	2.323	4.588	31.668	SCDO average
	[Disruptionseverity=1]	-1.888	2.096	.811	1	.368	-5.996	2.220	0.151	No impact
	[Disruptionseverity=2]	2.083	1.035	4.054	1	.044	.055	4.111	8.031	Slight impact
	[Disruptionseverity=3]	2.170	.882	6.055	1	.014	.441	3.898	8.755	Moderate impact
	[Disruptionseverity=4]	1.729	.848	4.158	1	.041	.067	3.392	5.637	Strong impact
	[Disruptionseverity=5]	0[a]			0				Reference category	Extreme impact
	[Beds=1.00]	1.370	.930	2.171	1	.141	-.453	3.193	3.936	B1 (under 100)
	[Beds=2.00]	.360	.501	.516	1	.472	-.622	1.342	1.433	B2 (100 to 299)
	[Beds=3.00]	.782	.654	1.432	1	.231	-.499	2.063	2.186	B3 (300-499)
	[Beds=4.00]	0[a]			0				Reference category	B4 (over 500)

Table 36. Results of ordinal regression

6.5.7 Disruption severity, disruption orientation, and performance (4x)

The following analysis refers to the same variables as in section 6.5.6, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for analysis

The aim was to investigate proposition 1d; whether the higher the severity of the disruption, the better the managers with higher supply chain disruption orientation perform, as described in Chapter 3 under the supply chain disruption orientation construct.

Hypothesis/Proposition

The null hypothesis in ordinal regression (as in most other forms of regression) is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis). The results of the standard diagnostic test for ordinal regression are presented in the diagnostic test summary in Appendix 5. Since *p*>.05, we retain the null hypothesis that the model has goodness of fit.

The test of parallel lines shows *p*>.05 and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall (*p*<.05), Table 37. Therefore, the null hypothesis is rejected and the alternate hypothesis is accepted.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	236.898			
Final	216.749	20.149	8	.010

Table 37. Significance (4x)

The model has moderate explanatory power of model (Nagelkerke =.174), Table 38, meaning that the model explains 17.4% of the variance in the dependent variable (performance post).

Pseudo R-Squared	
Cox and Snell	.158
Nagelkerke	.174
McFadden	.072

Table 38. PRS (4x)

Ordinal regression coefficients

Disruption severity (moderate impact) was statistically significant, showing a 12 times increased probability of going up one level in the dependent variable (performance – lines fulfilled post) compared to the reference category (extreme impact). Strong and moderate impact also showed a large increased probability of going up one level on the dependent variable, compared to the reference category (9.315 and 12.412 respectively) but not to a statistically significant extent. The exponent of the estimate was zero for 'no impact', most likely because of the very low number of cases in this category. SCDO average was not statistically significant, as shown in Table 39. Again, the categories relating to smaller numbers of beds showed increased probability of going up one level on the dependent variable (performance) compared to the reference category (over 500 beds), but the effect was not statistically significant.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERFPOST1 = 1]	2.200	1.816	1.468	1	.226	-1.359	5.760		
	[PERFPOST1 = 2]	2.766	1.822	2.306	1	.129	-.804	6.337		
	[PERFPOST1 = 3]	3.167	1.826	3.008	1	.083	-.412	6.745		
Location	SCDO_AVERAGE _NEW	.252	.437	.333	1	.564	-.604	1.107	1.286	SCDO average
	[Disruptionseverity =1]	-17.231	0.000		1		-17.231	-17.231	0.000	No impact
	[Disruptionseverity =2]	1.120	1.321	.719	1	.397	-1.469	3.710	3.065	Slight impact
	[Disruptionseverity =3]	2.519	1.207	4.356	1	.037	.153	4.884	12.412	Moderate impact
	[Disruptionseverity =4]	2.232	1.189	3.526	1	.060	-.098	4.561	9.315	Strong impact
	[Disruptionseverity =5]	0^a			0				reference category	Extreme impact
	[Beds=1.00]	-1.077	.934	1.328	1	.249	-2.908	.755	0.341	B1 (under 100)
	[Beds=2.00]	-.303	.467	.421	1	.517	-1.219	.613	0.739	B2 (100 to 299)
	[Beds=3.00]	.812	.619	1.722	1	.189	-.401	2.025	2.253	B3 (300-499)
	[Beds=4.00]	0^a			0				reference category	B4 (over 500)

Table 39. Results of ordinal regression

6.5.8 Performance and feedback (5)

Rationale for the analysis

The aim was to investigate proposition P2e; whether there is a positive relationship between the performance feedback given after a supply chain disruption event and higher performance in shortage management, as described in Chapter 3 under the supply chain disruption performance construct.

Hypothesis/Proposition

The null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis). The results of the standard diagnostic test for ordinal regression are presented in the summary of diagnostic tests in Appendix 5.

The goodness of fit test gave a mixed result, with $p<.05$ for Pearson (indicating that there is not goodness of fit), but $p>.05$ for deviance (indicating that there is goodness of fit). This means that there is some uncertainty about whether the model has goodness of fit.

The test of parallel lines shows $p>.05$ and, therefore, we retain the null hypothesis that the slope coefficients are the same across response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall ($p<.001$), Table 40.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	167.609			
Final	136.669	30.941	4	.000

Table 40. Significance (5)

The model had moderate explanatory power (Nagelkerke =.250), Table 41, suggesting that the model explains 25% of the variance in the dependent variable (performance immediate).

Pseudo R-Squared	
Cox and Snell	.224
Nagelkerke	.250
McFadden	.112
Link function: Logit.	

Table 41. PRS(5)

Ordinal regression coefficients

Feedback average was a statistically significant independent variable (*p*<.001, CO 2.440), suggesting that a one unit increase on feedback is associated with a 2.44 increased probability of going up one level on performance, as in Table 42. Although some levels of bed numbers were associated with increased CO compared to the reference category (for example, under 100 beds has CO of 4.233 compared to reference category), none of these were statistically significant.

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/ category name
Threshold	[PERF1 = 1]	-.721	.735	.963	1	.326	-2.162	.719		
	[PERF1 = 2]	1.384	.623	4.926	1	.026	.162	2.606		
	[PERF1 = 3]	3.324	.688	23.348	1	.000	1.976	4.672		
Location	FEEDBACK _AVG_NEW	.892	.180	24.500	1	.000	.539	1.245	2.440	Feedback average
	[Beds=1.00]	1.443	.878	2.699	1	.100	-.278	3.164	4.233	B1 (under 100)
	[Beds=2.00]	.238	.468	.258	1	.611	-.679	1.154	1.268	B2 (100 to 299)
	[Beds=3.00]	.695	.573	1.470	1	.225	-.429	1.819	2.004	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 42. Results of ordinal regression

6.5.9 Performance and feedback (5x)

The following analysis refers to the same variables as in Section 5.9, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for the analysis

The aim was to investigate proposition P2e; whether there is a positive relationship between the performance feedback given after a supply chain disruption event and higher performance in shortage management, as described in Chapter 3 under the supply chain disruption performance construct.

Hypothesis/Proposition

The null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero, and the alternate hypothesis is that they are greater than zero.

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

The results of the standard diagnostic test for ordinal regression are displayed in the summary of diagnostic tests in Appendix 5

The goodness of fit test gave a mixed result, with $p<.05$ for Pearson (indicating that there is not goodness of fit), but $p>.05$ for deviance (indicating that there is goodness of fit). This means that there is some uncertainty about whether the model has goodness of fit.

The test of parallel lines shows $p>.05$ and, therefore, we retain the null hypothesis that the slope coefficients are the same across the response categories of the dependent variable.

The main findings from the ordinal regression are reported below.

Model significance overall

The model was statistically significant overall ($p<.001$), Table 43.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	213.029			
Final	152.746	60.283	5	.000

Table 43. Significance (5x)

The model had high explanatory power (Nagelkerke = .440), Table 44, suggesting that the model explains 44% of the variance in the dependent variable (performance post).

Pseudo R-Squared	
Cox and Snell	.397
Nagelkerke	.440
McFadden	.216

Table 44. PRS (5x)

Ordinal regression coefficients

Feedback from managers was a statistically significant independent variable (*p*=.009, CO 1.644), suggesting that a one unit increase on feedback is associated (as shown in Table 45) with a 1.644 increased probability of going up one level on performance. Feedback from ‘other’ was also statistically significant (*p*<.001, CO 2.386) suggesting that a one unit increase on feedback is associated with a 2.386 increased probability of going up one level on performance. This indicated that both forms of feedback are statistically significant predictors of performance (post) but also that feedback from ‘other’ seems to be a somewhat more powerful predictor than feedback from managers.

Although some levels of bed numbers were associated with decreased or increased CO compared to the reference category, none of these were statistically significant.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERFPOST1 = 1]	2.76	0.739	13.955	1	0	1.312	4.209		
	[PERFPOST1 = 2]	3.518	0.769	20.96	1	0	2.012	5.025		
	[PERFPOST1 = 3]	4.022	0.792	25.8	1	0	2.47	5.574		
Location	FEEDBACK_REGMGR_NEW	0.497	0.19	6.826	1	0.009	0.124	0.87	1.644	Feedback re manager average
	FEEDBACK_regother_NEW	0.869	0.219	15.749	1	0	0.44	1.299	2.386	Feedback re other average
	[Beds=1.00]	-0.597	0.904	0.437	1	0.509	-2.369	1.174	0.55	B1 (under 100)
	[Beds=2.00]	-0.945	0.531	3.166	1	0.075	-1.985	0.096	0.389	B2 (100 to 299)
	[Beds=3.00]	0.505	0.687	0.54	1	0.462	-0.841	1.851	1.657	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 45 - Results of ordinal regression

6.5.10 Buffering, bridging, and performance (6)

Rationale for hypothesis/proposition

The aim was to investigate proposition P2f; whether pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone).

The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

Recoding of variables

An average was created from all the measures of buffering (BUF1 to BUF6) and similarly for bridging (variables BRIPOST 1 to 7). These were the independent variables in the regression. The dependent variable was performance ('lines fulfilled immediate') and bed numbers were included as control variables.

The results of the standard diagnostic test for ordinal regression are shown in the summary of diagnostic tests in Appendix 5.

The goodness of fit test gave a mixed result with $p<.05$ for Pearson (indicating that there is not goodness of fit) but $p>.05$ for deviance (indicating that there is goodness of fit). This means that there is some uncertainty about whether the model has goodness of fit.

The test of parallel lines ($p<.05$) shows that the assumption of the slope coefficients being the same across response categories was not met. However, this is a very conservative test, as we have mentioned earlier, and the model fit is statistically significant and there is some explanatory power in the model, as shown in the Pseudo R Squared. It was decided to retain the model, therefore, despite this assumption not being met.

The main findings from the ordinal regression are reported below.

Model significance overall

The model is statistically significant overall ($p<.05$), but not at a high level of statistical significance, Table 46. This suggests that the model is weak and shows only a slight (though statistically significant) improvement over the intercept alone (as demonstrated clearly in the very similar -2 Log-likelihood figures for the intercept and the final model).

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	240.918			
Final	228.895	12.023	5	.034

Table 46 - Significance (6)

The explanatory power of the model is low (Nagelkerke =.102), Table 47. Suggesting that the model explains 10.2% of the variance in the dependent variable (performance immediate), but still provides some predictive power.

Pseudo R-Squared	
Cox and Snell	.092
Nagelkerke	.102
McFadden	.043
Link function: Logit.	

Table 47. PRS (6)

Ordinal regression coefficients

Table 48 shows that the only independent variable which was statistically significant was BRIPOST average (p=.006, CO 1.693) suggesting that a one unit increase in BRIPOST leads to a 1.693 increase in the probability of increasing one level on the dependent variable (performance) when all other variables are held constant. As with some previous analysis, some effect of bed size can be observed (bed levels 1 to 3 all have greater CO of being in a higher category of performance than the reference category, 500 beds, but this effect is not statistically significant).

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERF1 = 1]	0.091	1.987	0.002	1	0.963	-3.803	3.985		
	[PERF1 = 2]	2.105	1.953	1.162	1	0.281	-1.723	5.933		
	[PERF1 = 3]	3.881	1.977	3.853	1	0.05	0.006	7.757		
Location	BUF1to6_average	0.479	0.54	0.789	1	0.375	-0.579	1.537	1.615	BUF 1 to 6 average
	BRIPOST 1to7_AVG	0.526	0.19	7.665	1	0.006	0.154	0.899	1.693	BRIPOST 1 to 7 average
	[Beds=1.00]	0.794	0.84	0.892	1	0.345	-0.853	2.441	2.211	B1 (under 100)
	[Beds=2.00]	0.423	0.455	0.864	1	0.353	-0.469	1.314	1.526	B2 (100 to 299)
	[Beds=3.00]	0.75	0.537	1.948	1	0.163	-0.303	1.802	2.116	B3 (300-499)
	[Beds=4.00]	0^a			0				reference category	B4 (over 500)

Table 48. Results of ordinal regression

6.5.11 Buffering, bridging, and performance (6x)

The following analysis refers to the same variables as in Section 6.5.10, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for hypothesis/proposition

The aim was to investigate proposition P2f; whether pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone). The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

Recoding of variables

An average was created from all the measures of buffering (BUF1 to BUF6) and also for bridging (variables BRIPOST 1 to 7). These were the independent variables in the regression. The dependent variable was performance ('lines fulfilled post') and bed numbers were included as a control variable.

The results of the standard diagnostic test for ordinal regression are shown in the summary of diagnostic tests in Appendix 5. The goodness of fit test gave $p>.05$ (indicating that there is goodness of fit).

The test of parallel lines ($p<.05$) shows that the assumption of the slope coefficients being the same across response categories was not met. However, this is a very conservative test and as the model is statistically significant and there is some explanatory power in the model, as shown in the Pseudo R Squared, it was decided to retain the model, therefore, despite this assumption not being met.

The main findings from the ordinal regression are reported below.

Model significance overall

The model is statistically significant overall (p<.001), showing a high level of statistical significance, Table 49. This suggests that the model is good and shows a significant improvement over the intercept alone.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	255.591			
Final	209.691	45.900	5	.000

Table 49. Significance (6x)

The explanatory power of the model is high (Nagelkerke =.340), Table 50, suggesting that the model explains 34% of the variance in the dependent variable (performance post), but still provides some predictive power.

Pseudo R-Squared	
Cox and Snell	.307
Nagelkerke	.340
McFadden	.157

Table 50. PRS (6x)

Ordinal regression coefficients

Table 51 shows that BRIPOST average (p<.001, CO 3.778) was statistically significant, suggesting that a one unit increase in BRIPOST leads to a 3.778 increase in the probability of increasing one level on the dependent variable (performance post) when all other variables are held constant. BUF was not statistically significant (p=.070). As with some previous models, some effect of bed size can be observed (bed levels 1 to 3 all have greater CO of being in a higher category of performance than the reference category of 500 beds), but this effect was statistically significant only in the category of 300-499 beds which showed a 3.484 times increased probability of going up one level on the dependent variable (PERFPOST 1) compared to the reference category.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/ category name
Threshold	[PERF POST1 = 1]	-.659	2.107	.098	1	.754	-4.788	3.470		
	[PERF POST1 = 2]	-.027	2.107	.000	1	.990	-4.157	4.104		
	[PERF POST1 = 3]	.434	2.108	.042	1	.837	-3.698	4.567		
Location	BUF1to6_aver	-1.089	.601	3.285	1	.070	-2.266	.089	0.337	BUF 1 to 6

	age									average
	BRIPOST1to7_AVG	1.329	.244	29.620	1	.000	.851	1.808	3.778	BRIPOST 1 to 7 average
	[Beds=1.00]	-.829	.820	1.023	1	.312	-2.436	.777	0.436	B1 (under 100)
	[Beds=2.00]	.093	.485	.037	1	.848	-.857	1.043	1.097	B2 (100 to 299)
	[Beds=3.00]	1.248	.619	4.064	1	.044	.035	2.462	3.484	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 51. Results of ordinal regression

6.5.12 Bridging and buffering in response to supply chain disruption (7)

Rationale for analysis

The aim was to investigate proposition P2g; whether buffering actions in response to supply chain disruption are more effective than bridging actions in shortage management performance, as described in Chapter 3 under the supply chain disruption performance construct.

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone). The results of the standard diagnostic test for ordinal regression are presented in the summary of diagnostic tests in Appendix 5. The goodness of fit test shows that there is a good fit between the data and the model (p>.05).

The test of parallel lines gave p<.05, indicating that the null hypothesis of the test (that the location parameters, or slope coefficients, are the same across response categories) should be rejected. The assumption of parallel lines is not met.

The main findings from the ordinal regression are reported below.

Model significance overall

The model overall was not statistically significant (p>.05), Table 52. Therefore, we accept the null hypothesis (that the coefficients of all the independent variables are equal to zero).

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept	228.210			

Only				
Final	224.031	4.179	5	.524
Link function: Logit.				

Table 52. Significance (7)

The explanatory power of the model was very low (Nagelerke .037), Table 53, suggesting that the model explains just 3.7% of the variance in the dependent variable (performance immediate). This is not surprising given that the model overall is not statistically significant.

Pseudo R-Squared	
Cox and Snell	.033
Nagelkerke	.037
McFadden	.015
Link function: Logit.	

Table 53. PRS (7)

Ordinal regression coefficients

None of the independent variables in the model were statistically significant. BUF average shows some increased probability of being at a higher level in the dependent variable, as do the lower levels within the variable bed numbers but not to a statistically significant extent. As shown in Table 54, BRI shows a negative estimate coefficient (-.165), which translates into a CO of less than 1 (0.848). This means that, as BRI increases, so the probability of being at a higher level in the dependent variable decreases, but not to a statistically significant extent.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/ category name
Threshold	[PERF1 = 1]	-1.580	2.025	.609	1	.435	-5.550	2.389		
	[PERF1 = 2]	.352	1.982	.032	1	.859	-3.533	4.238		
	[PERF1 = 3]	2.067	1.992	1.077	1	.299	-1.837	5.970		
Location	BUF1to6_average	.535	.559	.914	1	.339	-.561	1.631	1.707	BUF1to6_average
	BRI1to7_average	-.165	.229	.521	1	.470	-.614	.284	0.848	BRI1to7_average
	[Beds=1.00]	.874	.835	1.094	1	.296	-.763	2.511	2.396	B1 (under 100)
	[Beds=	.243	.454	.288	1	.592	-.646	1.133	1.276	B2 (100 to

	2.00]									299)
	[Beds= 3.00]	.762	.534	2.037	1	.154	-.285	1.809	2.143	B3 (300-499)
	[Beds= 4.00]	0^a			0				reference category	B4 (over 500)

Table 54. Results of ordinal regression

6.5.13 Bridging and buffering in response to supply chain disruption (7x)

The following analysis refers to the same variables as in section 6.5.12, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for analysis

The aim was to investigate proposition P2g; whether buffering actions in response to supply chain disruption are more effective than bridging actions in shortage management performance, as described in Chapter 3 under the supply chain disruption performance construct.

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone). The results of the standard diagnostic test for ordinal regression are provided in the outline of diagnostic tests in Appendix 3

The goodness of fit test shows that there is a good fit between the data and the model ($p>.05$). The test of parallel lines gave $p>.05$ indicating that the null hypothesis of the test (that the location parameters (slope coefficients) are the same across response categories) should be retained. The assumption of parallel lines is met.

The main findings from the ordinal regression are reported below.

Model significance overall

The model overall was statistically significant ($p<.001$), Table 55. Therefore, we reject the null hypothesis (that the coefficients of all the independent variables are equal to zero).

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	287.689			
Final	229.172	58.517	5	.000

Table 55. Significance (7x)

The explanatory power of the model is high (Nagelkerke .414), Table 56, suggesting that the model explains 41.4% of the variance in the dependent variable (performance post). This is not surprising given that the model overall is not statistically significant.

Pseudo R-Squared	
Cox and Snell	.374
Nagelkerke	.414
McFadden	.200

Table 56. PRS (7x)

Ordinal regression coefficients

BUFPOST ($p<.001$, CO 0.349) and BRIPOST ($p<.001$, CO 3.730) were statistically significant. These statistics indicate that for a one unit increase in BUFPOST there is a 0.349 times reduced probability of increasing one unit on the dependent variable (PERFPOST1, as shown in Table 57). As the CO is less than one, this signifies a decreased probability of going up one unit on the dependent variable and implies a negative relationship between the BUFPOST and the dependent variable. BRIPOST has a positive relationship with the dependent variable (for example, a one unit increase in BRIPOST leads to a 3.73 probability of going up one level on the RV). There was no significant relationship between bed numbers and the dependent variable.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERFPOST 1 = 1]	0.405	1.033	0.154	1	0.695	-1.619	2.43		
	[PERFPOST 1 = 2]	1.085	1.037	1.095	1	0.295	-0.948	3.118		
	[PERFPOST 1 = 3]	1.6	1.043	2.353	1	0.125	-0.444	3.644		
Location	BUFPOST 1to6_average	-1.052	0.291	13.055	1	0	-1.623	-0.481	0.349	BUFPOST1to6_average
	BRIPOST 1to7_AVG	1.316	0.241	29.849	1	0	0.844	1.789	3.73	BRIPOST1to7_AVG
	[Beds=1.00]	-0.651	0.834	0.609	1	0.435	-2.284	0.983	0.522	B1 (under 100)
	[Beds=2.00]	-0.099	0.501	0.039	1	0.843	-1.08	0.882	0.905	B2 (100 to 299)
	[Beds=3.00]	0.945	0.632	2.238	1	0.135	-0.293	2.183	2.573	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 57. Results of ordinal regression

6.5.14 Bridging and buffering in response to supply chain disruption (8)

Rationale for analysis

The aim was to investigate proposition 3i; whether the impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact, as described in Chapter 3, under the organisational response construct.

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone). The rationale for choice of test (ordinal regression) is discussed in Section 6.4 (Analysis).

The results of the standard diagnostic test for ordinal regression are shown in the summary diagnostics tests in Appendix 5. As both Pearson and deviance statistics are $p>.05$, the data has goodness of fit with the model.

The test of parallel lines gave $p<.05$ showing the null hypothesis of the test (that the location parameters, or slope coefficients, are the same across response categories) should be rejected. The assumption of proportional odds was not met which means that there is some uncertainty about the validity of the results. However, as the model is statistically significant, the goodness of fit was passed, and the model has some explanatory power it was decided to retain the model.

The main findings from the ordinal regression are reported below.

Model significance overall

The model overall was statistically significant (p<.05), Table 58, therefore, the null hypothesis was rejected and the alternate hypothesis accepted.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	279.012			
Final	264.126	14.885	7	.037

Table 58. Significance (8)

The model showed low explanatory power (Nagelkerke .126), Table 59, indicating that the model explained 12.6% of the variance in the dependent variable (performance immediate).

Pseudo R-Squared	
Cox and Snell	.113
Nagelkerke	.126
McFadden	.053

Table 59. PRS (8)

Ordinal regression coefficients

The only independent variable which was statistically significant was BRIPOST (p=.001, CO 1.922) indicating that for a one unit increase in BRIPOST, the probability of going up one level increases by a factor of 1.922. BUF and BUFPOST showed positive relationships with the dependent variable (performance), but not to a statistically significant extent. BRI was the only independent variable which showed a negative relationship with the dependent variable (for a one unit increase in BRI, the probability of being at a higher level of the dependent variable decreased slightly), although the effect was not statistically significant, as shown in Table 60. Again, a smaller number of beds showed a positive relationship with the dependent variable, but not to a statistically significant extent (all categories in bed numbers showed increased chances of being at a higher level in the dependent variable of performance than the reference category of over 500 beds, but not to a statistically significant extent).

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERF1 = 1]	-0.662	2.079	0.101	1	0.75	-4.736	3.412		
	[PERF1 = 2]	1.302	2.041	0.407	1	0.524	-2.699	5.303		
	[PERF1 = 3]	3.131	2.06	2.31	1	0.129	-0.907	7.169		
Location	BUF1to6_average	0.26	0.58	0.201	1	0.654	-0.877	1.397	1.297	BUF1to6_average
	BUFPOST1to6_average	0.261	0.29	0.809	1	0.368	-0.307	0.828	1.298	BUFPOST1to6_average
	BRI1to7_average	-0.424	0.275	2.383	1	0.123	-0.962	0.114	0.654	BRI1to7_average
	BRIPOST1to7_AVG	0.653	0.205	10.171	1	0.001	0.252	1.055	1.922	BRIPOST1to7_AVG
	[Beds=1.00]	0.776	0.85	0.834	1	0.361	-0.889	2.442	2.173	B1 (under 100)
	[Beds=2.00]	0.471	0.465	1.022	1	0.312	-0.442	1.383	1.601	B2 (100 to 299)
	[Beds=3.00]	0.794	0.548	2.103	1	0.147	-0.279	1.867	2.213	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 60. Results of ordinal regression

6.5.15 Bridging and buffering in response to supply chain disruption (8x)

The following analysis refers to the same variables as in Section 5.16, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for analysis

The aim was to investigate proposition P3i; whether the impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact, as described in Chapter 5, under the organisational response construct.

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone). The rationale for choice of test (ordinal regression) is discussed in Section 6.4

The results of the standard diagnostic test for ordinal regression are summarised in the diagnostic tests in Appendix 5. As both Pearson and deviance statistics are p>.05, the data has goodness of fit with the model. The test of parallel lines gave p>.05, showing the null hypothesis of the test (that the location parameters, or slope coefficients, are the same across response categories) should be retained. The assumption of parallel lines is met.

The main findings from the ordinal regression are reported below.

Model significance overall

The model overall was statistically significant (p<.001), Table 61, therefore, the null hypothesis was rejected and the alternate hypothesis accepted.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	288.215			
Final	217.153	71.062	7	.000

Table 61. Significance (8x)

The model has very high explanatory power (Nagelkerke .484), Table 62, indicating that the model explained nearly half (48.4%) of the variance in the dependent variable (performance post).

Pseudo R-Squared	
Cox and Snell	.436
Nagelkerke	.484
McFadden	.247

Table 62. PRS (8x)

Ordinal regression coefficients

BRI and BRI post were statistically significant independent variables, but BRI has a negative relationship with the dependent variable (PERFPOST 1), being associated with a 0.343 probability of going up one level in the dependent variable while BRIPOST has a positive relationship with the dependent variable, being associated with a 5.889 times increased probability of going up one level in the dependent variable, as shown in Table 63.

Lower levels of beds showed a negative relationship with the dependent variable, but not to a statistically significant extent (categories 1 and 2 in bed numbers showed decreased chances of being at a higher level in the dependent variable of performance than the reference category of over 500 beds). Category 3 of beds showed increased chances of going up one level in the dependent variable compared to the reference category but again this was not to a statistically significant extent.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERFPOST1 = 1]	-3.778	2.31	2.675	1	0.102	-8.306	0.749		
	[PERFPOST1 = 2]	-3.102	2.303	1.815	1	0.178	-7.615	1.411		
	[PERFPOST1 = 3]	-2.506	2.297	1.19	1	0.275	-7.008	1.996		
Location	BUF1to6_average	-1.074	0.658	2.66	1	0.103	-2.364	0.217	0.342	BUF1to6_average
	BUFPOST 1to6_average	-0.614	0.325	3.577	1	0.059	-1.25	0.022	0.541	BUFPOST1to6_average
	BRI 1to7_average	-1.07	0.358	8.932	1	0.003	-1.772	-0.368	0.343	BRI1to7_average
	BRIPOST 1to7_AVG	1.773	0.311	32.488	1	0	1.163	2.383	5.889	BRIPOST1to7_AVG
	[Beds=1.00]	-1.026	0.882	1.353	1	0.245	-2.755	0.703	0.358	B1 (under 100)
	[Beds=2.00]	-0.153	0.527	0.084	1	0.772	-1.186	0.88	0.858	B2 (100 to 299)
	[Beds=3.00]	1.08	0.661	2.67	1	0.102	-0.215	2.376	2.945	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference cate	B4 (over 500)

Table 63. Results of ordinal regression

6.5.16 Varying response - effect on performance (9)

Rationale for the analysis

The aim was to investigate proposition 3h; whether varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management, as described in Chapter 3, under the organisational response construct. The rationale for choice of test (ordinal regression) is discussed in Section 6.4

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone).

The results of the standard diagnostic test for ordinal regression are summarised in the diagnostic tests in Appendix 5. Since p>.05, we retain the null hypothesis that the model has goodness of fit. As p<.05, we reject the null hypothesis that the location parameters (slope coefficients) are the same across response categories. In addition, the assumption of proportional odds is not met. This means that the findings may be unreliable, although as mentioned earlier this is a very conservative test.

The main findings from the ordinal regression are reported below.

Model significance overall

The model overall is not statistically significant (p=.098), Table 64. The model does not add any predictive power as compared to no model (intercept only). Therefore, we accept the null hypothesis and reject the alternate hypothesis.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	142.457			
Final	133.161	9.296	5	.098

Table 64. Significance (9)

The explanatory power of the model is very low (as we might expect given that the model overall is not statistically significant), Table 65. The Nagelkerke value of .080 suggests that just 8% of the variance in the dependent variable (performance immediate) is explained by the model.

Pseudo R-Squared	
Cox and Snell	.072
Nagelkerke	.080
McFadden	.033

Table 65. PRS (9)

Ordinal regression coefficients

Although the model overall was not statistically significant, as shown in Table 66, one independent variable (vary response internally) was statistically significant (p=.029, CO

1.622), suggesting that a one-unit increase in 'vary response internally' leads to a 1.622 increase in the probability of going up one level on the dependent variable (performance).

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval		Cumulative Odds (CO)	Variable/category name
							Lower Bound	Upper Bound		
Threshold	[PERF1 = 1]	-0.904	1.14	0.629	1	0.428	-3.139	1.33		
	[PERF1 = 2]	1.123	1.071	1.1	1	0.294	-0.975	3.221		
	[PERF1 = 3]	2.867	1.098	6.813	1	0.009	0.714	5.019		
Location	Varyrespintern _NEW	0.484	0.222	4.739	1	0.029	0.048	0.919	1.622	Varyrespintern_NEW
	Varyresptime _NEW	0.059	0.239	0.06	1	0.806	-0.411	0.528	1.061	Varyresptime_NEW
	[Beds=1.00]	1.064	0.835	1.623	1	0.203	-0.573	2.702	2.899	B1 (under 100)
	[Beds=2.00]	0.352	0.445	0.627	1	0.429	-0.519	1.223	1.422	B2 (100 to 299)
	[Beds=3.00]	0.924	0.535	2.982	1	0.084	-0.125	1.973	2.52	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 66. Results of ordinal regression

6.5.17 Varying response - effect on performance (9x)

The following analysis refers to the same variables as in Section 6.5.16, but with PERFPOST1 rather than PERF1 as the dependent variable

Rationale for the analysis

The aim was to investigate proposition P3h; whether varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management, as described in Chapter 3, under the organisational response construct. The rationale for choice of test (ordinal regression) is discussed in Section 6.4.

Hypothesis/Proposition

The global null hypothesis in ordinal regression is that the coefficients of all the independent variables are equal to zero and the alternate hypothesis is that they are greater than zero (that the model has greater predictive power than the intercept alone).

The results of the standard diagnostic test for ordinal regression are provided in the summary of diagnostic tests in Appendix 5. Since p>.05, we retain the null hypothesis that the model has goodness of fit. As p<.05, we reject the null hypothesis that the location parameters (slope coefficients) are the same across response categories and the assumption of proportional odds is not met. This means that the findings may be unreliable.

The key findings from the ordinal regression are reported below.

Model significance overall

The model overall is not statistically significant (p=.106), Table 67. The model does not add any predictive power as compared to no model (intercept only). Therefore, we accept the null hypothesis and reject the alternate hypothesis.

Model Fitting Information				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	149.122			
Final	140.042	9.080	5	.106

Table 67. Significance (9x)

The explanatory power of the model is very low (as we might expect given that the model overall is not statistically significant), Table 68. The Nagelkerke value of .078 suggests that just 7.8% of the variance in the dependent variable (performance post) is explained by the model.

Pseudo R-Squared	
Cox and Snell	.070
Nagelkerke	.078
McFadden	.031

Table 68. PRS (9x)

Ordinal regression coefficients

None of the independent variables were statistically significant which is to be expected given that the model overall was not statistically significant, as shown in Table 69.

Parameter Estimates										
		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval			
							Lower Bound	Upper Bound	Cumulative Odds (CO)	Variable/category name
Threshold	[PERFPOST1 = 1]	-0.642	1.095	0.343	1	0.558	-2.787	1.504		
	[PERFPOST1 = 2]	-0.138	1.093	0.016	1	0.899	-2.281	2.005		
	[PERFPOST1 = 3]	0.21	1.093	0.037	1	0.847	-1.932	2.353		
Location	Varyrespintern _NEW	0.204	0.227	0.806	1	0.369	-0.241	0.648	1.226	Varyrespintern_NEW
	Varyresptime _NEW	-0.186	0.247	0.567	1	0.451	-0.67	0.298	0.83	Varyresptime_NEW
	[Beds=1.00]	-0.613	0.811	0.571	1	0.45	-2.203	0.976	0.542	B1 (under 100)
	[Beds=2.00]	-0.328	0.447	0.538	1	0.463	-1.203	0.548	0.721	B2 (100 to 299)
	[Beds=3.00]	0.857	0.552	2.414	1	0.12	-0.224	1.939	2.357	B3 (300-499)
	[Beds=4.00]	0[a]			0				reference category	B4 (over 500)

Table 69. Results of ordinal regression

6.6 Cross-cutting analysis

The aim of this part of the data analyses is to select triangulation sources that have different foci and different strengths so that they can complement each other, as recommended by Miles, Huberman and Saldana (2014). Using triangulation enables corroboration from diverse sources which enhances the trustworthiness of our analysis. However, where conflicting and inconsistent findings are identified due to different data facets and data collection methods used, their combined effects build on each other to compose a three-dimensional perspective of the phenomena under consideration.

After bringing together the data analysis of both the quantitative and qualitative methodologies proposition by proposition, the multi data sources were scrutinised and summarised, as below, with each proposition being addressed in turn highlighting the analysis foundation.

Proposition 1a: the stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management

Using information drawn mainly from survey SPSS backed up by the focus group, the quantitative analysis showed a statistically significant relationship between SCDO and immediate performance, which increases by a factor of 25.48 for every one unit of SCDO. Although there was a similar positive relationship with SCDO for post-performance, it was not statistically significant. From the focus groups, it was noted that during the big shortages some units are managing it better than others, not just simply the availability of stock in different regions, with the emphasis being on the orientation of the team involved. The orientation of the unit with regards to supply chain disruptions, according to the focus groups' word cloud outputs, were that it was a valuable factor in successful shortage management. In addition, the predominate advice given from the interviews by the managers that showed the highest performance (+8 out of 10) was the vigilant orientation category (Figure 33).

Proposition 1b: the lower the role of the actor responsible for making supply chain disruption action decisions, the lesser the shortage management performance

From the quantitative analysis, no statistical relationship was shown for role and shortage performance with either immediate or post-performance. However, the results from the interviews did show a strong relationship with role, with the stand-out role against performance being a senior role and, by contrast, the less qualified role of pharmacy technician scoring lowest on both shortage performance and patient performance.

Proposition 1c: the larger the number of hospitals in a trust, the stronger the supply chain disruption orientation of a unit

The one consistent from both the focus groups and interviews was that, although size did have influence on the performance of post disruption shortage management, the strength and possible causation of that relationship and also the direction was not simple to quantify, with mixed explanations in either direction from the qualitative research analysis.

However, the results from the quantitative analysis showed no significant relationships between the number of hospitals in a trust and stronger disruption orientation***.***

Proposition 1d: the higher the severity of the disruption, the better the managers with higher supply chain disruption orientation perform

From the quantitative analysis, categories 2, 3, and 4 of disruption severity are associated with increased probability (ranging from 5.637 to 8.755) of going up one level on the dependent variable immediate performance, compared to the reference category (extreme impact), as well as a moderate association of disruption severity with the post-performance variable.

The focus groups also indicated that there was a difference in the performance from different hospital units, with ‘response complaint noise’ being higher in supply chain managers that were not so strongly supply chain orientated.

Proposition 2e: there is a positive relationship between the performance feedback given after a supply chain disruption event and higher performance in shortage management

From the quantitative analysis, there was a significant relationship between both immediate and post shortage performance with feedback given. With both immediate and post-performance having a statistically significant positive relationship at the ($p<0.001$) level, R squared 2.44. In the case by case qualitative variable analysis, during the interviews 66.67% of the cases gave 'really good' feedback, averaging 8.25

for performance shortage and 8.17 for performance patient, showing a very strong positive relationship.

Similarly, the focus groups noted the importance of feedback for good performance, with a successful team dynamic being described as having good feedback interaction from the clinical team prescribing the drugs for the patients on the hospital wards. Again, from all the focus groups' query output run on the NVivo software, the word cloud had feedback as a dominant theme mentioned.

Proposition 2f: pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management

From the quantitative analysis, there was a significant relationship between post bridging actions and immediate performance, and both buffering immediate and post bridging actions in post shortage performance. In the interviews, although there was no set pattern of which actions were taken, it was often indicated that the buffering action was the first common response. However, in both the interviews and the focus groups, a high level of complexity was involved, and the dynamic nature of the response spectrum was predominating, with those that dynamically reacted quickly having the best performance.

Proposition 2g: buffering actions in response to supply chain disruption are more effective than bridging actions in shortage management performance

From the quantitative analysis, no association between buffering and bridging actions were shown with immediate performance, however there was strong association between buffering post and bridging post actions with improved shortage performance, and a negative relationship between post buffering and performance and a positive relationship between post bridging and post-performance.

This finding was confirmed by the interviews' cross-case variable analysis, with a higher shortage management performance in bridging than buffering (averaging 8 out of a possible 10 compared to average 6.3 out of 10 respectively), with the use of bridging and buffering in combination scoring highest.

Proposition 3h: varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management

From the interviews, there was a strong relationship between using dynamic actions and performance in shortage management, with a dynamic average of 8.30 from a possible score of 10 for performance shortage management and 8.10 for performance patient. Similarly, this was confirmed in the focus groups with change and performance being key themes. By varying response actions over time, the general consensus from the group discussions was that this would be the most effective approach.

However, although there was a relationship, there was no statistically significant relationship demonstrated by the quantitative analysis.

Proposition 3i: the impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact

From the quantitative analysis, there was a significant relationship with bridging actions and immediate performance over time, and similarly with bridging actions and post-performance (R^2=0.48), with buffering actions also showing a positive relationship, although not a statistically significant one.

The interviews saw the constant dynamic actions of both buffering and bridging having a changing impact, with over 8 out of 10 being constant dynamic actions. In addition, the focus groups commented that a buffering action, for example, would change in impact in the first 8 weeks compared to the period 8 to 16 weeks because of the change in supply availability.

6.7 Summary

In summary, Chapter 6 presents the data analysis of both the qualitative methodology first and then the quantitative methodology in a mixed method approach. It ends by considering the joint analysis for each of the 9 propositions in turn. By ultimately combining the results of the analysis in a cross cutting narrative, including conflicts, it allows a synthesis of the results to highlight the new empirical contribution through insights to the existing post disruption theory framework and understanding.

Chapter 7, following an introduction, discusses these research results and analysis in the wider theoretical and management setting. It considers the implications and contributions of both the academic and managerial in separate sections and then ends with the discussion summary.

7 Discussion

7.1 Introduction

This chapter will begin by re-introducing the key research themes identified in Chapters 1 to 3, the introduction, research background, supply chain review of pharmaceuticals and disruptions and the research question, to provide context for this research's discussion. It will then discuss and critique the data findings and analysis in Chapters 5 and 6 and its contribution to the theoretical landscape to give meaning to the research. Following this, the next section considers the management implication for this research in the intense pressure of the pharmaceutical delivery 'coal face'. Lastly, this chapter will conclude by providing a summary of the discussions before going on to introduce the research conclusions chapter: Chapter 8.

The heightened interest in the better management of supply chain disruptions has been largely due to the rising costs associated with their impact. The need to improve supply chains' resilience to these disruptions has prompted the growing importance of this research area. Supply chain resilience has been considered in literature from multiple perspectives including, but not limited to, crises management (Grewal, Johnson and Sarker, 2007), industrial systems and engineering (Ng and Sy, 2014, Li and Zhao, 2010), network theory (Greening and Rutherford, 2011, Peck, 2005, Turnquist and Vugrin, 2013), risk management and systems theory (Wagner and Neshat, 2010, Gaudenzi and Borghesi, 2006, Ho, Zheng, Yildiz et al., 2015). All of these approaches have their strengths and weaknesses, for example, the Greening and Rutherford (2011) research included an extensive review of 485 articles including transaction cost economics (TCE), resource dependency, resource based theory (RBT), buyer-seller, economic organisation, network formation, social network, and supply chain disruption but no testing of hypothesis.

Following on from the extensive literature review, this research extends the novel framework theory of earlier academic work on understanding the antecedents of managers' responses to supply chain disruptions by Bode, Wagner, Petersen et al. (2011), jointly based on an information processing theory (Galbraithe, 1973, Tushman and Nadler, 1978) and resource dependency theory perspective (Pfeffer and Salancik, 1978). The Bode, Wagner, Petersen et al. (2011) research addressed the call to augment resource dependency theory with other theoretical lenses (Hillman, Withers and Collins, 2009) and was pioneering in the context of interfirm relationships, with the exception of qualitative studies by (Grewal, Johnson and Sarker, 2007, Primo and Dooley, 2007). By building resource dependency and information theory background and then considering the disruption coping strategies on the response spectrum to be buffering and bridging, this built on the prior research work on large American firms and environmental and organisational determinants in activities that 'buffer' from the social political environment, and activities which 'bridge' with that uncertain environment (Meznar and Nigh, 1995). Their research work pulled from previous work related to contingency theory (Fisher, 1998), resource dependency theory and strategic management. From the original theory, Bode, Wagner, Petersen et al. (2011) framework, supply chain disruption orientation was shown to be a main effect subsequent to the occurrence of a disruption in a firms motivation to act, where stability is the conjoint driving force for firms to take response actions drawn from both information processing theory (Galbraithe, 1977) and resource dependency theory (Pfeffer and Salancik, 1978), with supply chain orientation having the greatest effect to directly affect bridging and buffering. The Bode, Wagner, Petersen et al. (2011) research found that a high supply chain disruption orientation makes a firm more likely to craft and execute a specific response for reducing the likelihood and impact of future supply chain disruptions. However, although it was suggested that this might lead to superior performance and competitive advantage because of earlier work on the performance success of information processing approaches to change (Miller and Friesen, 1982) and quick and precise responses to environmental changes being linked to superior performance (Edmondson, 1996, Dyck, Frese, Baer et al., 2005), supply chain disruption orientation was never before empirically tested against post disruption performance outcomes.

This research did test this hypothesis directly and further broke down the performance captured into the dynamic output that it is, i.e., into time sections from the disruption occurrence. By considering the response actions as dynamic, rather than static and ‘either or’ and then further examining the resultant post response performance in shortage management, this research empirically tested a moving response output to specific supply chain disruption events. Other research taking an industrial systems and engineering perspective looking at resilience optimisation problems have taken a dynamic approach (Ng and Sy, 2014); looking at dynamic transient behaviour when system parameters are imprecisely known. This has its theoretical roots in stock management dynamic system model (Sterman, 1989) and Industrial Dynamics (Forrester, 1961).

Sections 7.2 and 7.3 discuss the theoretical and managerial implications of the findings and analysis of this research.

7.2 Theoretical Implications from the research

Several important academic implications emerge from the research results, and these will be addressed per construct with the main findings from each of the propositions in the following sections.

7.2.1 Supply chain disruption orientation construct

The first construct considered in the research was supply chain disruption orientation through the testing of the propositions (P1a-P1d). Supply chain disruption orientation was a new concept introduced into the supply chain management literature by Bode, Wagner, Petersen et al. (2011) in considering post disruption response actions. This research findings from proposition 1a were that the stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management, and was indeed confirmed as statistically significant by the quantitative methodology. This was true for both immediate shortage management performance (up to 8 weeks) and post shortage management performance (8 to 16 weeks). Further, it was also supported by both of the qualitative research procedures used; the interviews and the focus groups' analysis.

This supports the normative speculation by Bode, Wagner, Petersen et al. (2011), and also previous studies emphasising the importance of firms' orientations and cultural traits in enhancing a firm's capabilities for dealing with adverse events (Edmondson, 1996, Dyck, Frese, Baer et al., 2005). It also confirms previous work in the risk management literature by Autry and Bobbitt (2008), for example, where they considered orientation towards risk and operational performance. From information processing theory, organisations maybe more active in using information more effectively and perform higher to influence its uncertain environment (Galbraithe, 1973). Further, firms with a high supply chain disruption orientation would be more likely to be active in their approach, drawing on the research work by Daft and Weick (1984). Active firms are both proactive and assertive, so are less likely to accept the environment as a given, so rather than being slower to respond like a passive firm would behave, active firms are more likely to be quick to respond. This speed of response to supply chain disruptions has been identified as important in previous work in the literature considering factors underlying supply chain disruption response (Chadist, 2012, Johnson, 1999, Grewal, Johnson and Sarker, 2007). Based on their empirical research, Chadist (2012) proposed four constructs in the relationship between response time and factors underlying response; preparation, organisational development, partnerships, and appropriate reserves. However, the theory that greater response speed can reduce the impact of disruption is a broad statement, and this research went deeper into the response alternatives into immediate and post response actions and their relative immediate and post performances on shortage management in the dynamic post disruption environment. This research found that different actions were taken at different stages of the post disruption time gap and different performances were the output. The interplay between the response actions over time has an effect on performance outcomes, for example, taking post buffering actions on their own led to poor performance. So, using reserves by increasing capacity or inventory at a certain timeline from the disruption can have an adverse effect on performance; the key relationship is that between the supply chain orientation and performance. The dynamic decisions made by the higher supply chain orientated firms about whether to expand interfirm or intra firm dependencies are more likely, according to this research, to have better performance outcomes.

The research findings of the proposition P1b showed mixed results, with the P1b testing that the lower the role of the actor responsible for making supply chain disruption actions decisions, the lesser the shortage management performance. The results showed no statistically significant relationship from the quantitative methodology, but a relationship between higher role and performance in the qualitative interviews. This was in contrast to previous quantitative findings on boundary rationality bias based on real options theory (Tiwana, Wang, Keil et al., 2007). Proposition P1b was included to try and take account of the boundary conditions, based on boundary rationality theory (Simon, 1979) in which a firm makes response decisions. Boundary rationality encompasses two central concepts: search and satisfying. The search scope is capped by what Simon (1979), describes as an aspirational level that defines at the outset of the search process what constitutes a good enough solution. It could be argued that the lower the role an individual manager has in an organisation, the less scope they would have in the response actions they can take. Prior research confirmed this with higher management associated with more bridging actions (Andrews, 1971, Freeman, 1984). Mintzberg (1973) also considered managerial roles as how decision making choices and their requirements are determined by the manager's role. The limits that managers have by their ability to process large amounts of complex data and the access to that data can affect the ultimate outcomes (Hult, Ketchen and Slater, 2004).

From the qualitative method of interviews, there was an equal spectrum of respondents who had either limited access to information and easy access to multiple sources of information, each comprising a third of the total interviewees. This suggests that those charged with managing shortages do not have a uniformed standard when it comes to accessing information. However, over a quarter of those interviewed did have multiple sources of information. This is an explanation of why there was some variation in the level of shortage performance. This is in line with previous research but it is only a weak result as it is not supported by the quantitative results.

Proposition 1c, was that the larger the number of hospitals in a trust, the stronger the supply chain disruption orientation of a unit. In previous research, system membership was reported as an important factor in selecting response actions to uncertainty, probably as a result of corporate policies intended to centralise functions and minimise costs (Fennell and Alexander, 1987). Size was a salient factor, as noted in previous research studies; for example, by Pfeffer and Salancik (1978) who proposed that largeness increases organisational power relative to a firms environment, and the relationship between a firm and its external environment depends on the firm's scale. However, the results from this research were in contrast to prior research and no statistically significant relationship was proven in the quantitative tests between the larger the number of hospitals in a trust and the supply chain orientation of a unit. Although the qualitative methods showed some relationship, the results were mixed, so again no strong positive relationship. However, the qualitative interviews and focus groups did give insights as to why this could be, including that each hospital and each group of hospitals forming a trust have different functional and managerial priorities, such as focuses on surgery or emergency specialities or workloads, but also that the staff orientation in a particular hospital was not determined by size. For example, in this research one participant who had worked in the different environments of both a large urban hospital and a smaller regional hospital had observed a contrasting management team supply chain orientation. At odds with the extant literature, it was observed by the participant that the smaller regional hospital had a better supply chain orientation, including speed of response to supply chain disruptions. The explanation given was not only the improved agility in getting actions completed due to the closer proximity between departments and short decision management chain, but the overall commitment and drive to get the shortage problems relieved was greater in the regional hospital; whereas in the larger hospital trust, there was less individual responsibility taken for actions in response to disruptions. In general, this research determined no statistically significant pattern between the variables of size and supply chain orientation, in either a positive or a negative direction. This could be due to the diversity of the organisations involved or to other factors to be determined by further research in this area.

Proposition 1d of the supply chain disruption orientation construct tested whether the higher the severity of the disruption, the better the managers with higher supply chain disruption orientation perform. In earlier research on supply chain disruptions by Hendricks and Singhal (2005), it was observed that organisations do not perform uniformly. (Liu and Cruz, 2012) studied the impact of corporate financial risk and economic uncertainty on the values, profit and decisions of supply chains. They found that suppliers are willing to sacrifice some profit margins to gain more business from manufacturers with lower financial risk and with lower sensitivity to economic uncertainty. However, their approach was based on simulated data instead of using real data. Prior research also suggested a correlation between increased resilience and improved supply chain performance (Pettit, Fiskel and Croxton, 2013). Criticisms could be raised on the methodological approach of their single methodology of focus group, and their research was also based on a single company in the retail vertical over a short period, although it does contain a strong conceptual basis and detailed taxonomy.

This research, based on both quantitative and multiple methods qualitative research, found a statistically significant relationship between the higher severity of the disruption, the better the managers with higher supply chain disruption orientation perform. In the quantitative results, the shortage performance of the highly supply chain orientated units were highest on the immediate (up to 8 weeks) performance and moderate with the post (8 to 16 weeks) shortage management performance. The qualitative methods also produced strong relationships between higher severity disruptions and higher shortage performance, particularly from all the focus groups' outputs. So, in severe disruption situations the higher units performed better overall, which is in agreement with the extant literature on supply chain risk management. However, as this concept of supply chain disruption orientation is a new concept, albeit based on previous work on active and passive firms, for example Daft and Weick (1984), it is the first time it has been tested empirically as a concept. Further, it not only tests the concept of supply chain disruption orientation against disruption severity against real data based on real performance, it looks at the changes in performance over time from the start of the disruption. This is important as when deploying a strategy to mitigate the impact of a supply chain disruption, be it severe or not so severe, managers responsible for taking action choices need to know which is the best option through the disruption period, not just what to do when the disruption first strikes.

As shown in the results of this research, the higher supply chain disruption orientated units perform best in shortage management immediately after the disruption, and although this high performance is still better than their peers in the post-performance (8 to 16 weeks), there is a drop off in level. This could be accounted for perhaps by complacency but more likely is that disruption response choices are limited for all managers, whether their unit is of high supply chain disruption orientation or not. In addition, as the disruption progresses more information becomes available from the interfirm relationships (Grewal, Johnson and Sarker, 2007). However, even in these difficult circumstances, the research results show a higher performance for the larger severity disruptions both immediately and post the disruption impact. By addressing the research gap, this research also addresses the lack of research and practitioner based studies in comprehensively addressing the selection of the most appropriate strategies in particular scenarios. As noted by Ho, Zheng, Yildiz et al. (2015) in their research on supply chain risk management, scholars should evaluate and select the best mitigation strategies among various individual and integrated strategies with respect to both efficiency and effectiveness.

7.2.2 Supply chain disruption performance

The second construct in this research study was supply chain disruption performance through the testing of the propositions (P2e-P2g). The first proposition tested was P2e: that there is a positive relationship between the performance feedback given after supply chain disruption event and higher performance in shortage management. Making disruption response decisions that give either a positive or sub optimal performance are ‘of the moment’ unless the managers and organisations can learn from that performance (Peck, 2005). Choosing the option that seems correct at the time may take account of real options but if taken within a managerial vacuum, the effect of those decisions and the knowledge gained from those choices will be lost. Actors making autonomous response decisions may hold disparate views, and their interpretations may overlap without reaching consensus on meaning (Gioia and Thomas, 1996). This research extends the previous work on post disruption response decision making, because although the supply chain disruption performance construct of this research is grounded in the information processing perspective, as did Bode, Wagner, Petersen et al. (2011) and (Bowersox, Closs and Stank, 1999), it also draws upon the organisational learning literature. It also refers to the previous work by Hedberg (1981), which raised the question of whether firms forget what they have learned from previous supply chain disruptions. In summarising the extant literature of organisational learning, Hult, Ketchen and Slater (2004) identified four key learning elements: knowledge acquisition, information distribution, information interpretation, and organisational memory. By including the support of empirical performance information from prior and ongoing response decisions, diverse views on concepts can be resolved.

This research found that the proposition P2e between feedback and performance to be confirmed as having a significant relationship in the quantitative analysis, with both a strong relationship with the immediate (up to 8 weeks) shortage performance and a clear relationship with the post (8 weeks to 16 weeks) shortage performance. Further, both the qualitative data collection methods produced positive relationships with both the patient and the shortage performances in shortage management through the interview analysis and the focus groups' analysis outputs. This is vital, as the results of this research are not only empirical based data from post disruption actions but also measure the dynamic aspect of post disruption action, taking account of first response actions and follow up actions, which reflect the real world dynamic environment. These results are in line with expectations from previous work on catastrophic disruptions, crisis management, and interfirm relationships. Grewal, Johnson and Sarker (2007) found that during response implementation, a feedback loop leads to sense making. Although their research was a thorough case study based approach, it was constrained to two manufacturing industries, hi-tech and steel, and lacked empirical quantitative examination. Nevertheless, it did give interesting insights into positive use of feedback loops and the concept of sense making in disruption management. First on the unfolding crisis itself. As the crisis progresses, more information about the crisis event and its effect in the interfirm relationships become available. During this unfolding, the disruption picture within the interfirm relationship often changes considerably, secondly by using an effective feedback loop, potential disruption effects rippling through the unit’s interfirm network can be discerned more easily. Managers have the ability then to re-evaluate the situation and engage in further sense making through the evolution of the disruption by communicating through their interfirm and intrafirm networks. The second reason for the feedback loop during the response action repertoire choice is that after a response action has been taken, the unit appraisal of the consequence of that choice can be crucial (Dickson, 1992). The uncertainty inherent in disruption response is a game of chance, but as the process evolves managers gain more information about the effectiveness of the unit's response in stemming damage caused by the crisis (Mintzberg, 1990).

Having a constant feedback loop allows for the adaption of response action in a consensus direction; this echoes current thinking on supply chain resilience literature, for example, the adaption based supply chain resilience research by Ivanov and Sokolov (2013). They take a quantitative approach using control theory balancing supply chain protection and adaptability, taking account of managers' risk perceptions, risk strategies, and supply chain capability. However, control theory also has its critics as not being dynamic enough and too static (Craighead, Blackhurst, Rungtusanatham et al., 2007). But non-linear control theory has received support for its adaption capabilities in the fast moving consumer goods industry (Spiegler, Potter, Naim et al., 2016), where a system dynamics approach combining nonlinear control theory (NCT) and simulation modelling is applied to evaluate the resilience performance of a distribution centre replenishment system. Ivanov and Sokolov (2013) argue this mitigates uncertainty and increases the resilience of supply chains from the control theoretical perspective – control adaption. This incorporates an adaptive cycle into supply chain resilience, as did (Ponomarov and Holcomb, 2011). Further, in the additional work on supply chain resilience by (Ivanov, Sokolov and Dolgui, 2014), building on Grewal, Johnson and Sarker (2007), they describe the ripple effect, which describes the impact of a disruption on supply chain performance and the need for a disruption scope of changes in the supply chain structure. They had built on earlier works, for example, from socio-ecological systems research, which used the concept of resilience, the capacity to buffer change, learn, and develop as a framework for understanding how to sustain and enhance adaptive capacity in a complex world of rapid transformations. Two useful tools for resilience-building in social-ecological systems are structured scenarios and active adaptive management (Folke, Carpenter, Elmqvist et al., 2002). Including feedback contingency from performance is a further extension of the Bode, Wagner, Petersen et al. (2011) model, as shown below in figure 51.

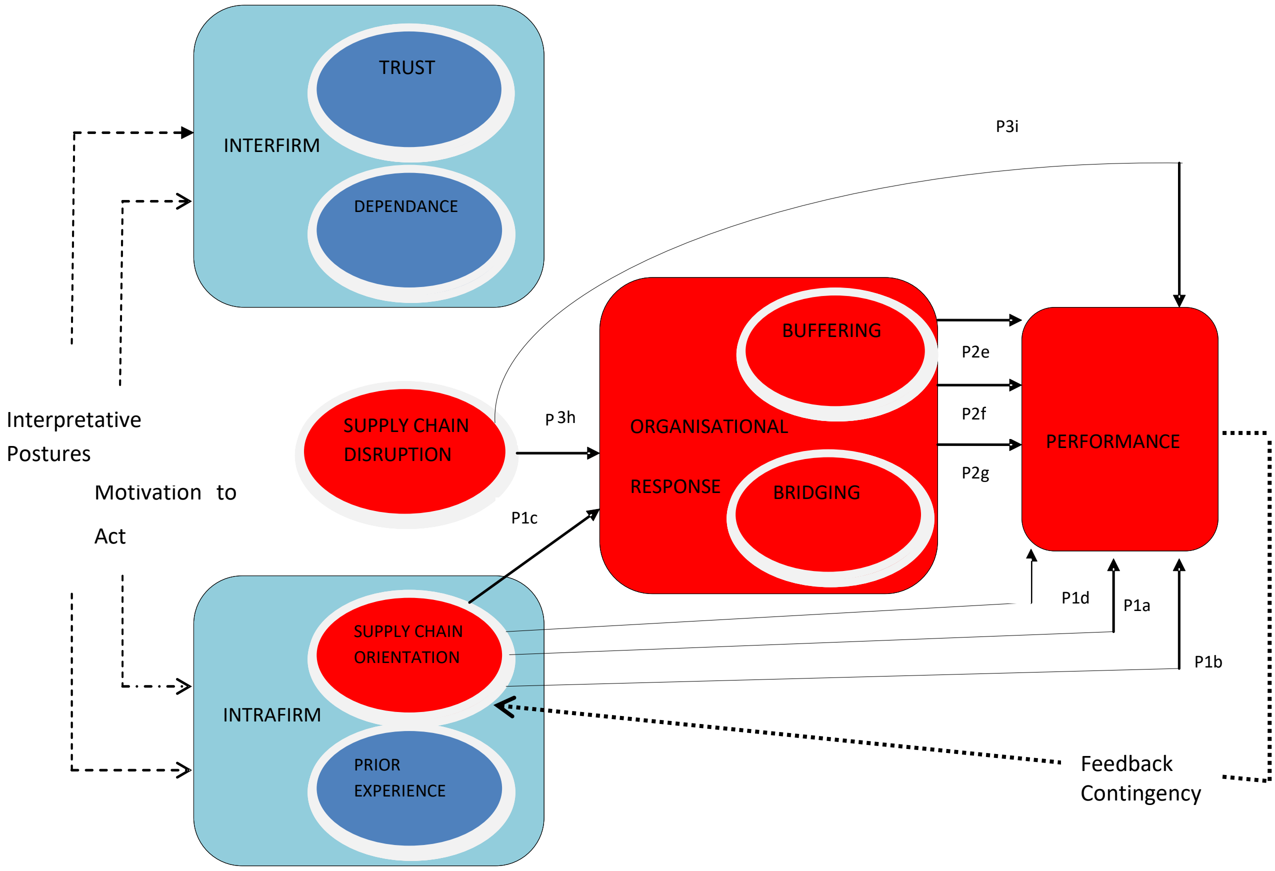


Figure 51. Extended model of organisational responses to supply chain disruptions, including action response, output performance and feedback contingency

As shown in the extended model, the information theory and dependency theory that underpins the interpretive posture and stability motive, understanding the drivers of strategic action selection, is further enhanced by the post disruption outcomes by the inclusion of cognition, i.e., the awareness of 'action and outcome' building on earlier works of the adaptive cycle (Ponomarov and Holcomb, 2011), learning and performance (Peck, 2006), social contingency theory (Sims and Lorenzi, 1992), and sense and respond (Lin and Luby, 2005). By including the feedback contingency, it allows for back and forth learning in the dynamic environment prevalent in the post supply chain disruption process where active variation and combination of strategies is more effective in tackling shortages. As shown in the results of this research, the feedback contingency allows for better supply chain disruption orientation and shortage management performance.

The next proposition, P2f, investigated by this research was whether pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management. The examination of the interplay of buffering and bridging in the post disruption response environment builds on and extends the Bode, Wagner, Petersen et al. (2011) framework beyond the antecedents of response decisions in supply chain disruption post environment but considers the action choice effects and efficiencies using empirical based performance data. The interaction of different mitigating strategies is still not fully understood and could be due to a multitude of supply risk factors, for example, because of a lack of vendor diversity, supplier diversity, or sole sourcing (Wagner and Neshat, 2010, Ho, Zheng, Yildiz et al., 2015, Tummala and Schoenherr, 2011). This research found that in the quantitative analysis, both immediate buffering (up to 8 weeks) performance and post bridging performance (8 to 16 weeks) was positively related in a statistically significant effect. In addition, in the qualitative research units that took dynamic actions reached higher performance levels. The results that initial buffering actions followed by bridging actions over the post disruption dynamic is in keeping with the theory of why this sequence may happen (Fennell and Alexander, 1987), where buffering involves trying to keep the environment from interfering with internal operations, or trying to insulate itself from external interference, then bridging occurs as firms seek to adapt organisational activities to conform to external expectations. Bridging implies that the firm actively seeks to exceed regulatory requirements in its industry, and promote internal adaption to changing external circumstances. However, the effectiveness of this interplay sequence is a new insight as called for by (Meznar and Nigh, 1995, Bode, Wagner, Petersen et al., 2011). It also reflects other research in supply chain resilience in the need to reduce vulnerability in supply chains (Jüttner and Maklan, 2011) and to explore relationships between agile and resilient practices to identify synergies, thereby allowing unification and integration of the two approaches in supply chain management (Carvalho, Barroso, Virginia et al., 2012).

The last proposition in the second construct supply chain disruption performance was P2g, which considered if buffering actions in response to supply chain disruption are more effective than bridging actions in shortage management performance. This addressed the research gap in the current research on supply chain risk management, for researchers to appraise and select the important mitigation strategies among various strategy options with respect to both efficiency and effectiveness (Ho, Zheng, Yildiz et al., 2015). Nonetheless, no supply chain strategy is ever likely to be risk free, and vigilance is needed even in the best managed supply chain, as well as a dynamic approach (Peck, 2006), and managers can only take actions that are available in reality, as per real options theory, based on the types of flexibility available (Tiwana, Wang, Keil et al., 2007).

The quantitative research analysis in this study found the proposition P2g as not proven, hence the choice of using buffering actions rather than bridging actions per se, to enhance shortage performance does not have a positive indication. However, conversely the quantitative results did show that using buffering and bridging actions *together* was associated with improved shortage management performance. This is in line with previous research speculation by Bode, Wagner, Petersen et al. (2011), that post disruption actions of buffering and bridging may not be mutually exclusive, i.e., they could be effectively used at the same time. It is also in line with supply chain disruption research on interfirm linkages by Grewal, Johnson and Sarker (2007), who found that, when forced to react so quickly that their response was instinctive to respond to crisis triggering event, managers' choices of actions to take get compressed and their sense making occurs in parallel, therefore combining strategies to mitigate a problem. This may explain, to some extent, why this happens, but it does concur with other current thinking in supply chain resilience literature that combining strategies can improve outcomes, reduce vulnerability, and improve resilience (Vlachos, Iakovou, Papapanagiotou et al., 2012). Specifically, the data analysis showed that post bridging actions and post-performance were associated positively together, whereas in contrast using post buffering on its own produced poor shortage management performance. This was in line with the qualitative analysis, which showed that there was a higher performance in shortages using bridging as opposed to buffering, however, by combining bridging and buffering actions together the best overall performance was demonstrated. Again, this is in line with existing work on the success of combining strategies and not just taking a single static path and demonstrating flexibility to enhance supply chain resilience (Sheffi and Rice, 2005, Jüttner and Maklan, 2011, Ponis and Kronis, 2012).

7.2.3 Organisational Response

The final construct of organisational response included two further propositions to fully answer the research question. These were the propositions (P3h-P3i) to investigate the organisational response construct, which incorporates prior work on organisational adverse environmental events. Supply chain processes are often measured against time (e.g., on time deliveries, picking rates, etc.), as opposed to some other physical dimension or quantity (e.g., picking accuracy, product tolerances, etc.), as noted by Christopher and Peck (2004). The dynamic management approach to post disruptions active management is connected with adjusting the response alternatives over time according to the situation presented, and it has been used in resilience optimisation from other academic lenses, for example, industrial and systems engineering (Ng and Sy, 2014). The first proposition, P3h, addressed the contention that varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management. The results of the quantitative analysis did find an association, although not statistically significant. The qualitative analysis did, in contrast, support the proposition in both the interview and focus group collection methods. The fundamental reason dynamic given in the qualitative reasoning was due to the duration of the shortage and the nature of the medicines in shortage. This could be explained then by the contextual nature of the industry setting where the disruption occurs, in line with the determinist approach to contingency which imposes constraints on managers' choices (Burns and Stalker, 1961, Lawrence and Lorsch, 1967). If, for example, due to a regulatory shut down of a solitary supplier of a unique medicine based overseas and there is no local alternative is available, dynamic response is required in the altered environment. Explanations of supply network disruption have tended to take a focal firm or a dyadic perspective. These perspectives are adequate when considering disturbances (i.e., responses to uncertain demand), which do not require any new ties to be made in response to the destruction of existing ties. However, in circumstances where either nodes or ties have been removed from the network, the surviving actors are compelled to seek new relationships (Greening and Rutherford, 2011). In such circumstances, it may not actually improve the shortage measurement performance, for example, as measured in the quantitative analysis, the fill rate, but it would maintain some or part of the supply back to an even equilibrium. This is at the nucleus of supply chain resilience as defined by (Christopher and Peck, 2004) which is the ability of a system to return to its original (or desired) state after being disturbed.

The last proposition of the organisational response construct was to test whether the impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact. The increased focus on mitigating approaches and dynamics has been rising in strategic management research, including the development of decision support tools for the design of resilient dynamic systems when faced with environmental lack of confidence due to disruptions (Ng and Sy, 2014, Seferlis, Vlachos, Iakovou et al., 2008, Peck, 2006, Bhattacharya, Geraghty and Young, 2009 , Mishra, Sharma, Kumar et al., 2016). This proposition, P3i, however, newly examined whether the impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact. The quantitative analysis did confirm that both bridging and buffering actions vary over time, and that bridging actions enhanced both immediate and post shortage management performance, with buffering showing a relationship with performance but not as strong.

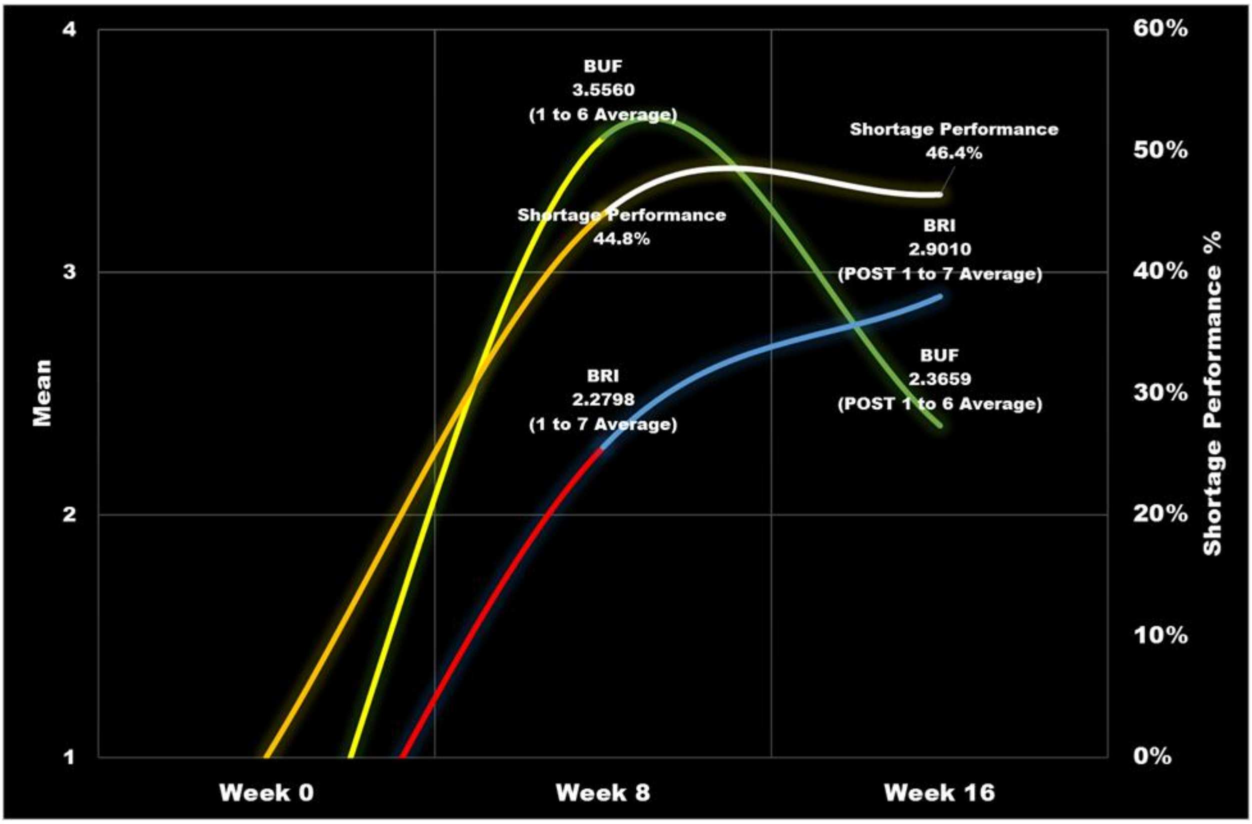
Bridging and Buffering Dynamic

The evidence from both the qualitative collection methods and analysis concurred with the quantitative collected data, with respond strategy variation regularly used and subsequent changes in shortage performance. This is congruence with earlier research by Xu, Wang and Zhao (2014) p106 who stated “an important determinant for the changing of supply chain performance is the time when resilient measures take effect”. In the Figure 52, below with the accompanying key to the graph, shows the performance of lines filled immediately PERFIMM (up to 8 weeks) and lines filled post disruption PERFPOST (8 weeks to 16 weeks), measures and the buffering and bridging means for both the 8 weeks and 16 week averages. The bridge immediate and post, and buffering immediate and post means are taken from the outputs in the descriptive statistics variables in the data analysis (Table 13). The lines filled immediate performance and lines filled post performance are drawn from the descriptive statistics of the quantitative analysis in section 6.2.1 as shown in Figure 42 and 43 respectively.

Speed of response and decision making has been found in previous research as noted by Pearson and Clair (1998) p.73 “crisis management efforts will be more successful if information is disseminated quickly, accurately, directly, and candidly”. However, this research highlights that although a high awareness and readiness (through strong SCDO) produces higher performance in shortage management, managers must have the insight that mitigating actions should be varied in a dynamic over time since the impact. As shown below in the Figure 52, bridging and buffering actions are taken at distinct stages (in time) resulting in differing performance outcomes. So just to react quickly is not enough, managers need to have the foresight of the complexities of processing time. For example, a new supplier might emerge or clinical necessity prevents a possible mitigation action being taken. As seen in Figure 52, later time period (Post) buffering actions are reduced while bridging actions accelerate. This insight can be used when implementing a shortage improvement program, through use of SCDO dynamic capabilities, by combining the SCDO program with variation and dynamics coupled with dynamic adaption through feedback as will be discussed in the proposed supply chain roadmap in section 7.4.

As shown in the summarising Figure 52 below, the buffering and bridging actions taken in the first 8 weeks were different to each other, and they again changed after the 8-week period for both bridging and buffering in a dynamic affect over time. As seen by the shortage performance line, the shortage performance percentage fill rate result at the 76-100% level changed and increased from the immediate period to the 8 week to 16 week period from first impact of the disruption.

Buffering & Bridging Dynamic Interplay: Shortage Performance Impact



	BUF 1 to 6 Average (WEEK 8)	BUF POST 1 to 6 Average (WEEK 16)	BRI 1 to 7 Average (WEEK 8)	BRI POST 1 to 7 Average (WEEK 16)	Shortage Performance x10 (WEEK 8)	Shortage Performance x10 (WEEK 16)			
Mean	3.556	2.365867	2.279762	2.900952	4.48	4.64			
	Week 0	Week 8	Week 16						
BUF	0	3.556	2.365867						
BRI	0	2.279762	2.900952						
Shortage Performance	0	0.448	0.464						
								PERFIMM	PERFPOST
						PERF	76-100%	44.8	46.4

Figure 52. Buffering and bridging dynamic, including shortage performance

This is an important finding because response strategies in post disruption events demonstrated their dynamic versus static nature when developing theoretical frameworks to understand both supply chain resilience and the antecedents of response actions, whether the motivation to act for stability or interpretative postures, and must adopt appropriate underpinning academic theories in line with this dynamic nature. Supply chains are not static so theories need to build in dynamic variation, as noted by Fawcett, Waller and Bowersox (2011) p3. “our world is chaotic and dynamic”. Supply chain risk based frameworks made prior to a disruption may need to be scrapped or adapted in a dynamic environment. Frameworks need to be empirically tested, for example, the research work by Ponomarov and Holcomb (2011), where research opportunities are abundant but constructs need to be operationalised. This is in line with research by Teoh and Zadeh (2013), who produced a strategic management resilience model but based the model on a single case study, which has limitations because it cannot claim the findings as definitive. Also in congruence with Ivanov, Pavlov, Dolgui et al. (2016) whose research looked at dynamic management of time critical supply chain under ripple effect using immediate adaption programs, although their work was simulation based with an emphasis on costs, revenues and profits. Simulation has its drawbacks as shown in a recent study on distinguishing the effects of business to business (exchange partnership) on information quality. McKnight, Lankton, Nicolaou et al. (2017) conceded that the nature of a laboratory experiment could make it hard for respondents to imagine what they would do if they were a purchasing manager and having to assume they have a had a continued relationship.

Bridging actions are external to a unit based on resource based theory (Hillman, Withers and Collins, 2009, Pfeffer and Salancik, 1978), and buffering actions are internal to a unit, according to information processing theory (Galbraithe, 1973), however, they both allow for ongoing adjustments. By using adaption to provide an integrated approach, as (Stevens, 1989) proposed at an operational level, the supply chain is the connected series of activities which is concerned with planning, coordinating, and controlling material, parts and finished goods from supplier to customer. At a theoretical level neither resource dependency theory or information processing theory are singularly able to explain the motivations that drive response decisions and need to be integrated to allow for vulnerability in external resource provision and internal level effective operation, as suggested by this research's empirical experiment outputs.

7.3 Theoretical Implication Summary

This research looks specifically at post disruption responses and the interaction between the alternatives of buffering and bridging actions. The research question is: how do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management? The research used three constructs of supply chain disruption orientation: supply chain disruption performance, and organisational response conceptual forms to break the question down into key research areas to be explored in-depth.

To extend the current literature, this research looked through the same lenses of information processing theory and research dependency theory as previous research, with their mutual roots in the open system paradigm that strives for an orderly and reliable pattern of resource flows. However, it looks more closely at the back-and-forth between buffering and bridging actions to mitigate disruption post disruption event, and included boundary rationality theory and dynamic response action. It further empirically tested the original nominal conclusions on performance outcomes of the Bode, Wagner, Petersen et al. (2011) theory framework in unique and critical public sector service environments in multiple countries to extend the insights into interfirm relationships beyond the manufacturing based private sector (active and passive firms). In contrast to research based on a preventative approach built on a security perspective (Lu, Koufteros and Lucianetti, 2017) of detection, studying what happened prior to an event and during disruption episodes, this research looked at how and why managers responded to events post disruption; whereas other risk management research also found a positive relationship between the mitigating strategies of buffering and bridging with supply chain performance in general (Mishra, Sharma, Kumar et al., 2016) and that buffering and bridging are not at the opposite ends of a continuum (Meznar and Nigh, 1995). This research considered actual supply chain post disruption events actions considering supply chain orientation, not standard firm typologies and accounting for a new perspective in boundary rationality and dynamic action interaction. It further considers other aspects in the existing literature response factor spectrum (of prior experience, trust, and dependence) through examining the interplay of buffering and bridging with shortage performance, including response feedback loop, role, organisational size, impact severity, and the extension of the understanding of the newly introduced concept of supply chain disruption orientation.

In so doing, it illuminates varying patterns of responses over time and action spectrums by actors, with outcome performance changing as a result. This is in congruence with earlier work on general management behaviour, for example, flexibility (Tomlin, 2006), reinforcement theory (Komaki, Coombs and Schepman, 1996) and social cognition theory, as noted by Sims and Lorenzi (1992) p234, *"A consequence is the result of a behaviour; a consequence is contingent upon the behaviour"*. But this research augments these earlier works and further highlights that there are multiple factors influencing behaviour post supply chain disruption, not just the leadership of the organisation itself but the supply chain disruption orientation of the responsible teams within the organisation. By including feedback and accounting for dynamic variation in post disruption performance, the new concept of supply chain disruption orientation is extended and gives further insights and understanding of action mechanisms and their interaction with respect to actual shortage management performance. By introducing these new variables, the existing theoretical framework is moderated by highlighting the modified causal relationships. Valuably this application of new academic theory development provides insights to how to improve post management of supply disruptions.

The extended framework provides insights on how shortage performance can be affected by mitigating strategies taken after the supply chain disruption impacts, and how feedback, dynamic action and supply chain orientation enhances that performance. While many risks are supply chain specific, stemming from for example choice of supplier, inventory decisions and dependency of the supplier (Thun and Hoenig, 2011). Macroeconomic and wider environmental risks stemming from for example political, economic, social, regulatory and natural environment impact all firms (Peck, 2005).This framework can be applied to other industries potentially because the underlying concepts of for example sense and respond (Haeckel, 1999, Lin and Luby, 2005), dynamic management (Grewal, Johnson and Sarker, 2007), adaptive resilience (Pettit, Fiskel and Croxton, 2013) are not pharmaceutical supply chain specific. Also as Breen (2008) found in her risk management research, similarities exist between industries in the causal risk factors amongst industries affecting shortages. As this framework has indicated positive applicability to the medicines acute care medicines supply chain, it is possible those risk factors can be mitigated using this extended framework. However, it should be mentioned that even within the same industry different response frameworks might be required, and as noted by Breen (2008) the pharmaceutical supply chain has a unique criticality not often found in other environments. Blair (2012) also highlighted the high level of regulation in the medicines supply chain, which could affect the specific circumstances in the performance outcomes. Further, Savage, Roberts and Wang (2006) found the relatively low cost of logistics to revenue ratio in the pharmaceutical industry compared to other industries, and this might influence mitigating response strategy mix (buffer and or bridge) and duration from the impact. Given that the extended framework provides insights into the application of shortage management strategies in the drugs supply chain disruption management, it provides a new opportunity for testing its generic applicability for future research. A theory helps you identify the limits of generalizations, Corvellec (2013) p.12 notes “A theoretical framework specifies which key variables influence on a phenomenon of interest and highlights the need to examine how those key variables might differ and under what circumstances”.

The new framework in Figure 51 describes the relationship between the key variable of SCDO which the results have shown a positive relationship with shortage performance in both time since disruption impact segments. Alternative industry settings could potentially improve performance by focusing on this key variable which this framework highlights works even when the severity of the disruption is elevated, so could be applicable in industries that are subject to severe disruption impacts. With crisis readiness research such as Mitroff and Alpaslan (2003) showing that 95% of Fortune 500 companies are not prepared for an unfamiliar event there is a real need to understand disruption response variable interplay, and this new framework provides new insights into underlying mechanisms. SCDO from the framework highlights the firms that have high awareness and consciousness of supply chain disruptions perform better in shortage management, this has also been seen in other industries for example in the mobile phone industry. A fire at the Philips microchip plant in Albuquerque, New Mexico 2000, caused major disruption downstream to both Nokia and Ericsson. Nokia reacted quickly as they were better prepared for the risk of disruption and were quickly able to select the correct buffer or bridge technique i.e. select an alternative component supplier so customers received product. Ericcson took weeks to absorb the information and react causing losses to the company by the end of the year of $1.68bn (Latour, 2001). As found by Supply Chain Council Report (2002) reducing disruption impact requires that executives understand the types of disruptions present in global supply chain systems and develop methods for discovering disruptions in a timely responsive fashion The extended framework, describes the importance of the feedback loop contingency, as a constant evaluator of the buffer or bridge mitigating strategy choice. Industries with highly developed information systems could readily adopt this type of feedback where the adoption of the so called ‘internet of things’ or IOT as described by Xu, He and Li (2014), is advanced using intelligence monitoring systems for example RFID tags, sensors, and wireless communication technology enabling instant feedback. Industries such as the food industry for example. Today’s food supply chain (FSC) is extremely distributed and complex. It has large geographical and temporal scale, complex operation processes, and large number of stakeholders (Liu, Han, Zhang et al., 2016). Similarly in the automotive industry, where multi-tiered supply chains are highly complex and elongated but with well-developed intelligence monitoring systems (Keller, Dang, Fritz et al., 2011). Introducing dynamism and variation variables with a combined mitigating response strategy through the organizational response construct as shown in the extended framework would be more readily applicable in industries in less static environments. However research should not suggest all-encompassing solutions that ignore the existence or competing position of other theories (Holweg and Bicheno, 2016). But past approaches have in some cases also ignored the wider institutional environment in which companies work (Hines, Wilding and Holweg, 1999). Industries that have benefited in the past from managerial dynamic capabilities are for example fast moving consumer goods (FMCG), (Kunc, 2007). Dynamic capabilities are where good processes of managerial decision-making, extend throughout the firm, to determine which resources managers identify as strategically important and how they combine them. As shown in the extended framework including both the interfirm and intrafirm aspects of dynamic capabilities improve shortage performance management. The theoretical framework uses then a combination of resilience strategies to mitigate disruption impact and this approach has been successfully applied in other industry settings indicating possible generic applicability. In the readymade garment industry in Bangladesh research by Chowdhury and Quaddus (2015) found in congruence with this study that developing and selecting a portfolio of supply chain resilience capabilities in order to mitigate the vulnerabilities was the preferred approach including back-up capacity, building closer relationships and responsiveness. Similarly multi industry research based on oil and gas, food and beverage, textiles and apparel, wood products, paper products, chemical products, rubber and plastic products, basic and fabricated products, electrical and optical equipment, automotive and transport and furniture by Brandon-Jones, Squirea and Van Rossenberg (2015) found that slack resources and visibility can help to mitigate the effects of frequent disruptions on plant performance with complex supply chains. This suggests that the extended framework which combines the mitigating strategies of buffering and bridging with enhanced supply chain disruption orientation and variability with feedback offers significant opportunities for generic application building on and giving further insights into the theoretical building blocks of existing knowledge of disruption response mechanisms.

The following section considers the implications for management.

7.4 Managerial Implications

This study is based on the real-world of the pharmaceutical industry, which has been experiencing ongoing shortages because of disruptions from both controllable and non-controllable factors, such as manufacturing issues and transportation delays, with resultant negative patient impact (Breen, 2008). Public health systems, such as the NHS, are large, complex organisations with convoluted operational processes that are constantly subject to change, and would benefit from operational component assessments and benefit from objective benchmarking of processes and performance of the pharmaceutical supply chain within the NHS, as called for by previous healthcare researchers (Ritchie, 2002).

The managers who participated and contributed to this research are actively engaging in the problem of managing pharmaceutical shortages. Problems caused by medicine shortages are serious, threaten patient care in hospitals, and require urgent action. As highlighted in a recent survey, medicines are not simple items of commerce; they are an essential component of patient care and in the hospital sector they must be administered to the patient in a timely manner. This is particularly the case for patients taking medicines which have a significant clinical consequence when doses are missed, such as anti-psychotics, anti-epileptics, immunosuppressives, and anti-cancer drugs (European Association of Hospital Pharmacists, 2014).

The issues relating to patent and licensing causing shortages due to conflict between patient and profit, diversion of manufacturing and exploitation mean that mitigating strategies for managers are hampered. Mitigating strategies at the macro level can include for example regulations by governments, although this can have negative as well as positive outcomes as discussed in more detail in section 2.5.5. Firms can for example co-locate with suppliers, which can shorten disruption lengths (Habermann, Blackhurst and Metcalf, 2015) although this is not so easy for large public health sites. However buffering and bridging strategies can provide some assistance for example by holding greater capacity and or through greater information exchange but the shortages challenge caused by patent and licensing will be not be easily overcome.

The industry based steering committee, drawn from the pharmaceutical acute secondary care sector, played a vital role in assisting the research study to navigate its way through the complex intra and inter organisational supply networks that exist.

However, the steering committee and management participants were not initially able to recognise the response spectrum frameworks being discussed, not because they did not get involved with or take the action choices, but because, at the operational level, shortage management is a day-to-day activity and not defined or articulated into sets of specific options. There was, however, an earnest appetite from the practitioner cohort in learning more and benefiting from insights in improved shortage management practice and subsequent performance, not from a self-serving objective but from an altruistic driver towards support and care for often very ill patients in their care.

Understanding how people make decisions can be helpful for explaining and predicting their behaviour (Robbins, Judge and Campbell, 2010). Making practitioners and managers directly involved with taking operational disruption response decisions and those involved in managing these groups at a local, regional, and national level, including those departments involved in supplier contracting, regulation and policy, would benefit from a response concept awareness either through ongoing training or by peer group meeting at an industry or practice association level.

Focusing on the main insights indicated in this post supply chain disruption response research, it is urged that managers take account of the following observations:

7.4.1 Supply chain disruption orientation

The study showed that, from the cross cutting analysis, a high supply chain disruption orientation was positively related to higher performance in shortage management.

The suggestion from the research that shortage management performance is correlated with the orientation of the unit and managers responsible for making the response decisions is a novel management insight. Anecdotally from the qualitative discussions, there is an awareness that not all units are performing equally on shortage management. Performance inequality in any large organisation on most parameters (whether financial, operational, or ethical) is normal, and this research was based in three different countries; England, Wales, and Ireland, so this comes as no surprise given the different environments in which each hospital unit, trust, or region operates. However, like in many large organisations, the explanations or the current thinking on why these differences exist could differ widely. This is especially true when multiple stakeholders are involved, limited resources are available and where management time is caught up in the day to day administration of complex operations within highly regulated environments. However, the benefits of considering the key measurement items used to conceptualise supply chain disruption orientation and comparing against a current framework by management leadership, potentially using a gap analysis, could identify where individual units or groups of units and trust could be strengthened. The concept, as articulated in the discussions with the steering group and in the focus groups, was not familiar, and furthermore, no set of formalised shortage performance measures had been put in place. This may seem surprising considering the well-known management axiom that what gets measured gets done, and as pointed out by Schlesinger and Heskett (1991), the most important costs those derived from poor service rarely get measured. However, in the real world situation of pharmaceutical medicine practice where shortages are constant and ongoing, and each disruption and every drug therapy is potentially unique, standardising a shortage measurement tool (for example, a measurement scorecard) is a complex task, which requires not only agreement on definitions of shortages across a wide range of stakeholders but also as the acute secondary care service provision is largely in the public sector, and so the public gaze, such measurements need to be approved at a government and policy level.

One additional method of introducing the supply chain disruption orientation into the consciousness of practitioners and managers is through a method already used in part successfully and as a result recognised through the qualitative analysis of this research on effective advice to give to other disruption shortage managers; this was to be use a vigilant orientation. Those units and managers which implemented and encouraged vigilant orientation had the higher performance in shortage management. So, this is one attribute which already existed and could be built upon for promoting supply chain disruption orientation. Further, that could be implemented more widely to promote supply chain disruption orientation concept using the most effective method in improving shortage performance, which was the use of a shortage champion. Not every unit has a specific person nominated as shortage champion due to resources as well as possibly leadership and priorities, but if this could be encouraged, they could be used to deliver the supply chain disruption orientation attributes message.

7.4.2 Feedback Contingency

The study results revealed that there was a positive association between performance feedback given after a supply chain disruption event and higher performance in shortage management

The implication then from the research is that the introduction of improved performance feedback would indicate higher shortage management performance could be achieved. Feedback whether positive or negative can be used to adjust actions in real time, which is an additional observation augmenting the existing (Bode, Wagner, Petersen et al., 2011) model of supply chain response based on 'past experience'. Also, if there an alternative that can be approved or need to source another, or a medicine that is off license either from own country or abroad for example. Given the positive association with improved performance and its relationship to learning organisations, it should warrant further interest in evaluating and managing supply risks. It also encourages leaders to understand the key lessons learned from the use of live feedback on shortage performance. This could be done in an informal way per unit or regional practitioner meetings, not necessarily discussing all disruptions to supply, which can run into hundreds per week on a consistent basis, but, for example, using weekly or monthly contemporary stock reports' aggregated highlights. Ideally, however, the feedback dynamic contingency could be formalised into the standard operating practices across a set of pilot hospital units to test whether this research's results do indeed result in real world shortage management improvements, with the possibility that if the pilot was a success either wholly or in part it could be rolled out on a wider basis where practicable and approved by the appropriate regulatory and ethical bodies.

However, there is, like any large organisation, scepticism about change management and new initiatives as found in the qualitative research discussions, one participant summarised that: *"We are worried; it's a bit like the banks, we are getting so good at dealing with shortages that the* [pharmaceutical] *companies do not have to worry about them. So, there is no onus or pressure on the companies to sort the issue because they know that the NHS is good at managing the consequences of their failures".*

As noted by Nakano and Oji (2017) firms may need a driving department such as a supply chain management steering group with the support of top management to build these process improvement capabilities. This could be assisted by updating practitioner guidelines, where for example the guidelines have no reference to feedback contingency but are built on an identify, analyse, plan and execute model like the ASPH drug disruption guidelines.

7.4.3 Buffering and Bridging effective interplay

The results of this research indicate a positive relationship between sets of scenarios of buffering and bridging actions at different time periods from the disruption's first impact, namely immediate and post i.e., up to 8 weeks and 8 to 16 weeks. Including, for example, that combining both actions could lead to superior performance in shortage management. From a practical aspect within the pharmaceutical industry, this could be a challenge to test in a real-world scenario, as unlike a clinical trial phase four where the protocol for the medicine has already been tested and approved at each stage before, imposing a ‘practice in advance’ would be challenging both from a regulatory and ethics perspective. However, this again could be piloted from a retrospective secondary data methodology by recording and assimilating what actions were taken and what performance outcomes resulted. In this way, patterns could be analysed to benchmark this study's findings. Alternatively, simulation modelling could be used for the same purposes, and be practically less intrusive and require lesser ethical approval. As discussed previously, additional awareness training and understanding could be delivered to key stakeholder groups so that managers become aware of the study’s findings, although a single research study in the extensive public health system, where multiple studies are carried out along with those still pending approval, would need the necessary support through the likes of a steering group.

7.4.4 Varying disruption response actions over time

Practically, the managers and pharmaceutical delivery practitioners already dynamically adjust their response actions over time from disruption impact. However, given the research’s findings with positive performance improvement in shortages, it would encourage risk managers and management leaders not only to try and record and analyse this dynamic effect a practical level and compare it to inventory stock management from a risk benefit perspective, but also to identify, whether through empirical review of secondary data, for example, action taken against the ‘out of stock’ sheets where possible, to foster dynamic feedback in systems format and then review it against performance over time. Alternatively, at a management appraisal opportunity periodically to investigate whether the individual managers are using a dynamic approach or a single approach, whether by pattern over time period or consistently irrespective of time from disruption. This research identified through qualitative investigation where individual managers only used one particular response option, irrespective of the circumstance. This could be because of too close an association with a particular supplier, or alternatively no commitment to fostering a partnership or collaborative approach. Either way, if this response behaviour could be identified and modified, shortage management improvements could possibly be improved in these cases, depending on the particular shortage context and medicines and therapies involved.

7.4.5 Role and shortage disruption performance

Existing work on role matrix to examine what pharmaceutical practitioner actors actually carry out has been and will continue to be carried out in large organisations, such as public health systems. This could be from a policy and costs incentive but recent internal work on pharmaceutical roles matrix within the England based secondary acute care sector (as shown in Appendix 3) shows the diversity of the roles themselves and the cross functional responsibilities in their duties and responsibilities in that matrix. Given the suggested results from this research, considering boundary rationality where the access to information and decision levers could influence shortage management performance, this could be taken into account in the next roles matrix review. As these reviews take a lot of time and resources to complete, it would be encouraged that the shortage management aspect and potential effect on performance be included in the considerations of the matrix attributes. The regulatory nature of the public health environment, the role titles, related authorities, and access as a result of altered responsibilities could give better access to individuals and wider boundaries to managers and individuals involved with and responsible for shortage management, and potentially improving shortage management performance. As shown in the findings of this research, the inevitable slow down due to approval process is already a time lag of form filling due to hierarchical and regulatory requirements. This slows down response time, hence the need for constant vigilance orientation. Any potential to improve this friction in the system through role matrix revision could be beneficial.

7.4.6 Managerial Implications Summary

In summary of the managerial implications, this research contributes to practice by the insights given to practice managers of how supply chain disruption orientation of front line teams can influence the positive outcomes in the management of shortages. This is vital for practice, as noted by a recent European shortages survey: when a medicine cannot be delivered at the instant of patient demand, every stakeholder in the healthcare system is affected (Pauwels, Simoens, Casteels et al., 2015).

The use of feedback and the action – performance dynamic in an operational setting is a constructive approach, as is a better understanding of and awareness in the interplay of mitigation strategies against actual outcomes in shortage reduction. Insights and understanding of varying mitigation strategies over time since the disruption, either in combination or as separate tactical interventions in different post disruption time continuums, is an effective shortage management strategy. Lastly, individual managers do not work in isolation and further do not work in a vacuum; their access to information and knowledge is bounded by their reality, understanding this when constructing effective skill set matrixes for role templates can improve shortage performance management and overall resource policy.

The below supply chain road map Figure 53, lays out a process plan to illustrate to practice stakeholders and managers how to improve shortage management performance at the operational level.

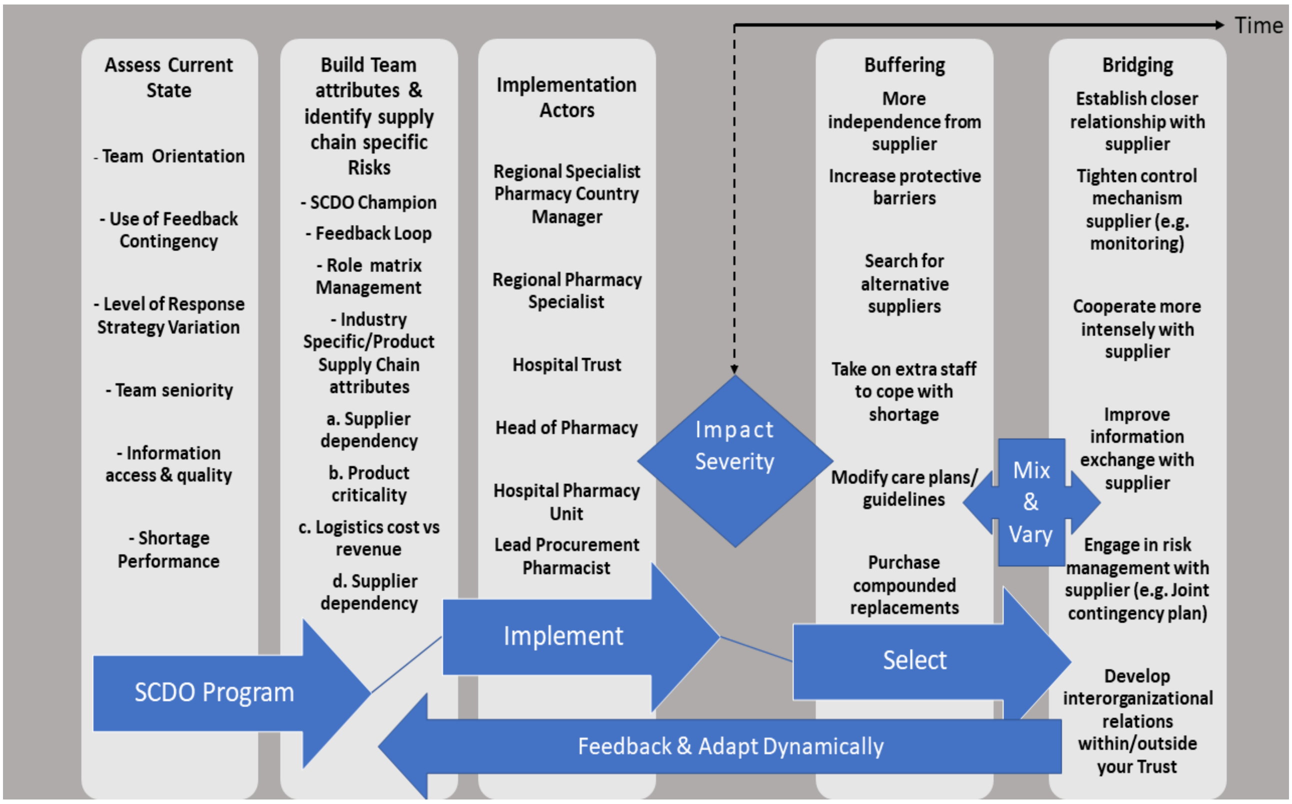


Figure 53 Supply Chain Road Map

The reason for the inclusion of the roadmap is to draw together the positive elements of the research findings. So, when attempting to improve shortage performance after a disruption has occurred managers can be not only better prepared to deal with it by fostering stronger supply chain disruption orientation, but be more effective in performance terms. Management roadmapping was developed by Monomakhoff and Blanc (2008) and is a method supported by the roadmap (a pattern for modelling organisational capabilities with good practices), and by management mechanisms. It is used for transferring good practices, and assessing locally and globally organisational capabilities (Rauffet, Cunha and Bernard, 2016). An important matter in organisational learning in distributed organisations is the codification of local innovations, the transfer of this knowledge, sometimes called ‘good practices’, and the use of these practices to increase the organisational capabilities of each entity. Thus, an organisation must share the practices it wants to implement, but it has also to check if these practices are understood and correctly used by operational subsidiaries.

To increase the organisational capabilities organisational learning is required, and organisational learning is defined as a “collective endeavour which aims at increasing, in a continuous and active way, individual and organisational knowledge and skills” (Senge, 1990) p117. The roadmap follows the five step principles of organisational adaption as described by Szulanski and Jensen (2006). They explain the different transformation stages from a local innovation into a conceptualised organisational practice and then into a transferred organisation capability. In the supply chain roadmap (Figure 53), the stages that underlies the formation of the pillars stages are: step 1 acquisition: an organisational need is identified and knowledge is found locally (by expert or operational workers), to address this requirement, step 2 adaptation: knowledge is modified and combined, to become organisational knowledge and to be adapted to future learners, step 3 application: this adapted knowledge is communicated and transferred to the learners, step 4 acceptation: management around the applied knowledge must be done so that knowledge is effectively acquired by learners and becomes an organisational capability, step 5 appropriation: organisation uses the transferred knowledge and skills efficiently.

The roadmap describes these principles in practice with first three pillars (acquisition & adoption) the introduction of a supply chain program, firstly with the assessment of the status for example (information and quality) - is there an agreed shortage metric, if not define it with an agreed common typology. As noted by Wowak (2016) the lynchpin for traceability centre on boundary-spanning solutions and coping mechanisms stemming from information processing and knowledge that cross functional, firm, and geographic boundaries and considers both supply chain and technology elements . Additionally, for example (feedback contingency) - is performance outcome of each shortage recorded and feedback, if not capture the outcome data by week, so it can be readily available in summary to be feedback to practitioners. Currently many proactive units in hospitals record and capture in a weekly shortages report. This includes: date shortage was added, name of the drug, strength and pack size, form, brand and manufacturer and the expected date of return to stock. The report also contains a list of discontinued lines for cross reference. At present however, these reports provide only a running commentary and are not linked to any formal performance and feedback capture. This is a key point of which of the elements need to be emphasised and included in the program. The second pillar requires an understanding of the industry and product(s) to be included in the programme, and is a generic step irrespective of industry. The application principle is represented in the last three pillars in the roadmap. The third pillar describes the implementation actors which are listed but these could be replaced with other roles depending on country where implemented, and will apply the high supply chain orientation and dynamic variation in responses. The last two pillars of the road map show the two response mitigating strategies, which can be combined and varied during the time from impact in a dynamic and adaptable response to maximise shortage management performance in application. The response strategies are engaged through the prism of the severity of the impact of the shortage, which will be visible through the ongoing capture of the out of stock weekly reports in summary. The final element is the flowback of performance to enable the implementation actors to interpret dynamically the action behaviour in performance terms as shown by the arrows in Figure 53, so that the response mix (Buffer or Bridge or Both) can be perfected as necessary, through the time from impact mediated by the severity of the impact. This last stage represents the principles of acceptance and appropriation, where the improved performance enhances acceptance and the capabilities are recognised and transferred successfully to the organisational unit. By using this roadmapping approach the internal resources can be optimally exploited to create significant assets for the organisation in a continual lifecycle of capability in line with other resource view based research (Helfat and Peteraf, 2003, Pettit, Fiskel and Croxton, 2013).

7.5 Overall summary: theory and practice

Bringing together the theoretical and managerial implications in order to better understand how the mitigating strategies of buffering and bridging affect shortage management performance, there is a need to extend the existing theoretical framework of Bode, Wagner, Petersen et al. (2011). The inclusion of a feedback loop linking the performance outcomes to the supply chain orientation of the management unit improves the shortage management outcomes. As suggested by Sims and Lorenzi (1992), effective management strongly suggests a performance orientation, however, it is not just the individual employees linked to overall organisational achievement, rather it is predicated on the team action dynamic decision making and post disruption variation strategy that will produce enhanced shortage management results. By understanding and documenting shortages outcomes in an ‘action and result’ dynamic, information processing theory and cognition are combined, and through the incorporation of boundary rationality, the stability drivers of dependent resource theory are better harnessed for shared value supply chain disruption orientation through self-management. This research has shown that buffering and bridging actions as mitigating strategies in shortage management are effective tools, depending how and when they are applied; however, it is noted that they are not the only strategies available, which is a potential limitation. Chapter 8 describes the research conclusions, limitations, and future research suggestions.

8 Conclusion

8.1 Research reflections

This research answered the call for more strategic management research on supply chain disruptions, in particular the lack of empirical work, which may be due to the lack of commonly accepted definitions, lack of a conceptual framework, or the difficulty in collecting data around events that are unpredictable (in terms of where and when they will occur). This paucity of research is despite an increasing acceptance (reinforced by perceived risk) that disruptions will occur, be it, for example, through natural phenomena (weather), social political (terrorism) or elongated supply chains (Greening and Rutherford, 2011, Ho, Zheng, Yildiz et al., 2015). However, this research has made new academic contributions to research by examining post supply chain disruptions, extending the theoretical framework of Bode, Wagner, Petersen et al. (2011), augmenting the need to balance the larger body of work on prior supply chain disruption decisions and risk management. By identifying new factors that moderate or mediate key relationships within the existing theoretical framework, the concept of supply chain disruption orientation is extended and new causal relationships are identified through the expansion of thesis constructs: supply chain disruption orientation; supply chain disruption performance and organizational response, contributing to extant theory.

The investigation formulated one research question to address this, and the three constructs were used with the subsequent relevant nine research propositions to be tested to answer the research problem. Each proposition was used to give novel insights into the interplay between response action mitigation strategy options to answer the research question**:** how do the actions of buffering and bridging in response to supply chain disruption events affect the performance of shortage management. These included an examination of the concept of supply chain disruption orientation, giving new insights and concept refinements; additional factors through a boundary rationality lens of role and size were incorporated in the buffering and bridging interaction considered. Further, original insights were examined in disruption severity and feedback contingency, as well as the varying of response action empirically tested performance consequences. All the propositions examined the performance outcomes in terms of shortage management in empirical evidence terms, rather than the previous nominal only research work. In addition, to account for the dynamic nature of supply chain disruption response spectrum and subsequent performance over time, each action and performance measurement was categorised uniquely into immediately after the disruption and then after a defined period from the disruption's initial impact. The interaction of buffering and bridging was examined in the context of shortage management in a public health context, which takes into account the importance of new settings for supply chain resilience development (Carvalho, Barroso, Virginia et al., 2012), rather than the often research-based settings of private manufacturers.

The importance of addressing the current and ongoing practical problems facing shortages in pharmaceuticals due to the ongoing supply chain disruptions is vital. As noted by Huq, Pawar and Rogers (2016) supply chain disruptions lead to a change in strategies at the macro-level (reconfigurations) however, the effect of disturbances at the micro-level, in particular on supply chain performance metrics has been little studied, this research tackles this gap directly. There are massively increasing shortages which effect both practitioners and patients. Acute and chronic shortages of various pharmaceuticals and particularly of sterile injectable products are being reported on a global scale, prompting evaluation of more effective strategies to manage current shortages (Li, Subramanian, Anderson et al., 2015). Wider financial implications of not taking steps to improve outcome performance of response actions were outside the scope of this study but with a current day to day NHS budget of £108bn, any marginal efficiency gains through more effective post disruption management would produce cost benefits. Spending is expected to rise to £123 billion in 2020/21, of which £111 billion will be for the day to day running of the NHS (Full Fact, 2017). However, this is not just a UK and Ireland issue; a recent US based survey mentioned 86% of hospital pharmacists reported that medicine shortages are a current problem in the hospital they work in in terms of providing the best care to patients, and from the hospital pharmacy 66% of respondents said that medicine shortages affect their hospital pharmacy on a daily or weekly basis (PharmTech, 2017).

To meet this significant research problem, this study used a robust triangulated methodology rather than singular quantitative methodology, or emerging grounded theory, which had been used in previous post disruption research. As noted by Miles, Huberman and Saldana (2014) findings are more dependable when they can be buttressed from several independent sources. In addition, commonalities between findings of the different data sets revealed a convergence in interpretation. This blended method proved effective allowing both the how, what, and the why questions to be addressed. Further, by using resource based theory, boundary rationality and information processing theory as a lens to construct quantitative collection methodology with a multi-country online survey, and combined with a qualitative collection methodology using both interviews and targeted focus groups, it provided a compelling mixed methodological approach.

8.2 Limitations and future research directions

Several limitations of this research could be considered in the interpretation of its results; however, all empirical research has limitations. Despite the encouraging results of the tests reported here, some constraints on the data collection include:

1. Larger response rate for stronger reliability
2. Only one industry, albeit a large and complex organisation, was included
3. Only the downstream buyer side of the supplier – buyer dyad, was considered

In addition, the performance timeline from disruption was arbitrary, although based on the interaction with the research steering group. Different results could have been discovered if shorter or longer periods had been chosen, but generally it was in line with the participant's expectations. However, further research could look at a more longitudinal study approach rather than retrospective, in addition to different time slots looking at, for example, quantification of the identified drop in shortage performance in later buffering in contrast to the rise in later bridging shortage performance. This would extend part of this research's findings, in particular the uneven performance scores over time since the supply chain disturbance, and could also build on the existing study by capturing the response action and effect dynamic over a longer time period than 12 months. The medicines in shortage sample was selected by frequency of occurrence and recognizability by the target group, and although an 'other' medicines option was offered, different retrospective timelines could potentially have different drugs in shortages with different indications and response actions taken.

The research used the UCLH medicine shortage data base as a ready source of which drugs had been in shortage, and was highlighted (by the expert steering committee) as the most widely used repository for recording drug shortages from across the UK. However, limitations to the use of any retrospective database exist including for example variation in design, inclusion criteria, consistency and objectivity (Peterson, Nau, Cramer et al., 2007). As the ten most frequent medicines selected for the initial drug population pool, were then reviewed by the expert practice steering group with a specified typology, replacing two of the items which ensured the medicine sample pool of five items was relevant and valid. The final sample pool included a range of drug types for different therapeutic treatments. The inclusion of specific medicines in the survey using a specific medical shortage situation improves the design of the research instrument by strengthening reliability (Doty and Glick, 1998). By specifying the medicines and requesting month of occurrence, it improved the trustworthiness of the survey answers recorded and transferability of the research process employed, so that the results of this research were not unduly affected using the UCLH retrospective database as it did not rely solely on the database for the final sample pool.

This research has shown that buffering and bridging actions as mitigating strategies in shortage management are effective tools, depending on how and when then are applied; however, it is noted that they are not the only strategies available, which is a potential limitation. That said, other strategies were considered; for example, from the five operational strategies for managing disruption risk (Wang, Gilland and Tomlin, 2010), however, many of these are already encapsulated, and those that are not, such as demand management, are more ethically challenging to apply in a patient health related drug shortage disruption. The underlying theories of information processing and resource dependency combined with boundary rationality in the context of post supply chain disruption which instigate shortages is a starting point for further investigation where the stability motive and motivation to act are bounded by the context of the decision maker and the dynamic feedback on performance received. However, this researches choice of performance measurement and the importance of the metric used could be a potential limitation. Also, the performance was completed as a self-reported metric in the survey, offering potential self-bias, however, as the data collection was completely anonymous, no individual or group gain could have been the motivation for incorrect reporting. Moreover transcripts were closely scrutinised and coding scheme employed, to counter potential threats pertaining to bias and reactivity common to qualitative research as recommended by Bloomberg and Volpe (2015). Performance measures are, however, always difficult to define (Beamon, 1999), and the process of choosing appropriate supply chain performance measures is difficult due to the complexity of these systems, though it was widely accepted that fill rate was by far the most common method used in the industry and easily recognisable and available, hence why it was advised to be used in this research by the practice expert steering group. Like all metrics, they can be critiqued but one has to start somewhere to deliver insights. In science, we seek to balance curiosity with scepticism (Babyak, 2004); this said, alternative metrics could be tested and combined to verify the results and to add to the research area in future work. Further, post supply chain disruption action is suggested to be analysed in terms of financial metrics rather than purely operational and patient performance outcomes.

Other limitations were that, although feedback and performance positively related in the quantitative analysis, it was also positively related to other factors. This needs further investigation, however, the challenge for all research studies is that they are not infinite in time and resource. It does offer the opportunity for further quantitative study to validate these outputs for future theoretical frameworks. For example, it could be argued other perspectives such as system dynamics and non-linear control theory could be applied to feedback contingency in the extended framework model as shown in Figure 51. However, these alternatives also have certain limitations. In linear control theory analytics linearity requires strong assumptions regarding demand back-ordering and negative orders (i.e. physical returns), and imposes heavy burdens on possible relationships between parameters (Ivanov and Sokolov, 2013). Although these limitations can potentially be eliminated with the use of system dynamics theory, as shown in the study by Villegas and Smith (2006) on the analysis of inventory and order oscillation trade-offs. A stochastic modelling approach is an alternative methodology that could be explored in future research, however this research focus was on empirical field based evidence to test the extended model. Examining empirical evidence is a valid approach for identifying building blocks of theories and concepts to support the development of new scientific fields. Indeed, "scientific knowledge is often rooted in practice: culture and society existed before we had anthropology and sociology" (Bouthillier and Shearer, 2002) p.33. Vahdani et al. (2011) developed a hybrid multi-stage predictive model for supply chain collapse recovery analysis in light of continuity management. Although these techniques have high practical relevance the stabilizing controllers still remain a critical bottleneck (Mayne, Rawlings, Rao et al., 2000). Another critical issue in applying this type of modelling to supply chain research is the centralized controller and its functions. In technical systems, the controller is a technical device (e.g., a sensor) that adapts within milliseconds system to behavior based on error identification (Spiegler, Potter, Naim et al., 2016) . The controller in the real-world pharmacy is a manager, or more precisely, a number of managers as part of a team with possible conflicts of interests, hence the importance of supply chain disruption orientation. Even if a deviation in supply chain execution has been identified, the model controller will not be able to change anything. The challenge with modelling real world behavior is the complexity and range of possible outcomes and the sensitivity of those outcomes, especially when assumptions are changed. Relying too heavily on stochastic modelling can create a false sense of accuracy and a tendency to be less prepared to address downside risk and short-term volatility (Friesen, 2016).

Ethical constraints in the public health organisation arena meant strict limitations on protocols, which then meant only a smaller than expected pool could be approached and encouraged to participate, however, from a practical observation such pre-data collection preparation actually improves the ultimate response rates due to a clearer understanding of participants due to better prepared protocols. In future work, localised studies with onsite participation would also produce rich and intense results at the operational level, however, would be potentially more difficult to generalise. Future work could test the buffering and bridging interplay performance outcomes in shortages in different geographies; in private versus public health or other public-sector provision, including direct and indirect costs implications. Moreover, the policy aspect of the implications of changed performance could be investigated to consider the research gap of post supply chain disruption beyond the operational level. A macro level investigation could investigate, for example, best practice across public health systems, for example, in potentially a meta-analysis style approach to inform policy level decision making managers.

This research used validated and reliable triangulated methodology with a robust data analysis, however, other novel methodological approaches could be used, for example, simulation and optimisation modelling to overcome the regulatory and ethical constraints within public health services. Triangulation (as for all methods) possesses strengths and weaknesses, each of which must be critically acknowledged and addressed throughout the analytic process (Farmer, Robinson, Elliot et al., 2006). Alternatively, cross industry focus groups could bring together both sides of the supplier and buyer spectrum. By including the supplier side an alternative set of opinions could have been revealed, with different drivers and were excluded due to the time and resource constraints of this research.

The research study focused on the downstream part of the whole pharmaceutical supply chain very close to end users that being the secondary care acute hospital sector as this is where the severe effects of shortages are impacted, and mitigating strategies in high demand. However as discussed in section 2.5 there are also consequences and impacts in the supplier side, and opportunities to improve throughout the end to end supplier chain including government departments at a country level and in regional and international levels, as the pharmaceutical supply chain has long been a global operation (Booth, 1999, Ni, Zhao, Ung et al., 2017). Future researchers could look to extend the scope of this study by including suppliers and distributors in an end to end supply chain research investigation to address all of the elements in the end to end supply chain as shown in Figure 12, taking a broader view of supply chain resilience as recommended by Wright (2013). This would pose many challenges due to the complex nature and multi layers as supply chain involved as shown in the Breen (2005) pharmaceutical supply chain map in Figure 7. As noted by Kauppi, Longoni, Caniato et al. (2016) today's global supply chain normally contains hundreds of members, or even thousands. It is infeasible to get them all work together on risk management. A more realistic way would be to let a smaller number of close partners cooperate initially. However it could be a promising project, and it could be achieved by concentrating on one or two suppliers of a limited amount of specific medicines, and study each component end to end from raw material provider to contract manufacturer(s) (CMO) of the ingredients (which could be India or China) through primary manufacturing process to secondary manufacturing processes of packaging, and then through to the downstream supply chain engaging with wholesaler, distributors and prewholesalers through to a hospital trusts group and individual pharmacy unit in the destination country. Including suppliers in future research in disruption response would be useful as suppliers are a critical part of the supply chain and product development process, as noted by Chadist (2012) p.279, " the [supplier] relationship and frequent communications are critical to rapid response". Supply resilience has been examined particularly from a global sourcing aspect (Goetschalckx, Vidal and Dogan, 2002, Manuj and Mentzer, 2008), but the supply chain's exposure to vulnerability can refer only to a part of the supply chain (atomistic vulnerability) or to the entire supply chain (holistic vulnerability) (Svensson, 2000). Whereas this research only focused on the downstream disruption response part of the supply chain, an end to end supply chain would provide further insights into holistic vulnerability.

Other perspectives could be used to examine the internal relationships and supply chain resilience issues considered in this research, for example, from an analytical ideology rather than a scientific approach, including an organisational psychological approach, a social political or power based approach. Health policy makers in particular are attracted to scientific certainty, and demonstrable relationships, but have subjected social and economic research to tough criticism for being too academic and theoretical, and of minor practical use (Walt, 1996). The inclusion in this research of the supply chain road map for practitioners provides a ready point of guidance to improve shortage management.to contribute both to application and scholarly theory.

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Appendices

Appendix 1: Supply Chain Resilience and Disruption Table

Table 70: Supply chain resilience and disruption

Focus Key:	
M- Mitigation	P- Product Design/ sc Design
P- Operational/Production	DS- Decision Tools
I - Risk Identification & Measurement	O- Optimization
F - Finance	C- Capabilities

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Analytical review	2012	R Andersson	Resilience in the supply and demand chain a new management strategy	
		B Mansson		
		D Y Hamidi		
Analytical review - Early Concept development	2004	M Christopher	Building the Resilient Supply Chain	
		H Peck		
Analytical review - Early Concept development	2006	M Christopher	Creating Supply Chain Resilience through Agile Six Sigma	
		C Rutherford		
Analytical review - Early Concept development	2005	Y Sheffi	The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage	
Analytical review	2005	Y Sheffi	A Supply Chain View of the Resilient Enterprise	
		J Rice		
Single method of focus groups was used on	2010	J Pettit	Ensuring Supply Chain Resilience :	Y
single company in the retail vertical over short period		J Fiskel	Development of a Conceptual Framework	
strong conceptual basis & detailed taxonomy		K Croston		
Framework requires empirical testing, & contructs	2011	S Ponomorow	Understanding the Concept of Supply Chain Resilience	
operationalising. Research opportunities abundant		M Holcomb		

PERSPECTIVE	METHODS	THEORY
Quality Management	Literature review :5 principles that characterise supply chain resilience:	Total Quality Management, Hendricks & Singhal (1996)
	risk management culture, agility, design-and innovation-led organisations, collaboration	
	& spreading and anchoring of the vision, goal, values and methods	
Supply Chain	Literature review/UK govt Emergency planning	Classic Decision Theory
		'at Risk: vulnerable; likely to be lost or damaged'
Supply Chain - Optimum Leanness	Literature review including example manufacturers using Six Sigma	Process Control : Lean Six Sigma
	for example Motorola & Ford	
Strategic Management	Literature Review - Including empirical studies of Toyota,J&J,US Navy	Vulnerability framework & map
Strategic Management	Literature Review	Vulnerability framework & map
		Company position & responsiveness
Supply Chain	Grounded : Focus Groups	Supply Chain Resilience Framework (Strategic Management)
	Retail & Fashion retailer - Limited Brands	Resource based approach to strategy analysis (Grant, 1991)
Logistics	Integrative literature review	Development theory of Social Psychology (Conrad et al,1999) , Adaptive Cycle Theory
		(Carpenter et al, 2001) & emerging theory of Resilience

FOCUS	KEY	CONTRIBUTION
Quality Management Philosophy	C	Quality management philosophy improves the companies' resilience,
		due to increased agility & strengthened ability to handle variability
		& risk management
Mitigation - Process control perspective	M	Framework for improved supply chain risk
		identification
Quality control to reduce process variability	Q	Using Six Sigma approach to reduce internal risk
		whilst improving sc efficiency & effectiveness
Enterprise wide	M	Building in redundancy,flexibility can reduce sc vulnerability
Supply Chain disruption Mitigation	M	Increasing flexibility to improve resilience
Supply chain resilience	C	Supply Chain Resilience framework in terms of measureable variables,
		create tool for management, defined 14 capabilities
Concept of resilience multidimensional &	C	Supply chain resilience framework - Interdisciplinary understanding of the concept
multidisciplinary		Conceptual framework of relationship between logistic capabilities & SC Resilience

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Understanding of why question in sc vulnerabilities	2005	H Peck	Drivers of supply chain vulnerability: an integrated framework	Y
lacks practical approach for managers, or full				
taxonomy of risk				
Preliminary basis for future simulation	2008	M Falasca	A Decision Support Framework to Assess Supply Chain Resilience	
optimisation analysis		C Zobel		
		D Cook		
Three pronged methodological approach	2007	J Blackhurst	An empirically derived agenda of critical research issues for managing	Y
Review recognises current early stage of		C Craighead	supply chain disruptions	
disruption research and weaknesses in non dynamic		D Elkins		
optimisation & control,game theory,simulation tools		R Handfield		
Novel approach in this context in current literature	2010	M Wagner	Assessing the vulnerability of supply chains using graph theory	Y
		N Neshat		
ABS well tested technique, however single	2007	P Datta	Agent Based Modelling of Production/Distribution systems to improve	Y
industry focus - highly specialised potential		M Christopher	Resilience	
difficulties in generalisation		P Allen		
Mixed method strong approach but focus on	2005	U Juttner	Supply Chain Risk Management : Understanding Business Requirements	Y
large companies. Lacks guidance on how managers			from a Practitioners Perspective	
select from strategies , Manuj & Mentzer (2008)				

PERSPECTIVE	METHODS	THEORY
Network theory & Complex	Exploratory case study - Aerospace (military) Industry	Supply chain disruption viewed through the lens of network related
systems theory	Validated by cross industry interviews with SC managers from other critical sectors	theories ; Dynamic Capabilities (Teece et al,1997;Heide & John, 1990;Heide & Stump,1995)
	Normative - Understanding rather than positivist	social exchange theory (Anderson & Narus,190)
Supply Chain Design	Simulation modelling - Quantitative approach	The Resilience Triangle Tierney & Bruneau (2007)
SC disruption management	Exploratory Automotive case study, semi structured interviews cross industry	Normal Accident Theory (Perrow,1984)
Resource Dependency Theory	& focus groups	
(Pfeffer et al, 1978) Strategic		
Contingency Theory (child,1972)		
Risk Management	Survey across 8 industries SC Executives	Graph Theory (Gibbons, 1985)
	Using Graph Theory to provide supply chain vulnerability indices for industries	
Decision making process impacts	Case Study - Agent Based Simulation Modelling - Paper Tissue Manufacturer	Using ABS to address disturbances & subsequent Forrester affect
		Agency Theory
Systematic Supply Chain	Exploratory quantitative survey (Cross industry) and qualitative	
practitioners	Focus group with SC managers	Supply Chain Risk Management Concept & a structure for research issues in SCRM

FOCUS	KEY	CONTRIBUTION
Sources & Drivers of sc Vulnerability	C & R	Conceptual model of a supply chain as an
Networks response to disruption		interactive adaptive system.
Assessing sc resilience to disasters	I	A DS framework to assess supply chain resilience
		3 main determinates - Density, Complexity & Node Criticality
Disruption analysis, mitigation & sc Design	P	Disruption Discovery, Recovery, Supply Chain Redesign
for Resilience		
Quantification & mitigation of sc vulnerability	I	Supply Chain Quantification
Modelling the integrated production/distribution	P	ABS method to understand key issues for understanding operational resilience
system under uncertainty conditions		in production distribution systems
Business requirements for sc risk management	M	Business requirements from practitioner perspective
from a practitioner perspective		Structure for research issues in SCRM -
		Philosophy, Principles, Processes

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
	2011	H Calvalho	Integrating Lean, Agile, Resilience and Green Paradigms in Supply Chains	
		C Cruz-Machado		
Dynamic monitoring requires implementation of	2009	A Bhattacharya	On the Analytical Framework of Resilient Supply-Chain Network Assessing	
information system. Conceptual framework		J Geraghty	Excursion Events	
requires validation.		P Young		
Lacks statistical testing (e.g.SEM)	2006	M Faisal	Supply Chain risk mitigation: modelling the enablers	Y
generalises on results from Indian Manufacturing		D Banwet		
		R Shankar		
Exploratory lacks empirical follow up	2008	L Breen	A Preliminary Examination of Risk in the Pharmaceutical	Y
			Supply Chain (PSC) in the National Health Service (NHS) UK	
			(UK)	
Limitation single focal company &	2006	B Gaudenzi	Managing risks in the supply chain using the AHP Method	Y
industry vertical (medical/dentistry)		A Borgeshi		
Robust mixed methodology large heterogeneous	2011	C Bode	Understanding responses to supply chain disruptions:	Y
sample size (although all manufacturing)		K Petersen	Insights from Information Processing and Resource Dependence	
with strong statistical analysis & theoretical basis		L Ellram	Perspectives	

PERSPECTIVE	METHODS	THEORY
Supply Chain Management	Literature Review	LARG paradigms (Lean -Womack et al (1990),Agility- Christopher (2000),Fan et al. (2007),
		Resilient , Christopher & Peck (2004),Carvalho & Machado (2009),ANP, Saaty (2001)
Resilient Strategic Management	Descriptive analysis	Built on Christopher & Peck (2004) ; Snyder et al. (2006) SC Resilience work
	Gestated quantitative decision-support approach	New paradigm proposes stochastic dynamic decision making
		tools for trade-offs among multiple & conflict criteria to build resilience
		Development of ISM (Interpretative structural modelling (Warfield,
Supply Chain Risk Management	Interpretive structural modelling (ISM) - Indian SME Manufacturers	
	(Identifies & summarises relationships among specific variables to define a problem)	1974; Sage, 1977) with regards to interpreting SC risk management mitigation
Supply Chain Risk Management	Focus groups PSC stakeholders, suppliers & wholesalers	Developed study based on earlier work on sc Risk management including
	NHS professional & government bodies	Blackhurst et al (2008) ; Chopra & Sodhi (2004)
		Developed study goal of establish the "trade-off" required in complex
		decision-making situations, such as consideration of different objectives based on
Supply Chain Risk Management	Case study using Analytical Process Model to prioritise SC Objectives & identify Risks	different criteria Goodwin & Wright (1998)
	Dental & Medical Supplies , 4 key managers from focal company	
Information Processing &	Case study using cross industrial survey of manufacturers Germany,Aus,Switz	New holistic theory of organizational responses to sc disruptions ,authors
Resource Dependence		integrate organizational informational processing ,Galbraith (1973;Tushman & Nadler
		(1978) & resource dependence, Pfeffer & Salancik (1978), at the dyad level (interorganisational)

FOCUS	KEY	CONTRIBUTION
Integrating Multiple Paradigms in SCM	I	Identification of the conceptual relations among LARG - SCM
Event Excursions	I	Conceptual analytical framework for resilience of SC Networks
Strategies for Low probability -		by assessing excursion events
High Impact disruptions (LPHI)		Decision for buffer location in system - 'shock absorbers'
Reducing risk by addressing probability	M	Presentation of enablers and classification into driver/dependant
& direct impact		category unique in SC Risk Management
Risk management in Pharmaceutical	I	35 Prevalent risks identified and categorised - impact, occurance & controllability
Supply Chain		
Evaluation method for supply chain risks	I	Model used for setting up priority hierarchy for risk management
		New Theoretical Model - providing insights into the mechanisms
		that shape organizational responses to supply
Strategic Disruption Response	R	chain disruption

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Excluded transaction costs in	2009	N Bakshi	Co-opetition and Investment for Supply-Chain	
analysis		P Kleindorfer	Resilience	
	2010	C Colicchiaa	Increasing supply chain resilience in a global sourcing context	Y
Proven simulation technique with 5,000 replications		F Dallaria		
Requires combination with cost model for practice		M Melacinib		
Strong method focus on industrial sector	2011	U Juttner	Supply Chain Risk Effect & Knowledge Management	Y
		S Maklan		
Analytical review	2006	C Tang	Robust strategies for mitigating supply chain disruptions	
Large scale empirically tested 760 usable responses	2007	S Wagner	An empirical investigation into supply chain vulnerability	Y
Drawback German based low risk country vs. US/JP		C Bode		
Extensive simulation but single Automotive based	2012	H Carvalho	Supply Chain Redesign for Resilience using Simulation	Y
excludes behavioural examination		A Barraso		
		V Machado		
		S Azevedo		
		V Cruz Machado		
Analytical, ideological rather than scientific approach	2010	M Vickers	Resilience in Organizational Actors & Rearticulating Voice Towards	
		A Kouzmin	a humanistic critic of New Public Management	
Analytical, thorough review	2012	S Ponis	Supply Chain Resilience: Definition	
		E Koronis	Of Concept And Its Formative Elements	

PERSPECTIVE	METHODS	THEORY
Disruption risk - Security & Disasters	The Harsanyi–Selten–Nash bargaining framework is used to model	Bargaining theory under incomplete information ,Myers (1979), Principal-agent theory
	the supply chain participants' choice of risk mitigation investments	Laffont & Martimort (2001) - Moral Hazard & Information rent (reward for safe suppliers)
Supply Chain Risk Management	Mapping of Supply process of a home appliance retailer in Italy	Supply Chain Lead time as a proxy for Supply Chain resilience in context of inbound
	with suppliers located in China. Monte-Carlo simulation method	supply, building on earlier work by Christopher & Lee (2004); Christopher & Peck (2004):
	Scenario analysis using Supply Lead Time (key area of vulnerability selected)	Christopher & Rutherford (2004)
Supply Chain Resilience	Longitudinal Case Study of 3 supply chains	Supply chain risk management concept
	Cable,Timber & Chemical Companies (Interviews,workshops)	
Supply Chain Strategy	Integrative Literature review	Total Quality Management, Hendricks & Singhal (1996),
		Apprehension without action, Rice & Caniato (2003); Zsidisin et al. (2000, 2004)
Supply Chain Risk Management	Industrial,Service & Trade firms survey (cross section execs SCM) Germany	Normal Accident Theory (Perrow, 1984) and High
	Testing SC Vulnerability Hypothesis using Ordinary Least Squares (OLS) analysis	Reliability Theory, Roberts (1990) to be further explored to identify further scv factors
Supply Chain Resilience	3 Echelon case - Simulation study (Portuguese Automotive)	Designed in resilience building on resilience foundation works based on mitigating strategies,
Improvement	1st,2nd tier suppliers & outsource entity. Two performance measures	principles and interventions. including Rice & Caniato (2003)
	per SC entity - Lead Time ratio & Total Cost	Tang (2006);Christopher & Peck (2004);Vlachos & Xanthopoulos (2007)
Human Actors Resilience	Literature Critique	Trait theory, Korac-Kakabadse & Kouzmin (1997), Organisational theory, Kouzmin (1980;83);
with Organisations		Dixon & Kouzmin (1984), Public Choice theory, Dixon et al. (1996;98); Kouzmin et al. (1997)
Psychological Perspective		
Supply Chain Resilience	Systematic & Structured Literature review	Basis of 4 formative elements of supply chain resilience (SCR) based on previous works
		on following by element ; (1)Agility based on flexibility :Swafford et al. (2006) & velocity:
		Christopher & Peck (2004), (2) Redundancy; Sheffi (2005), (3) Collaboration;
		Lee (2004); Singh and Power (2009), (4)Knowledge of supply chain network physical
		& informational structure (Hong & Choi, 2002)

FOCUS	KEY	CONTRIBUTION
Gaming quantification	F	Framing of mitigating financing before and loss sharing post disruption
Inbound Supply Risk Management	I	Proposed a simulation-based framework
(Global Sourcing)		a tool for a preliminary evaluation of efficiency of
		resilience via dual approaches - Mitigation and Contingency planning
Global Financial Crisis as major demand risk	C	The conceptualisation of SCRES and the empirical findings
disruptive event		regarding its relationship with SCRM and SCV
SC resilience Capabilities		
Flexibility,Visibility,Velocity,Collaboration		
Reduction of Impact of Supply Chain Disruptions	M	Ways to reduce Impact: - Supply Alliance Network
on Supply Chain Operations		
Relationship between SC Vulnerability	I	Compiled and empirically validated constructs for
and SC Risk		different classes of supply chain risk sources
Evaluate SC Scenarios for improved resilience	M	Simulation allowed comparison of SC Behaviour post disturbance
How mitigating strategies affect performance		under two SC resilience design strategies
How trauma affects Organisations	C	Trait Theory Development (Korac-Kakabade & Kouzmin,1997)
		(personality traits in organisational actors)
Conceptualise SC Resilience & Identify	C	4 SC structural Elements as antecedents of SC Resilience
Capabilities to contain disruptions &		Flexibility, Redundancy,Collaboration
relationship capabilities to SC Resilience		SC Physical & Information Structure
		Which are proposed to examined as conceptual
		constructs through their current on-going research

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Fills gap of lack of empirical case study on	2012	O Khan	Aligning product design with the supply chain: a case study	Y
product design - sc alignment, triangulated validation,		M Christopher		
although opportunity to expand to other industries		A Creazza		
Analytical wide review, anecdotal	2004	S Chopra	Managing Risk To Avoid Supply-Chain Breakdown	
		M Sodhi		
Comprehensive disruption incident analytical review	2003	C Pickett	Strategies for Maximising Supply Chain Resilience Learning from the Past	
within time band using mainly desk research			to Prepare for the Future	
Used appropriate grounded approach to develop	2008	I Manuj	Global supply chain risk management Strategies	Y
theory due to literature gaps		J Mentzer		
Novel theory based framework but requires	2012	H Carvalho	Agile and resilient approaches to supply chain management:	
validation through large empirical research as		S Azevedo	influence on performance and competitiveness	
framework built on anecdotal & empirical evidence		V Cruz-Machado		
from the literature				

PERSPECTIVE	METHODS	THEORY
Supply Chain Management	Longitudinal Case Study - Single Fashion Retailer UK	Ulrich and Eppinger (2000): product complexity reduced
		through modularity;Sharifi & Pawar (2002);Fine (1998) concurrent engineering
		Pero et al. (2010) and Lo and Power (2010): frameworks for aligning product design & sc
Supply Chain Risk Mitigation	Literature review of cross Industry company case studies	Risk/Reward trade off, News vendor problem, Chopra & Meindl (2003)
		Kane (2001) Inventory controls, Lee et al. (1997) "Bullwhip Effect in Supply Chains"
Supply Chain Risk Mitigation	Literature review of case studies - Case is Organisation impacted	Inventory Optimization Theory, Just in Time/ Just in Case trade off, centralizational risk
	with regards to disruption event & SC disruption, resilience culture	Resilience= visibility + control
Supply Chain Risk Mitigation Strategies	Qualitative 14 interviews & focus group cross industry	Risk management strategies, Juttner (2003;2005), risk management theory development due to lack of e
	Decision making SC managers grounded theory approach	due to lack of existing theory
Supply Chain Resilience & Agility	Literature review induction approach to build theory	Merging of agile and resilient approaches in the supply chain management context
in Supply Chain Management		

FOCUS	FOCUS C	CONTRIBUTION
Product design & supply chain to identify	P	Product Design alignment with SC has
impacts on a firm’s SC responsiveness		positive significant impact on SC resilience & responsiveness
and resilience		Benefits of 'design centric' approach in scm
Mitigating strategies to avoid supply chain	M	Assessing Impact, Trade-off, risk tailored approaches
breakdown		
Mode of failure and impact outcomes	M	Supply Chain Resilience strategy based on failures modes
from experience		
Risk Management Strategies	I	Identifying the most important antecedents to
in Global Supply Chains		selection of risk management strategies and linking the antecedents to appropriate
		strategies.
		Moderating affect on risk on :Team Composition,Complexity &
		Inter-Organisational learning
Relationships between agile &	I	Identification of the conceptual relationships among
resilient approaches, supply chain competitiveness		agile and resilient supply chain practices and performance
& performance.		Conceptual framework facilitates future researchers
		explore the proposed relationships
		between the agile and resilient practices to identify
		synergies, thereby allowing the unification/integration of the
		two approaches in supply chain management

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Methodology work for decision support technologies	2013	T Ng	A Resilience Optimization Approach for Workplace Inventory Control Dynamics	
		S Cy	under Uncertainty	
Analytical literature review	2010	H Pfohl	State of the art in supply chain risk management research:	
		H Ko"hler	empirical and conceptual findings and a roadmap	
		David Thomas	for the implementation in practice	
Used rolling horizon decision making	2008	P. Seferlis	An Optimal Control Theory-Based Framework	
common method for efficient practical decision		D. Vlachos	for Supply Chain Resilience	
making in a dynamic environment, Chand et al.(2005)		E. Iakovou		
		A. Xanthopoulos		
Analytical literature review	2012	D Valchos	Building Robust Supply Chains by Reducing Vulnerability and Improving	
		E Lakovou	Resilience	
		K Papapanagiotou		
		D Partsch		
Robust academic case study based on automotive	2012	L Nunes	Combining FDSS and Simulation to Improve Supply Chain Resilience	Y
vertical		S Figueira		
		V Cruz Machado		

PERSPECTIVE	METHODS	THEORY
Industrial Systems & Engineering	Dynamic modelling with Eigen value sensitivity analysis	Stock management dynamic system model, Sterman (1989), Industrial Dynamics Forrester
		(1961), Resilience of workforce inventory systems, Towill (19820 Transfer function models
Supply Chain Risk Management	Literature review and integrating summary	Capital market theory, Weber et al. (2001), New Institutional Economics, Junginger (2005)
	of conceptual papers & empirical studies	
Supply Chain Resilience & Disruption	Stochastic modelling (Simulation) using a predictive optimal control scheme	Control Theory ,Seferlis & Giannelos (2004)
Supply Chain Risk Management	Literature review including regulations, and business cases	Review highlights the need for integration of SCRM strategies including ;Avoidance
		modelled:Mudrageda and Murphy (2007),Wu & Olson (2008),Viswanadham & Raghavan,(2000)
		& Raghavan,(2000); Control:Ellergaard (2008),Sheffi (2007), Cooperation:Cruz (2008):
		Flexibility (agility):Tang & Tomlin (2008),Peck (2005), Yu et al.(2009)
Supply Chain Disturbance Management	Automotive case study with 4 scenarios' & using Fuzzy Set Theory (FST)	Decision Support Systems to address unstructured problems , Spragg & Watson (1986)
	to model uncertainty & effects on SC, & uses discrete event simulation	
	using ARENA to assess implementation/contingency plans	

FOCUS	FOCUS C	CONTRIBUTION
Dynamic workforce inventory planning	DS	Development of decision support tools
		for design of resilient dynamic systems under uncertainty
Identification of main principles in	I	17 Principles of Supply Chain Risk Management
SC Risk Management & evolutionary steps		
for implementation		
Quantification of disruption impact &	O	An optimization based
resilience improvement		framework for enhancing resilience of a supply chain
Reduction of vulnerability & resilience	M	Integration of SCRM strategies to improve Resilience
improvement		
Discuss the analysis of the effects of SC disturbances	DS	Novel approach using SC performance index to select
& implementation of mitigation/contingency plans		best operational policy for improved SC Resilience
using a Fuzzy Decision Support System (FDSS)		

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Used well researched formal quantitative tools	2013	D Ivanov	Adaption Based Supply Chain Resilience	
combined with operational techniques.But Control		B Sokolov		
theory - static not dynamic, Blackhurt et al.(2003)		J Kaschel		
Analytical research based on extraction of	2010	Y Li	Analyzing Deformation of Supply Chain Resilient System based on Cell	
theory from ecological resilience, novel		L Zhao	Resilience Model	
but would be strengthened by real world testing				
Uses strong academic foundation	2013	J Lambert	Multiscale approach to the security of hardware supply chains	Y
of previous work in applying it with specific		W Wheeler	for energy systems	
focus on energy hardware, Single industry centric		I Linkov		
Four distribution centres and 39 customer locations	2013	M Turnquist	Design for resilience in infrastructure distribution networks	Y
were included in the simulation, system resilience		E Vugrin		
explored relevant to infrastructure/engineering sector				
Extensive review of 485 articles including TCE,	2011	P Greening	Disruptions and supply networks: A multi-level, multi-theoretical	Y
Resource dependency, RBT,buyer-seller,		C Rutherford	relational perspective	
economic organization, network formation				
social network & scd, but no testing of hypothesis				

PERSPECTIVE	METHODS	THEORY
Supply Chain Planning	Quantitative approach using Control Theory	Mitigating uncertainty and increasing resilience of supply chains from the control theoretic perspective
	balancing SC protection & adaptability taking account of	perspective - controlled adaption
	managers risk perceptions, risk strategies & SC stability	
Systems Engineering	Building of Mathematical model of Supply Chain Resilience System with 2 members,	Cell resilience model, Zhao (2008)
	researched SC deformation rules and quantitative simulation carried out using Matlab	
Energy security	Literature review includes editorial on combining Resilience Engineering	Design choices for human-automation systems in
	& Risk Analysis, drawing upon energy grid case study in FT. Belvoir	or abnormal situations
		Caravalho et al.(2012); Huber et al. (2012); Hollnagel et al. (2006)
Distribution Networks Resilience	Optimization computer modelling using example distribution network	System resilience, Vugrin et al. (2010)
	airline & 39 customers	Design-for-resilience in infrastructure systems
		Little (2002); Fiksel (2003); Petersen & Johansson (2008); Mansouri, et al. (2010)
Supply Chain Disruptions	Literature Review ,contextual analysis	Supply chain/network disruption - relationship between the nature of a disruption (described
: Network & relationships		by its network context and location) the urgency of response & post disruption network
		structure, Sheffi and Rice (2005),Knight & Harland (2005),Gulati & Gargiulo (1999)

FOCUS	FOCUS C	CONTRIBUTION
Mitigating uncertainty & increasing resilience	M	Adaption based SC Resilience Framework
Resilience analysis		Control Theory approach to uncertainty
		& Resilience, and insights for decision makers
Changing rules of SC system deformation	C	Novel approach using cell concept to represent
under sustained accumulated risk		SC system taken from Zhao (2009)
		System deformation gradually increases with
		certain relationships
Multiscale approach to address modelling &	M	Defines a multiscale approach for energy hardware sc modelling
decision-making for energy system hardware SC		& model from system scale to granular scale
		with associated vulnerabilities
Disruption scenario probabilities & resilience	F	Framework for network design trade-offs &
capacity with regards to investment alternatives		optimal network design against
		a set of uncertain disruptive events (combined contingency/mitigating)
Network structure post disruption	C & R	Consideration of disruption as opposed to disturbance
		Disruption specific propositions & new conceptual framework
		with Network structure influencing recovery time & impact

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Analytical literature review	2006	T Glickman	Security, Visibility, Resilience : the keys to mitigating supply chain	
		S White	vulnerabilities	
Thorough case study approach, constrained based	2007	Grewal R	Crises in business markets: implications	Y
on manufacturing hi-tech and steel.		Johnson J	for interfirm linkages	
		Sarker S		
Constrained by number of cases used	2007	M Primo	Manufacturing firm reaction to	Y
& retrospective interview use		K Dooley	supplier failure and recovery	
		M Rungtusanatham		
Novel approach using two previous models	2012	S Gaonkar	Analytical framework for the management of risk in supply chains	Y
in combination		N Viswanadham		
Positive contribution using practical management	2011	A Barroso	Supply Chain Resilience Using the Mapping Approach	Y
tool from management practice. Further research		V Machado		
needed on other industries/multi products				

PERSPECTIVE	METHODS	THEORY
Supply Chain vulnerabilities	Literature Review	
mitigation		Conceptual framework
		Moberg et al.(2003) Action plans for effective integration
Crises Management	Literature synthesis & qualitative study consisting of in depth	Interfirm relations & linkages (Anderson et al.1997; Dwyer et al. 1987;
	interviews with 27 managers from 13 firms; use of	Johnson 1999). Risk propensity response, Sitkin & Pablo (1992)
	data from two contrasting cases (Hi-Tech & Steel product manufacturer)	Crisis management & perception: Abolafia & Kilduff (1988);Milburn et al. (1983)
Supplier failure & recovery	Case studies via interviews of 4 US aerospace & electronics manufacturers	Critical supply failure Ellram (1991);Bowersox & Closs (1996)
Organizational response		Reaction to supplier service failures,Lockshin & McDougall (1998); Duvarsula
		et al., 2000; Pujari, 2004; Yanamandram & White, 2006
Supply Chain Risk Management	Mapping of propagation supplier events due to supplier non performance, develop	Optimization model, adapted from the Markowitz model
	two mathematical programming-based preventive models for strategic level deviation	Credit risk minimisation model
	and disruption management	
Supply Chain Management	Case study Portuguese Automotive based on mapping approach	Mitigation policy , Zsidisin et al. (2000);Svensson (2003);Christopher & Peck (2004)
	(single product X, 3 suppliers & assembler), using value stream mapping (eVSM(TM)	Value stream mapping & Lean, Womack & Jones (1998),Ohno (1988),Rother & Shook(1999)
	software	

FOCUS	FOCUS C	CONTRIBUTION
Supply Chain activities or characteristics	C	Three main key capabilities identified as mitigating
related to the mitigation of SC Vulnerabilities		SC disturbances : Security, Visibility & Resilience
		Promotes Moberg et al (2003) action plans for effective integration
		interorganisational teams, investing in IT & engaging in
		more practical & applied sc research
Organisational responses to	M & R	A process model of crisis - 5 phases
crisis & impact on Interfirm relationships		that details how crises may play out in Interfirm relationships
		propose a typology of crises and crisis management tactics
what is the impact of a supply failure and	F & R	Supplier failure & recovery impact a manufacturer's dissatisfaction with a supplier
recovery on manufacturing firm dissatisfaction		the antecedent to costs involved with supplier development or switching
with the supplier		
Strategic level approach minimize costs	F	New cost minimization & optimization models
& supplier choice in disruption management		for SC Risk based on Markowitz Model and credit risk
		minimization model, combining optimisation & cost
Identifying if supply chain is resilient	M	Use of mapping approach to support disruption management
to a specific disturbance & supporting		decision making and implementation of mitigating policies
managers decisions to adopt mitigating strategies		

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
A systematic guide to conducting vulnerability	1999	B Asbjornslett	Assess the vulnerability of your production system	
analysis, although excluded empirical work		M Rausand		
	2007	J Blackhurst	The Severity of Supply Chain Disruptions:	
		C Craighead	Design Characteristics and Mitigation	
		M Rungtusanatham	Capabilities	
		R Handfield		
Cross industry study used measurement approach based or	2010	A Stephenson	Benchmark Resilience: A study of the resilience	Y
based on similar earlier work in same location, low		E Seville	in the Auckland Region	
response rate but thorough approach		J Vargo		
would benefit from research in other locations		D Roger		
Used case study to address the 'how' question	2013	S Teoh	Strategic resilience management model	Y
Single case study limitation because cannot		H Zadeh	complex enterprise system upgrade implementation	
claim the findings as definitive but basis for future				
Only reviewed international journal articles, while excluding the conference papers, master and doctoral dissertations, textbooks.Solely based on analysis from theacademic rather than the practioners viewpoint.	2015	W Ho	Supply chain risk management: a literature	
		T Zheng	review	
		H Yildiz		
		S Talluri		

PERSPECTIVE	METHODS	THEORY
Production systems vulnerability	Vulnerability Analysis using scenarios approach via the input/output model	Complex (vulnerable) systems (1984), Input/Output Model
	& two step vulnerability analysis	Vulnerability of the system, Perrow (1984) Reason (1989, 1990) Meister (1991)
Supply chain risk management	Cash study	Mitigation & strategy
Organizational Resilience	Cross industry web survey & interviews of 68 organisations (7% response rate)	Benchmarking, Anderson & Pettersen (1996); Codling (1996)
		Resilience measurement tool, McManus (2007)
		Crisis management, organisational beliefs, Mitroff et al.(1989)
		Resilient Organisations, Seville et al. (2008)
Strategic resilience Management	Single Case study of Utility company during a major IT upgrade	Resilience management , McManus et al.(2007),
		Management mindfulness, Weick & Sutcliffe (2006), Transactive decision making
		(Noble 2000) and Resilience motivation, Gooch & Warburton (2009)
Supply chain risk management	Literature Reveiw of 224 journal articles 2003-2013	Chronologicl list from both quantitative and qualitative research

FOCUS	FOCUS C	CONTRIBUTION
Vulnerability in relation to production systems	C	Relationship between threats and vulnerabilities
assessment		
Risk Management Strategies	M & R	Design management strategies & risk
Test the proposed resilience measurement tool	I	new web-based survey tool to measure and benchmark organisational resilience.
& to explore the resilience in the Auckland region		
Strategic resilience management development	M	Inductively derived strategic management resilience
in order to survive the unforeseen challenges		model, demystifying threats for more effective
occurred during a complex ES upgrade process.		decision making & executing restoration plans
Risk management strategies	M & I	Thorough reveiw identifying substantial research gaps for further study
		proposed five common risks and new definition
		arising across various types of supply chains, including macro risk, demand risk,
		and infrastructural risk (information risk, transportation risk and financial risk)

Table 70 (continued)

CRITIQUE	DATE	AUTHORS	TITLE	EMPIRICAL
Based on single respondent in manufacturing with considerable non response rate where multicollinearity may exist and reluctance of participants to share real risk of catastrophe,	2017	G Lu Lucianetti	Supply Chain Security: A Classification of Practices and an Empirical Study of Differential Effects and Complementarity	
		X Koufteros		
		L Lucianetti		
One country based survey India so cannot be genralised, only used single methodology, single typology not generalizable across different industries	2016	D Mishra	Bridging and Buffering:Strategies for mitigating supply risk and improving supply chain performance	
		R Sharma		
		S Kumar		
		R Dubey		

PERSPECTIVE	METHODS	THEORY
Supply chain risk management	Survey of 462 firms in US & Italy	Supply chain security management
Supply chain risk management	Survey of 184 India organisations	Social exchange and contigency theory

FOCUS	FOCUS C	CONTRIBUTION
Risk and practice from security perspective	M & I	Classification of SCSM practices into four classes and particularly the development of indicators that reflect each category
		Probing the relative efficacy of each class of practices to explain variability in SCS performance. Evidence suggesting that detection practices are the supreme choice
Risk mitigation	M & I	Considers different strategic orientations, prospector,defender and analyser.Considers strategic selection and overall supply chain performance

Appendix 2: Survey Instrument

ONLINE SURVEY

Section A Characteristics & Overview

This research project investigates supply chain orientation and focuses on post disruption events in the supply of pharmaceuticals medicines within an NHS hospital. It is concerned with how actions taken after a supply chain disruption, can have on shortage management. Shortage management is a challenge in any environment and especially important in the healthcare arena. By participating in this research, new insights can be discovered to possibly improve approaches to this problem. Please be advised that participation is entirely voluntary and you can withdraw from the study without any penalty or consequences; after submitting your answers you will have one week to notify the researcher that you wish to withdraw. Please be assured that the data collated from the responses to the questions below will be anonymised to protect identity and will remain confidential.

1. Having read the briefing statement above, and you are happy to proceed, please check the below.
Yes
No

2. This questionnaire is the main method of data collection. To compliment this survey and gain further information, limited telephone interviews will be conducted on a random sample basis. To be eligible for possible selection please indicate below & remember to add your e mail in the last survey question Q65.
Yes
No

3. What is the number of staffed beds you serve?
<100
100-299
300-499
>500

4. Is your hospital in a collaborative hub or federation?
Yes
No

5. What is your region?
London
South
North
Middle & East of England
Other (please specify)

6. What is your In patient medication budget (£ million)?
<1.5
1.5-5.0
>5.0-10
>10

7. What is the number of Pharmacist FTE’s involved in your units pharmacy execution process (running orders,paying invoices,goods delivery etc.)
0-5
>5-15
>15-50
>50

8. Is your hospital in a collaborative hub or federation?
Yes
No

9. What is your current position title?
Pharmacist Technician
Lead Pharmacist Technician
Lead Procurement Pharmacist Regional

Pharmacist Specialist
Other (please specify)

10. How long have you been in your current position?
<1 year
1-3 years
>3-5 years
>5-10 years
>10 years

11. How would you describe your degree of knowledge about disruption management?
Not Knowledgeable at all
Some knowledge
Average knowledge
Good knowledge
Extremely knowledgeable

12. Is your hospital a standalone institute or one of several in a Trust?
Standalone
2-3
4-5
6+

13. We feel the need to be alert for possible supply chain disruptions at all times.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree
Not sure/ not applicable

14. Supply chain disruptions show us where we can improve.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree
Not sure/ not applicable

15. We recognize that supply chain disruptions are always looming.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not Sure/not applicable

16. We think a lot about how a supply chain disruption could have been avoided.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

17. After a supply chain disruption has occurred, it is analysed thoroughly.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

18. We feedback performance data on the alternative response taken to our regional management.
Strongly Disagree

Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable
19. We feedback performance data on the response alternative taken to all the other regions managers.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

20. We vary our response to disruptions depending on our business unit needs.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

21. We vary our response to disruptions depending on the length of time from initial occurrence.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

22. We understand we are part of a supply chain system and compromises must be made with our supply chain partners.
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

23. Do you feel you have ready access to relevant and usable information to enable correct decision making?
Strongly Disagree
Disagree
Neither agree nor disagree
Agree
Strongly Agree
Not sure/not applicable

Please find below in Question 24 a list of medicines that have experienced disruptions to their pharmaceutical supply chain. Please select only one of the medicines, then answer all the remaining questions 24 to 64 for the medicine you have selected in Question 24.

Section B Medical Shortage

24. Please select one of the following disruptions
Lidocaine Injection
Aciclovir Infusion Solution & Powder
Glycopyrronium Bromide Injection
Ketamine Injection
Lorazepam Injection
Other (please specify)

25. What was the severity of the disruption?
No impact
Slight impact
Moderate impact

Strong impact
Extreme impact

26. In which month did the initial disruption occur?
January
February
March
April
May
June
July
August
September
October
November
December

27. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Make us more independent of this supplier or the purchased item.
Never
Seldom
Sometime
Often
Almost always

28. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following activities?
Increase our protective barriers against disturbances in the supply of the purchased item.
Never
Seldom
Sometime
Often
Almost always

29. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Search for or develop one or more alternative supplier(s) for the purchased item.
Never
Seldom
Sometime
Often
Almost always

30. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Taken on extra staff or resources to cope with such disruptions.
Never
Seldom
Sometime
Often
Almost always

31. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Modified/developed policies (care plans/guidelines)
Never
Seldom

Sometime
Often
Almost always

32. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Purchased compounded replacement pharmaceuticals.
Never
Seldom
Sometime
Often
Almost always

33. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Make us more independent of this supplier or the purchased item.
Never
Seldom
Sometime
Often
Almost always

34. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Increase our protective barriers against disturbances in the supply of the purchased item.
Never
Seldom
Sometime
Often
Almost always

35. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Search for or develop one or more alternative supplier(s) for the purchased item.
Never
Seldom
Sometime
Often
Almost always

36. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Taken on extra staff or resources to cope with such disruptions.
Never
Seldom
Sometimes
Often
Almost always

37. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Modified/developed policies (care plans/guidelines)
Never
Seldom

Sometimes
Often
Almost always

38. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Purchased compounded replacement pharmaceuticals.
Never
Seldom
Sometimes
Often
Almost always

39. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Establish a closer relationship with this supplier in order to collaborate better in case of supply chain disruptions.
Never
Seldom
Sometimes
Often
Almost always

40. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Tighten the control mechanisms on this supplier (e.g., more monitoring).
Never
Seldom
Sometimes
Often
Almost always

41. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following activities?
Cooperate more intensively with this supplier.
Never
Seldom
Sometimes
Often
Almost always

42. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Improve information exchange with this supplier.
Never
Seldom
Sometimes
Often
Almost always

43. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Engage in risk management activities with this supplier (e.g. development of joint contingency plans).
Never
Seldom
Sometimes

Often
Almost always

44. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Developed inter-organisational relations within your regional area
Never
Seldom
Sometimes
Often
Almost always
Medical Shortage (Continued)

45. Actions (Immediately after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Developed inter-organisational relations outside your regional area
Never
Seldom
Sometimes
Often
Almost always

46. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Establish a closer relationship with this supplier in order to collaborate better in case of supply chain disruptions.
Never
Seldom
Sometimes
Often
Almost always

47. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Tighten the control mechanisms on this supplier (e.g., more monitoring).
Never
Seldom
Sometimes
Often
Almost always

48. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Cooperate more intensively with this supplier.
Never
Seldom
Sometimes
Often
Almost always

49. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Improve information exchange with this supplier.
Never

Seldom
Sometimes
Often
Almost always

50. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Engage in risk management activities with this supplier (e.g. development of joint contingency plans).
Never
Seldom
Sometimes
Often
Almost always

51. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Developed inter-organisational relations within your regional area
Never
Seldom
Sometimes
Often
Almost always

52. Actions (8-16 weeks after the disruption)
Since the disruption, to what extent has your business unit pursued, or made plans to pursue, the following
activities?
Developed inter-organisational relations outside your regional area
Never
Seldom
Sometimes
Often
Almost always

53. Of the medicine affected by the disruption,
What was the percentage of the lines fulfilled during the period up to 8 weeks after the disruption first occurred?
0-25%
26-50%
51-75%
76-100%

54. What was the percentage of the lines fulfilled during the period 8 weeks to 16 weeks after the disruption first occurred?
0-25%
26-50%
51-75%
76-100%

55. What was the average time to fulfil order during the period up to 8 weeks after the disruption first occurred?
Immediate
1 day
2-3 days
4-5 days
>6 days

56. What was the average time to fulfil order during the period 8 to 16 weeks after the disruption first occurred?
Immediate
1 day
2-3 days
4-5 days

>6 days

57. What was the proportion of orders satisfied in full during the period up to 8 weeks after the disruption first occurred?
0-25%
26-50%
51-75%
76-100%
58. What was the proportion of orders satisfied in full during the period 8 weeks to 16 weeks after the disruption occurred?
0-25%
26-50%
51-75%
76-100%

59. Were there any procedures delayed or cancelled as a result of the disruption?
Yes
No

60. Were any patients stay prolonged?
Yes
No

61. Was there any change in practice?
Yes
No

62. Was there any compromised patient care?
Yes
No

63. Were patient(s) given suboptimal care?
Yes
No

64. Was there any health consequences?
Yes
No

65. To receive a free copy of the results of the published report please enter your e mail address here:

Appendix 3: Roles Matrix

GRADE	TITLE	Communication		Personal and Professional Development		Health, Safety and Security		Service Improvement		Quality		Equality and Diversity	
Pharm	Pharmacy Business Services Manager	4abcef	4	4abce	4	3abcd	3	3abefg	3	4abcde	4	3ade	3
TMP25	Pharmacy Procurement Manager	3abcd	3	3abcde	3	2abcd	2	2	3	2	3	3ade	3
TMP26	Pharmacy Computer Manager	3abcd	3	3abcde	3	2abcd	2	2	3	2	3	3ade	3
A+C5	Pharmacy IT Officer	2abde	2	2abcf	2	1	2	2abcd	2	2abcd	2	2ab	2
A+C5	Pharmacy Distribution Facilitator	2	3	2abcf	2	1	2	2abcd	2	2abcd	2	2ab	2
A+C4	Pharmacy Procurement Officer	2abc	2	2abcf	2	1abcd	1	2abcd	2	2abcd	2	2ab	2
MTO5	Non-SterileProduction Manager	3abcd	3	3	4	3abcd	3	3acde	3	3acde	3	3ade	3
MTO4+++	Distribution Services Manager	3abcd	3	3abcde	3	3abcd	3	3acde	3	3acde	3	3ade	3
MTO3	Snr Pharmacy Technician Distribution	3abcd	3	2abcf	2	1	2	2abcd	2	2abcd	2	2ab	2
SATO	Pharmacy Distribution Supervisor	2abc	2	2acf	2	1abcd	1	1abc	1	1abce	1	1abcd	1
SATO+++	Tabletting Technical Officer	2abcd	2	2acf	2	1	2	1abc	1	2abcd	2	1abcd	1
AncB	Pharmacy Assistant Distribution	1abc	1	1a	1	1ab	1	1ab	1	1abc	1	1abcd	1

Appendix 4: Summary of Quantitative Analysis Table

ID	Query no	independent variable	Control variable/s	dependent variable	Test used	Model significant overall?	Parallel lines assumptions met?	Good-ness of fit assumptions met?	Pseudo R^2	independent variables which are sig
1	1 Proposition 1a. The stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management.	SCDO average (new)	BED NOS	PERF1	Ordinal regression	Y	Y	Y	.366 (36.6%)	SCDO_AVERAGE_NEW
1x	1 Proposition 1a. The stronger the supply chain disruption orientation (SCDO) of a unit, the higher the performance in shortage management.	SCDO average (new)	BED NOS	PERFPOST1	Ordinal regression	Y	Y	Y	.084 (8.4%)	None
2	Proposition 1b. The lower the role of the actor responsible for making supply chain disruption action decisions the lesser the shortage management performance	ROLE (categorical / ordinal) SCDO average (new	BED NOS	PERF1	Ordinal regression	Y	Y	Y	.394 (39.4%)	SCDO_AVERAGE_NEW
2x	Proposition 1b. The lower the role of the actor responsible for making supply chain disruption action decisions the lesser the shortage management performance	ROLE (categorical / ordinal) SCDO average (new	BED NOS	PERFPOST1	Ordinal regression	N	N	Y-	.112 (11.2%)	None
3	Proposition 1c. The larger the number of hospitals in a trust, the stronger the supply chain disruption	Hospital NOS	none	SCDO average new	ANOVA / Kruskal-Wallis	N, not sig using either test	n/a	n/a	n/a	None

ID	Query no	independent variable	Control variable/s	dependent variable	Test used	Model significant overall?	Parallel lines assumptions met?	Good-ness of fit assumptions met?	Pseudo R^2	independent variables which are sig
	orientation of a unit									
4	Proposition 1d. The higher the severity of the disruption, the better the managers with higher supply chain disruption orientation performance	DISRUPTIONSEVERITY (independent variable) – scale	BED NOS	PERF1	ORDINAL RGERESSION	Y	N	Y	.430 (43%)	SCDO average and (from disruption severity) No impact Slight impact Moderate impact Strong impact
4x	Proposition 1d. The higher the severity of the disruption the better the managers with higher supply chain disruption orientation perform	DISRUPTIONSEVERITY (independent variable) – scale	BED NOS	PERFPOST1	ORDINAL RGERESSION	Y	Y	Y	.174 (17.4%)	Moderate impact (from the disruption severity variable)
5	Proposition 2e. There is a positive relationship between the performance feedback given after a supply chain disruption event and higher performance in shortage management Variables: PERFORMANCETOTAL and FEEDBACKTOTAL (FEEDBACKREGMGR+FEEDBACKREGOTHER)	FEEDBACKTOTAL (FEEDBACKREGMGR+FEEDBACKREGOTHER (an average of two SCALE variables)	BED NOS	PERF 1	ORDINAL RGERESSION	Y	Y	Mixed	.250 (25%)	Feedback average
5x	Proposition 2e. There is a positive relationship between the performance feedback given after a supply chain disruption event and higher	FEEDBACKTOTAL (FEEDBACKREGMGR+FEEDBACKREGOTHER (an average of two	BED NOS	PERPOSTF 1	ORDINAL RGERESSION	Y	Y	Mixed	.440 (44%)	FEEDBACKREGMGR FEEDBACKREGOTHER (not bed nos)

ID	Query no	independent variable	Control variable/s	dependent variable	Test used	Model significant overall?	Parallel lines assumptions met?	Good-ness of fit assumptions met?	Pseudo R^2	independent variables which are sig
	performance in shortage management Variables: PERFORMANCETOTAL and FEEDBACKTOTAL (FEEDBACKREGMGR+FEEDBACKREGOTHER)	SCALE variables)								
6	Proposition 2f. Pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management	BUFFIMMEDIATE (HIGH SCORE) + BRIDGPOST (HIGH SCORE)	BED NOS	Perf 1	ORDINAL RGERESSION	Y	N	Mixed	.102 (10.2%)	BRIPOST only
6 x	Proposition 2f. Pursuing an initial buffering strategy followed by a bridging strategy enhances performance in shortage management	BUFFIMMEDIATE (HIGH SCORE) + BRIDGPOST (HIGH SCORE)	BED NOS	PERFPOST 1	ORDINAL RGERESSION	Y	N	Y	.340 (34%)	BUF BRIPOST BEDS cat 3
7	*Proposition 2g. Buffering actions in* response to supply chain disruption are more effective than bridging actions in shortage management performance	BUF 1 to 6 BRI 1 to 7	BED NOS	PERF 1	ORDINAL RGERESSION	N	N	Y	.037 (3.7%)	None
7 x	Proposition 2g. Buffering actions in response to supply chain disruption are more	BUFPOST1 to 6 BRI POST 1 to 7	BED NOS	PERF POST1	ORDINAL RGERESSION	Y	Y	Y	.414 (41.4%)	BUFPOST BRIPOST

ID	Query no	independent variable	Control variable/s	dependent variable	Test used	Model significant overall?	Parallel lines assumptions met?	Good-ness of fit assumptions met?	Pseudo R^2	independent variables which are sig
	effective than bridging actions in shortage management performance									
8	Proposition 3i. The impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact	1) BUf 1 to 6 2) BR1 to 7 3) bufpost 1 to 6 b 4) BRIPOST 1 to 7	BED NOS	PERF1	ORDINAL RGERESSION	Y	N	Y	.126 (12.6%)	BRIPOST1to7_AVG
8 x	Proposition 3i. The impact of buffering and bridging actions in response to supply chain disruption vary over time from the first impact	1) BUf 1 to 6 2) BR1 to 7 3) bufpost 1 to 6 b 4) BRIPOST 1 to 7	BED NOS	PERFPOST1	ORDINAL RGERESSION	y	y	y	.484 (48.4%)	BRI + BRIPOST only BUFPOST comes close
9	Proposition 3h. Varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management	(VARYRESPINTERN+ VARYRESPTIME)	BED NOS	PERF1	ORDINAL RGERESSION	N	N	Y	.080 (8%)	Only Varyrespintern_NEW
9 x	Proposition 3h. Varying a firm's supply chain disruption response actions dynamically post event improves performance in shortage management	(VARYRESPINTERN+ VARYRESPTIME)	BED NOS	PERFPOST1	ORDINAL RGERESSION	N	N	Y	.078 (7.8%)	None

Table 71.Quantitative analysis summary

Appendix 5: Diagnostic Tests Summary

Supply chain disruption orientation and Performance (2)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	147.500	140	.316
Deviance	134.748	140	.609

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	188.743			
General	180.108[b]	8.635[c]	8	.374

Role, supply chain disruption orientation, and performance (3)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	208.798	262	.993
Deviance	165.545	262	1.000

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	193.022			
General	171.991[b]	21.031[c]	16	.177

Role, supply chain disruption orientation and performance (4)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	Df	Sig.
Pearson	266.110	262	.418
Deviance	209.008	262	.993

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	240.540			
General	209.655[b]	30.885[c]	16	.014

Disruption severity, disruption orientation, and performance (4)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	174.899	229	.997
Deviance	148.954	229	1.000

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	173.389			
General	131.909[b]	41.480[c]	16	.000

Disruption severity, disruption orientation, and performance (4x)

Goodness of Fit

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	240.701	229	.285
Deviance	184.362	229	.986

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	216.749			
General	207.794[b]	8.955[c]	16	.915

Performance and feedback (5)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	103.468	77	.024
Deviance	89.564	77	.155

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	136.669			
General	125.344	11.324	8	.184

Performance and Feedback (5x)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	195.371	142	.002
Deviance	117.037	142	.938

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	152.746			
General	142.200[b]	10.546[c]	10	.394

Buffering, bridging, and performance (6)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	279.432	241	.045
Deviance	198.784	241	.978

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	228.895			
General	204.620[b]	24.275[c]	10	.007

Buffering, bridging and performance (6x)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	261.761	241	.171
Deviance	183.843	241	.998

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	209.691			
General	169.086[b]	40.605[c]	10	.000

Buffering, and bridging in response to supply chain disruption (7)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	257.030	232	.124
Deviance	189.598	232	.981

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	224.031			
General	198.350[b]	25.681[c]	10	.004

Bridging and buffering in response to supply chain disruption (7x)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	323.940	352	.856
Deviance	224.777	352	1.000

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	229.172			
General	223.031[b]	6.141[c]	10	.803

Bridging and buffering in response to supply chain disruption (8)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	355.441	362	.587
Deviance	264.126	362	1.000

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	264.126			
General	227.889[b]	36.238[c]	14	.001

Bridging and buffering in response to supply chain disruption (8x)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	353.966	362	.609
Deviance	217.153	362	1.000

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	217.153			
General	202.689[b]	14.464[c]	14	.416

Varying response – effect on performance (9)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	121.179	100	.074
Deviance	89.866	100	.756
Link function: Logit.			

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	133.161			
General	107.879[b]	25.283[c]	10	.005

Varying response – effect on performance (9x)

Goodness of Fit

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	115.675	100	.135
Deviance	93.739	100	.657

Parallel Lines

Test of Parallel Lines[a]				
Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	140.042			
General	.000[b]	140.042	10	.000