Dynamics of Supply Chain Failure.

Karsten Cox BA (Hons) MBA.

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Abstract.

In today's highly competitive global manufacturing industries, the reality facing most prime or focal manufacturing organisations around the world is one where resources have been reduced, inventory has been drained, technology spending curtailed, and processes that are not core to an organisation's business have been scaled back and / or outsourced. In competitive global marketplaces prime manufacturers simply cannot afford to have any area of their operations compromised. Supply chain operations need to be robust and resilient in order to retain and increase market share. Supply chain failure is a phenomenon that can potentially cause major issues for many organisations, especially when failure becomes persistent.

Supply chains may under-perform or fail in different ways. Here we are concerned with a particular kind of supply chain failure, persistent failure over time, which occurs when a supplier fails persistently to provide the level of quality and delivery performance originally expected or specified in an agreed contract. The phenomenon is observed in industries where there is a lack of substitute suppliers with adequate design and production capability and / or capacity, potentially high switching costs, and regulatory and accreditation issues. The goal of this research is to provide managers at prime manufacturing organisations with an effective way to understand their supply environment and provide insights to help identify and resolve supply problems that might otherwise become persistent failures.

In this research project, we seek to understand and rationalize what persistent supply chain failure is, identify why it happens and what influences it. This is achieved by conducting new primary empirical research to examine the 'mechanisms' and 'dynamics' of persistent failure and how organisations react to persistent adversity in supply chains. Multiple case studies have been conducted in the Aerospace Industry to understand and explain the nature of the phenomenon of persistent failure. An analysis of the extensive empirical evidence collected has enabled a new model of persistent supply chain failure be developed using causal loop diagrams. The 'Persistent Failure' model helps to understand the causes of the phenomenon and helps to identify mitigating strategies that can limit its emergence in supply chain relationships. The empirical study, the qualitative and quantitative analyses, and the causal loop model of persistent failure provide a significant contribution to the body of knowledge in purchasing, supply chain and operations management.

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OEM	Original Equipment Manufacturer.
NTSB	National Transport Safety Board.
SME	Small Manufacturing Enterprise.
SABRe	Quality Management System used by the Prime.
IMP	International Marketing and Purchasing.
SORB	Sales Order Review Board.
IPR	Intellectual Property Rights
PFMEA	Process Failure Mode Effects Analysis.
NPI	New Product Introduction.
PPAP	Parts Productions Approval Process.
MRPC	Material Requirements Planning Controller.
C Class	Consumable Class Part.
NADCAP	National Aerospace and Defence Accreditation. Programme.
FMCG	Fast Moving Consumable Goods.

Chapter 1 – Introduction.

1.0 Background and motivation.

This work is concerned with supply chain failure in manufacturing industries. Preventing supply chain failure from happening and the required actions and organisational transformations involved are the subject of numerous literature and research articles, covering a number of literature domains. The research literature considers supply chain failures in two broad streams. The first examines events that are out of the control of the supply chain such as natural disasters, civil unrest as an example (e.g. Natarajarathinam et al., 2009). Such significant events may be anticipated to some degree but generally cannot be predicted. The second stream concerns failure in the operation of the supply chain such as process failures (e.g. Craighead et al., 2004). These types of failures may potentially be identified and dealt with by manufacturers conducting internal and external audits of their suppliers and taking appropriate corrective action (e.g. Power and Terziovski, 2007). However, in this work we are concerned with a third type of supply chain failure: understanding what happens when an organisation can identify and observe supply chain failure happening but seems incapable of preventing the failure from re-occurring. Such failures may become much more damaging than an isolated incident. They may become a persistent failure that can seriously harm an organisation’s ability to successfully produce and deliver its products, and with this cause harm to its reputation and its ability to secure repeat business.

In this work we are particularly concerned with the inbound supply chains of large industrial manufacturing companies, typically labelled as OEMs, primes, or focal supply chain organisations. The related concepts of OEM (Original Equipment Manufacturer), prime and focal organisations are considered for instance, in studies by Harland (1996), Harland et al., (2004) and Clivillé and Berrah (2012) and refer to the ‘major player’ in a supply chain that may be the most powerful entity, possibly the largest entity, and typically the designer and controller of the supply chain. In this study we use the term ‘prime manufacturer’, or simply ‘the prime’, for this type of industrial organisation throughout the thesis.

In today’s highly competitive global manufacturing industries, the reality facing most prime manufacturing organisations is one where resources have been reduced, inventory has been drained, technology spending curtailed, and processes that are not core to an organisation's business are scaled back and / or outsourced. In an uncertain recovery, supply chain operations need to be more scalable and flexible (Wu and Olson, 2010). In competitive global marketplaces prime manufacturers cannot afford to fail in any area of their operations (Choi and Krause, 2006). Supply chain failure is a phenomenon that can potentially cause major issues for many prime manufacturing organisations, especially if failure becomes persistent.

In order to save costs and remain competitive, macro-economic conditions have forced large scale and complex prime manufacturers that would traditionally have produced parts, sub-assemblies, components and systems in-house, to re-evaluate how they do business. This involves making decisions to source particular parts, sub-assemblies, systems, and products from external supply chains. However, this activity has been found to equate to greater risks in meeting production planning timescales and achieving the required levels of quality and delivery (Flynn et al., 2016). The risks to a prime manufacturer are increased when reliance is switched from internally controlled processes to externally managed processes in the supply chain (Zsidisin and Wagner, 2010). In high tech and complex project-based manufacturing, organisations may face more risks related to supply chain failure because of the limited number of companies that are capable of supplying the type of technology that a prime company may need. This type of industry may also be less attractive or prohibitive to small manufacturing companies because of the high manufacturing investment, set up, and development costs, which means that barriers to entry are very high (Grundy, 2006), further limiting the number of potentially capable suppliers.

A recent example that demonstrates how outsourcing components can lead to supply chain failure is the case of Boeing's problems in the development and subsequent very late launch and delivery of the Dreamliner 787 aircraft (Kotha et al., 2013). It promised to offer a revolutionary change in airframe design with greater operating efficiency and a reduction in environmental impact. Boeing's 787 strategy was to outsource a higher proportion of production than had ever previously been the case (Piercy, 2009). However, the supply chain problems experienced by Boeing eventually led to very extensive delays and subsequent in-service safety issues. The most highly publicised incident was that caused by faulty batteries, which resulted in a fire on an ANA aircraft in the US. In fact all of the initial operators of the aircraft experienced the same problem (NTSB Report, 2013[1]). These issues led to a global grounding of all Dreamliner aircraft. Out-of-service aircraft can cost airlines many thousands of pounds every day due to disruption costs (Elahi et al., 2014).

This example highlights the potential risks that organisations face when they decide to outsource components and systems that have historically been manufactured and developed in house (Tang, 2006). In this case, significant technical problems were encountered from systems that were acquired from external suppliers within Boeing's first tier supply chain such as the on-board batteries, electrical wiring and particularly the composite material used to create the skin of the aircraft (Kotha and Srikanth, 2013). The problems encountered by Boeing also resulted in the company being forced to push back its initial scheduled first deliveries of the Dreamliner at least three years later than originally planned resulting in very significant profit implications for Boeing with compensation payments to its customers and to those suppliers that could supply on time. Even so, this was not enough time for Boeing to prevent the issues from re-occurring when the aircraft were initially in production and service.

Such scenarios are not just a concern in the most complex project-based manufacturing (Ambulker et al., 2015). The automotive industry is not immune to failures emanating from their suppliers. Famous automotive brands have been hit with a number of high profile quality failures in recent years resulting in embarrassing product recalls and subsequent losses of revenue (Choi and Chung, 2013). In particular, a major portion of such failures has been attributed to parts that were sourced externally (Natarajarathinam et al., 2009) and significantly, it seems that no auto-producer is immune to such supply chain failures. Even the staunchest advocate of effective supplier management – Toyota - has been affected in recent years (Hammond, 2013).

Toyota's 'sticking accelerator pedal' issue caused three separate recalls over a three year period. The company responsible for supplying the electronic accelerator pedals to Toyota (CTS Corporation) had also experienced issues with Chrysler vehicles who recalled 35,000 Dodge and Jeep models due to 'sticky gas' pedals (Dyer and Nobeoka, 2000). Overall, the disruption is estimated to have cost Toyota two billion dollars in lost revenue (Hammond, 2013). A major reason that the issue went on to become a critical problem for Toyota was because it was not identified within the

[1] NTSB Report – *Auxiliary Power Unit Battery Fire Japan Airlines Boeing 787-8, JA829J Boston, Massachusetts January 7, 2013.*

manufacturing testing procedure during initial product development and supplier contracting or in early production. Due to contractual obligations and conducting lengthy standard industry procedures for detailed root cause analyses, the issue had already manifested itself as a persistent problem for Toyota in volume production. It should have been important for Toyota to resolve the issue as quickly as possible since the cost of attracting new customers is significantly higher than retaining existing ones (Fornell and Wernerfelt, 1987). Unfortunately for Toyota, they failed to capture and mitigate the problem in time to prevent the issue from seriously damaging the company's legendary reputation for quality, lean manufacturing methods, and supplier management (Dyer and Nobeoka, 2000; Choi and Chung, 2013).

Some years prior to Toyota's much publicised problems another case of supply chain failure that persisted within the automotive industry was that of the Firestone tyres fitted to Ford's Explorer, Mercury and Mountaineer models. High failure rates of the Firestone tyres fitted to these models were identified between 1990 and 2000 (Biggemann and Buttle, 2008). By the end of 2000 there was a significant death toll attributed to this by regulatory authorities in the United States. This was estimated at more than two hundred and fifty, with some three thousand incidents in total being associated with the 'defective' Firestone tyres (Moll, 2003). The subsequent approach adopted by Ford and Firestone to manage the crisis not only severely damaged their century-old relationship but also enabled other parties to exploit the failure for their own commercial gain. The consequences resulting from these organisations' inability to deal with persistent failure included significant impacts on each company's bottom line, as well as damage to their brand reputations (Biggemann and Buttle, 2008).

Great efforts have been made by manufacturing organisations, large and small, in almost every industry in recent decades to adopt strategies that seek to make themselves as efficient, streamlined and competitive as possible in order to survive and prosper. The methods required to do this have been widely researched and much talked about in the literature (Holweg, 2007; Kaplan and Norton, 2008). The ability to achieve effective recovery from failure is an important responsibility of the operations and supply functions in manufacturing companies and one that has also been addressed by service organisations (Miller et al., 2000). However, the phenomenon of persistent supply chain failure is one area within purchasing, supply chain and operations management that has received little or no attention. As will become evident from the review of literature in Chapter 2, there are gaps in the literature seeking to understand and explain why organisations in some manufacturing sectors seem powerless to resolve supply chain problems in a quick and responsive manner, resulting in failure persisting in the supply chain. The absence of specific research literature on a topic that is prominent in the practitioner world is conspicuous.

This research project is being conducted in order to investigate, analyse and evaluate the phenomenon of persistent supply chain failure. The work seeks to understand what persistent supply chain failure is, what causes it, and its effects on prime manufacturing organisations with extensive supply bases. The initial research conception for the study defined persistent supply chain failure as:

> "*Persistent supply chain failure results when a supplier consistently fails to provide the level of quality and delivery performance originally expected or specified within an agreed contract. Due to a lack of substitutes with adequate design and manufacturing capability or capacity, and potentially high switching costs, opportunities to source components, sub-assemblies or systems or to develop new capability elsewhere are not economically viable and / or are extremely time consuming; thus resulting in the persistence of supply chain failure" (MacCarthy et al., 2014).* [2]

The above paragraph highlights some of the characteristics of operating environments where the phenomenon of persistent failure may occur, in particular long timescale industries such as aerospace where the product lifecycle is extensive in terms of design and development, supplier contracting and production, often measured in decades.

1.1 Research background.

A comprehensive review and analysis of the supply chain management literature has been conducted. Key supply chain research literature topics were identified and examined to determine if they contained questions, information, findings or insights that were relevant to situations or scenarios that could contribute to, or be causes of persistent failure in the supply chain. The research literature domains examined in the study comprised: Supply Chain Management; Risk Management in the Supply Chain; Supply Chain Quality Management; Supplier Development; Power, Leverage and

2 MacCarthy, B. L, Kauppi, K and Cox, K (2014) "The Dynamics of Supply Chain Failure", *21st International Annual EurOMA Conference, Palermo, Italy, 20-25 June 2014, "Operations Management in an Innovation Economy".*

Dependency in the Supply Chain; Performance Management in the Supply Chain; Relationship Management in the Supply Chain; Project and Programme Management; and Service Recovery. Literature on System Dynamics was also investigated once it was decided that causal loop diagrams would be a valuable method to examine and illustrate the cause and effect relationships that may result in persistent supply chain failure.

An outcome of the literature review was that little or no literature was found that identifies or focuses specifically on the phenomenon of persistent supply chain failure. A contributory factor to this may be that organisations will make efforts to hide such failings from the outside world to prevent negative information from reaching potential customers or the media. The examples given in the introductory section became well-publicised because of the global prominence of the organisations involved, the publicity associated with these failures, and the interest of the media and business sources in how the issues had arisen and how they would be resolved.

The literature examined for this study tends to focus on related but different types of scenarios, for example how organisations identify and attempt to mitigate failure before it happens and how they deal with previously identified failures quickly once they happen (Zsidisin et al., 2000). Such research often portrays a positive image of an organisation. The message it tends to give is – the organisation has failed but got it right in the end, and here is how. The phenomenon of persistent supply chain failure does not show this kind of positivity. As will be evident in the empirical study for this research, the language of practitioners leans much more towards understanding and developing coping strategies – getting by somehow.

Much of the supply chain management literature asserts that the long-term success and sustainability of an organisation at least partly depends on the reliability of its suppliers and the level of satisfaction reported by its customers. In other words, the entire supply chain must be successful (Chandra and Kumar, 2000) for a company to grow and be competitive. It is rare that an organisation will admit that it does not have control of its supply chain (Flynn and Flynn, 2005) as strong supplier management capability is often sought by potential customers. The supply chain literature does not tackle issues concerning failures that persist and do not go away no matter how much attention and resources a prime manufacturer commits to resolving the problem. By attempting to capture and define key events that come together to cause persistent supply chain failure, this research will help to gain a better understanding of those factors and events and to develop ways of managing them, i.e. to identify the most appropriate supply chain strategies that are needed to adequately deal with persistent failure.

1.2 Research aims, objectives and expected contributions.

The principal aim of this research is to *understand what persistent supply chain failure is and to understand why and how it happens*. The work seeks to examine and understand the ‘mechanisms’ and ‘dynamics’ of how organisations react to this kind of adversity in supply chains. The study will focus on large hi–tech industrial prime manufacturers and their suppliers. A key component of the research framework formulation process has been to identify and then specify a set of research questions that capture the essence of what we seek to study in this research. Pertinent questions help the researcher to determine how data collection and subsequent analyses should be conducted, structured and developed so that meaningful and informed findings and insights are obtained. The research questions for this study have been posed following an extensive literature review covering a range of both academic and practitioner literatures. The outcome of the review was that there are indeed gaps in the literature concerning the research topic. To adequately capture, understand and explain the phenomenon of persistent supply chain failure, three research questions have been formulated:

- ***Research question one (RQ1)****:* What is persistent supply chain failure and how can it be understood?

Research question one is the primary question the study aims to answer - an exploration of the origins of persistent failure and its effect on an organisation. By studying the literature and comparing it against empirical findings, an understanding of the phenomenon and why it happens or rather, is allowed to persist, will be gained.

- ***Research question two (RQ2):*** What factors drive persistent supply chain failure and what are the interrelationships between them?

Research question two seeks to identify the causal factors and understand how they are related. By conducting new empirical research and analysing the data obtained in an appropriate way, a causal model explaining the persistence of supply chain failure will be developed to enable greater understanding of the phenomenon.

- ***Research question three (RQ3):*** What supply chain strategies can be adopted to help resolve different types of persistent failures effectively?

Answering these research questions will contribute and add new knowledge to the existing literature in supply chain and operations management. Identifying what persistent supply chain failure is, the factors that cause it, how they are linked, and the mitigation strategies that are available will generate an understanding of how and why persistent failure happens in large hi–tech prime manufacturers and will provide insights for purchasing and supply chain managers on how to mitigate against this type of failure.

1.3 Overview of research methodology and design.

The work has been conducted with organisations operating in the aerospace supply chain, an application domain where persistent supply chain failure is observed. Given the content of the research questions a case study methodology utilizing qualitative research techniques (Yin, 2009) was chosen to provide the empirical evidence to allow further analysis of the phenomenon under study.

The study was conducted with one prime aerospace manufacturer and multiple first tier suppliers. The research approach aimed for a dyadic supply chain perspective on supply chain failure to enhance the richness of the research in the context of the contemporary research literature. Case studies were conducted with multiple interviewees in five first tier supplier organisations and with key supply chain managers from the prime manufacturer. The research questions provided a framework to undertake the qualitative case studies.

To understand and answer research question 2, an approach from Systems Dynamics - causal loop modelling (Morecroft, 2009) – was selected. Causal loop diagrams have been created to capture and illustrate linkages between activities that could develop and result in persistent supply chain failure. Causal loop diagrams are constructed using a process of coding of empirical raw data (Stall–Meadows and Hyle, 2010). Causal loop diagrams show strong emergent themes as linkages between key variables (Sterman, 2000). In coding raw data, key variables attributed to cause and effect of failure are identified. Each loop aims to provide a visual representation to explain how persistent supply chain failure occurs. Capturing mental models of the participants, which is a technique from Systems Dynamics modelling (Groesser and Schaffernicht, 2012), was used to assist in creating causal loop diagrams for each theme based on the findings from the semi-structured interviews. An understanding of the casual mechanisms and dynamics of persistent supply chain failure can help managers within an organisation. The usefulness of the research and subsequent output will be described so that the implications for wider industrial use of the model can be examined.

The work has been conducted in three stages as briefly explained below.

1.3.1 Research phase one: Exploratory study and data collection.

The research approach encompasses a case study design as proposed by Yin (2009), incorporating a research instrument and protocol design, data collection, analyses, followed by validation. Research phase one has been split into two stages, the first involving semi-structured interviews conducted with participants from the aerospace first tier supply chain followed by a repeat process with participants from a leading aerospace manufacturer's global supply chain management division. All interviews were conducted on site at the suppliers' and prime manufacturer's facilities. In total, five first tier suppliers participated in the study. They were chosen on the basis of their relationship with the prime and because they had at various points in the recent years been strongly associated with persistent supply chain failure by the prime. Nineteen supplier participants were interviewed at each first tier supplier covering every topic making a total of thirty five interviews. Eleven employees from the prime participated covering fourteen interviews making a total of thirty participants with a total of forty nine interviews conducted in stage one. It must be noted that due to the sensitivity of the issues being investigated (i.e. issues around failure) this was not an easy activity to carry out as all participating suppliers were currently contracted and conducting business with the prime.

Prior to commencing the semi-structured interviews at both the supplier and prime manufactures' facilities, protocol documents[3] were established in order to give the process the required structure, rigour and research robustness. This was put in place to enable the best possible opportunity for capturing rich data and also to provide protection for all interview participants in terms of confidentiality. All interviews were recorded and subsequently transcribed.

The purpose of conducting semi-structured interviews was to concentrate the research on identifying linkages with findings made from the literature review and to adequately answer the research questions. Stage two focused on strengthening the

[3] Example – *Provided in Appendix One*.

exploratory phase findings with views and insights from business and supply chain management professionals from the prime in order to gain perspective from both sides of the supply chain relationship.

1.3.2 Research phase two: Analysis.

Research phase two has also been separated into two distinct stages. The first involves qualitative analysis, which was conducted in order to identify common themes of causality related to persistent supply chain failure as identified during research phase one and to examine links between the interview findings and the literature. An axial coding technique was adopted (Strauss and Corbin, 1990; Yin, 2009) as a systematic method for analysing and interpreting the interview data. This was carried out in order to tease out emergent themes from the data. The aim was to identify both consistencies and differences in responses to the interview questions from both sides of the dyad. It was hoped that key themes would emerge through consistent answers to the interview questions. Differences in perspective, are also important in understanding the phenomenon being studied. The identified issues and captured themes were also assessed against the current literature in order to identify and establish the contribution that the research could make to the state of knowledge on the phenomenon under study.

For stage two, a causal analysis has been conducted using causal loop diagrams to visually demonstrate how variables interact to cause an effect that either reinforces the problem or balances / reduces it (Sterman, 2001). An initial version of the supply chain persistent failure model was developed in stage 2.

1.3.3 Research phase three: Validation.

The purpose of research phase three was to test and validate the causal loop diagrams and the initial persistent failure model. Research phase three began with a complete review of all previously obtained data including each of the original interviews with participants from both the first tier suppliers and the prime. Each original participant was given the opportunity to review the information they provided in the exploratory phase of the research. This validation process was carried out to ensure that the information originally collected was still relevant and topical after the passing of time. The process formed a pre-requisite to the major critique of the model. Validation of the persistent failure model was carried out by conducting a workshop with supply chain management professionals. It was a significant stage of the research process and was carried out to strengthen both the methodological rigour and the overall validity of the model and the process resulted in an amended final version of the supply chain persistent failure model.

1.5 Structure of the Thesis.

The thesis consists of eight Chapters, which provide the reader with a detailed description of events that happened throughout the research process. The overall structure of the thesis aims to guide the reader towards an understanding of the contribution to knowledge given and the managerial implications that this entails.

In Chapter 2 (Literature Review) a detailed analysis of the relevant literature is provided covering various aspects of the operations and supply chain management domain. The review focuses on the literature domains that have been analysed to gain knowledge and understanding of supply chain failure. Against each case, the cause and effect and subsequent mitigation strategies of supply chain failure adopted by industry have been examined. The key literature domains examined draw on a range of subject areas that are related to the cause and effect of persistent failure. The analyses provide justification of the research questions by identifying gaps in the literature. The analysis highlights where the literature is currently silent on each issue, focusing where the research and design methodology process needs to concentrate in order to confirm, add to, or refute the literature.

Chapter 3 (Methodology and Research Design) provides a detailed description of the research method and design adopted throughout the research process. Activities described in the Chapter include the first tier semi-structured interview method and the protocol design adopted to manage each case study. General information is provided about the first tier suppliers that took part in the study and information on the interview participants from both the first tier suppliers and the prime. In keeping with a rigorous research process, the method adopted for first tier suppliers was replicated for the prime manufacturer. The Chapter discusses the qualitative analysis design and method and provides a description of causal analysis and how it was conducted. The Chapter concludes with a description of how the work was validated.

Chapter 4 (Qualitative Analysis) provides a commentary on the findings from both the first tier and prime semi-structured interviews during the exploratory phase of the study. An explanation of the emergent themes from both research streams is then given based on first order coding analysis. The description of this process is followed by a discussion of the empirical findings in the context of the literature, which focuses on comparing each captured theme and the contemporary literature.

Chapter 5 (Causal Analysis) provides a thorough description and justification of the development of the causal loop variable names using the captured themes that were described during Chapter four. A brief description is then given of how each of the variables link together, followed up by an illustration of each loop. Once each loop is highlighted, the first major iteration of the causal loop model demonstrating persistent supply chain failure is presented.

Chapter 6 (Validation) describes the findings and observations from the validation workshop conducted at the prime. It includes findings from the first tier and prime participants by re-examining the interview data captured during the exploratory phase. The model is dissected from the bottom up in order to present the participants' observations and critique of the model. This is done to show the methodological rigour of the research process that permeated the entire data collection and analysis sections. As a consequence of the critique of the model from the validation workshop, Chapter 6 shows the final iteration of the persistent failure model. A description of the model and how it was developed is subsequently provided giving a brief explanation and justification of what changed and what remained the same.

Chapter 7 (Discussion) presents a detailed discussion of the persistent supply chain failure model in the context of the literature. For each loop in the model, whether the literature is confirmed or refuted is discussed. Additionally, throughout the Chapter, an identification of whether the literature is currently silent on each captured issue is given, providing clarification about where and how the study and the model add to existing knowledge.

Chapter 8 (Conclusions) concludes the thesis with a detailed evaluation of each research question in relation to the study. Key research findings culminating in a consolidation of the theoretical and management contributions that the research study has provided are then given. The Chapter concludes with an examination and evaluation of the limitations of the study and areas of potential further research are provided.

Chapter 2: Literature Review.

The purpose of Chapter 2 is to provide a comprehensive review of literature relevant to the study of persistent supply chain failure. The Chapter aims to identify and clarify key gaps in the existing literature and to justify the research questions proposed in Chapter 1. Importantly, this Chapter seeks to clearly define the topic of study (Baker, 2000) and justify the need for the research to be conducted. The Chapter also aims to identify the principal themes that will guide the research design and methodology used in the study.

A wide breadth of literature was reviewed during the study because there appeared to be little or no subject areas or research streams specifically focusing on persistent supply chain failure. Hence, a range of subjects that could potentially influence the research and help to underpin relevant research questions had to be explored. After an extensive review of the literature, research focusing specifically on persistent supply chain failure appeared to be non–existent, providing a major motivation for the present study.

The review commences with a brief general overview of Supply Chain Management (e.g. Lambert and Cooper, 2000) followed by a detailed investigation of a number of key literature streams: Risk Management in the supply chain (e.g. Zsidisin et al., 2000); Supply Chain Quality Management (e.g. Yeung, 2008); Power, Leverage and Dependency in the supply chain (e.g. Cox (2001); Supplier Development (e.g. Krause and Ellram, 1997); Performance Management in the supply chain (e.g. McAdam et al., 2008) and Relationship Management in the supply chain (e.g. Håkannson and Ford, 2004). Included within the section on risk is discussion of Contingency Management (e.g. Donaldson, 2001). Further literature domains were also examined because it was anticipated that they would also provide useful insights to the research and help answer the research questions. They included Project and Programme Management (e.g. Rodrigues and Bowers, 1996); System Dynamics (e.g. Sterman, 2000) and finally Service Recovery (e.g. Tax et al., 1998). The flow of the literature review has sought to highlight and reflect these subject crossovers.

2.1 Literature Domains.

The main purpose for conducting a literature review is to avoid 'calamities of ignorance' and the reinvention of what is already known (Baker, 2000 p.220). In order to conduct a thorough review of the literature, the following process was adapted from

Hart (1998, p. 32): *define the topic; think about the scope of the topic; think about the outcomes; think about the housekeeping; plan the sources to be searched; search the sources listed.*

The next stage in the process was to identify the key literature subjects that would help define and provide adequate coverage for the chosen topic. The main purpose of this activity is to build an understanding of related theoretical concepts and terminology (Rowley and Slack, 2004). The next step was to identify peer reviewed research journals most relevant for the research topic (Webster and Watson, 2002). Although the search parameters were not constrained, the main targeted journals initially consisted of: *Journal of Operations Management; International Journal of Production Economics; International Journal of Production Research; Journal of Supply Chain Management; International Journal of Project Management; Supply Chain Management: An International Journal; Journal of Purchasing and Supply Management; International Journal of Operations and Production Management.*

2.2 Supply Chain Management.

Christopher (1992) argued that leading edge companies came to a realisation that real competition is not '*company against company*', but rather '*supply chain*' against '*supply chain*' (Mentzer et al., 2001). But what is a supply chain? According to Mentzer et al., (2001 p. 4) the term *'Supply Chain*' is defined as*: "A set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finance, and / or information from a source to a customer".*

In earlier work, Cooper and Ellram (1993) described *supply chain management* as the management of the distribution flow from supplier to the end user. However, despite being adopted by organisations in various different ways since the early nineteen eighties, a universally accepted definition of the terms '*supply chain management*' and what they encompass has not yet been agreed within the literature (Ellram and Cooper, 2014). Mentzer et al., (2001) suggested that the terminology '*supply chain management*' caused confusion for those who studied it (Mentzer et al., 2001 p. 5). Notwithstanding, the continuing trends of outsourcing and globalisation has forced prime manufacturers to investigate and identify effective methods for coordinating the flow of materials with suppliers in order to ensure components are delivered on time, at the correct quality level, and at minimum cost, thus enabling competitiveness (Ellram and Cooper, 2014). This has resulted in the practice of supply chain management being widely used throughout industry with almost all manufacturing organisations having some dedicated functions or departments that concentrate on managing external suppliers in some way. The extent to which supply chain management is emphasised within manufacturing organisations depends on the proportion and amount of components that are sourced externally. Tan et al., (1998) explain how supply chain management *'brings together trading partners with a common goal of optimisation and efficiency'*. They describe this as the purchasing / supply perspective and suggest that it is the lead organisation that attempts to manage / coordinate the processes and operations of separate organisations to achieve one goal (Tan et al., 1998).

Echoing Christopher (1993), Lambert and Cooper (2000) developed a framework for supply chain management that showed how modern organisations no longer compete as autonomous businesses but rather supply chains. Their research indicated that managing the supply chain involves three interrelated elements: (1) the supply chain network structure; (2) supply chain business processes; and (3) the management of components (Lambert and Cooper, 2000 p.81). The framework was later updated to include relationships and networks of large major organisations (Clivillé and Berrah, 2012), noting that processes were cross functional (Lambert and Enz, 2017 p. 5). The relationships and networks share innovative information and learn from each other (Harland, 1996). Harland et al., (2004) developed a model that identifies nine different types of inter organisational networking and collaboration activities within the supply network which included *Partner Selection; Resource Integration; Information Processing; Knowledge Capture; Social Co-ordination; Risk and Benefit Sharing; Decision Making; Conflict Resolution and Motivation* (Harland et al., 2004).

Research on supply chain management has identified how strategic collaborations and issues concerning relationship management between buyers and suppliers is a key to reducing the risk of failure and improving performance (Teller et al., 2016).

2.3 Risk Management in the Supply Chain.

The concept of Risk Management has received considerable attention over the past few years within the operations and supply chain management literature (e.g. Zsidisin et al., 2000; Kleindorfer and Saad, 2005; Sharma and Bhat, 2014; Ho et al., 2015). Risk management research that focuses on how organisations seek to identify and mitigate against the cause and effects of supply chain disruptions is also quite extensive (e.g. Kleindorfer and Saad, 2005; Bode and Wagner 2015; Kauppi et al., 2016; Busse et al., 2017). According to Zsidisin et al., (2004) supply chain risk can be defined as: *“The probability of an incident associated with inbound supply from individual supplier failures or the supply market occurring in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety”*. Research describes how purchasing organisations may not be able to reduce the uncertainties associated with suppliers, and must instead construct buffers to protect against the effects of manifested uncertainties (Zsidisin et al., 2000 p. 187).

Arguably the most significant contributor to literature on risk management in the supply chain is Paul Kleindorfer, his work spanning a forty five year career. His biggest contribution to the field concerned the challenges of managing risks in operational settings (Cohen and Kunreuther, 2007), concentrating on supply chain disruption risk and its potential causes (Kleindorfer and Saad, 2005). Kleindorfer examined risk management issues from a number of perspectives such as linking risk assessments with risk management themes for low probability, high consequence events, risk management of natural hazards and catastrophic risks (Cohen and Kunreuther 2007) and studies investigating supply chain resilience to supply and demand disruption (Bakshi and Kleindorfer, 2009). His key study resulted in a conceptual framework for risk analysis, which characterised the importance of identifying linkages between risk assessments, risk perceptions and the development of risk management strategies (Cohen and Kunreuther, 2007 p.526).

Another consistent contributor to research on supply chain risk management is George. A Zsidisin. His research, conducted over a fifteen year period, has focused on the tools and techniques that organisations use to assess what their risks are, and the probability of them occurring. The research found that key tools adopted by organisations to manage risks are based around risk assessments (Zsidisin et al., 2000). When conducting a risk assessment, key stakeholders are invited to participate in the process. All of the identified risks then require a mitigation plan. The research highlighted how adoption and effectiveness of risk management tools such as risk assessment methodologies depend on the size of the organisation with SME’s being unlikely to adopt risk management processes (Zsidisin and Wagner, 2010). Sharma and

Bhat (2014) identified that many companies invest minimal time and resources into capturing and mitigating supply chain risks. This could be due to limited resources and the inability to assess all possible risks (Mandal, 2011).

Organisational approaches to outsourcing products are also reviewed from a risk management perspective. Topics that are commonly explored in the area of risk consist of approaches to managing global risks and the subsequent impact on issues such as hidden cost, lead time pressure and buying organisation to first tier supplier integration problems (e.g. Ritchie and Brindley, 2000; Auden et al., 2006; Manuj and Mentzer, 2008; Antelo and Bru, 2010; Christopher et al., 2011; Vedel and Ellegaard, 2013). Previous studies have sought to identify the characteristics of supply chains in relation to frequency of disruption (e.g. Choi and Krause, 2006; Craighead, 2007). Bode and Wagner (2015) found a positive relationship among organisations with higher complexity in skills and knowledge, hierarchical levels and geographical spread with the frequency of supply chain disruptions. Essentially, the greater the size of the organisations that operate within a supply chain then the greater the complexity, which in turn increases the risk of supply chain disruptions.

Organisational approaches to outsourcing have also spawned research focusing on supply chain agility and supply chain resilience. This is concerned with how organisations respond in a timely and effective manner to market volatility and other uncertainties, allowing buying organisations to maintain a competitive position (Gligor, 2014). Literature on supply chain agility and resilience is closely related to studies that investigate the effect of demand uncertainties that can exist within supply chains (e.g. Tang and Tomlin, 2008; Kerkkänen et al., 2009; Rossetti and Unlu, 2011; Kaman et al., 2013; Ho and Fang, 2013; Gligor, 2014; Pereira et al., 2014; Xie et al., 2014; Ambulker et al., 2015; Jabbarzadeh et al, 2017). Studies found that demand fluctuations and supply variations can result in increased inventory levels and delayed deliveries resulting in a reduction in supply chain agility and resilience. Flynn et al., (2016) identified that decision makers rarely have demand information when making inventory decisions, which can increase the risk of high inventory through the buffering of stock. The buffering of stock is a strategy used to mitigate against the risk of demand uncertainties and late deliveries (Mishra et al., 2016).

The concept of Contingency Management is an area of risk management related to the macro–economic environment (Donaldson 2001). The main difference between the two research streams is that although they both essentially examine risk in its differing forms, contingency management focuses on how organisations proactively manage crises in supply chains that are out of their control (Natarajarathinam et al., 2009). Research has found that smaller manufacturing companies tend not to have defined structures in place to explicitly manage contingency risks but can monitor the macro environment through observing relevant media channels (Tenhiälä, 2011). Therefore, it is usually the larger prime manufacturers who are concerned with ensuring that first tier suppliers make adequate provisions for contingency management in return for being awarded contracts. This includes examining the type of risks faced by manufacturing organisations and identifying how they can affect supply chains (e.g. Chopri and Sodhi, 2004; Sheffi and Rice, 2005; Ellis et al., 2010; Zsidisin and Wagner, 2010; Bode et al., 2011; Ambulkar et al., 2015 and Kim et al., 2015).

Other research on contingency management analyses event-based issues and focuses on significant disasters and recovery from subsequent supply chain disruptions. The main issues covered are those events that have been caused either by well documented natural or man-made disasters or events that have occurred internally within a manufacturing plant, for example, events that resulted in large scale organisational disruption such as fire, equipment failure or industrial accidents and natural disasters (e.g. Donaldson, 2001; Norrman and Jansson, 2004; Natarajarathinam et al., 2009; Ergun et al., 2010; Hammond, 2013; Elahi et al., 2014; Morrice et al., 2016). A notable consequence of having dramatic and often catastrophic events being publicised in the media and popular press is that organisations are now explicitly aware that these events can and do happen (Bode et al., 2011). One such incident that has been discussed in the literature refers to events that affected the mobile phone giant Ericsson in the early noughties after a fairly innocuous fire at one of their sub- tier suppliers. The incident, despite being described in the literature as a relatively inauspicious one, cost Ericsson a reported $11bn to $21bn in lost sales due to the fact that production had to stop because of the lack of an alternative source (Norrman and Jansson, 2004). At that time, it was identified that Ericsson neither had alternative sources nor was prepared for the kind of incident that occurred (Sheffi and Rice, 2004). Ericsson were publicly criticized for the way they handled the aftermath (Marley et al., 2014). The disruption caused by the fire led Ericsson to re-evaluate its entire philosophy on risk and contingency management. The more general supply chain management research literature and that focusing on supply chain risk and contingency management clearly acknowledge that supply chain failures occur but do not discuss or address issues related to persistent supply chain failure.

2.3 Supply Chain Quality Management.

An area of the literature that is related to the study of persistent supply chain failure focuses on understanding whether stringent approaches to quality management within a buying organisation can lead to improved supply chain performance (e.g. Power and Terziovski, 2007; Yeung, 2008; Basu, 2014; Quang et al., 2016). A second area focuses on how quality management practices affect risk in the supply chain (e.g., Clemons and Slotnick 2016) and a third examines quality management practices adopted by buying organisations including evaluations of the overall effectiveness of quality management within the supply chain (e.g. Foster 2008; Zu et al., 2008; Han et al., 2011; Kim et al., 2012; Zhang et al., 2012 and Barouch and Ponsignon 2016).

The literature has sought to obtain insights into the effectiveness of quality management with studies that examine how quality management practices affect supply chain performance (e.g. Kuei et al., 2001; Flynn and Flynn, 2005; Soltani et al., 2011 and Narasimhan and Schoenherr, 2012). The literature describes how a method for improving quality management performance begins with rigorous supplier selection activities (Ramudhin et al., 2008). Organisations should measure competing suppliers on the basis of product quality, delivery lead times and price (Ekici, 2013). There is also recognition that achieving improvements in quality performance throughout the supply chain is resource intensive and time consuming for all organisations, hence the extensive literature and studies on supplier selection processes (González et al., 2004). However, it has been noted that due to complexity and diversity of the real world, a methodological framework for operating an effective supplier selection model had yet to be developed (Chai et al., 2013).

Improvement of quality management adherence throughout all supply chain processes leads to cost reduction, improves resource utilisation and increases process efficiency (Fernandes et al., 2017). Studies have been conducted in order to identify the costs of quality that supply chain organisations have to absorb in order to improve quality (Wee and Wu, 2009). The literature highlights how buying organisations succeed when they are able to reduce the costs of quality and as a consequence, disruption (Elahi et al., 2014). Ramudhin et al., (2008) developed a model that sought to calculate all of the costs attributed to improving quality in supply chain network design. They found that their model was able to identify suppliers with high cost of quality implications for buying firms. Reducing additional costs of quality failures helps significantly to increase performance and with it profit margin (Ramudhin et al., 2008). Attempting to reduce the cost of quality leads companies into further developing quality processes and procedures that improve quality performance throughout the supply chain.

The literature highlights the importance of supply chain participants adopting the quality management processes and procedures of hi-tech complex manufacturing organisations (Fernandes et al., 2017). Research has also identified that collaborative relationships between buyer and suppliers are key to ensuring adequate supply chain performance from outsourced systems and components (Quang et al., 2016). The literature challenges the notion that the existence of a well-established quality control certification held by a prospective first tier supplier guarantees that the supplier has control over their processes and procedures. Studies suggest that it is often the case that they do not (Diaye et al., 2014). To reduce the risk of supply chain management failure, ISO 9000 [4]certification is a requirement within the sourcing process for many organisations throughout many industries (specifically AS9100 for the aerospace sector[5]). A study by Yeung (2008) found that while ISO 9000 serves as a foundation in purchasing management as a minimum quality level standard, it does not necessarily reduce the risk of failure or support strategic supply management, which he found to be a fundamental element of improving performance and reducing the cost of quality. However, later research conducted by Diaye et al., (2014) highlighted how the existence of ISO certifications within the supply chain can improve performance, even with suppliers who do not possess the certification but interact closely with suppliers who do (Diaye et al., 2014 p. 5409).

The literature investigates how buying organisations monitor adherence to quality management systems within supply chains. Research has found that buying organisations are conducting ever more onerous capability audits in order to reduce the risk of failure. The success of a capability audit often depends on how it is conducted and what is uncovered (Salama et al., 2009). The aim is to not simply improve quality

[4] ISO 9000 – *International Standard for Quality Management Systems.*
[5] AS9100 – *The aerospace industry version of the ISO quality process standard*.

adherence of the supplier, which is a cost to the buying organisation (Tse and Tan, 2012), but to ensure that such improvements are self-perpetuating and sustainable over time (Sancha et al., 2015). Power and Terziovski (2007) conducted research that looks at how organisations have increasingly started to carry out audits that look to gauge the effectiveness of quality management systems within manufacturing organisations. Part of their research expands on this notion by identifying the perceptions that clients have on the way auditors conduct their work. Buying organisations deploy auditors to conduct assessments aimed at monitoring compliance and look to evaluate the operational capability of their suppliers. The buying organisation seeks to quantify the level of risk posed by the supplier to judge if capability in the supply chain matches their or the end customer's requirements (Yim, 2014). If potential issues are not identified then the risk of failure is likely to increase, resulting in repeat audits later on. To add value, audits need to be capturing key issues at an early stage, otherwise the chances of failure are increased. Buying organisations want to ensure that suppliers do not pose a risk to continuity of supply and potentially cause disruption to the wider organisation (Chopra and Sodhi, 2004). The auditor is requested to examine a supplier's compliance to the company's own quality management system and ensure that they also fulfil industry requirements. It is therefore no surprise that Power and Terziovski (2007) found that companies felt they were being audited for compliance rather than for continuous improvement opportunities. Their findings suggest that, in general, auditors believe they are promoting continuous improvement methodologies at the organisations they are auditing and are contributing to improved performance.

Quang et al., (2016) conducted a recent study of the empirical literature that sought to identify correlations between quality management initiatives led by the buying organisation and improvements in supply chain management performance. They found that such research was still limited. Flynn and Flynn (2005) is one of the studies that specifically looks at whether the existence of a quality management function within an organisation improves supply chain management performance. They identify how organisations have a symbiotic relationship with their supply chain that recognises that each contributes to the others success, describing this as the *'Horizontal Effect'*, which is encouraged by the adoption of quality management practices (Flynn and Flynn 2005 p.3434).

Morrison (2015) investigated the effect of 'workarounds' carried out by organisations to limit disruption caused by product quality issues. These are short term 'quick fixes' conducted by manufacturers to essentially circumvent their own quality management systems in order to resolve problems more expediently (Morrison, 2015). This could happen due to a lack of available resources needed to quickly mitigate failures. Some research attempts to rationalise the causes of such failures (Tse and Tan, 2012). An earlier study conducted by Repenning and Sterman (2001) found that despite a number of tools and techniques widely available to organisations giving guidance on how to improve product quality there had been little improvement in the ability of organisations to incorporate these innovations into their daily activities (Repenning and Sterman 2001).

Although the supply chain quality literature is substantial, the issue of persistent supply chain failure has not been addressed either explicitly or implicitly.

2.4 Power, Leverage and Dependency in the Supply Chain.

The concept of 'Power' has been described as 'Bargaining Power' or 'Power Asymmetry' in studies regarding its effects on relationships in a supply chain and its impact on supply chain performance (e.g. Cox et al., 2001; Crook and Combs, 2007; Sheu and Gao, 2014). Leverage has been described as 'using what you have for maximum advantage' and is commonly associated with the identification of supplier positioning in a buyer supplier relationship with respect to how important one party is to the other in terms of turnover or spend (Cox et al., 2004 p.347). Dependency, or 'interdependency' as it is often described in the literature, is seen as the level of reliance that two parties have on each other in order to survive (Krause and Ellram, 2014). The literature also describes 'lock in' situations, which refer to instances where one party is very heavily dependent on the other (Narasimhan et al., 2009).

There is much debate about the best way for buyers to manage business relationships with suppliers (Cox, 2004). Approaches that seek to explain how the concept of power influences one party in the buyer / supplier relationship over the other is discussed in the literature. The power perspective focuses on how competence in procurement and supply management must start from an understanding of the bases of supplier power and business strategy (Cox 2001). Cox et al., (2001) define how four basic dyadic structures form a power matrix, which are: (i) buyer dominance, (ii) supplier dominance, (iii) buyer-supplier interdependence, and (v) buyer-supplier independence. These are intended to help buyers identify the type of relationship most likely to develop and form the backbone of the power perspective (Cox, 2001). Later work by Cox et al., (2004) looks beyond the original contribution made with the power matrix and considers the interactions within an extended network of business relationships. This is referred to as a power regime (Cox, 2004). Power regimes are composed of a number of interlocking, but discrete, management sub-regimes. Identifying how to manage the buyer / supplier relationships appropriately through the identification of relationship power regimes may be cyclical with changing market trends.

As the purchasing business function has developed and grown in strategic significance and understanding, further questions have been asked about which party appropriates the most value out of a relationship. This is an area where buyers from large organisations may become unstuck and where the power regime may begin to shift from the buyer to the supplier, thus potentially causing higher costs and lower performance in the future (Forslund and Jonsson, 2009). There is an acknowledgement by Cox (2004 p.346) in the literature that: *"Buyers need a guide to action when they confront the universe of real world circumstances that can occur when managing supply and suppliers. This is what is meant by 'appropriateness' or the art of the possible"*.

Identification needs to be made of the relationship with the supplier and how they view the buyer in their plans strategically in the future (Meehan and Wright, 2012). From this starting point it is possible to explain why it is only by analysing supply chain networks (and the power regimes operating within) that buyers can fully understand the relationship management choices available to them, and make appropriate choices between alternatives should the need arise (Cox et al., 2004). The literature also suggests that managing power regimes appropriately requires buyers to consistently monitor the relationship between themselves and the supplier, especially in times when organisations want to limit the cost of a relationship (Acharyulu, 2012). For a buyer to develop a successful relationship with a supplier, the buyer has to decide the most appropriate way to manage commercial transactions with suppliers (Crook and Combs, 2006). Best practice rejects the historic focus on adversarial buyer relationships with suppliers in favour of a long-term collaborative approach based on trust and partnership / alliances (Nyaga et al., 2013).

At the opposite end of the relationship management spectrum is the International Marketing and Purchasing Project (2004) championed by Håkansson since 1982. They focus on how four elements: products, services, money and society form the basis of a clear set of roles and responsibilities that the buyer and the supplier need to carry out (Metcalf et al., 1990). Their studies are also widely referenced in the literature on power with regard to the importance of evolved relationships (Håkansson and Ford, 2004). They emphasise the notion that many approaches to understanding and managing business relationships are based on the false idea that relationships are some kind of management technique that can be employed by managers at their discretion (Håkansson and Ford, 2004 p.248). It is formulated on the notion that the business world is viewed as an atomistic structure of independent actors within markets (Håkansson and Ford, 2004 p.249). The research suggests that business relationships are instead an inevitable outcome from the nature of business and hence beyond the complete control of either participating company (Vaaland and Håkansson, 2003). This is a contrasting perspective to the work by Cox et al., (2004) who believe that supplier relationships are based on leverage, alignment, and organisational positioning, factors which can be manufactured or created whereas Håkansson's research suggest that the relationships in supply networks are far more naturally formed. A more recent study by Hou et al., (2016) sought to examine how organisations react when exposed to different power positions. They found that buyers or customers who are perceived as exploitative and use coercive power can harm relationships and prompt suppliers to use protective behaviour against them.

Research on the subject of power often leads to the conclusion that whoever holds the leverage in a relationship then has an advantage in the relationship (Bastl et al., 2013 p.9). During difficult circumstances, if a buyer does not hold leverage with a supplier and the interaction becomes negative for the buyer, they will seek to end the relationship and go elsewhere if possible (Benton and Maloni, 2005). However, there are circumstances where the buyer does not have this option for many reasons such as a lack of substitute products and / or limited suppliers within the supply chain (Wallace and Choi, 2011). Historically, a common method of identifying market leverage used by practitioners is carried out by analysing market position using the Kraljic matrix (Kraljic, 1983). For example it would seem logical that a dominant buying organisation would have an advantage over a smaller supplier and would hold a good degree of leverage (Handley and Benton, 2012) because of the potential size of the business they could offer. However, the smaller first tier supplier could be the sole manufacturer and / or hold intellectual property rights for a key component in the buying organisation's product. The buying organisation may be the only customer for that product (Kähkönen, 2014); therefore they are equally reliant on each other.

Understanding the buyer–supplier relationship is essential in understanding the exchange relationship from a strategic perspective (Møller et al., 2002). Buyers need to understand the circumstance they are in and what scope exists for them to augment their power relative to that of suppliers. Mechanisms of interdependencies that exist within supply chain relationships are important in identifying the potential effects of a misaligned relationship when one player is heavily more dependent on the other (Narasimhan et al., 2009; Lacoste and Johnson, 2015). By investigating social exchange theory, Narasimham et al., (2009) identified how dependencies can develop within supply chain relationships and one party can become essentially locked into the relationship. This can affect performance and relationships in the event that the buyer does not have the opportunity to resolve the problems quickly due to limited options in the supply chain. If a buying organisation finds itself in this position then over time they can become overly dependent on their supplier (Crook and Combs, 2006). However, it has been found that paradigms of power do exist between suppliers and buying organisations that have an effect on value in the supply chain (Kähkönen et al., 2015). The supplier could be strategically aligned to another customer or competitor where they are consistently the high performing supplier (Pulles et al., 2016). Although the power, leverage and dependency literatures do not address the issue of persistent supply chain failure directly, they do give pointers to important factors that affect the nature of supply chain relationships and may therefore help to illuminate the causes of the phenomenon.

2.5 Supplier Development.

Supplier Development has been defined by Krause and Ellram (1997 p.39) as: *"Any effort of a buying firm with a supplier to increase its performance and / or capabilities and meet the buying firm's short and / or long-term supply needs".* Supplier development has been described within the literature as a method adopted by buying organisations for improving supplier performance (Wen–Li et al., 2003).

The study of supplier development utilises many different methodologies, including exploratory empirical studies and multiple case studies conducted at many different organisations throughout the world (Sánchez-Rodríguez et al., 2005). Much of the literature aims to understand how organisations adopt such methods by implementing initiatives with the intention of improving performance (e.g. Wen – Li et al., 2003; Humphreys et al., 2004; Wagner, 2006; Sánchez-Rodríguez et al., 2005; Krause et al., 2007; Carr and Keynak, 2007; Routroy and Pradham, 2011). The literature provides key insights into the activities that organisations carry out to achieve improved performance through supplier development. The findings highlight how factors such as senior management involvement and alignment of strategic goals between the buyer and suppliers are frequently reasons underpinning successful supplier development initiatives leading to improved performance (Humphreys, et al., 2004). Identification of the critical success factors help buyers to develop competitive advantage within the supply chain (Routroy and Pradham, 2013). The literature also suggests that improvement initiatives are most successful when the business relationship between the buyer and supplier is mature and suppliers can obtain preferred status **(**Negati and Robelledo, 2013**)**. Wagner (2010) examines the effect of social capital theory on the success of supplier development initiatives, finding that successfully deployed initiatives occur when the buying organisation is willing to invest in long term relationships. He also found that this has a positive effect on the outcome of a supplier development initiative and its effect on the supply chain performance. By persevering with initiatives, buying organisations are much more likely to experience an improvement in supply chain performance over the long term (Williams, 2007). Arroyo-López et al., (2012) identified that a major issue with supplier development initiatives is the tendency for buying organisations to abandon them far too early in the process if implementations do not result in an immediate improvement. Their research also identified how initiatives that take longer to complete may prove to be less successful (Arroyo-López et al., 2012). This is dependent on whether the initiatives have been intentionally implemented to mitigate against short term failure rather than to improve strategic suppliers over a longer period of time (Watts and Hahn 1993; Krause and Ellram, 1997).

Studies seek to examine how supplier development is carried out operationally by buying organisations and highlights the conditions that motivate organisations to implement improvement initiatives (e.g. Krause et al., 1997; Chan and Kumar, 2005 and Friedl and Wagner, 2012). Further studies seek to understand why supplier development initiatives are implemented by the buying organisation. The literature examines the causality of the implementations and provides an examination of whether the outcome of initiatives do actually result in increased sustainable performance over time (e.g. Wagner, 2011 p.277; Busse et al., 2016). Sánchez-Rodríguez et al, (2005) found that the implementation of improvement initiatives can help to predict purchasing performance. The aim of their research was to help buying organisations utilize supplier development initiatives in order to identify target suppliers versus those to eliminate. They found that suppliers who are less likely to improve after the introduction of development initiatives are those which could be considered for elimination (Sánchez-Rodríguez et al., 2005). Friedl and Wagner (2012) also conducted research that sought to identify which suppliers the buying organisations should choose to develop versus those suppliers that need to be switched. However, they found that the conditions of the supply chain could be improved if the buyer organisation chooses to develop the supplier when the switching costs are high instead of finding a new supplier each time.

There is recognition within the supplier development literature, that suppliers play a crucial role in the success and continuity of a relationship between the buyer and the seller (e.g. Williams, 2007; Mortensen and Arlbjørn, 2012 and Pulles et al., 2016). Wagner (2006 p.554) contends that: *"To compete and survive in industries where capable suppliers are limited to only a few, firms must seek, build up and maintain relationships with capable suppliers and extract the maximum value through such relationships"*. Organisations that supply to these types of industries come in all shapes and sizes. A large proportion of suppliers may be far smaller than the organisations they are supplying but they protect themselves because they own intellectual property rights for components or specific processes (Williams, 2007). According to Krause and Ellram (1996 p.39), Supplier Development can be seen as being important to organisations due to the fact that: *"In order to compete in their respective markets, buying firms must ensure that suppliers' performance, capabilities and responsiveness equals, or surpasses that experienced by the buying firm's competitors"*.

The literature on supplier development includes case studies conducted by Wagner (2006) that investigates a variety of manufacturing industries in Germany. The literature also incorporates further studies that examine large multinational manufacturers, some of which have a reputation for embracing a culture of continuous improvement such as Toyota and Honda (e.g. Govindan et al., 2010; Marksberry, 2012). In a situation where a supplier happens to be a larger organisation than the customer, it can be an extremely difficult endeavour for a buying organisation to try and develop the supplier in areas such as quality, delivery and cost or conduct training (Mortensen and Albjørn, 2012). This might be because the supplier is strategically aligned to another industry or a larger competitor within the market. Linkages between supplier development success, improved performance and supplier relationships in terms of relationship length are a further sub category of the research on supplier development (e.g. Wagner, 2006; Wagner and Krause, 2009 and Wagner, 2010). These studies have all identified that supplier development initiatives perpetrated by the buying organisation are all necessary to improve supply chain performance and reduce risk of failure from occurring in the future. The research has shown that closer collaborative causal relationships between buyers and suppliers is key to ensuring the success of supplier development initiatives (Busse et al., 2016). Although not dealing directly with persistent supplier failure, the supplier development literature does acknowledge that a supplier may need to develop and improve its capabilities. There are various studies that provide rich evidence and insights on when this is needed and the likelihood of success.

2.6 Performance Management in the Supply Chain.

Due to the added attention given to it by practitioners, there is a considerable amount of research conducted on performance management activities within the supply chain between the buying organisation and its suppliers (Thorpe and Beasley, 2004). The empirical literature examines the effects of performance management processes and procedures across many industries. As such, performance management is considered one of the key literature domains in the study on supply chain failure. This is because performance management is the principal method used by buying organisations and their suppliers to gain the necessary visibility required to understand the performance gap between agreed service levels, current performance and best practice (Choy et al., 2007). The literature identifies how buying organisations often have multiple systems and mechanisms in place to highlight issues that suppliers may exhibit that could cause disruption for the buying firm. Performance management processes and procedures are meant to act as early warning systems and provide buyers with visibility on how suppliers are performing versus agreed metrics (De–Waal and Counet, 2009). Aside from acting as a mechanism for ensuring agreed performance is maintained, performance management topics cover a wide spectrum of industrial scenarios. Some literature seeks to identify how processes and procedures carried out by buying organisations have an effect on the performance of their suppliers and if it assists key suppliers to improve performance (Schaltegger and Burritt, 2014). More commonly, studies provide a description of the systems being used by organisations to manage performance either internally or throughout the supply chain (Merschmann and Thonemann, 2011).

A key part of the literature concerns studies that highlight potential gaps in the effectiveness of performance management systems, which represent the most risk to the buying organisation (Koufteros et al., 2014). Such systems need to provide organisations with an appropriate level of operational visibility enabling greater collaboration between the buyer and supplier. Greater visibility and understanding of how a supplier is performing is a fundamental factor for the development of good commercial relationships between organisations within the supply chain (Corsten et al., 2011). Benchmarking studies of organisations considered to be world class manufacturers have found evidence that the implementation of performance measures and systems throughout the supply chain facilitates greater visibility for buying organisations (e.g. Lockamy and Spencer, 1998; Maestrini et al., 2017). Should managers at the buying organisation not be provided with accurate information, their ability to align actual supply chain performance with agreed performance levels is reduced (Pongatichat and Johnson, 2008). The resulting effect can cause negative metrics to be displayed against suppliers. Another negative effect of disparities between information being received by buying organisations could be that the picture presented of performance is not representative of actual reality (McAdam et al., 2008). Misaligned performance management systems that fail to provide managers with a true reflection of reality can be very disruptive to the supply chain and can result in buying organisations placing unnecessary resources and focus on the supplier. Alternatively, insufficient focus may be placed on a supplier (Meng, 2012). Either way, there is a risk that long term damage or disruption could be caused to the buying organisation and the associated supplier (Koufteros et al., 2014).

It is important to make the distinction between performance management and performance measurement as the two subjects, although related, do not necessarily address the same things. McAdam et al, (2008) identified the need for more studies that would attempt to measure and benchmark activities or practices upstream within the supply chain. Considerable attention is given in the literature to defining Performance Metrics, commonly referred to as Performance Measurement (e.g. Cook and Hagey, 2003; Koufteros et al., 2014 and Laihonen and Pekkola 2016).

Literature on performance measurement primarily consists of five activities; selecting performance variables, defining metrics, setting targets, measuring and analysing performance (Forslund, 2014). Managers at buying organisations require the flexibility that real-time information can provide in order to ensure that supply chain performance does not fall below agreed limits. Laihonen and Pekkola (2016) conducted a study that sought to identify whether a new type of performance measurement system that focuses on knowledge transfer throughout the supply chain could add value and lead to improved performance. They found improved supply chain performance measurement could be achieved through shared learning combined with knowledge transfer.

A recognised and frequently practiced application of a performance measurement system adopted by many organisations is that of the balanced scorecard (Kaplan and Norton, 1996). The methodology involves a multitude of measures and metrics that seek to show managers how the organisation and its supply chain are performing. The usefulness of a balanced scorecard is judged on the expediency and accuracy of available data (Barnabe, 2011). However, for some, this has represented a massive undertaking based on the size of the organisation and the sheer diversity of metrics and measures being analysed. Negative consequences of an underdeveloped performance measurement system include buyers spending too much time reporting issues rather than managing resolutions (Germain et al., 2008). The resultant time delays can force the buying organisation into becoming reactive (Barnabe 2011, p.453).

The effect of outsourcing activities on firm performance is also an element of performance management research that has received some attention (Kroes and Ghosh, 2010). Lahiri (2016) conducted empirical research by investigating articles that directly discuss outsourcing activities conducted by firms over a twenty year period. The study found that the effects of outsourcing on firm performance were inconclusive with some reporting positive, others negative, and some mixed results. This is important because outsourcing non-core activities is an established practice throughout many different industries in order to reduce costs and is often considered an important strategy to ensure improved performance (Prahalad, 1993). However, alternative research findings are now revealing a contradictory perspective on the long term success of outsourcing strategies. It has been recognised that outsourcing components into the supply chain can increase the risk of a failure occurring (Demeter, 2014). Outsourcing strategies have now moved beyond simply non-core and non-value added activities and has moved into key components and services (Corsten et al., 2011)**.** Although the performance management and measurement literature is wide and varied, the issue of persistent supply chain failure has not been addressed.

2.7 Relationship Management in the Supply Chain.

The subject of relationship management consists of research with a high level of diversity (Lettice et al., 2010). Studies that are related to the topic of persistent supply chain failure range from how relationship management influences performance (e.g. Møller et al., 2003; Forslund and Jonsson 2009; Cadden et al., 2010; Lui et al., 2012; Lambert and Shwieterman, 2012; Forslund 2014 and Zou et al., 2014), to research on how organisations interact with each other to gain advantages in the market (e.g. Choi et al., 2002; Hornibrook et al., 2009; Singh and Power, 2009; Zhang et al., 2009; Knoppen et al., 2010 and Rebolledo and Nollet, 2011). Many supply chain management topics have links with relationship management issues that occur between buyer and supplier (Fynes et al., 2008). Observations from the literature suggest that the performance levels of the supplier are to some extent characterised by the type of relationship that exists between the buyer and supplier (Lee and Johnson, 2012).

Studies that seek to understand how relationship management affects performance typically analyse the factors, processes and strategies that generate mutual successes in the industry (Cadden et al., 2010). These are reported as 'win–win' collaborations that exhibit the alignment of organisational goals, cultural fit, embedding information systems and resources into both parties' organisations (Wilding and Humpries, 2006). This aspect of the literature tends to be descriptive, focusing on 'how' and 'why' relationships work effectively between two companies. In this type of scenario, Forslund and Jonsson (2009), highlighted how suppliers can become complacent over time if they begin redirecting efforts towards new and more lucrative commercial opportunities. This can become a significant issue for the buyer as described later by Forslund (2014), who subsequently found a correlation with the type of relationship between buyers and suppliers and logistics (delivery) performance. Overall, she found that positive performance can depend on a good relationship (Teller et al., 2016) although there is contradictory research suggesting that placing too much emphasis on supplier relationships can lead to buying organisations wasting time, effort and resources that result in a reduced performance if not managed correctly (Zhang et al., 2009).

Studies have shown that despite the advances in information technology and supply chain visibility, key interactions between organisations within the supply chain are still managed by employees; therefore relationship management issues remain significant (e.g. Ik–Whan et al., 2005; Roh et al., 2008 and Williams et al., 2013). Williams et al., (2013) found that a higher level of supply chain visibility does not necessarily improve responsiveness or the quality of information. Instead they found that greater integration between buyers and suppliers was more likely to improve relationships and increase responsiveness (Williams et al., 2013). The main focus is on identifying how communication influences information flows and improves visibility through increased leverage and responsiveness (Williams et al., 2013). In fact the significance of the Williams et al., (2013) study can be extended throughout the supply chain. It has been identified that improved cooperation and information transparency can result in increased supply chain performance (Wadhwa et al., 2010). Jacobs et al., (2016) in a study that incorporated survey results from 214 China-based manufacturing companies, observed how positively perceived internal communication within the organisation actually facilitated positive communication with suppliers.

Trust has been defined as the belief that another company will perform actions that will result in positive outcomes for the buying firm as well as not take unexpected actions that will result in negative outcomes (Anderson and Narus, 1990). The presence of trust between buyer and supplier plays an important role in strategic relationships resulting in improved supply chain performance (Terpend and Ashenbaum, 2012). When trust is absent, one of the parties may be reluctant to share information or feel less motivated to learn about how to work with the other party (Fynes et al., 2008). A topic discussed in other literature domains suggests that the development of trust is an important relationship management strategy (Ik-Whan et al., 2005). In the situation that a supplier and its customers do not trust each other, then it is unlikely that they will be willing to share key information or communicate effectively (Lui et al., 2012). If such events do occur, organisations struggle to align their organisational goals and systems effectively, potentially leading to supply chain failure. Following a study conducted on 101 captive suppliers in the aviation industry, Clauss and Speith (2016) found that strategic alignment and effective governance, has a positive effect on buyer and supplier performance. The literature investigates how suppliers can form relationships with other suppliers, which then has an effect on the buyer supplier relationship if used to the suppliers' advantage (Choi et al., 2002). This does to some extent drive the way in which buying organisations communicate with, and manage relationships with the external supply chain (Møller et al., 2003).

Further examination of the literature describes a concept defined as supplier de–selection or dissolution. The term *'dissolution'* has been defined as: *"The act of formally ending or dismissing an assembly, partnership, or official body: 'The dissolution of the marriage' (Oxford English Dictionary, 2016)"*. Chen et al., (2013) have described dissolution metaphorically as when buyer and supplier get 'divorced', ending their established relationship. Significantly, dissolution could be considered during the next stage in the process after supply chain failure has occurred. This literature is related to the considerable amount of research carried out on understanding the ease of moving from one supplier to another once a relationship has reached its conclusion and the effect this has on buyer-supplier power (e.g. Kraljic, 1983; Cox, 1999; Gelderman and Weele, 2003; Grundy 2006). Research on dissolution, however, is probably less frequent due to the emotive subject of failure. It is far more difficult for would-be researchers to find participants willing to divulge such sensitive information (Ellegaard and Anderson, 2015). When prime manufacturers experience failing performance, they are faced with the choice to either commit resources to resolve problems with suppliers or to end the relationship and place resources into developing new supply chains (Krause et al., 1998). The ability to switch suppliers expediently is dependent on a number of factors because not all industries have an abundance of substitute suppliers (Gelderman and Weele, 2005). In these circumstances, sometimes the only option buying organisations may have is to develop existing suppliers and attempt to fix problems. It is in these situations that supplier positioning and power dominance can have an effect on the buyer (Cox, 2004). The risk to the buying organisation is perpetuated when the supplier is one of only a handful of sources able to supply the product.

The body of literature that exists on this topic shows that relationships between buyer and suppliers can be dynamic and may be temporary, resulting in strategies aimed at dissolving partnerships (Krause and Ellram, 2014 pp.206). The literature investigates what has been described as the 'dark side' of buyer-supplier relationships (Villena et al., 2011). This hints at a plethora of reasons why relationships fail including a lack of adequate information being provided throughout the supply chain through to weak communication or participants who do not wish to alter behaviour irrespective of the need to do so because of changing conditions (Wagner and Krause, 2009). Changing economic conditions is viewed as a cause for a strategic rethink that may require relationship dynamics to change also (Autry and Golicic, 2010). Added to this, the power dynamic between buyer and supplier shows that supply chain relationships and / partnerships do not always align on all issues (Gelderman and Weele, 2005). Key work into this subject area shows that relationship management and in particular traditional methods of communication such as talking on the telephone rather than modern methods such as email, can have a critical bearing on how relationships play out (Carr and Kaynak, 2007).

Managers have been actively encouraged to create more competition and position themselves against suppliers and competitors (Crook and Combs, 2007). The result is that organisations tend to now have a blend of suppliers from which they single source or have too many suppliers, often described as tail spend[6]. In these cases they may be looking to end relationships in order to consolidate and cut down on resource costs (Krause and Ellram, 2014). Another dynamic comes when relationship breakdown is caused by cost or perceived un-competitiveness on the part of the buyer. Alert suppliers will be aware of their position in the market and may position themselves in an area of strength so that the buyer simply cannot move supply quickly (Kähkönen, 2014). Seeking to place themselves into a position of strength for competitive advantage is utilised by every supplier to some extent (Lacoste and Johnson, 2015). Although not dealing directly with persistent supply chain failure, the

[6] Tail Spend – *Multiple supplier's with limited supply of parts and low spend. These suppliers represent a variable cost to the buyer.*

performance management and relationship management literatures potentially provide insights on many aspects of the topic.

2.8 Project and Program Management.

In conducting the review of the contemporary literature, a body of project management literature was identified that examines key characteristics of project management failures (e.g. Lindahl and Rehn, 2007; Sanderson 2012). The basic literature typically defines project failures as 'failure to achieve cost, time and quality targets' (Sage et al., 2014). Project management failures frequently concern project planning where project timelines are significantly underestimated (Sage et al., 2014). A further common project management failure is the inability to satisfy key stakeholders (Sutterfield et al., 2006). Such failures may occur when project managers fail to manage key project stakeholders because of ineffective communication skills (Sanderson 2012).

There are similarities between project planning and aspects of manufacturing planning. In a construction project for example, demand may be fixed but the project can still experience changing requirements from the customer (Germain et al., 2008). Similarly, in manufacturing, especially project-based manufacturing, demand requirements change because of uncertain customer requirements at the outset and / or production re-schedules. The importance of effective planning in both disciplines is critical to successful delivery (Turner and Zolin, 2012 p.95). Further to these observations, ambiguous business needs and unclear vision have also been highlighted as causes of project management failure (Yeo, 2002). A further link between project management and manufacturing failures is the issue of poor or inadequate definitions of requirements and scope (Yeo, 2002 p.245). If the requirements are not fit for purpose in the first instance then problems with quality, time delays, and costs are likely to occur and potentially reoccur later.

Unsurprisingly, projects of any kind may be accompanied with significant elements of risk (Aritua et al., 2011). A major topic in the project management literature is its relationship with risk management (e.g. Raz and Michael, 2001; Aritua et al., 2011; Sanderson, 2012). Research studies have aimed to understand how risks are identified, managed and mitigated in large scale projects. All potential risks should be examined in order to identify potential causes leading to future project management failure such as pressure to reduce time and cost whilst simultaneously improving quality (Cagliano et al., 2012). These pressures also occur in manufacturing and often determine the competitiveness of organisations in their respective markets (Zwikael and Smyrk, 2015). An analysis of the project management literature in relation to the supply chain management risk literature, shows that major project management failures can also be attributed, at least to some extent, to inadequate risk analysis and incorrect assumptions regarding risk analysis (Haji-Kazemi et al., 2013). Managing key project stakeholders effectively is viewed in the literature on project management risk as critical to the success of a project (Dainty et al., 2002).

An early study conducted by Elonen and Artto (2003) at two organisations in Finland found that special tasks requiring urgent attention on a project such as identifying and recovering from a serious failure are often given to an existing member of staff rather than employing a project manager (Elonen and Artto, 2003). From this point onwards they will adopt a 'pseudo role' similar to that of a project manager and are expected to deliver the project on behalf of the organisation as well as their normal role (Engwall and Jerbrant, 2003). The literature suggests the practice of organisations delegating key projects to existing members of staff rather than appointing professional project managers is not uncommon. Organisations often favour appointments from within to remedy a failure (Van de Merwe, 1997). As a result of selected individuals conducting such work in addition to their normal jobs, the capability and capacity to identify and resolve the root cause of a problem may be diminished. A very early study by Avots (1969) found that personnel picked to lead projects within an organisation are often not paid any more than their normal package for conducting project work. Avots (1969) suggested this was one reason why projects failed. It was later observed that should a project succeed then the reward will be either a promotion or more money but this is never guaranteed (Turner and Mueller, 2003).

The project management literature also contains studies that focus on how System Dynamics can be used to identify and illustrate characteristics of project failure and can be used to help project managers to learn from project mistakes (e.g. Rodrigues and Bowers, 1996; Chapman 1998; Lyneis and Ford 2007; Boateng et al., 2012; Wang et al., 2017). Project management researchers have been utilising System Dynamics methodologies to illustrate research findings in relation to feedback from practitioners over a number of years (Lyneis and Ford, 2007). Systems Dynamics has been used by project management researchers specifically to identify and understand common areas of failure within a project. These include identifying resource bottlenecks and where issues have occurred or could occur in the future (Snyder and Cox, 1985). Research has highlighted conceptual frameworks using simulations and the causes and effects of failures determined through empirical studies (Rodrigues and Bowers, 1996).

2.9 System Dynamics.

System Dynamics and System Thinking was developed in the 1950's as a result of work first carried out by J. W Forrester who began using computer-aided models to simulate cause and effect systems within supply chains. The field of research was initially known as Industrial Dynamics (Angerhofer and Angelides 2000). The research highlighted effects such as feedback, time delays and oscillatory behaviour within supply chains. Forrester devised a simulation called the *'Beer Game'*, which he used to demonstrate these effects on supply chains. The game simulates a typical supply chain (Sterman 2005) and demonstrates to the players how unstable supply chains can be despite complete visibility by all of the participants of what is going on during the game. The game demonstrates how the participants often fail to comprehend time delays leading to stock outs in parts of the supply chain and excess inventory in others, thus increasing costs and lead times despite a constantly stable demand flow from the customer. The game is used to highlight the *'bullwhip effect'* (Lee et al., 1997), which is the effect of demand signal distortion and the instability it causes throughout the supply chain (Sterman 2005).

System Dynamics has been extensively used to model supply chains (e.g. Forrester 1961; Morecroft, 1985; Lee et al., 1997; Akkermans et al., 1999; Sterman 2000; Anderson et al., 2000; Dogan and Sterman 2005). The research covers a range of studies that seek to contribute to theory building to solve supply chain problems, as well as work to improve the modelling approach (Angerhofer and Angelides 2000). Research by Akkermans et al., (1999) using Systems Dynamics helps to inform the study on persistent supply chain failure because it investigates how and why attempts at achieving effective supply chain management can be so difficult and fraught with challenges. Through the development of causal loop diagrams they investigate the underlying mechanisms that result in vicious cycles for some companies and virtuous for others (Akkermans et al., 1999). Likewise, the case study conducted by Anderson et al., (2000) on the American machine tool industry sought to simulate the effects of production volatility on the supply chain. This stream of research helps to inform the study on persistent supply chain failure because it advocates the improvement of communication and collaboration as a means to reduce supplier volatility from the effects of demand signal distortion (Anderson et al., 2000).

System Dynamics concepts and tools have been used by researchers in a variety of domains to provide a systematic management view of strategic and operational issues in organisations (Rodrigues and Bowers, 1996). System Dynamics models have been used to identify major causal factors that link together to significantly influence the success or failure of a project (e.g. Love et al., 2002; Jalili and Ford, 2016). By conducting System Dynamics simulations before the commencement of major construction projects, important interrelationships between all functions of the project can be captured and mapped (Kapsali, 2011). It has been demonstrated that System Dynamics can be used to identify where a major project had gone off track and the actions needed to give project managers insights into where and how to get the project moving in a positive direction (Yang and Yeh, 2014). Such models incorporated the use of causal loop diagrams to show cause and effect of factors that link together to create or result in particular outcomes. Formulating System Dynamics causal loop diagrams may give project managers the ability to focus and plan specific areas of a project (Lyneis and Ford, 2007). The ability to visually capture and demonstrate interactions between critical factors can positively influence the outcome of a major project. In addition, the greater visibility that System Dynamics potentially provides may enable project managers to significantly improve important facets of the project management process such as stakeholder management (Chapman, 1998). A significant reason for this is that Systems Dynamics can highlight the existence of inherent 'systems' within projects that develop naturally as a consequence of past decisions or actions and that, if not remedied, may reinforce factors that ultimately result in failure (Lyneis et al., 2001). A further potential benefit of this method is that the effect of actions taken by management to counteract systemic effects can be modelled before costly disruptions occur as a consequence of the change (Howick and Eden, 2004). The project management literature does deal with failures that persist over the course of a project, particularly large projects, and therefore it is natural to consider its relevance in the context of persistent supply chain failure. Equally the application of Systems Dynamics thinking and causal loop diagramming to understand project management dynamics may provide insights to further understand and analyse persistent supply chain failure.

2.10 Service Recovery.

Service Recovery refers to those actions designed to resolve problems, alter negative attitudes of dissatisfied customers and to ultimately retain those customers in service operations (Miller et al., 2000). Studies that investigate the concept of service recovery have been carried out in order to understand how organisations attempt to improve service operations and performance or mitigate against failure (Williams and Moore, 2007).

One such outcome is where studies attempt to understand how organisations regain customer satisfaction and confidence after significant failure and / or disruption has been caused (e.g. Tax et al., 1998; Hocutt et al., 2006; De Matos et al., 2007; Bhandari et al., 2007 and Huang, 2011). Studies on service recovery have sought to analyse the initial customer responses to failure and seek to characterise the emotions that motivate the buyer towards repeat business with the seller's organisation (e.g. Chebat and Slusarczyk, 2003, Rio–Lanza et al., 2009 and Edvardsson et al., 2011).

The outcome of the initial research into service recovery motivated others to attempt to understand how effective the service recovery initiatives have been (Tax et al., 1998; Miller et al., 2000). It has been observed that fulfilling specific criteria such as a perceived high recovery effort by the seller with some form of compensation can result in significantly positive effects for the seller (Augustus de Matos et al., 2007). In addition, the literature identifies corrective actions that enable sellers to recover from failure by ensuring that they do not lose dissatisfied customers. The studies have shown that in order to regain satisfaction, sellers need to solicit a social recovery in the form of etiquette such as an apology (Krishna et al., 2011; Hur and Jang, 2016). However, a key strategy to reduce the impact of service failure is to ensure that failures are dealt with expediently and that the buyer / supplier interface is efficient (Sousa and Voss 2009). The type of failures that are examined tend to be dealt with directly between the manufacturer or 'seller' and the customer (Edvardsson et al., 2011).

A research stream of particular interest is that on the 'Service Recovery Paradox'. A notable contribution to this phenomenon came from McCollough and Bharadwaj (1992) in their research on post-recovery satisfaction. They made the observation that effective recovery strategies can lead to the customer rating a service encounter or provider more favourably than if no problem had occurred in the first place (Tax et al., 1998 p.64). These observations have sparked numerous studies aimed seeking to identify whether there were sufficient foundations to the theory (e.g. Miller et al., 2000; Magnini et al., 2007; Michel and Meuter, 2008; Michel et al., 2009). One subsequent study carried out by Michel and Meuter (2008) concluded that the recovery paradox could exist but only in extremely rare circumstances. Failure can give the seller or service provider the opportunity to successfully recover in turn creating loyalty and trust with the buyer (Krishna et al., 2011). However, both service success and failure of recovery are very much the result of operational activities of the organisation (Miller et al., 2000 p.388). If the industry is highly competitive and has plenty of substitute products for customers to choose then the task of retaining dissatisfied customers becomes much harder to achieve. The key ingredients required to solicit a recovery paradox are shown to be clear and concise communication, timeliness, and empowerment of staff by enabling them to have the authority to make quick decisions that affect the outcome of the recovery (Bhandari et al., 2007). Perspectives from service operations management may help to inform the study of persistent failure in supply chains, particularly in relation to the service recovery paradox.

2.11 Characteristics of supply in the Gas Turbine / Aerospace Industry.

The commercial aerospace industry is valued in the region of $300bn globally, which includes production, maintenance, repair and overhaul (Richter and Walther 2017). Due to rapid growth, the sector has doubled in size over the past five years with 89% of the industry being based in the United States and Europe (Aviation Week Network, 2015). The industry is largely controlled by a very small number of global players in both the airframe and engine businesses. Due to the safety critical nature of the products produced within the industry, each sector is highly regulated across the supply chain at all levels to ensure that the products supplied are ultimately airworthy and safe in use. The sector is characterised by high-tech engineered products that consequently involve very large scale and complex supply networks. Therefore, the issue of strategic fit between suppliers of all components throughout the supply chain is an important one within the gas turbine manufacturing industry (Routroy and Pradham, 2011).

Typically, due to the high level of complexity required for each component, there are only a relatively small number of capable suppliers globally that can manufacture to the required standards. Pulles et al., (2016) in their study on preferential resource allocation, describe how managers from the buying organisation need to identify the significance of effectively securing resources from the supplier as they could be competing for this with competitors. The gas turbine manufacturing industry does not have the same level of competition within the supply chain compared with industries such as automotive or with larger manufacturers in terms of high volume of components per year. The attractiveness of the gas turbine manufacturing industry comes due to the potential longevity of the supply contracts, a feature that is uncommon in other industries. However, for some, this represents a risk to the buying organisations because suppliers may not necessarily be incentivised to support a supplier development programme where the return benefits will be experienced and spread over a number of years (Matook et al., 2009). However, potential new entrants to the gas turbine industry are usually attracted by the length of contracts on offer due to the extensive aftermarket business that is typical of the industry (Nagati and Robelledo, 2013). Therefore, suppliers are incentivised to develop strategies that ensure they are able to retain business on large scale projects without the threat of rival competition (Crook and Combs, 2007).

However, persistent supply chain failure is a real issue that continues to cause significant disruption for the major aerospace / gas turbine manufacturers. The example of Boeing was noted in the introductory Chapter. Key players such as Pratt and Whitney are experiencing problems with their new turbo fan gas turbine engine which has caused delivery disruption for the new Airbus A320 Neo aircraft, whilst problems with cabin the equipment supplier Zodiac of France is holding up production of the Airbus A350 aircraft (Hollinger, 2016).

2.12 Gaps in the Literature and Justification of Research Questions.

An important objective of this literature review was to establish the need to research the phenomenon of persistent supply chain failure and identify appropriate research questions based on clear gaps in the literature. The intention was to examine the literature and then use the findings to lay the foundations of the study and help to develop the methodology and research design, discussed in Chapter 3. The analysis has provided the required information needed to clarify what and where the gaps are in the contemporary research literature. Table 2.1 provides a summary of the literature domains examined including key contributors and interview topics created to investigate the identified gaps in the literature and the need to answer the research questions during the exploratory phase.

Table 2.1 Key Literature Themes Investigated During The Empirical Research.

Literature Concept	Example Key Papers	Exploratory Phase Interview Topics
• **Supply Chain Management**	• *Lambert and Cooper (2000)* • *Mentzer et al, (2001)* • *Cooper and Ellram (1993)*	• *Supply Chain Management Practices*
• **Risk and Contingency Management in the Supply Chain**	• *Zsidisin., Panelli & Upton (2000)* • *Kleindorfer & Saad (2005)* • *Capar & Narayanan (2009)*	• *Descriptions of Risks* • *Demand Management in Relation to Risk* • *Sourcing Risks Contingency Risks*
• **Supply Chain Quality management**	• *Flynn & Flynn (2005)* • *Power & Terziovski (2007* • *Yeung (2008)*	• *Understanding Quality approaches* • *Examination of Quality practices* • *Quality Management Risks*
• **Power, Leverage and Dependency in the Supply Chain and Relationship Management in the Supply Chain**	• *Cox (2001)* • *Hakannson & Ford (2004)* • *Forslund and Jonsson (2009)*	• *Understanding effects of Power and Leverage* • *Identification of Dependency* • *Effect of Relationship Management on Performance* • *The Effect of Communication Strategic Alignment and Trust*
• **Supplier Development**	• *Krause and Ellram (1996)* • *Humphreys & Chan (2004)* • *Wagner (2005)*	• *Supplier Development Processes* • *Supplier Development Challenges*
• **Performance Management in the Supply Chain**	• *Thorpe & Beasley (2004)* • *McAdam, Hazlett & Gillespie (2008)* • *Koufteras et al, (2014)*	• *Performance Measurement* • *Performance Risks* • *Aligning Organisational Requirement with Capability* • *Supplier Development Activities*
• **Project and Programme Management**	• *Rodrigues and Williams (1998)* • *Chapman (1998)* • *Sanderson (2012)*	*Not Included*
• **System Dynamics**	• *Sterman (2001)* • *Morecroft, 2009* • *Kampman (2012)*	*Not included*

• **Service Recovery**	• *Tax, Brown and Chandrashekaran (1998)* • *Miller et al, (2000)* • *Craighead et al, (2004)*	• *Recovering from Failure*

The key gap in the literature is the lack of research that seeks to evaluate *persistent* failure that continues to disrupt prime manufacturing organisations in some industries over a period of time. This leads to the first research question for this research:

RQ1 '*What is persistent supply chain failure and how can it be understood?'*

It was also clear from the review of the literature that many issues can influence each other in relation to supply chain failure. Therefore, it is necessary to understand which factors interact to increase the chances of persistent failure. This has led to the second research question for this study:

RQ2: *'What factors drive persistent supply chain failure and what are the interrelationships between them?'*

In order to develop a legitimate model that could be used by managers to understand and potentially mitigate against persistent supply chain failure it was important to investigate and identify supply chain recovery strategies, which lead to the third and final research question:

RQ3: *'What supply chain strategies can be adopted to help resolve different types of persistent failures effectively?'*

Gaps in the literature on risk and contingency management contributes to the justification of RQ1 and RQ2. The contemporary literature focusing on Risk and Contingency Management within the supply chain is an important theme because it provides an examination of how both buyers and suppliers identify potential failures and how they mitigate them. However, despite the research focus, studies do not analyse the relationships between variables that can link together to eventually cause failures that recur and persist over an extended period of time. For example, research does not examine how key operational risks can link together to become so volatile that, over time, if not remedied, become more difficult and costly for buying organisations to mitigate without experiencing disruption. In addition, there are notable differences between the research that focuses on sourcing risks and the concept of supply chain failure. The differences can be seen through examining the methods developed to identify potential risks. These tend to focus on preventing failure from happening in the first instance (Giunipero and Eltantawy, 2003). It is the supply chain's reaction to failures that have already happened which is interesting for the research on persistent supply chain failure.

Literature on supply chain quality management identifies a number of concepts that resonate with the research on persistent supply chain failure and contribute to justifying RQ1. Much of the current empirical research focuses on identifying what a robust quality system looks like (Zhang et al., 2012) and how buying organisations seek to measure supply chain performance. The literature does not examine the characteristics of an ineffective quality management system and what effect this has on supply chain performance over time. In contrast, this research on persistent supply chain failure addresses a gap in the literature by clarifying the role that inadequate quality management systems and practices play in both causing persistent supply chain failure and the activities that buying organisations can use to address this.

Literature that examines the concept of buyer and supplier power and the effects these have on business relationships and strategy is also important for understanding potential causes of failure in the supply chain. This literature contributes towards framing and justifying RQ1 and RQ2. Although many studies have been conducted that attempt to identify and describe the effect of buyer–supplier power asymmetry, leverage and interdependency on supply chain management performance, none consider persistent failure. Some studies attempt to understand how dependencies between two parties in a supply chain relationship can ultimately lead to commercial lock-in, which increases the effect of an adversarial relationship (Narasimhan et al., 2009). However, an identified gap in the literature centres around how current research has not yet been expanded to investigate the effect that buyer–supplier dependencies can have on the supply chain (Nair et al., 2011). Existing literature does not investigate if or how dependency can become a cause of persistent failure and its ramifications for key relationships within the supply chain when problems persist. The research on persistent supply chain failure seeks to identify these effects.

The majority of the literature on supplier development has concentrated on understanding the circumstances that lead to improvement initiatives being conducted with chosen suppliers. Answering RQ1, RQ2 and RQ3 will help to address gaps in the supplier development literature. The current literature seeks to address ways in which buying organisations utilize improvement initiatives to improve performance (Nagati and Rebolledo, 2013). However, there is limited research that attempts to understand how buyers manage improvement initiatives when both parties fail to mitigate against disruption in the short term (Morrison, 2015) or if failure persists despite improvement initiatives being instigated. A further identified gap in the research is the identification of whether supplier development initiatives can actually cause increased problems for the intended recipient over a period of time should an initiative prove unsuccessful.

Literature investigating supply chain performance management systems adopted by buying organisations was found to be extensive and covers a wide subject area. There is no apparent research that explicitly investigates how buying organisations react to supply chain failure once it has been identified through their performance management system. The literature does not address the actions that buying organisations take to mitigate against a failure that is already causing disruption persistently, nor does it seek to understand the point at which the buying organisation takes action to mitigate against failure. A further related topic that could potentially contribute to persistent supply chain failure is the misalignment of performance management systems and the effects that this may have on organisations within the supply chain (Busi et al., 2006). The research examines the cause of performance measurement misalignment and suggests that this can exacerbate the risk of failure throughout the supply chain (Johnston and Pongatichat, 2008). However, the current literature does not investigate the specific effects this has on the buying organisation or suppliers' behaviours.

Further significant gaps identified in the literature review concern relationship management in the supply chain. The findings from the literature review on this topic further justify RQ1, RQ2 and RQ3. Some literature investigates cause and effect of strained relationships but does not extend to cover what happens when the buying organisation has no immediate substitutes to resource from, therefore delaying a possible exit from the failing supplier (Meehan and Wright, 2011). In an acrimonious relationship, a lack of sourcing options could become a serious issue and may contribute to persistent supply chain failure. Closely related research examines the effectiveness of communication between buyer and suppliers, investigating the type of communication that can lead to improved supply chain performance (e.g. Ruey–Jer et al., 2010; Jacobs et al., 2016). However, the empirical literature fails to adequately address the effect of minimal communication throughout the supply chain and how this can potentially reduce a supplier’s performance. There is literature that describes how a lack of communication can create tensions with suppliers whose business is not seen as critical or core to the buyer (Ellegaard and Anderson, 2015) but it does not investigate how the effects can contribute towards supply chain failure. Some related studies within the relationship management domain investigate circumstances surrounding when buying organisations decide to end a longstanding relationship with a supplier and why (Pressey and Qui, 2007) but does not address the issue of the buyer being unable to source from elsewhere quickly.

Some similarities have been identified in the literature on project management that specifically concentrates on the causes and effects that influence large scale project failures and also practices that are associated with project success (Turner and Zolin, 2012). The literature describes characteristics of failures that occur during large scale projects and investigates project risks and uncertainties (Sanderson 2012). The literature also highlights how lessons learnt from case studies conducted on manufacturing organisations has influenced studies on project management (Sage et al., 2014 p. 543).

The service recovery literature concentrates on the direct customer to seller interaction within service based industries and examines how sales representatives manage customers from a state of dissatisfaction to a position where an irate customer becomes very satisfied and the business is therefore retained (Craighead et al., 2004). This literature from the service domain further justifies RQ2 and RQ3 because the current supply chain literature does not explore how the process works in a supply chain management scenario. However, it is clear that existing service recovery literature in service operations management incorporates a very different set of characteristics to those being managed in complex manufacturing supply chain contexts such as measuring the performance of the seller based on how expedient and effective the problem is dealt with (Cho et al., 2012 p.802). Within the service recovery literature, failures are either dealt with immediately in order to stand a chance of retaining businesses or the customer’s business is lost.

Thus, overall, the literature review shows an absence of research on persistent supply chain failure but does highlight a number of key research themes that are relevant to, and that should inform a study into the topic.

Chapter 3: Research Methodology and Research Design.

Chapter 2 has reviewed the supply chain and operations management literature and identified research questions for the topic under investigation in this work. The review has provided a clear justification for the research questions by highlighting key gaps in the literature. A further motivation for the review was to identify the most appropriate type of research that could help to answer the research questions. The purpose of Chapter 3 is to justify and describe in detail the research process that was adopted and followed throughout the study to address the research questions posed (Singh, 2015). The Chapter includes:

- A review of the structure selected for the research study.
- A description of the research setting including information about the participants and their associated companies.
- Analysis of the data gathering process and protocols for different types of participants in the study (first tier suppliers[7]and the prime manufacturer[8]) (Barrett et al., 2011 pp.333).
- A review of the steps taken to validate the research findings and ensure that the methods applied are rigorous, robust and repeatable (Borgström, 2012 pp.845).
- The data collection phases, which consisted of several phases and stages (Beverland and Lindgreen, 2010 pp.60), are explained.

Section 3.1 briefly presents the philosophical perspective adopted for the study. Section 3.2 explains the research design. Section 3.3 provides a comprehensive discussion of the research methods and the two stages of research phase one (Exploratory). Section 3.4 describes research phase two (Analysis), which is also divided into two stages. How the data analysis and model formulation processes were conducted is described. Finally section 3.5 addresses research phase three (Validation), describing the validation processes conducted with first tier suppliers and with the prime manufacturer.

3.1 Philosophical Approach.

Table 3.1, adapted from Perry et al., (1997, pp.547), highlights the potential paradigms that could have been utilized for the research methodology. The table briefly describes

[7] To be referred to as *'First tier supplier' throughout this research.*
[8] To be referred to as *'The prime' throughout this research.*

how ontological, epistemological and other methodological assumptions are interpreted by the four most common paradigms used for qualitative research (Perry et al., 1997).

Table 3.1 Adapted from Perry et al., (1997, pp.547).

Paradigm				
Element	Positivism	Critical Theory	Constructivism	Realism
Ontology	The reality being studied is real and apprehensible	The reality is "Virtual" and shaped by social, economic, ethnic, political, cultural, and gender values crystallized over time.	There are a series of multiple local and specific "constructed" realities.	The reality being investigated is "real" but only imperfectly and probabilistically apprehensible.
Epistemology	Objectivist: The findings of the study are considered true.	Subjectivist: Value mediated findings.	Subjectivist: Created findings.	Modified objectivist: The findings from the study are probably true.
Common Methodologies	Experimental/surveys: The verification of hypothesis is chiefly conducted by using quantitative methods.	Dialogue/dialectical : The researcher is a "transformative intellectual" who changes the social world within which participants live.	Hermeneutical/ Dialectical: The researcher is a "passionate participant" within the world being investigated.	Case studies/convergent interviewing: The use of triangulation to interpret research issues by qualitative and by some quantitative methods such as structural equation modelling.

The philosophical approach taken for this research project is that of critical realism (Bryman and Bell, 2011). The decision to adopt this paradigm as a philosophical stance stems from the need to capture and analyse real life events or occurrences (Roberts, 2014). According to Easton (2010 pp.119): *"Critical Realism assumes transcendental realist ontology, an eclectic realist interpretivist epistemology and a general emancipatory axiology".* The table explains how the critical realism paradigm suggests that participants assume their thoughts and observations on the reality they exist within are real (Adamedis et al., 2012). However, this can only be considered from each participant's own perspective and is therefore considered imperfect even if what they are conveying is comprehensible (Easton, 2010). This suggests the paradigm's compatibility and relationship to the ontological 'reality' that events being observed are real, but it is not obvious to those who exist within them (Hodgkinson and Starkey, 2012). Participants will describe what they perceive to be reality; therefore, it must be assumed that observations will be slightly different each time they are made. As such, identification and emergence of general themes from interview data for instance will involve an amount of considered interpretation in order to understand, interpret and categorize observations.

The same can be said for epistemology, as a qualitative researcher following a critical realism paradigm can only assume that the insights and observations captured during the research are true (Rotaru et al., 2014). The epistemological positioning described by critical realism also fits well as the most pertinent method to follow in order to derive an appropriate methodology for case study research (Buch – Hanson, 2014). This has been achieved by obtaining evidence from real life examples and scenarios that are perceived as being true by the participants but again, not immediately visible.

Table 3.1 also demonstrates how a common methodology used by researchers adopting a critical realism paradigm is to conduct case studies. This approach was adopted during the empirical phase of the study of persistent supply chain failure as a method of capturing real life data. It was evident that a suitable method would be to conduct case studies as a way to identify and extract meaningful and insightful information and to capture the 'hidden systems and activities' that lead to cause and effect relationships, i.e. 'the way things are around here' (Levitt and March, 1988). In general, case studies are a common method of capturing real life data from a critical realism philosophical stance in social science research (Yin, 2009). An overview of the overall research design is given first below, followed by a detailed description of each aspect of the research process, including the case study methods used.

3.2 Research Design.

Development of a robust research process is key to ensuring that sound methodological rigour is achieved (Meredith, 1998 pp.448). It was therefore important in this study to first identify gaps in the literature and then design a research study that would reliably fulfil the key motivation behind the study which is to identify and understand key cause and effect relationships of persistent supply chain failure. The research design was developed as a consequence of the need to address the research questions and the gaps identified in the literature.

3.2.1 Unit of Analysis.

The principal unit of analysis for this research study on persistent supply chain failure is the dyad comprising a prime manufacturer and a first tier supplier. In seeking to identify and understand persistent supply chain failure, the unit of analysis chosen includes implicitly the first tier supplier's sub-tier supply chain because the first tier supplier is deemed responsible by the prime for all sub-tier suppliers from which they source sub-components that may be used to produce a component supplied to the prime.

3.2.2 Research Design Process.

This process was influenced by recommendations from Yin (2009). Figure 3.1 summarises the research approach, phases, stages and sequence adopted for this study.

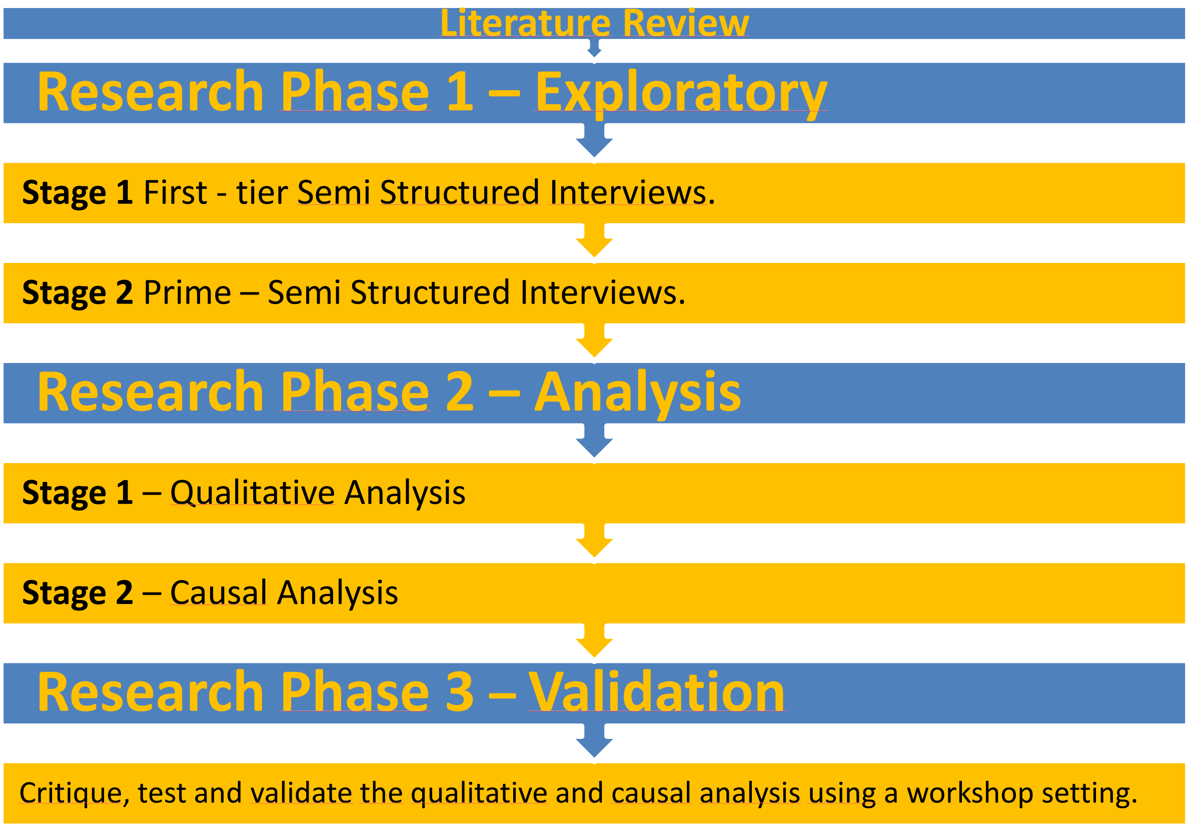


Figure 3.1 Research Design Process.

The research design consists of three phases. Each phase in the design builds on the information gathered from the previous phase, providing a guiding framework for the research (Stuart et al., 2002). Research phase one entitled the 'Exploratory Phase' consists of empirical study conducted through case studies in two stages. Stage one adopts a multiple case study approach conducted with five first tier suppliers. All participating first tier suppliers are important suppliers to the prime company and all have manufacturing facilities in the UK. Stage two consists of one case study with multiple participants carried out with the prime manufacturer from the gas turbine manufacturing industry in order to obtain a dyadic perspective incorporating buyer and suppliers. Key aspects of the research phase one protocol documents are discussed throughout this section.

Phase two entitled 'Analysis' is an analysis of the data obtained from the case studies conducted throughout research phase one. It includes an explanation of the coding approach used to identify the key themes and factors related to the antecedents and explanatory factors of supply chain failure. Research phase two was also divided into two stages carried out in sequence i.e. a qualitative analysis of the data from phase one and followed by a causal analysis of the data. Phase two will also provide explanation of the techniques adopted to develop causal loop diagrams, which have been used to capture and illustrate supply chain failure processes.

Research phase three entitled 'Validation' involved review and critique by suppliers of the original findings, and a workshop process carried out with the prime manufacturer in order to validate the persistent failure model that was developed as a consequence of research phases one and two. Phase three was divided into three parts. The first part is a re–validation of all interview data captured during phase one. This was followed by a pilot study test run that ultimately leads to a description of the workshop validation exercise.

3.2.3 Rationale for Adopted Research Design.

This research identifies, defines and describes a phenomenon that is not apparently evident in the contemporary operations and supply chain management literature – persistent failure (Stuart et al., 2002 pp.420). The aim is to contribute to research knowledge by developing an understanding of the causes and subsequent effects of persistent failure. From a practice perspective, the research aims to provide purchasing and supply chain managers with a model that will assist them in developing strategies to avoid persistent failure over the long term or mitigate its effects.

The focus for business and management research is new theory development, i.e. exploring a new theme for research using qualitative data to ascertain new theory (Eisenhardt, 1989). Therefore, the starting point is to establish a baseline for the research (McCutcheon et al., 2002). The exploratory nature of the research requires data collection strategies that are free from the constraints of quantitative analysis (Wacker, 1998) as real life scenarios need to be captured and interpreted that are out of the control of the researcher (Easton, 2010). At the outset there are no initial boundaries or parameters in which to position the work. The exploratory nature of the research means that these have to be established as the research progresses (Yin, 2009). According to Voss et al., (2002), the most appropriate way in which to ascertain information that is rich in newly identified insights and that provides an opportunity for analysis is to use a case study approach.

3.2.4 Justification for Conducting Case Studies as a Method of Research.

McCutcheon and Meredith (1993, pp.241) note the unique strengths of case study research for developing new theories and examining unfamiliar situations. The exploratory nature of the research also means that there could be key elements or facets to the subject that are not immediately apparent (Flynn et al., 1990). Any further insights could potentially develop into significant answers or propositions needed to explain or justify findings that are significant in answering the research questions (Stuart et al., 2002). Yin (2009) refers to case studies that are designed to determine "how" or "why" events occur as explanatory studies. Gaining access to experienced practitioners was a critical element for this study. Practitioners are often influential or may be responsible for the actions that determine events. The capture of insightful information provides the researcher with the potential to obtain first hand and explicit insights through observations that may not have been possible using other methods of data collection (McCutcheon and Meredith, 1993). This has the potential to assist in the identification of common themes and sub–themes, as well as differences in perspectives, which will help to formulate answers to the research questions in a rigorous way.

Case studies, and in particular semi-structured interviews, also represent a flexible way in which to elicit useful information because they can be extended to include additional participants or functions that provide greater detail to support the research propositions, should this requirement emerge from the initial data collection exercises. Should such details emerge, then case studies are generally flexible enough to accommodate the additional research design structure (Eisenhardt, 1989). However, these activities need to be controlled because of the potential pitfalls of case study analysis, which includes an unmanageably large amount of data (Yin, 2009).

Establishing key themes and trends from a vast amount of recorded data originating from a plethora of semi-structured interview research participants can be an extremely onerous task (McCutcheon and Meredith, 1993 pp.244). However, despite the risk of failing to identify saturation (O'Reilly and Parker, 2012), additional participants can be assimilated into a research study provided that the case study protocol is consistent and the structure of the research is easy to replicate (Yin, 2009).

Making sense of large volumes of data combined with being able to adequately replicate the study are essentially the key areas of criticism against using case study research from academics that prefer the use of other data collection and analysis techniques (Thomson and McLeod, 2015). Therefore, methodological rigour through solid research design is one of the most important aspects of case study research (McCutcheon and Meredith, 1993 pp.247).

3.2.5 Challenges in Conducting Case Studies.

Given the sensitive nature of the research topic examined in this study, choosing to first conduct case studies as a means of exploratory research is wholly appropriate for a number of theoretical and practical reasons. To retain focus for the research, it was decided that the most appropriate course of action was to conduct multiple case studies on suppliers who were or have in recent times been connected with supply chain failures that had caused protracted disruption for the prime manufacturer. The approach presented its own set of challenges as every participating supplier was supplying products to the prime throughout the research process. In particular it was a significant challenge to persuade potential participants to take part in semi-structured interviews on a difficult subject and to ensure open and honest answers were provided.

Five companies (including a pilot study) kindly agreed to facilitate and participate in the interviews. All five suppliers were initially approached by email followed up by a telephone call in order to confirm meeting arrangements. During the calls, more details regarding the purpose of the study and its desired outcomes were given. The fact that the lead researcher was an employee of the prime at the time of the research also provided further challenges. However, there were also benefits to being an employee of the prime because, without the prior network and industry contacts, getting permission and organising extensive interviews would have been much more difficult given the focus of the study on failure.

3.3 Introduction to the Exploratory Case Studies (Research Phase One).

In planning phase one it became clear that there was a need for the study to address perspectives from both sides of the supply chain dyad (Ellram and Henrick, 1995). This approach was adopted to understand more fully the nature of the interactions between the buyer and supplier and to help identify if themes raised by one party were corroborated or not by the other. Identification of corroborated themes from both sides strengthens the findings of the study. Identification of differences in perspectives also yields interesting insights to be examined.

3.3.1 Phase One Stage One – First Tier Supplier Data Collection Protocol.

The semi-structured interview protocol for participants from first tier suppliers was adapted from Yin's (2009) case study protocol. A review of case study literature found that the first step in conducting case study research is to ensure and guarantee the protection of employees at each case study site (Yin, 2009). In this study the principal protection that was needed was to reassure participants that the observations and the views recorded would not be used in any written reports, presentations, or verbal discussions on the research in any way that identified the participants or their organisations. To ensure the protection of employees, full anonymity was guaranteed should the participants not want to be named. An ethics plan was drawn up and approved by the School's ethics board prior to the interviews.

In order to test the case study protocol document (Ravenswood, 2011) the first case study investigation was classed as a pilot study (Voss et al., 2002). The reason for this was to identify any issues that arose in operating the protocol and addressing these in subsequent interviews. This acknowledges that the protocol could potentially change and evolve from case to case but the purpose of the pilot was to eliminate glaring errors that could threaten the methodological rigour of the research process.

3.3.1.1 First tier Supplier Selection.

The first tier suppliers targeted to participate in the study manufacture different parts, assemblies and systems that go into a variety of final products produced by the prime. The systems are brought together during manufacturing to assemble a gas turbine engine. In this study the targeted suppliers manufacture parts, assemblies and systems with varying degrees of engineering complexity. A proportion of the supplier base is classified by the prime as a 'design owner' because the supplier owns the intellectual property rights (IPR) and are the design authority for the products they supply. The remaining suppliers produce parts from designs that are developed and owned by the prime and are classified as 'make to print' suppliers. The targeted companies also supply different volumes of products depending on the number of engine types their component is used on and the quantity per engine. The criteria and justification for eventual selection included:

- First tier suppliers currently experiencing consistently poor performance.
- First tier suppliers with a history of poor performance over the previous five years.
- First tier supplier availability i.e. those available to participate in the research.
- Interest and willingness to participate in the research.

Each of the participating first tier supplier doing business with the prime has in recent years been subject to measures put in place to improve their performance. The central purpose of this strategy is to enable the suppliers to become reliable and eventually class leading. The prime manufacturer in this study operates a supplier management system called SABRe, which is an intrinsic part of the prime's quality management system. All suppliers to the prime are governed by the processes and procedures specified by SABRe documentation and are mandated to adhere to the processes specified within the system. Each supplier agrees to 100% compliance to SABRe when entering into a contract to supply goods or services to the prime. Importantly, through this process first tier suppliers are obligated to manage their own sub-tier suppliers using processes and procedures that are specified in SABRe. The research on supply chain failure is influenced by SABRe because if a product is supplied by a first tier supplier that does not comply too the specifications mandated within the system then the prime will deem this to be a supply chain failure.

3.3.1.2 The Pilot Study – Supplier A.

The first company to agree to participate in this research project also became the pilot study organisation. Supplier A is an experienced manufacturer of high pressure rigid pipe equipment used for hydraulic controls and oil flow on a gas turbine engine. The main objective of supplier A is to be a significant player in various sectors of the markets in which they participate, including airframe, power plant, fixed and rotary wing encompassing extensive civil and military projects. Due to its size (based on number of employees and annual turnover) it can be classed as a small manufacturing enterprise (SME) with specialist capabilities in aerospace components. It has facilities in the south of the UK where it produces fabricated structures, pipe assemblies and ducts. The site is staffed by one hundred employees and generates 40% of their UK revenue. They also have a further site situated in the UK Midlands producing rigid and flexible pipes, manifolds and reference tubes for the aerospace industry. The site employs 154 people. Approximately 80 of those employees work in their machine shop producing flanges, bosses and machined casted elbows. The Midlands site represents 60% of supplier A's UK revenue. Supplier A has also acquired a machining facility in China. This was done at the request of the prime in order to reduce costs of production. This site currently employs 95 people. Supplier A's plan was to gradually transfer more work to China as their capability increased.

Supplier A has been supplying the prime on existing engine programmes for eight years. Notably, from all of the first tier supplier participants, supplier A was the organisation that was considered to be one of the most serious problems for the prime at the time the research was initiated in terms of consistently failing to meet agreed quality and delivery targets. Supplier A had been placed into an escalation process, called 'Red Flag', specifically due to poor performance. The red flag process consists of the prime enforcing major improvement activities and initiatives on the underperforming supplier and mandating that these needs to be completed within a specified timeframe. At supplier A the initiatives had been in place for a period of four years at the supplier's cost. However, it was mentioned by a participant from supplier A that minimal improvement in performance had actually been made. During the time that the case study research was carried out, supplier A was experiencing significant operational disruptions in its interactions with the prime manufacturer. Disruptions had been occurring for a number of years and as a result the relationship had become very strained.

Supplier A was initially approached and asked if they would be willing to be a case study organisation and potentially share some of their experiences and opinions on the causes of supply chain failure. The situation was very sensitive for the prime as supplier A was a key provider of rigid pipes on a number of key engine programmes for which it had a very strong pipeline of orders from Air framers. Fortunately, after consultation with the Managing Director, the supplier A contact person was able to confirm their participation in the study.

The research took place at Supplier A's Midlands based manufacturing facility. A total of five employees participated. All of the participants held managerial positions within the company, including the Sales Director, Quality Manager, Commercial Manager, Purchasing Manager and Operations Manager.

3.3.1.3 Case Study Supplier B.

Supplier B has a 90 year history as a bearing producer supplying to large original equipment manufacturers within the aerospace industry such as Rolls Royce Plc, Pratt & Whitney and General Electric (GE). They have been a supplier to the prime for the past 15 years, becoming a preferred supplier in 2003. Supplier B is positioned within the aerospace division of its parent company, which is a global organisation that supplies bearings to the manufacturing, construction, agriculture, automotive, pulp and paper, aircraft maintenance, marine and mining industries throughout the globe. The group consists of 140 sites situated in 32 countries with a total of circa 50,000 employees worldwide. Supplier B manufactures multiple bearings on all of the prime's key engine programmes. They also provide bearings to the prime's subsidiary in Germany that works on older engine programmes.

Supplier B was placed into delivery and quality red flag during 2010 as a result of consistently sub-standard performance on the prime's supply chain balanced scorecard. Throughout the duration of the research, the supplier was still being managed by the prime via the red flag escalation process. However, the effect of the red flag process has been inconsistent because overall performance had fluctuated between periods of sustained improvement through to periods of sustained under performance. As such, Supplier B met the criteria for investigation and was invited to participate in the study. Initial contact was made by email and then arranged by telephone. The research took place at Supplier B's UK manufacturing facility. Overall, five employees were interviewed including an Operations Manager, Quality Manager, Sales Manager, Commercial Manager, Buyer (Strategic and Operational combined).

3.3.1.4 Case Study Supplier C.

Supplier C has been providing products for aerospace applications for over 90 years since the beginning of aircraft and aero-engine manufacture in the UK. They also provide heat management systems consisting of radiators and cooling plates to the electronic / avionics, motorsport and power generation industries including a range of integrated heat transfer and fluid management products for the commercial and military markets. The products supplied include the design and manufacture of a small range of heat management and fluid system components specifically tailored for the prime's applications. Their products are used on both airframes and engines for fixed wing aircraft and helicopters.

Supplier C is part of an American owned multi-national engineering conglomerate. The intellectual property rights for the systems they design are all owned and patented by the supplier. That means the prime has a strategy of purchasing supplier C's product designs and incorporating them onto their own applications.

Supplier C has been maintaining a stable level of performance with the prime for the past five years. Prior to being bought out by an American conglomerate, their performance was well below the required agreed standard with the prime. However, as a consequence of their subsequent improvement, they have since been able to win further contracts with the prime. The performance levels of Supplier C have fluctuated over time, therefore they were asked to participate in the study.

Initial contact was made via email and then arrangements for the case study data collection activity including dates and times were made over the telephone. Requests for the roles and responsibilities of potential employee participants were sent by email. The contact then formulated the chosen day's interview schedule around the participant's availability. The event took place at their main manufacturing facility on the outskirts of Wolverhampton in the UK. In total, four employees were able to participate in the study. All of them held leadership / managerial positions within the company, including an operations manager, quality manager, sales manager, and commercial manager.

3.3.1.5 Case Study Supplier D.

Supplier D forms part of an international group providing complex engineering systems to key organisations within the aerospace and defence markets. They provide technological solutions to the aerospace and defence industry in manufacturing processes such as fabrications and machining. They operate a global supply chain to support complex aero-engine component manufacture and repair. They are focused specifically on aerospace OEM customers such as Rolls Royce Plc, Boeing (defence), Pratt and Whitney and the GE group. Supplier D has a policy of placing sites close to their key customers in North America and Europe. Over recent years, they have invested significant resources into their engineering capability coupled with similar investment to increase capacity. The group currently supply more than 1500 part numbers to the prime.

Commencing in February 2012 the manufacture of key components was transferred to Scotland from their production site in Lancashire in the UK. Supplier D has endured significant issues with quality performance since then. In recent times, supplier D has suffered from an inconsistent quality score against the agreed contracted performance indicators, which has affected delivery reliability. The main contributor has been the unstable performance of their key manufacturing facility in Scotland. The quality problems are compounded by an indifferent delivery score resulting in fluctuating performance levels. The continuing problems they have experienced since 2012 has contributed to a rich and insightful case study.

Unlike suppliers A, B and C, contact was established through a colleague currently working at the prime who had recent experience of managing the supplier as part of their day to day responsibilities. Therefore, initial contact was made by telephone, followed by planning of the event through email. Again, requests for targeted roles and responsibilities of potential employee participants were made. The agenda was developed to accommodate this in order to ensure the most relevant participants could contribute. The research eventually took place at their UK supply chain management office in Derby situated close to one of the prime's main administration buildings. Four employees participated. All of the participants held managerial positions within the company, including the companies managing director, operations manager (based at the Scottish facility), quality manager, and commercial / project manager.

3.3.1.6 Case Study Supplier E.

Supplier E is a manufacturer of precision machined and fabrication parts supplied predominantly to aerospace customers. Approximately 90% of their turnover is generated directly through business with the prime. Now in their 35th year, supplier E has been a strategic supplier on major aero-engine programmes for the prime since the late nineties. The company is based in Derby in close proximity to the prime's main UK facility, which has provided them with a number of advantages over larger organisations who compete with them to supply the prime. With just over one hundred employees working in their Derby facility supplier E can also be classified as an SME.

Despite this they hold more approval certificates with the prime than companies of far greater size and reputation.

However, the relationship between Supplier E and the prime has been a turbulent one over the years since the commercial relationship started. There have been periods of significant poor quality and delivery performance that have resulted in sanctions being imposed by the prime similar to the red flag process, the latest being five years ago. The sanctions resulted in a much closer working relationship with the prime. As such, Supplier E has since put measures in place to improve their performance and aspire to become a class leading supplier.

Supplier E was invited to participate in the research because they had been a consistently failing supplier that has since managed to turn poor performance into periods of good performance. It was hoped that these experiences would be shared by the participants during the semi-structured interview process in order to provide insights into why the organisation were consistently failing and what it took for them to recover and achieve a level of stability against agreed performance targets.

Contact and arrangements for the case study were organised via email. The research took place at Supplier E's supply chain management office in Derby situated a couple of miles away from the prime's main UK manufacturing facility. On this occasion only one person was permitted to participate in the interviews. The participant was the company's Managing Director. The main reason for this was because the company felt they could not afford to allow other employees time away from their duties during the working week. However, the Managing Director had been with the company since the beginning and due to its relatively small size, had an extremely good view of all aspects of the relationship with the prime manufacturer and therefore proved to be a rich source of information.

3.3.1.7 First Tier Supplier Participant Roles and Responsibilities.

Table 3.2 provides a brief overview of each of the first tier suppliers that agreed to participate in the study including the number of parts supplied to the prime and the complexity involved. Labelled A to E, 19 supply chain professionals, covering all five companies were interviewed. As is evident from the above discussion, the participating employees occupied a range of positions and levels within each organization.

Table 3.2 Overview of Case Study First Tier Suppliers.

Company	Product type	Number of Parts	Complexity	Number of Personnel Interviewed
Supplier A (Pilot)	Rigid & Flexible Pipes	High	Low	5
Supplier B	Bearing Manufacturer	Med	High	5
Supplier C	Heat Transfer Technology	Med	Med	4
Supplier D	Forged Rings (Supply chain Integrator)	High	Med	4
Supplier E	General Machining	Med	Low	1

The aim during each case study was to obtain a wide ranging set of views and perspectives from across the whole spectrum of the participating organization on the issues being investigated. Due to the nature of the research and its aims, there were a number of roles within each organization that could contribute to the semi-structured interviews. A list of targeted job roles and level of responsibility was provided to the main internal contacts from each participating company during the planning stages of each case study. It was important to specifically target positions within each company in order to involve employees who were best suited to answer the individual interview script and to avoid time wasting. Table 3.3 gives the actual job titles held by employees from each case study that participated in the research. The topics on which each participant was interviewed were based on their functional relationship with the interview subject themes under examination.

Table 3.3 First Tier Supplier Participant Information.

Job Title	Case Study	Abbreviation	Responsibilities	Justification for Interview
Managing Director	Supplier D Supplier E	MD	Accountable for the organization.	Knowledge of organizational performance / competitiveness in the market. Knowledge of future vision / strategy of the organization in line with customers' strategy and future market forecasts.
Sales Director / Manager	Supplier A	SDM	Accountable for all sales and new business development.	Knowledge of market trends and future business potential.
Project Manager	Supplier D	PrM	Project manage specific customer contracts.	Direct interface with the customer. First point of contact and tasked with

				solving all problems / issues to ensure supplier consistently achieves the agreed commercial targets.
Operations Manager	Supplier A Supplier B Supplier C Supplier D	OM	Accountable for production, manufacturing quality and delivery to customer.	Can provide overall picture of organizational performance i.e. quality / manufacturing improvements and efficiency programs. Be aware of best practice / standards within industry and within alternative industries.
Commercial Manager	Supplier A Supplier B Supplier C	CM	Contract management for both sales and procurement.	Detailed knowledge of customer requirements vs supply chain capability. Should understand where the organizations strengths and weaknesses lie within their supply chain management function and how it affects their ability to be competitive within the markets they serve.
Quality Manager	Supplier A Supplier B Supplier C Supplier D	QM	Owner and gatekeeper of the organization's quality process.	Should provide perspective on current sub-tier / market quality capability in line with company standards.
Purchasing Manager	Supplier A Supplier B Supplier C	PM	Overall responsibility for quality, delivery and cost from a supply chain performance perspective.	Overall knowledge of strength and weaknesses of operational purchasing and existing supply chain. Will also understand company objectives in line with vision.
Buyer (Operational and Strategic)	Supplier B	BO / BS	Responsibility for commercial relationships with suppliers and day to day contract management.	Overall knowledge of strength and weaknesses of operational purchasing and existing supply chain. The buyer will have understanding of all issues concerning quality, delivery and cost.

3.3.2 Phase One Stage Two – Prime Manufacturer Data Collection Protocol.

To avoid an unbalanced one-sided viewpoint, a dyadic exchange (Cox et al., 2001) featuring the prime's perspective on the issues being researched was a critical requirement for this study. This involved inviting specific employees from the prime to participate in semi-structured interviews at the prime's Derby facility. The case studies were conducted separately from the supplier case studies. It was a deliberate strategy not to link the prime participants with specific suppliers in order to avoid adversarial or defensive issues arising.

Table 3.4 briefly describes the prime's organisational structure and its global footprint along with key supply chain / purchasing statistics. The purchasing / supply chain functions provide cross functional support to all divisions of the company. All of the purchasing / supply chain activities are managed by teams based in different parts of the world depending on where the suppliers are located. These purchasing teams provide support for all engine programs covering all commodities in the aerospace, land and sea parts of the business.

Table 3.4 Demographic of the Prime Organisation.

Aerospace						*Land and Sea*		
Civil Large Engines	*Civil Small and Medium Engines*	*Defence*	*Supply Chain*	*Controls and Data Services*	*Strategy and Future Programmes*	*Marine*	*Power Systems*	*Energy*

Geographical Presence of the Prime Organisation (Including Supply Chain)				
Americas	*Europe, Middle East and Africa*		*Asia Pacific*	
United States	*United Kingdom*	*Italy*	*Australia*	*Thailand*
Brazil	*Africa*	*Norway*	*China*	*Vietnam*
Canada	*Austria*	*Poland*	*Hong Kong*	
Mexico	*Belgium*	*Russia*	*India*	
	Croatia	*Saudi Arabia*	*Indonesia*	
	Czech Republic	*Sweden*	*Japan*	
	Germany	*Turkey*	*Malaysia*	
	Finland	*UAE*	*New Zealand*	
	Denmark		*Singapore*	
	France		*South Korea*	

Supply Chain Management Key Statistics
• *Supply Chain includes 25 major supply partners* • *80% of engine is procured through the supply chain* • *Handle 200,000 part numbers per year – 260 million individual parts* • *Manage a total of 15,000 first tier suppliers across 70 different countries*

The main objective of the global purchasing function is to develop and deploy purchasing strategies that deliver reliable, safe and cost-competitive supply chain solutions across market sectors. That involves developing optimum solutions within the supply chain ensuring that quality and delivery are agreed and consistently achieved by first tier suppliers. Along with eliminating waste and developing breakthrough technologies, there is also a large focus on reducing costs and increasing competitiveness within the gas turbine industry. Therefore, effective management of suppliers is critical to achieving that aim.

The purpose of this stage of the research was to identify whether or not the perspectives of the prime's participants on supply chain failure and why it persists, agreed and correlated with the observations and perceptions from the first tier suppliers. Comparisons would significantly strengthen the conclusions drawn from the first tier participants and importantly the literature identified during Chapter 2. The overall dyadic findings from the exploratory phase sought to enrich the findings from the first set of case studies and strengthen the development of the causal loop model.

3.3.2.1 Prime Manufacturer Participant Roles and Responsibilities.

Due to the research aims and the subsequent interview questions being asked, there was a wide breadth of employees within the prime's organisation who could have potentially have contributed to the study. The methods adopted for the collection of data was to target experienced supply chain professionals with knowledge of all processes and procedures carried out by the prime in conjunction with the supply chain. Ideally all participants would have experience of working with at least one of the first tier participants from the first tier case study research, especially during times of consistent failure. It was hoped that they would therefore be able to reveal and articulate cause and effects of failure from the buyer's perspective.

In order to gain access to potential participants, the author contacted two previous colleagues (both former managers of the author) and asked if they would be interested and willing to participate in the research and also to help identify and enlist appropriate individuals with the requisite experience and occupying target positions to participate in the research. Both contacts agreed to help and between them they managed to enlist a group of 11 supply chain professionals from the prime to take part in the interviews. The roles and responsibilities of the participants who took part in the study are documented in table 3.5.

Table 3.5 Prime Interview Participant Information.

Job Title	Abbreviations	Responsibilities	Justification for Interview
Regional Purchasing Executive	RPE	Overall responsibility for quality, delivery and commercial performance. Reporting status to senior management.	Overall knowledge of strength and weaknesses of operational purchasing and existing supply chain. Will also understand company objectives in line with vision.
Regional Purchasing Manager	RPM	Responsibility for quality, delivery and commercial performance of a designated commodity.	Knowledge of strength and weaknesses of operational purchasing for a designated category.
Purchasing Development Manager	PDM	Responsible for identifying and improving all aspects of the purchasing process.	Overall knowledge of strength and weaknesses of current process and systems being utilized within the supply chain.
Production Planning and Control Manager	PPCM	Accountable for the complete production plan for designated commodities including original equipment, spares and new product introduction.	Responsible for meeting customer requirements on designated commodities. This includes the creation and deployment of business continuity plans.
Buyer Team Leader	BTL	Responsible for managing a team of buyers within a specific system / category.	Overall knowledge of strength and weaknesses of Operational purchasing for a designated supply chain. The buyer will have understanding of all issues concerning quality, delivery and cost with the supplier.
Buyer	B	Relationship owner with supplier	The buyer will have detailed and topical understanding of all issues concerning quality, delivery and cost with suppliers within their designated commodity team.
Material Requirements Planner (MRPC)	MRP	Manages customer demand profile with the supplier	Knowledge of all processes associated with delivery and manages the demand profile with the supplier for the prime. All fluctuations in demand are managed and communicated by the MRPC into the supply chain.
Quality Director	QD	Owner and gatekeeper of organizations quality process.	Should provide perspective on current market quality capability in line with company standards and alternate industry capabilities.
Supplier Development Manager and Technical Manager	SDTM	Is accountable for all supplier improvement projects in line with company business process deployment plan.	Can provide overall picture of supplier improvement projects in line with the future direction of the organization i.e. supplier selection criteria vs. existing supplier improvement programs. They should be aware of best practice / standards within

			industry and within alternative industries.
Global Commodity Leader	GCL	Commercial link between procurement and sales within the organization.	Detailed knowledge of organizations requirements vs. supply chain capability. Should understand where the organizations strengths and weaknesses lie within their supply chain management function and how it affects their ability to be competitive within the markets they serve.
Engineering Project Manager	EPM	Accountable for engineering projects related to production, manufacturing quality and delivery to customer.	Drive projects that directly affect the future direction of the organization i.e. quality / manufacturing improvements and efficiency programs. They should be aware of best practice / standards within industry and within alternative industries.

All of the participants were representatives of the prime's supply chain management division although some were functionally aligned to other departments such as the production planning and control manager (production planning and control), quality director (supplier quality), supplier development and technical manager (supplier quality) and engineering project manager (engineering). Due to the matrix structure of the organisation, all participants interact with other functions most notably with engineering, supplier quality and production planning and control but also spares /aftermarket, logistics and operations management / manufacturing. Therefore, the participants who volunteered to take part represented a wide spectrum from across the organisation with regard to the interview topics and could potentially provide valuable and rich insights to the research project.

3.3.3 Phase One Semi-Structured Interview Protocol.

The key aim of phase one was to seek understanding, insights and clarifications in relation to the research questions presented in Chapters 1 and 2 by conducting semi-structured interviews at both the first tier suppliers and the prime manufacturer. The construction of interview questions was also informed by the literature review. The following points demonstrate the objectives for the interview process during both the first tier suppliers' and the prime manufacturers perspectives:

- Understand and document how organisations manage supply chain failure with a particular focus on failure that persists over a considerable time period.
- Develop a definition of persistent supply chain failure.

- Identify and document how organisations recover from persistent supply chain failure.

Phase one was divided into two stages; stage one covered semi-structured interviews with first tier suppliers and stage two focused on participants from the prime. Phase one sought to identify what participants considered to be the key causes of persistent supply chain failure. To achieve this aim, themes and concepts discussed in the literature were also used to guide the development of two semi-structured questionnaires, one for the suppliers and one for participants from the prime. A copy of the complete interview questionnaire used for the first tier suppliers is included in Appendix 2[9]. The major elements of the questionnaires are discussed below.

Both the first tier and prime semi–structured interview protocols had to consider confidentiality rules particularly in relation to each company's image, brand and reputation and also for the protection of all participants. As a result, great attention was paid to the handling of commercially sensitive and confidential technical information provided by both sets of participants to protect reputations. It was evident that managers at the prime placed much more emphasis on protecting sensitive information and retaining confidentiality than most of the first tier suppliers. As such, before any interviews could take place, consent from the prime organization was required in the form of approval from the prime's legal team and the lead researcher's university. Prior to each stage, an ethics document was produced and approved by the university before the interviews could take place.

Fortunately, permission was gained to use Dictaphones in order to record both the first tier supplier and prime participants during all of the interviews prior to stage one and stage two. Interviews typically lasted approximately one hour with each participant. The major challenge experienced during the interviews at both the first tier suppliers and the prime was interviewees cancelling or re-arranging the interview time at short notice.

3.3.3.1 Risk and Contingency Management.

The purpose of conducting interviews on the theme of risk management was to identify and capture what the first tier and prime participants perceived as the key risks that could contribute to supply chain failure. The interview questions were also included to identify the extent of risk management practices and understanding of risk at the first

[9] Appendix 2 – *A Copy of the complete interview questionnaire used for the first tier suppliers.*

tier suppliers and the prime. This included identifying what methods / tools, if any, were being used to capture risks which would enable comparisons to be made with current literature. Further to this, questions were asked that sought to identify the level of participation in the risk management process internally at first tier suppliers and the prime and also joint buyer / supplier risk assessment initiatives. The key driver behind these questions was to identify whether deficiencies in the risk management process could contribute to supply chain failure. Further questions included in the interview script sought to capture sourcing risks. These types of questions were related to the transfer of risk from the prime to the first tier supplier and whether such an activity could also increase the risk of supply chin failure.

Contingency management was also included in the research. These questions were asked in order to understand the macro effects of external sourcing on the prime. The principal aim of the questions asked on this subject were to identify if outsourcing increased the risk of supply chain failure. The questions were also included to identify what measures, if any, the prime or first tier suppliers conducted for contingency management. The reason for including questions on the subject of contingency management was to enable comparisons to be made with current literature and to identify if the findings confirm or refute the literature.

3.3.3.2 Quality Management.

The purpose of conducting interviews on the theme of quality management was to identify and highlight common causes of supply chain failure from a technical or process perspective. An aim for the research was to capture and understand the level of intuitiveness of the prime’s quality management system and whether it was easily adopted and interpreted by first tier suppliers. A further aim was to identify and capture potential gaps in the effectiveness of the quality management system being used by the prime and to understand if, how, and why it might contribute to supply chain failure. Another key requirement of the interview questions was to capture insights into the extent to which first tier suppliers conducted the quality management system with, and passed the requirements of the system to their own sub-tier suppliers. General perceptions of the quality management system from both sides were also sought. The aim was to capture how both sets of participants viewed the overall robustness of the system and whether it helped prevent failure or possibly contributed to causing failure. The effectiveness of the system included the understanding of how failures were managed by both the prime and first tier suppliers. For example, an area of investigation was to identify the extent to which exercises were carried out in order to establish root cause of failure and also understand the prevalence of short term quick fixes carried out in order to minimise disruption.

Questions aimed at identifying the general perceptions of the auditing regime conducted by the prime were also asked of both the first tier and prime. The questions sought to identify the methodology behind audit schedules and to understand perceptions of the effectiveness from both sides of the dyad. Questions designed to capture understanding of ISO accreditations and whether they reduced the risk of failure in the supply chain were also included for both sets of participants.

3.3.3.3 Power and Relationship Management.

For reasons of practicality and time constraints it was decided to amalgamate the power and relationship management related questions into one set of semi-structured interview questions for both the first tier and prime participants. The purpose of conducting interviews on the theme of power and relationship management was to identify and highlight common causes of supply chain failure related to dependency and leverage between the parties. The interview questions sought to identify the effects of power, leverage, and dependency on the relationship dynamics between the prime and the first tier supplier in order to identify if this could be a factor or cause of persistent supply chain failure. The question set was also intended to identify the effect of relationship management issues on performance of the first tier and the prime. Further to this, it was hoped that the participants from both sides of the dyad would provide insights into the how relationship management issues could affect supply chain performance. The interview questions sought to capture the effectiveness of communication between first tier suppliers and prime manufacturers and its influence on supply chain failure. Questions were formulated in order to identify the extent to which communication could improve visibility, increase leverage and responsiveness. The interview questions also sought to understand strategic alignment and trust in order to identify the current relationship between the prime and first tier suppliers and highlight if issues of strategic alignment and trust could be attributed towards causing supply chain failure. The questions, responses, comments, and findings from the first tier and prime participants were also intended to confirm or refute the existing literature and identify if new knowledge had been obtained.

3.3.3.4. Supplier Development.

The purpose of asking questions on the theme of supplier development was to identify and highlight the effectiveness of supplier improvement initiatives during episodes of supply chain failure. The interviews were intended to capture if and how supplier development contributed to preventing supply chain failure over the long term or whether it had an opposite effect. The inclusion of a semi-structured interview section on supplier development also aimed to identify and capture the effect of supplier development on overall performance at the prime. It was also intended to complement potential linkages with existing literature on supplier development.

3.3.3.5 Performance Management.

The purpose of conducting interviews on the theme of performance management was to identify and highlight potential gaps in the effectiveness of the performance system being used by the prime and to understand if, how, and why the performance management system could contribute to supply chain failure. Questions were also added to the interview questionnaire in order to identify or confirm similarities with what the literature has already noted on the theme.

Semi-structured interview questions on performance were created in order to identify how much visibility the prime has on suppliers and how they are performing versus agreed metrics. This was to identify how the prime attempts to monitor the supply chain performance of first tier suppliers against predetermined contractual targets. The questions were also asked in order to identify if they were successful at preventing it or if they contributed to causing supply chain failure.

An understanding of how efficient the methods of performance measurement processes within the supply chain was also sought. These questions were included in order to gauge the perception from both sets of participants as to the success of the performance measures that were used by the prime. An important aspect of the interview script on performance management was to identify the distinction between performance management and performance measurement within the supply chain and whether the two aspects complemented each other, or not.

3.3.3.6 Service Recovery.

The purpose of conducting interviews on the theme of service recovery was to identify and capture the methods used by the prime and also first tier participants to recover from supply chain failure. The interview questions sought to identify how quickly the prime and first tier suppliers are able to identify problems within the supply chain and understand how quickly they are able to mobilize resources in order to understand problems and prevent them from causing disruption. Questions that sought to identify the number of personnel that the prime and first tier suppliers were able to commit to tackling failure were included. The set of questions on service recovery was also designed to identify whether the ability of the first tier suppliers to recover from failure quickly led the prime to award more work to them, i.e. whether the contemporary literature on the 'Recovery Paradox' in service industries was corroborated in a supply chain context.

3.3.4 Differences between Interview Topics.

In order to draw comparisons and identify differences between the perspectives across the dyad (Ellram and Hendrick, 1995), the protocol remained largely the same for both. The only deviations made from the original first tier protocol document was to amend all interview section questions so that participants from the prime could provide answers from their own perspective, i.e. what are the causes of persistent supply chain failure. Another change was the targeted prime manufacturer roles, responsibilities and functions were different to those of the first tier suppliers. This was reflected within the semi-structured interview script presented to the prime participants.

3.4 Research Phase Two – Analysis.

Research phase two is the data analysis phase. It has been divided into two stages. Stage one concentrates on the consolidation and subsequent analysis of all data gathered throughout research phase one. This includes the identification of common trends and themes that could be used to identify potentially harmful activities occurring throughout the supply chain that contributed to failure and its persistence. These are specifically those events that lead to or cause supply chain failure (Holmberg, 2000). Stage two aims to conceive, develop, and refine a comprehensive causal loop model that captures and illustrates cause and effect relationships throughout key functions of the prime and suppliers' businesses that result ultimately in supply chain failure persisting over time.

3.4.1 Brief Outline of the Qualitative Analysis Process.

The primary purpose of stage one of phase two was to bring together all of the captured information recorded during each interview and consolidate it in a format aimed at making it easier to analyse and interpret (Barrett et al., 2011). All of the information gained from the empirical research process was consolidated into a template[10] that made interpretation of the data more manageable. The template served as a repository for all transcribed recordings of the semi-structured interview data obtained from the participants from each of the five case study companies involved in the research. Essentially, the file was used to record and then subsequently analyse empirical data from both the first tier supplier and the prime manufacturer participants. The file enabled the researcher to consolidate large amounts of the data (approximately thirty five hours of interview data gathered during research stage one). The template facilitated the focusing and subsequent coding of the data (Stall-Meadows and Hyle, 2010). Figure 3.2 provides a description of how the coding process was conducted through to the development of causal loop diagrams that combined to create the final model. Phase two consisted of five steps overall broken down into stage one, which involved two steps and stage two which involved three steps. The coding process was carried out with the data sets from both stages of research phase one.

3.4.2 Stage One Qualitative Analysis.

Stage one of Phase Two commenced by adopting an axial coding technique (Yin, 2009) to analyse the interview data. It consisted of two coding steps as shown in Fig 3.2: step one is identification of general themes, and step two a consolidation of both the first tier and prime data collected during the semi-structured interviews. This was carried out to show trends and / or themes that emerged from the findings. Throughout each and every interview script key terms and phrases (Basit, 2003) that appeared consistently in each of the responses were recorded. These were all logged in preparation for the coding process. For example, questions related to causes of supply chain failure from a quality perspective would generate terms and phrases such as: ‘meeting specification’; ‘misinterpretation of customer’s drawings’; ‘inadequate non-conformance processes’.

A full description of each captured term and phrase is given later in Chapters 5 and 6. Often the questions asked yielded consistently repeated responses that were related to separate themes. A more detailed analysis and description is provided in Chapter 4 (Exploratory case phase one). The qualitative stage was conducted following the coding method adapted from Hahn (2008) that involves gathering all of the data together to conduct the first steps in the coding process. The coding process explains

[10] Coding File – *Appendix 3*

how the categorized data is converted into causal variables and then arranged into loops using a combination of causal coding (Narasimhan and Jayaram, 1998) in order to capture the systemic thinking of the participants (Groesser and Schaffernicht, 2012). An explanation of the coding process is described later in Chapters 4 and 5.

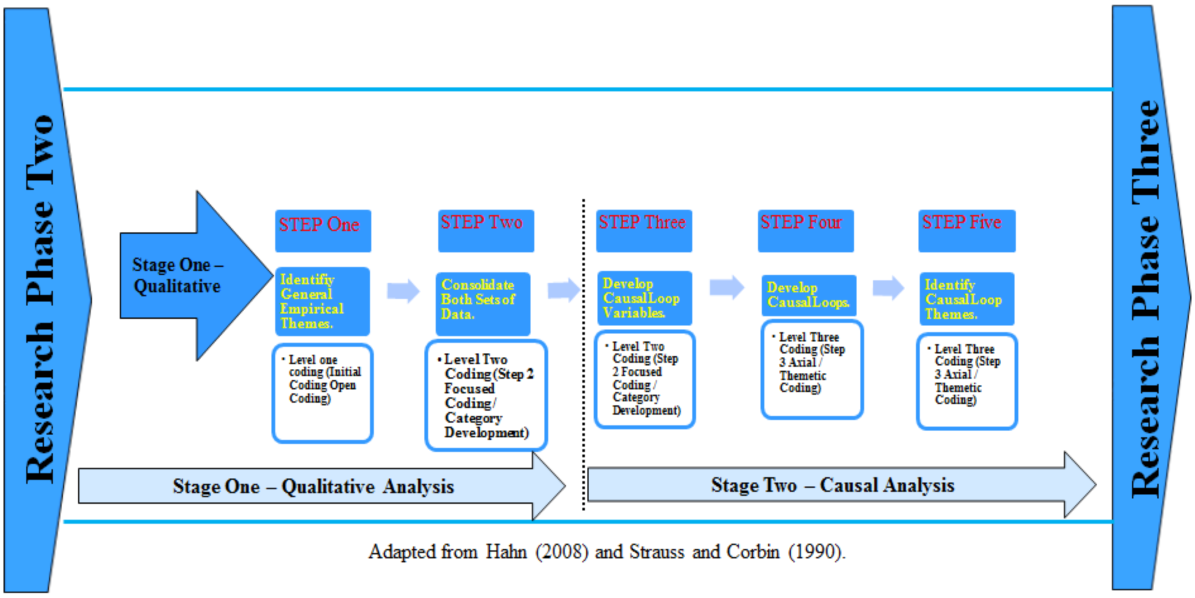


Figure 3.2 Coding Process for the Development of Causal Loop Diagrams.

3.4.3 Stage Two – Causal Analysis.

At this juncture, the process of generating answers to research questions RQ1, RQ2 and RQ3 began. The focus of the research and coding process mechanism shifted to identifying, capturing, and visually demonstrating the causality of persistent supply chain failure through causal loop diagrams. Stage two starts with step three, which involves the development of causal loop variables, step four involves the development of causal loops, and step five the identification of the causal loop quadrants. During step four, the coding method also changed to incorporate Strauss and Corbin's, (1990) thematic coding technique. The aim of step four was to begin the identification of the causal relationships between each variable (Sterman, 2001). Once the variables linked together, they form a causal loop that captures and visually demonstrates the effect on the system (Morecroft, 2009).

During this stage of coding and causal loop development, a process of identifying the systemic thinking of the participants (Groesser and Schaffernicht, 2012) was conducted to help form the loops. The eventual structure of all of the loops were then tested during the validation phase three. All of the identified loops joined together and formed a complete model that captures and demonstrates the causes and effects that result in persistent supply chain failure. Step five is also a continuation of coding level three. However, by this point all of the loops have been developed and could now be positioned into the key top level themes (Strauss and Corbin, 1990). The causal loop diagrams were constructed by identifying the key variables attributed to failure evident from the analysis of data. Consistently quoted topics and themes were developed into variables and placed into categories covered by the most pertinent lenses identified from the literature, e.g. Risk Management, Quality Management, Power and Performance Management. The variables were then broken down further into key themes associated with failure. Using the interview responses as justification, the established variables were then linked to corresponding variables based on causality, i.e. variables that create an effect on a process either positively or negatively when linked together (Morecroft, 2009). A more detailed description of the qualitative coding and variable name formulation process is given in Chapters 4 and 5.

3.4.3.1 The Use of Systems Dynamics – Causal Loop Diagrams.

Causal loop diagramming was adopted as the means to identify, capture, and demonstrate the mechanisms that allow supply chain failure to persist. The approach is used in the thesis to show the results of data analysis in model form.

Causal loop diagrams are an important tool for capturing and representing the feedback structure of systems (Sterman 2001, pp.137). A causal loop diagram is basically a word and arrow chart that shows interdependencies between variables (Morecroft, 2009 pp.30). All causal loop diagrams are constructed from the same basic elements: words, phrases, links and loops with special conventions for naming variables and for depicting the polarity of links and loops (Morecroft, 2009 pp.39). To illustrate how causal loop diagram modelling works in simple terms, Morecroft (2009) highlights the feed-back structure for births and deaths on the population size, which is shown in Figure 3.3. Polarities are shown using plus and minus signs. The plus sign situated next to the arrowhead is called a link polarity.

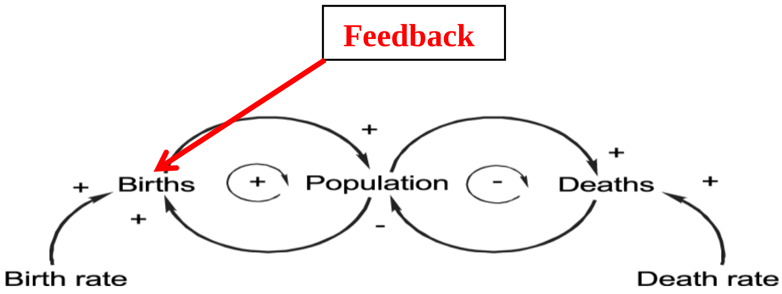


Figure 3.3 Birth Rate Causal Loop Diagram (Morecroft, 2009).

The diagram illustrates how key variables associated with population size are linked by arrows. The arrows show the causal influences between the variables (Kim, 1992 pp.2). The key dependent variables are Births, Population and Deaths. The system's exogenous variables are the birth and death rates. The birth and death rates have an effect on the number of births and deaths leading to either an increase in the population variable or a decrease (Morecroft, 2009). An increase in the birth rate has the effect of increasing the number of births more than would otherwise have occurred. An increase in the number of births increases the population size. As shown in Figure 3.3, feedback occurs in the loop because the greater the size of the population then the greater the chance of more births because the population is larger. In this case the link polarity denotes an increase in population because of the greater number of births. The plus sign is described as a positive link polarity because the number of births increases the population growth more than would otherwise have been the case if the birth rate had not increased (Sterman, 2001). Such a loop is described as a reinforcing loop. When the variables combine in this way they continually reinforce to increase the population growth. This kind of loop is typically labelled with the letter 'R' (Sterman, 2000) to symbolise that the loop has an increasing effect on the system (effect of 'Births' on 'Population').

Conversely, an increase in population will increase the number of deaths because a larger population will result in more deaths. The death rate directly counteracts or balances out the effect of a growing birth rate on the population than would otherwise have been the case (Morecroft, 2009). If there is an increase in the death rate then this will have the effect of increasing the number of deaths. An increase in the number of deaths has the effect of decreasing the population size. Therefore, the causal link polarity is denoted by a minus sign meaning that the link has a reducing effect on the loop and decreases the population size. The feedback outcome between the variables has the overall effect of balancing the population size against the number of births. The effect is called a balancing loop and is typically denoted with the letter 'B' to symbolise the reducing effect (the effect of 'Deaths' on Population).

Feedback between variables can be time dependent, meaning that the cause or effect can happen over a period of time or be delayed by a period of time. These are known as 'Time Delays' (Groesser and Schaffernicht, 2012). They appear on the directional arrow between two variables. When simulating a causal loop model, a period of time is usually incorporated into the model to simulate the effects between variables (Rahmandad et al., 2009). In order for a loop to be classified as reinforcing (a loop that continually increases its effect on a system over time), the number of positive linkage polarities in the loop has to be an even number i.e. 2, 4, 6 etc. (Morecroft, 2009). If there are an odd number of negative linkages i.e. 1, 3, 5 etc. then the loop has a balancing effect on the problem being analysed (Morecroft, 2009).

3.5 Introduction to Research Phase Three – Validation.

The aim of research phase three was to validate the data collected throughout research phase one and most importantly to critique the complete causal loop model on persistent supply chain failure. This was again carried out from a dyadic perspective in order to further strengthen the methodological rigor of the study (Ellram and Hendrick, 1995).

Research phase three commenced with a review of all previously obtained data. All of the information gathered during phase one including each of the original interview participants from both the first tier suppliers and then the prime were given the opportunity to review the information they provided again. A validation of the first tier and prime interview scripts was carried out to ensure that the information originally collected was still relevant and topical after the passing of time. The process was a pre-requisite to the major critique of the causal loop model, which was to be carried out in a planned workshop in which the model was tested with supply chain professionals from the prime manufacturer.

The workshop was conducted at the prime's main facility in the UK. Observations, inputs and critique from the workshop were then used to create a further iteration of the causal loop model in order to develop a model that reflected reality most accurately. The workshop sought to increase the methodological rigour of the model development process by enhancing the robustness of the research design.

In order to adequately test the data, the validation process was divided into separate stages (see Figure 3.4). The first stage involved the validation of original interview data provided by first tier supplier and prime participants during research phase one. The second stage was to conduct a pilot study pre-workshop testing of the model. The pilot study was treated as a run through of the planned information to be presented on the day of the workshop. Any issues with the information and material to be presented were captured here by the participants. A total of three supply chain professionals participated in the pilot study. One of the respondents had since changed jobs and was working for another eminent global engineering company with similar characteristics to the prime. The third stage was the workshop session held at the prime's facility.

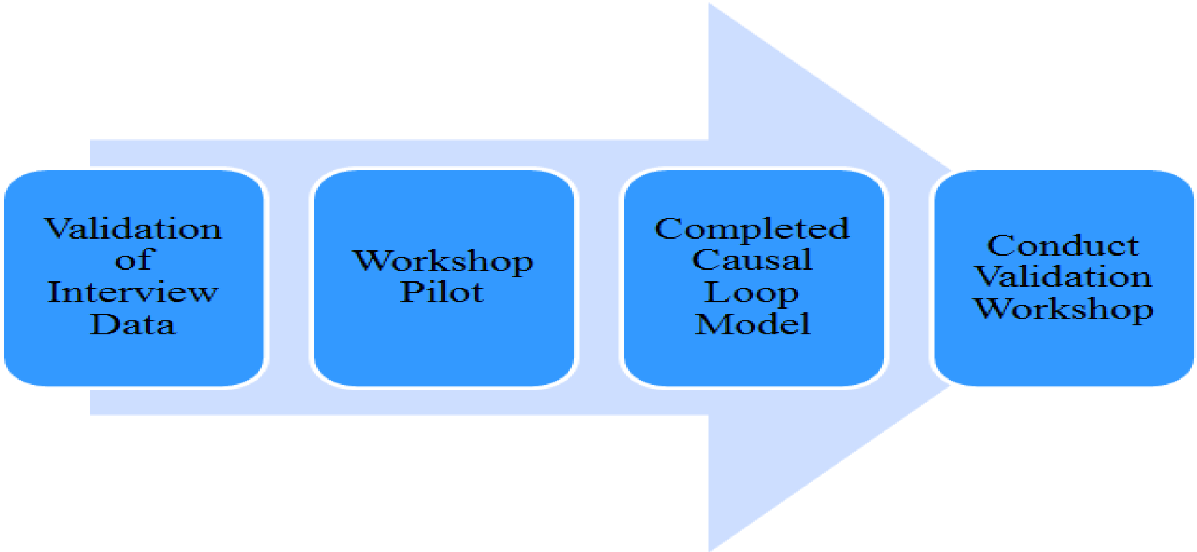


Figure 3.4 Research Phase Three - Validation Process.

3.5.1 Pilot Testing the Persistent Failure Model.

The findings and experiences taken from the pilot study were utilized to develop the most efficient and effective protocols for the planned workshop. The first session was held using video conferencing facilities due to the location of the participants in relation to the researcher. Approximately one week prior to each session, the participants were sent a brief supporting document that explained causal loop diagrams and how they worked. At the beginning of each meeting a brief explanation of how causal loop diagrams are constructed and what they try to show, was given. The causal loop model was systematically presented and explained from the bottom up. Each loop was explained in sequence until the entire model was built up (see example slide figure 3.5 below). It was anticipated that there would be much discussion during each session;

therefore they were both scheduled to take around two hours, which turned out to be sufficient.

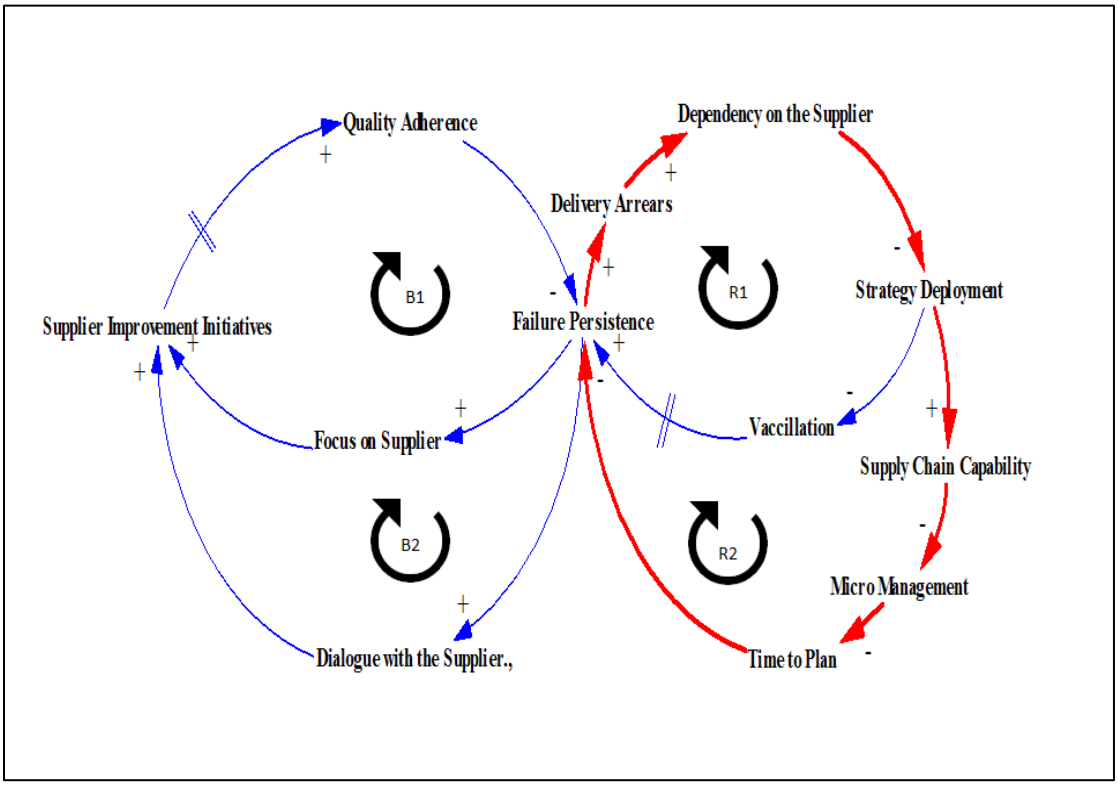


Figure 3.5 Construction of the Causal Loop Model Explained in Sequence.

Commentary explaining each variable and linkage was given to describe every stage of the development process from creating individual loops leading to the formulation of the complete model. Each participant was asked to comment on the overall construction of the model and the rationale behind its meaning. They were consistently asked throughout the exercise if they understood the thought processes and thinking behind each of the loops and whether they thought it was an accurate representation of reality. Comments on the final structure and set up of the model was also sought and captured. This was done in order to encourage a participative approach to the session to ensure that the participants would fully interpret how the loops were constructed and what each loop was seeking to convey.

3.5.2 Semi-Structured Interview Data - First Tier Suppliers and Prime Participants.

The main purpose for seeking validation of the semi-structured interview findings was to identify if the participants subsequently disagreed with any of their original observations given during exploratory phase one. Any updated information was then used to further improve the causal loop model, presentation and protocol prior to the validation workshop held at the prime.

The first tier supplier validation process involved returning to each facility and conducting the interview again with the original participants. The prime validation process was conducted exclusively via email.

3.5.3 Prime Workshop – Model Validation and Workshop Strategy.

The validation workshop held at the prime manufacturer represented a key milestone for the overall research process. The primary purpose of the workshop was to bring together experienced supply chain professionals with differing levels of seniority to validate and critique the persistent supply chain failure model and provide topical, relevant and valuable insights as to whether the model presented to them adequately reflected the 'reality' of managing aerospace supply chains. All comments, opinions and structured criticism were captured on a Dictaphone and also on flipchart paper. The information obtained from the validation workshop was then analysed and used to improve and refine the causal loop model. In the event that the participants disagreed with any of the identified themes, they were encouraged to explain what they thought did not work or why they did not believe the loops reflected reality adequately. The participants were then asked what they would change and also to provide suggestions on how they thought the themes should be structured or worded to better reflect reality. The opportunity to validate the finished model with highly knowledgeable personnel in the prime organisation provided rich additional insights.

A total of nine professionals employed by the prime took part in the workshop. Two of the nine professionals also took part in the semi structured interviews during exploratory phase one. The remaining seven participants did not take part during exploratory phase one, this meant that the majority of the participants were completely new to the research and provided a fresh perspective. For the remaining two participants, this was the first time they had seen the failure persistence model and how it was constructed. Neither were aware that the model would be the output of the semi structured interview questions. Therefore, they also looked upon the model with a fresh perspective. The participants came from a range of departments including procurement, production, engineering and production planning and control. Levels of seniority were also well represented ranging from Directors to a graduate trainee who was on a job rotation in the supply chain management function. The workshop session was split into a morning session commencing with a 40 minute presentation that described the objectives of the study and expectations of the workshop. This was followed by a breakout session in which the participants were divided into three groups of three, each supported by a researcher from the University. Two of the groups' were then tasked with analysing a specific part / quadrant of the model. The other group was tasked with analysing two parts of the model as it was divided into four parts. After a lunch break the afternoon session involved detailed feedback of the model from each group including suggested changes and also which elements they believed reflected reality at an appropriate level of detail.

The workshop ended with an open discussion on the potential application and benefits of the model and descriptions from the participants of how it could be used to help the prime avoid, mitigate against, or manage persistent supply chain failure. They were also asked to note any limitations of the model and the research in general if applicable. Finally, the participants were asked to provide feedback on how the model could be used to help the organisation to recover from persistent failure situations and how it could be used as a management tool by the organisation. All of the subsequent findings are analysed in Chapter 7 (Discussion).

It was anticipated that the content presented would stimulate much debate amongst the participants. As per the case study research method described by Stuart et al., (2002 pp.427) the session was facilitated by the lead researcher backed up by two research team members. The team member's primary role was to facilitate discussion concerning the model being presented. During the breakout sessions in the morning they each operated a Dictaphone in order to capture multiple findings and observations. Also, in accordance with field research practice as described in the literature (Meredith, 1998) all of the research team were required to take further notes in order to highlight identified issues with the model from the participant's perspective.

3.6 Chapter Summary.

The discussion above on methodology and research design has introduced the reader to the approaches and methods adopted for this research study. The Chapter has discussed the validity and reliability of the research design, which is based on conducting multiple case studies (Yin 2009). Three phases of the research study are described – empirical case studies, analysis, and validation. By developing and then following a systematic process throughout the study during the exploratory phase, qualitative and causal analysis phase, and finally the validation phase, the research design and methodology has sought to be demonstrably robust (Seuring, 2008). It was clear the research process needed to be considered with great care and that the three phase approach to validating the data would be time consuming and fraught with logistical challenges, which is why all potential risks had to be considered and challenges and mitigation plans had to be documented.

Chapter 4: Exploratory Study, Phase One – Empirical Evidence and Analysis.

The methodology and research design described in Chapter 3 explained how the exploratory phase was conducted in two stages, i.e. stage one focuses on the first tier supplier study and stage two focuses on the prime company. In Chapter 4, the evidence from each case study is presented, consolidated, analysed and discussed in sub-sections covering each of the semi-structured interview themes.

The investigation carried out throughout this Chapter is integral to the subsequent development and formulation of the Dynamics of Supply Chain Failure model. As noted in Chapter 3, the quality management system used by the prime is called Sabre. All first tier suppliers are required to follow the Sabre quality management system. The rules and regulations stipulated in Sabre are passed down the supply chain first by the prime and then by the first tier suppliers into their sub-tiers. Causes of failure are identified and categorised in accordance with the specified requirements documented within the Sabre management system.

4.1 Research Phase One – Exploratory Phase observations.

This section aims to establish the most consistent causes of failure identified by the target research group and to put them into specific categories and themes (Miles and Huberman, 1994). Each of the following sections documents and analyses key observations, empirical evidence and narrative descriptions obtained from the exploratory phase. The analysis conducted throughout this Chapter represents steps one and two of Figure 3.2 of the coding process presented in Chapter 3. The captured evidence is organised using the principal themes identified from the literature. Each sub-section starts by highlighting the key questions asked of participants under the relevant semi-structured interview theme, providing the reader with the context behind the observations captured during each interview. In the interests of space the indicative evidence presented to support the findings has had to be selective. Also, as will become evident, some of the issues identified under different themes are related and inter-mixed. All of the sub-themes captured under each main theme are consolidated into tables, which pinpoint key factors influencing supply chain failure in some way. The information captured in each table is then consolidated under identified themes at the end of the Chapter in Table 4.7.

4.1.1 Risk and Contingency Management – First Tier Suppliers Perspective.

Questions used in the first tier semi-structured interviews on risk and contingency management were:

1. *What are the key risks that contribute to failure for the organisation?*
    1.1. *Are risk assessments carried out to ensure these issues are identified and managed before they can contribute towards chronic long term failure scenario?*
2. *Can failure to identify and manage key risks at critical stages in a contract contribute to long-term chronic failure? If so how and when?*
    2.1. *Who is considered responsible for your organisations identification and management of risks?*
    2.2. *Are these identified risks flowed down to other members of the organisation / project teams?*
3. *What in your opinion are the key macro-economic factors that can contribute towards long term chronic supply failure?*

Table 4.1 provides a consolidation of the sub-themes captured in the semi-structured interviews conducted across the first tier suppliers on the subject of risk and contingency management.

Table 4.1 First Tier Suppliers - Risk Management.

Theme	General Sub – Themes (Coding Level One) Table 4.1
Risk Management (Including Contingency Management)	• Regular material schedule changes by the prime. • Lack of planning capability in the industry. • Poor lead time adherence by the prime. • Component specifications regularly issued late by the prime. • Untimely responses to questions asked by first tier suppliers by the prime. • Failure by the prime to manage and mitigate key risks at critical stages during contract formulation process. • Limited access to rare and exotic materials specified by the prime. • Sub-tier suppliers not being able to get funding from the banks due to cash flow issues because of late payment by the prime.

All of the participants said that failure to identify and manage key risks at critical stages in the contract formulation stage could contribute to failure. A key identified risk that was cited as a cause of failure from a risk management perspective was the existence of uncertain demand profiles. It was made clear that the uncertainty with the material schedules was not being caused by volatile shifts in demand further upstream from the end customer. Aerospace demand is relatively stable compared to other industries. It was mentioned that the uncertainty in demand schedules has come about as a consequence of poor planning by the prime and not as a result of industry demand fluctuations. A consequence of poor planning was shown to manifest itself in poor lead time adherence by the prime, which was also said to perpetuate risk of failure for the first tier suppliers.

To further compound the risk of failure, it was noted that component specifications were regularly issued late by the prime combined with a lack of responsiveness from the prime when first tier suppliers requested further technical clarification regarding newly submitted specifications or drawings. This was especially the situation when the prime specifies exotic or rare materials that need to be procured expediently in order to meet the requested delivery dates. Delays in delivery could place the first tier and sub-tier suppliers at financial risk due to the ensuing cash flow issues that could occur with sub-tier suppliers not being paid, potentially leading to poor credit ratings.

The purpose of investigating risk management during the exploratory phase was first to capture the activities or events that the participants perceived as key risks to the business and second identify the level of awareness within the supply chain of risk management techniques. The most consistently identified issue within the planning process concerned the number of material schedule changes made by the prime.

Supplier D manages between fifteen hundred to two thousand parts on behalf of the prime, which the participant viewed as representing a significant challenge to their organisation and their sub-tier supply chain. Participant OM–D suggested that consistently changing material requirement dates can have a huge effect on the risk and contingency management process of the supplier: *"Fifteen hundred part numbers are currently being managed. Some are dormant though because this is a legacy low volume commodity, predominantly legacy engines. Difficult to manage failure due to the low volumes and infrequency of demand, this is where we (supplier D) sometimes struggle".*

Participant OM–D also indicated that issues concerning delivery performance were often problematic enough for the supplier to commence conducting root cause analysis. The subsequent analysis had identified that regular material requirement changes did cause disruption: *"We can expect to get somewhere in the region of four hundred and seventy changes a week on average. Each of those has to be flowed down to the relevant sub-tier and each of those have to say whether they can meet the new dates imposed by the customer. Quite often that causes more confusion than anything".*

Participant OM–D also shared their belief that the overall planning capability in the aerospace supply chain was consistently poor with many first and sub-tier companies lacking capability within the planning discipline. The lack of capability in planning was cited as a risk that could contribute to supply chain failure should the effects of poor planning come to fruition: *"There is a lack of planning, not many companies are good at planning. Very poor at management and planning of projects".*

This was due to an inability to correctly align their supply chain planning tools with those used by the prime. Participant MD-E conveyed that something as simple as failing to monitor issues closely at any time during the process could result in a failure happening somewhere. However, participant CM-C provided their opinion on the most common risks that lead to failure from their perspective: *"Late specification issued by the customer, changes to the specifications. Also, untimely responses to questions (this is all happening on the XWB at the moment) which means we have to run around in circles in order to keep to deadlines.''*

Untimely responses to questions was a common theme that has permeated throughout the first tier research process and was mentioned during the interviews on other domains. The importance of adequate communication required to either prevent failures from happening or to quickly resolve them was noted as a key concern for the first tier participants, especially on matters concerning legacy components.

A universal risk that has affected all first tier suppliers and their sub-tier supply chain in recent years has been the economic crisis (Natarajarathinam et al., 2009). A consequence of that has been discussed by the first tier suppliers. They have said that they now considered the wider macro-economic environment when managing risks. The majority of risks listed can be attributed to cash-flow / funding issues. Participant MD-D suggested that obtaining finance was currently a big risk to sub-tier suppliers. This includes businesses not being able to get adequate funding from the banks or banks withdrawing funding because of weak business cases. Participant MD-D explained how it causes disruption to companies within the supply chain: *"This is happening now where funding is being withdrawn causing business to go into administration which in* *turn causes disruption to this business. Liquidity challenges for the banks, i.e. suppliers cannot grow or expand because risk of not being able to make loan repayments is high. The banks are very willing to lend money to anyone who doesn't need it but are less willing to lend to those who do".*

Perhaps surprisingly, none of the participants suggested that sub-tier suppliers or customers in financial trouble would not be selected to participate or be part of a supply strategy as a consequence of financial problems despite the issue being identified as a potential cause of supply chain failure.

4.1.2 Risk and Contingency Management – The Prime Perspective.

Questions used in the semi-structured interviews held at the prime on risk and contingency management were:

1. *What are the key risks that contribute to failure for the organisation?*
   1.1. *Does the prime review issues that caused previous quality / delivery failures via risk assessments when contracting with a supplier?*
   1.2. *To what extent is the prime accountable for learning and sharing information of previous mistakes with the supplier?*
   1.3. *Are risk assessments carried out to ensure these issues are identified and managed before they can contribute towards a repeat chronic long term failure scenario?*
2. *Does the prime conduct joint risk assessments with suppliers prior to key milestones during the contract formulation process?*
   2.1 If so how? If not why?
3. *What in your opinion are the key macro-economic factors that can contribute towards long term chronic supply failure?*
   3.1. *What actions (If any) are put in place to protect the prime from this causing chronic long-term supply failure?*

Table 4.1A provides a consolidation of the sub-themes captured during the semi-structured interviews on the subject of risk and contingency management held at the prime.

Table 4.1A Prime Participants – Risk Management.

Theme	General Sub – Themes (Coding Level One)
Risk Management (Including Contingency Management)	• Issues with overall robustness / effectiveness of the risk management process at the prime. • Risk assessments are not considered important enough to be conducted during the contract formulation process between the prime and first tier supplier. • First tier suppliers participate in risk assessments 'post event'. • Recognised lack of competency in planning, including the setting of unrealistic project timescales. • Regular uncertainty over available capacity in the industry affecting the prime's perception of demand. • Arms-length relationships with first tier suppliers.

It shows how participants from the prime focused on the actual risk management process in their responses, i.e., maturity, robustness and effectiveness of the process (Zsidisin et al., 2000) as being a risk to their business rather than describing what constitutes a risk of failure. The participants described how risk management as a discipline was still quite new to their business. They also described how joint risk assessments were not being conducted during the contract formulation stage suggesting that this was a consequence of traditional arms-length relationships with suppliers. It was discussed how first tier suppliers were only invited to participate 'post event' when a failure had already occurred and was already causing disruption. This was despite an overarching uncertainty regarding available capacity within first and sub-tier supply chains. This was also combined with observations that highlighted a perception that risk to any project was perpetuated by the prime due to the setting of unrealistic project time scales. All of these comments were captured despite there being clear acknowledgement that the lack of planning capability at the prime was a major risk.

All of the participants focused on the prime's internal processes throughout the interview and concentrated on highlighting how their organisation approached the identification of risk in the supply chain. It was noted by participant EPM that much of the suppliers' risk management / risk mitigation process is focused on mitigating risks that have been caused by the prime themselves: *"I think a lot of it is around the planning. I think we tend to not plan very well and have timescales that are not realistic. So we are always chasing our tails to make things happen. So we have got the situation whereby they want this in six months when really it needs a year to go through the* *validation and delivery and all those kind of things. Normally the timescales are that tight that you are always chasing and pushing. This is one of the key reasons I believe that setting unrealistic timescales sometimes results in your validation strategy being reduced so you don't do enough validation leading to quality issues and delivery problems. This is because you are trying to condense everything into a much shorter time space".*

Until relatively recently, the management of risk has been seen as a low priority and kept in the background. Participant EPM noted how suppliers are asked to participate in risk assessments post event but are not required to conduct a risk review during the contract formulation phase: *"Normally what happens is, if you have got a specific problem which might be an engineering problem or whatever, you would have the supplier as part of the risk assessment team to try and flush out and get right down to the root cause problem so yes. Now whether they do it jointly during contract formulation I don't think so. I think they will have a risk assessment to try and flush out the reasons why and where in order to try and rectify it. It is not normally done during contract formulation stage".*

Despite there being a requirement for suppliers to be involved in risk management processes, there was acknowledgement that relationships were still very much at arms-length. Participant EPM explained how the prime had a dedicated risk management department with risk experts whose role it is to facilitate risk assessments at the prime. These experts help clarify the difference between a risk and an issue during risk review sessions. However, participant EPM was asked whether the inclusion of a risk assessment helped during a crisis and when supply chain failure was happening: *"Not really, it kind of goes into panic mode. Firefighting kicks in. People are thrown at it. Invariably money is thrown at it and maybe a little later in the day they do look at the risk assessment but to be honest I think it is more firefighting and money and men are thrown at it".*

Two key risks for the organisation were identified as available capacity in the gas turbine manufacturing supply chain and the prime's perception of future demand. The availability of capacity in the supply chain was specifically highlighted by participant PDM as a key area for concern: *"Overall capacity within the industry, be that raw material availability and or capability that is directed into other industries. A lot of what we have tended to think about is focusing in on the suppliers themselves and* *on their processes. In reality their ability to conduct increasing levels of business for us is very dependent on them being able to secure resource to do so. So that would be my biggest concern, is there enough capacity in the industry to deliver what we need for growth going forwards?"*

Further to the comment another important observation was the acknowledgement made by participant EPM regarding the prime's lack of competency in planning components into the first tier supply chain, especially concerning new product introduction planning. The participants' viewpoint corroborates observations made by participants from the first tier supply chain, suggesting that planning capability is not adequate in the gas turbine manufacturing industry. From a contingency management perspective, it was mentioned that the prime's first and sub-tier supply chain covers a vast footprint in a number of environmental and geo-political hotspots. These comments highlight the level of immaturity that has existed at the prime concerning contingency management. However, the captured observations show that the subject has only started to be seriously followed due to events that have occurred over a period of time. Despite this, the subject still appears to be a relatively new concept at the prime.

4.1.3 Quality Management – First Tier Suppliers Perspective.

Questions used in the first tier semi-structured interviews on quality development were:

1. *What are the key factors that contribute to quality failure within the organisation?*
2. *How can you identify that the system is robust and can control a failure by preventing it from becoming chronic?*

   2.2 What is the process for managing a reoccurring failure?
3. *Does your organisation conduct process failure mode effects analysis PFMEA to ensure repeat problems don't occur?*
   3.1. Is this part of your sub-tier selection criteria to control potential failure from occurring down the supply chain?

Table 4.2 is a consolidation of the comments and sub-themes captured during the interviews based on quality management held with first tier suppliers.

Table 4.2 First Tier Suppliers - Quality Management.

Theme	**General Sub – Themes (Coding Level One)**
Quality Management	• Consistently failing to meet the prime's specification on parts. • Confusion surrounding the prime's auditing schedule. • Misunderstanding of ISO9001 accreditation and function.

	• Drawing definitions being supplied late by the prime. • Misinterpretation of the prime's drawings. • Inadequate planning for newly designed components / end product. • Poor communication throughout the supply chain. • Poor training by the prime on how to adhere to quality system.

One of the strong emergent themes involved first tier suppliers consistently failing to meet the prime's specifications. Although the first tier suppliers acknowledged that they had been involved in causing disruption due to failure, the first tier participants partly attributed this to a lack of understanding of the prime's technical specifications. These observations were also followed up by insights that suggested drawing definitions were regularly supplied late by the prime. It was also noted that when the first tier suppliers did eventually receive the drawings they were often misunderstood. There was also confusion as to the purpose of a customer audit. The perception appeared to be that audits were carried out by the prime as a result of failure and not to ensure standards are being met in order to prevent failure from happening in the first instance. Again, inadequate planning of newly designed components was cited as a potential cause of persistent supply chain failure.

The most commonly cited issue was not being able to consistently meet required specifications. Participant QM–A provided a clear definition: *"Anything that doesn't meet the specification or the customer requirements internally or externally".*

Further responses concerned the presence of ISO certification[11]. It is a mandatory requirement for first tier suppliers to hold ISO AS9100 accreditation in order to supply product to the prime. Selecting suppliers who hold the accreditation is a key control mechanism used to reduce the risk of non-conforming products being supplied and improve supply chain performance (Yeung, 2008). However, none of the interviewees believed that the presence of the AS9100 certification meant that quality failure was less likely to occur. Participant QM–B noted the following; *"The ISO9000 is just an in-depth review of the quality assurance system. The system should be able to give adequate assurance that the product conformity is going to be the absolute goal for the company. Naturally nobody wants to see the supply chain being disrupted with a huge amount of non-conformity going out of the factory. Therefore, the quality*

[11] ISO certification – *Designed to ensure that companies have processes and procedures that guarantee that a good level of quality for the product being supplied. This is awarded by a third party who is cerified to award the standard.*

assurance system is its safeguard but it doesn't mean to say that it will stop a supply chain getting saturated with non-conformances".

Despite ever changing aerospace industry quality standards, which are further amplified by the prime, some of the participant first tier suppliers have not significantly improved their quality management system or invested in new equipment or machinery in line with new requirements. However, some are adopting important improvement practices in order to compensate. Due to an aging issue with tooling and machinery, participant QM-B mentioned that they had recently started an initiative to conduct 'gage repeatability and reproducibility'[12] on all of their measuring equipment: *"We are currently on a programme whereby we are doing all of the gage R&R on all of our measuring equipment that we have onsite with various types of products and that is being done with various types of people. We most certainly will see benefits from these activities. It is the first time that we have had complete confidence in the way we measure our tooling. If you don't have complete confidence in the way you are measuring your finished goods then how can you have complete confidence in what you are shipping out. Eventually the project will be used to look at all of the machines".*

A further factor identified during the interviews was that the first tier suppliers tended to only have the resources to audit the quality performance of their key suppliers once a year. This represents a risk to the prime as there are a multitude of potential issues upstream that could cause a failure throughout the supply chain, i.e. human error, engineering issues, material issues, and misinterpretation of customer's drawings, inadequate planning, poor training and poor communication. Participant QM-D explains the challenges faced by the supplier in order to fully comply with Sabre: *"Due to the fact we have about one hundred and sixty sub-tiers (suppliers) we can't audit all of those suppliers more than once a year so we do a risk assessment based on cost and volume of the parts and also historical risk with the suppliers. We audit suppliers every month but we don't get across to every supplier".*

The analysis of the first tier quality management findings strongly identifies the following issues – not all first tier suppliers are adequately equipped to cope with the pace of changing requirements in the aerospace industry. Adoption of improvement techniques usually associated with lean manufacturing (Dyer and Nobeoka, 2000) and

[12] Gage R&R – *Process for ensuring that measurement gages for product inspection are statistically accurate for each measurement of a batch.*

continuous improvement (McAdam et al., 2008) seems to be very slow and may lag behind other industries. Not all first tier suppliers have the resources to adequately meet the requirements of the prime's stringent quality management system, particularly with respect to monitoring their own supply base.

4.1.4 Quality Management – The Prime's Perspective.

Questions used in the semi structured interviews held at the Prime on quality management were:

1. *What would you describe as a 'quality' failure?*
2. *Can causes of quality failure in the supply chain be attributed to the supply chain only or is the prime accountable also, if so why?*
   - 2.1. *What effect does a long term chronic failure have on the prime?*
   - 2.2. *What are the key factors that contribute to quality failure within the supply chain?*
3. *Does the existence of the ISO certification mean that quality failure (Long-term) are less likely to occur in the supply chain?*
   - 3.1. *Does the prime ensure that your suppliers have a robust quality system that can quickly identify, improve and control quality failures above and beyond ISO certification?*

Table 4.2A provides a consolidated view of the themes captured during the interviews on quality management held with participants from the prime.

Table 4.2A Prime Participants – Quality Management.

Theme	General Sub – Themes (Coding Level One)
Quality Management	• Inconsistent interpretations of prime's part specification and drawings. • Overly complex quality management system at the prime. • Lack of training for sub-tier suppliers in using the prime's QMS. • Poor information flows on quality issues through supply chain. • Inadequate documentation: paperwork being incorrect or part marking errors by first tier suppliers. • Overall lack of internal capability to adequately manage quality management system. • Weak auditing of supply chain capability combined with misinterpretation of ISO accreditation at the prime.

Consistent with the observations taken from the first tier participants, the participants from the prime also noted how inconsistent interpretations of component specifications and drawings greatly increased the risk of failure. Again, it was mentioned that this could be the result of an over complicated quality management system. The prime participants also noted how information flows through the supply chain were currently poor. This limits the chances of further improving understanding of the quality management system throughout the supply chain. A similarity between the observations taken from the prime participants compared to those from the first tier suppliers was the acknowledgement that there was a lack of capability internally to manage the quality management system at the prime. The prime participants suggested that there was a lack of capability to manage the prime's quality management system throughout the supply chain. Another similarity was the apparent inconsistent application of the ISO accreditation. The participants from the prime also believed that the presence of ISO accreditation did not reduce the risk of failure.

In addition to being asked for their insights on the causes of quality failure, the participants were asked if they thought that it was solely the responsibility of the first tier supplier or whether the prime was also responsible in some way for the failures. The participants identified that quality failures were on the whole a joint problem. Participant RPM acknowledged that some of the prime's inefficiencies can perpetuate problems in the supply chain: *"You can say both; ultimately the supplier is accountable for both i.e. the product delivery and is responsible for quality. The prime can contribute to that quality issue in numerous ways in terms of interpretation of specification and drawings. Vagueness around our expectations i.e. people interpreting our drawings differently etc. We can contribute".*

Participant SDTM provided a stronger response to the questions focused on causes of failure by providing an insight into the culture of quality at the prime towards their supply chain: *"This organisation is definitely accountable; it makes its systems so complex that it sets a supplier up to fail. It makes it so difficult to deal with it that it sets the supplier up to fail. In my opinion some of its measures are set up for the supplier to fail".*

Observations from the interviews suggest that there is an understanding of potential causes of quality failures to some level. However, there was also an underlying narrative concerning how the prime is slow to do anything about it or is seemingly accepting of issues as simply 'the way things are' (Levitt and March, 1998). Participant RPM, whose role it is to manage these issues on an operational level provides insight into what the main issues may be: *"There is always a spread in any failure and our organisation usually has some part to play, whether it be lack of clarity of requirements or lack of training given by our organisation to the supply chain. There are very few failures that are entirely black and white, i.e. one person rather than the process is responsible. The vast majority I would say are 80/20 one way or the other.*

Issues that can occur throughout the supply chain are a lack of clarity and understanding of standards and specifications. This is also the case with poor information flows about quality issues where there is a standard set of working instructions that have not been adequately passed down to first / sub-tier suppliers. It was also noted how short cuts were often made to documentation in order to rush them through to first tier suppliers. Participant QD described how constant quality issues such as paperwork being incorrect or part marking errors, for example one digit being wrong, were classified as failures by the prime. The prime directly manages only their first tier suppliers because of the size of the supply chain, transferring sub-tier management responsibility onto their first tier suppliers. This inevitably causes significant resource issues for the first tier suppliers but also to the prime who subsequently needs to validate and monitor the first tier supplier's own supplier management process. Participant QD explained why this is the case: *"We audit the first tiers and the sub-tiers are managed by the first tiers, we pay the first tiers to manage the sub-tiers [as part of the component price]. The size of the triangle gets exponentially bigger when you try and look at the sub-tiers as well. We couldn't resource it. There are hundreds of audits carried out each year on our first tiers alone. We make sure that they have a level of control. Part of the Sabre compliance audit is that they check the controls of what the sub-tiers have in place".*

A conclusion drawn from the quality management interviews conducted at the prime points to the possibility that neither party has the resources and capability to adequately manage the prime's extensive quality management system, in particular in relation to the sub-tier suppliers. Despite this, much of the risk is transferred into the supply chain on the assumption that suppliers with ISO accreditation are less likely to cause failures than others without. Those assumptions contribute to increasing the risk of failure within the supply chain.

4.1.5 Power and Relationship Management – First Tier Suppliers Perspective.

Questions used in the first tier semi structured interviews on power and relationship management were:

1. *What are the key factors that can contribute to chronic long-term failure for the organisation?*
2. *On what criteria does your company select its potential customers?*
   2.1. *Do you have favoured / non-favoured customers?*
   2.2. *If so what is the criteria for this, how do you decide what who is a favoured customer as opposed to a non-favoured customer?*
3. *Do you have a maximum leverage cap with your customers and suppliers? If so what is it and why?*
   3.1. *How quickly and easily can you re-source if a supplier is not performing thus effecting your performance?*

Table 4.3 presents the consolidated sub-themes captured from analysis of the semi-structured interviews conducted on the subject of power and relationship management at the first tier suppliers.

Table 4.3 First Tier Suppliers - Power and Relationship Management.

Theme	General Sub – Themes (Coding Level One)
Power and relationship management.	• First tier suppliers can become dependent on the prime. • First tier suppliers develop strategies to be preferred supplier or sole source. • Commercial redress and lack of supplier attention can lead to very hostile relationships. • Lack of leverage caps resulting in 'over leveraged suppliers' with the prime. • Poor communication with prime when supplier deemed not important. • Critical components are difficult to resource due to the prime's current process for changing source of supply.

A prominent theme that was captured during the interviews with the participants was how first tier suppliers could become dependent on the prime to provide a large proportion or the majority of their turnover. It was also found that some first tier suppliers actively develop strategies to become a sole source supplier to the prime. Additionally, some first tier participants reported that they were potentially over leveraged with the prime, which compounds the level of dependency. Poor communication was mentioned as being an issue within the prime's supply chain. However, a perception of the cause of poor communication was that the prime does not deem the first tier supplier as strategically important. Another interesting observation concerned how the process used by the prime to change source of supply was perceived by the first tier participants as notably difficult to achieve.

The interview script sought to capture potential causes of commercial lock in (Farrell and Klemperer, 2006) and to identify if a level of dependency existed in the supply chain. Customer dependency on the supplier was also an issue recognised by some of the first tier participants according to findings from the first tier interviews. To some extent, these strategies are widespread within the first tier supply chain. However, participant OM-C pointed out the risks associated with adopting sole source strategies: *"Commercial issues can drive a lot where a supplier can feel that he is not getting any redress or is getting ignored. He has got quality issues that need customer input or has a design change requirement that needs looking at but is getting ignored. Predominantly in the relationship thing, commercial redress / lack of supplier attention can lead to very hostile relationships that can result in really poor delivery or even non delivery; sometimes deliveries can be withheld to be used as leverage to get some attention".*

Equally, participant MD-E stated that their company strategy was to only contract with customers with whom they are assured of a long term relationship: *"If you are involved with a project from the start you want to work with people who want to work with you. In terms of customers, customers who we can have a long term relationship with, recognising that we have to start small to end up big, we are interested in customers who are in it for the long haul".*

However, although there is considerable research to suggest that developing and maintaining long term relationships can have a positive effect on supplier performance (Håkansson and Ford, 2004), this research suggests that over time there can also be negative side effects such as having too much business with one supplier, described as being 'over-leveraged' in the industry. The importance of communication with the supplier was noted by participant BS / BO-B: *"Quite often a supply chain failure is caused by poor communication, change of the goal posts, and raw material supply to a smaller supplier. In situations like this it mainly needs the influence of a larger business to make it happen".*

The participants were aware that being over leveraged with the prime was a potential problem. However, none of them stated that they had a specific policy to ensure that business with the prime only represented a certain percentage of their revenue. In general, however, the participants were very aware that sourcing product away from one supplier to another could be extremely difficult to achieve because of the prime's change of source process. Participant CM-C describes the different challenges faced: *"That depends on the type of product that we are trying to resource, i.e. if it is a nut or a bolt then it might be a lot simpler to resource than an IP related product"*.

Participant CM-C was describing the difficulties of changing the source of supply from one sub-tier supplier to another because of the mandatory process that the prime ensures all first tier suppliers follow, the prime calls this the 'source change process'. The first tier suppliers are aware that an onerous source change process can also work in their favour in case the prime wants to resource product away from them. Participant MD-E was the only interviewee who said that they could quickly resource product if a sub-tier supplier was not performing. All of the other companies suggested that this was extremely difficult for a number of reasons. Participant CM-C stated that it is not easy and it is very time consuming: *"One of the restrictions to that is the source change process that major customers have, which are quite often lengthy and require a lot of resource to resolve. This is one of our issues at the moment because we don't get the support from our customers that we need to in-order to resource parts"*.

It could be argued that some of them hold the upper hand in terms of leverage and / or positioning. For example, Suppliers A and B are subsidiaries of global corporate conglomerates and own the design rights (IPR) to the products that they supply. These companies are far less leveraged in terms of proportion of turnover with the prime. They have global sales of their products within the industry. The remaining participant companies are much smaller entities. They produce parts where the designs are owned by the prime and are far more leveraged towards the prime, engendering a reliance on orders needed to survive.

4.1.6 Power and Relationship Management – The Prime Perspective.

Questions used in the semi-structured interviews held at the prime on power and relationship management were:

1. *What are the key supply chain relationship factors that can contribute to chronic long-term failure for the organisation?*
    1.1 Has poor relationship management with suppliers by the prime contributed towards a breakdown in communication and subsequently poor supplier performance?
    1.2 Does the prime monitor the relationship with all suppliers or does it only concentrate on key strategic relationships?
2. *Does the prime select suppliers who have been known to have been involved in chronic long term supply chain failure in the past?*
    2.1 If so why? If not why not?
3. *Do you think that suppliers with specific core competencies / IPR are given more time to recover if a failure starts to become chronic?*
    3.1 If so why? If not why not?

Table 4.3A provides a consolidation of the sub-themes captured during the semi-structured interviews on the subject of power and relationship management held at the prime.

Table 4.3A Prime Participant – Power and Relationship Management.

Theme	General Sub – Themes (Coding Level One)
Power	• Breakdown in relationships can cause failure. • Lack of relationship continuity causes the relationship dynamics to change. • Failure by the prime to deliver on commitments made to first tier suppliers. • Poor information flow throughout the supply chain. Communication is often inadequate. • First tier suppliers are known by the prime to have strategies aimed at becoming sole source on rare complex components. • Lack of mature and workable sourcing strategies. • Perception that the prime fails to manage first tier supplier effectively. • Lack of knowledge about who appropriates power in the sub-tier.

The overriding theme captured during the interviews was how a breakdown in relationships with first tier suppliers increases the risk of supply chain failure. Further to this, the prime participants discussed how a lack of relationship continuity caused the relationship dynamic with first tier suppliers to change. These observations were directly related to comments made by the first tier participants who suggested that the prime regularly changed their point of contact, which was also noted by prime participants during the interviews. A further theme related to the perception that the prime often failed to deliver on commitments made to first tier suppliers, which led to negative relationships. It was felt by the participants that this could be due to poor information flow throughout the supply chain.

In discussing potential causes of failure, participants from the prime regularly mentioned the organisation's lack of mature and workable sourcing strategies. The problem was associated with how poor sourcing strategy formulation and deployment contributed to the prime not being able to manage their first tier suppliers effectively. This was attributed to the prime not understanding who appropriates the power in the relationships they choose to form with first tier suppliers. Participant B explains their perceived limitation *"Certain suppliers are the only suppliers who can do certain things. If the work is complex then we don't like to pull parts out if they are complex because supplier B will have the same issue so we will always try to work with the original supplier. It is very difficult to transfer these out and takes a long time"*.

Participant GCL suggested that causes of supply chain failure often began when the relationship between both sides initially break down. The participant explained how issues can occur when the nature of the relationship changes. These can potentially lead to problems: *"Issues tend to be where the relationship is broken. Subjective measures, i.e., people change, thus relationships change and people have a different agenda / scope on one or both sides. This can result in problems"*.

Similar to the comments made during the first tier interviews, the participants highlighted communication and not delivering on commitments as very important in developing and maintaining a positive relationship. Participant B explained how good communication with the suppliers meant the consistent sharing of important information: *"Communication is a big one. It is a big factor. We advise the supplier of future requirements but never give them the forward load, which damages relationships. We only advise them of the NPI quantity when we should give the volume for the full length of the contract which affects price and negotiations. Because we only communicate NPI batches[13] to the supplier they don't see us as a partner in the long term which affects our supply chain. Because of this suppliers have refused to quote"*.

The strength of the narrative here indicates that poor information flow was not unusual and can reoccur frequently and / or over a period of time. The opinion given by participant B was that the prime is aware that their overall communication is inadequate, yet key supply chain management employees such as the buyers, feel

[13] NPI batches – *New Product Introduction first production batch.*

powerless to do anything constructive about it. As previously identified in the study of power and relationship management, first tier and sub-tier suppliers often identify these constraints and capitalise on them. They do this by basing their sales strategies on encouraging the prime to use the supplier's IPR-owned technology on the final product. Again, the participants from the prime are more than aware of such strategies as described by the GCL: *"It is some suppliers' strategy to actively become the sole source of supply on rare complex commodities making it difficult to find an alternate source. Unless we are careful we end up engineering that single source onto our platforms, which makes it difficult to go elsewhere. There is a risk that we become beholden to suppliers who operationally haven't been a good performers, but have the technology that we need"*.

The consequences of allowing a supplier to effectively 'engineer' their products onto an engine are being acutely felt by the prime. This has now become an operational issue because they are obligated to contract with only a few suppliers on key systems due to there being little or no alternatives to generate competition within the industry. The lack of mature and workable sourcing strategies for key systems was mentioned by both participants in line with the perceived lack of supply options. The failure to manage suppliers effectively can and does erode and undermine the prime's own value proposition within the supply chain. The resultant effect is that suppliers are given the opportunity to push up costs and reduce the level of return for the prime. An important aspect of this research project is to understand why the prime is unable to identify who appropriates power in a sub-tier relationship.

4.1.7 Supplier Development – First Tier Suppliers Perspective.

Questions used in the first tier semi structured interviews on supplier development were:

1. *Do supplier development initiatives contribute towards preventing long term failure for the organisation?*

   1.1 If so how? If not why not?

2. *In the event of chronic long-term supply chain failure within your supply chain, do you deploy people into your supplier's in-order to facilitate recovery?*

   2.1 If so how quickly? If not why not?

3. *Have improvement initiatives been implemented by your customers and / or suppliers in the event of periods of chronic failure? If so what are they? Have they helped to improve chronic long term failure?*
   3.1 Are you currently still involved in any customer led activities that were started during chronic supply chain failure?

Table 4.4 is a consolidation of captured sub-themes related to supply chain failure from a supplier development perspective. Table 4.4 highlights that first tier participants described how a lack of resources limited their ability to conduct supplier development activities within their own sub-tier supply chain.

Table 4.4 First Tier Supplier - Supplier Development.

Theme	General Sub – Themes (Coding Level One)
Supplier Development	• Lack of supplier development resource to adequately manage its sub-tier suppliers. • Lack of flexibility in sub-tier management. • Level of resource committed by first tier suppliers depends on criticality. • Level of influence depends on leverage with the prime. • Planning capability needs to improve throughout the supply chain. • Initiatives are stopped after short term solution is identified.

The participants also articulated how the general size of their organisations tended to limit the amount of supplier development activities they were able to conduct per year. Therefore, deployment of precious resources was dependant on criticality, i.e. sub-tier suppliers who are causing the most immediate problems.

Observations made during the first tier interviews was that improvement initiatives would often be implemented in first tier suppliers by the prime, that do not have the volume of demand required to justify undertaking any improvement. The process of implementing such initiatives can end up costing the first tier supplier more than the actual benefit gained. Participant OM-D explained how they approached the implementation of supplier development initiatives within their own first tier supply chain: *"We don't make snap judgements so there would need to be a consistent trend of failure. We would make a report fairly quickly so we could see what the situations was. If it happened over a number of months we would go into the supplier and ask why the failure was occurring. We would ask the company to make an improvement plan.*

To deploy somebody would be a judgement call, i.e. value of the business, extent of the failure etc. We would monitor it from two months onwards. We monitor suppliers similar to the prime".

The majority of issues raised relate to available resources that are required in order to be able to fully engage in supplier development initiatives, both upstream and downstream in the supply chain. When larger suppliers suffer from failure it would appear they are more likely to throw additional resources at the problem. However, nearly all of the participant companies of a similar size i.e. Suppliers A, E and D (around 150 employees) and participant companies that were part of a much larger corporate group (Suppliers B and C) reported that they did not have the resources to call on in order to adequately manage or develop their sub-tier supply chain. Participant MD-E explained: *"I am not a big fan of simply throwing lots of resources at a problem. We often sit and joke that there are very few problems in the world that can't be solved if you throw money at them. There is some truth in that but that doesn't necessarily get to the root cause. The prime has this quick response team. They're not solving the problem, they're not looking at the root cause. They're about expediting a solution for those particular problems. Is it about having additional people? It is, but it has much more nuance than that…it is about making sure that you have the appropriate planning in place, to make sure you have the appropriate lines of communication in place. To me it is not so much about throwing resources at the problems but putting resources in early on to ensure you don't get problems later on. One problem for business is head room, how many resources should you have to be able to flex the business and cope".*

All of the participant first tier suppliers reported that they only have small teams of supplier development personnel dispersed across their supply chains. These personnel tend to visit suppliers once or twice a year. Supplier D was the only organisation that reported having supplier development personnel regularly conducting visits. The majority of the suppliers stated that they mostly conducted supplier development initiatives on a small scale involving two to three people visiting a supplier on an infrequent basis. Short visits are conducted rather than actually placing people at a supplier for periods of time like a larger OEM organisation might do in the event of failure. Also sub-tier suppliers are less likely to hand over control to a first tier supplier should a supply chain failure occur. Participant OM-D explains: *"It would be rare for* *a supplier to hand over to us control of a particular area but we can give them assistance to identify the root cause analysis".*

The level of influence depends on the leverage they have as a supplier (Gelderman and Weele, 2003). Participant OM-D suggested that you can assist suppliers to find the root cause of a failure but they will rarely find one without being pushed by the customer: *"What drives it is the interest that companies have in making improvements. Smaller companies sometimes don't see the benefit of having regular improvement initiatives, for example companies that are not looking to make improvements. People who are content at delivering to the standard that they are at. Implementing improvement initiatives into these companies is actually a very difficult thing to do. Any initiative takes time and is done in addition to the job you are doing currently. It depends on the measurement criteria that are set. Another factor is down to the reliance that you have on your customer's business".*

It would seem that on occasion both sides of the dyad can lose sight of where the real root cause lies such as planning capability throughout the supply chain. Subsequently, these initiatives are not often continued after a short term fix is found.

4.1.8 Supplier Development – The Prime Perspective.

Questions used in the semi-structured interviews held at the prime on supplier development were:

1. *Do supplier development initiatives contribute towards rectifying long term chronic failure and assists with recovery in the supply chain?*
    1.1. *If so how? If not why not?*
    1.2. *How important is it that suppliers adopt the initiatives and implement them into their culture rather than just reverting back to 'old ways' when the problem has been resolved.*
2. *During periods of sustained under performance occur, how much extra resource is dedicated to resolving the problem?*
    2.1. *Do you think extra / dedicated resources can help to mitigate chronic long term supply chain failure?*
    2.2. *If so why, if not why not?*
3. *During times of chronic supply chain failure have your suppliers deployed personal from their organisation into their problem suppliers? If so, for how long?*

Table 4.4A illustrates how the consolidated supplier development sub-themes identified from the interviews held at the prime capture some different viewpoints from those taken from first tier suppliers but also highlight some areas of agreement.

Table 4.4A Prime Participants – Supplier Development.

Theme	General Sub – Themes (Coding Level One)
Supplier Development	• Poor engagement with suppliers to implement improvement initiatives. • Heavy handed approach to managing improvement initiatives with suppliers. • Weaknesses in sourcing strategy formulation and deployment. • Communication issues preventing key stakeholders from seeing the real picture by middle management. • Short term fixes resulting in regular fire-fighting at the prime.

The prime participants reported poor engagement with suppliers when implementing improvement initiatives and also questioned the approach taken by the prime organisation on the whole. Sourcing strategy formulation and deployment was viewed as inconsistent and immature and a main reason for having to conduct more supplier development initiatives. However, similar to the findings from the first tier suppliers it was identified that there was a culture of favouring short term quick fixes over identifying root causes that had led to regular firefighting in order to quickly solve problems.

Participant SDTM was the prime's executive who contributed to the supplier development questions. Throughout the interview, this participant did not at any point apportion blame on first tier suppliers for persistently failing to deliver product. Instead they focused on how the prime operated and managed its supplier development processes. Despite a number of observations made concerning how to get suppliers engaged in improvement processes, and constructive criticism of the prime and sub-tier management of supplier development initiatives, participant SDTM firmly believed that supplier development initiatives could and often did contribute towards preventing failure for the organisation. The interview responses indicate that choosing the correct method of implementing improvement initiatives is key to engendering positive improvements within a first tier supplier. However, as participant SDTM explained, the methods sometimes chosen by the prime could be described as extreme: *"We had a vendor eighteen months to two years ago who had a chronic issue. It was related to one issue where they discovered that a lot of people were having or had had problems with* *this vendor so they sent in a parachute team who did a massive strip down of their quality system, their engineering controls and their manufacturing controls. That was eight people and they absolutely tore that vendor apart. Was that constructive? Well it made the vendor wake up but did it actually have the desired effect? Well we have got a slightly better vendor but we have not got a great vendor. Would a one to one have worked better? Over a period of time I believe so".*

Interpreting this statement suggests that despite causing significant disruption to the prime who subsequently committed vast resources, time and effort into fixing the problem, in the end the method adopted yielded little sustained benefits. The company remains a supplier but the reactive / aggressive 'throw all resources at it' approach does not work in all cases when a more considered approach over a period of time may have been more effective. Participant SDTM suggested that suppliers will often simply stand back and watch the prime manufacturer fix problems. When the problem is resolved and the pressure abates, the supplier will return to their normal way of working: *"If you go in with a big mob handed team you can probably fix lots of things very quickly but will you get engagement from the supplier, probably not because you are doing the work rather than them doing the work. They stand back and let you get on with it. You walk away and you are then back to the sustainment thing because nobody bought into what you are doing. On the one to one actions, the one to one development allow them to do the actions, which allow them to come up with the solutions that allow them to put things right".*

A combination of weak purchasing strategy formulation together with a potential lack of communication skills can combine to reduce the effectiveness of supplier development initiatives within the supply chain. The success of supplier-led initiatives was also put into question in terms of whether an actual tangible improvement was received by the supplier In essence, the major difference between failures reported by the prime was that the prime seems to have difficulty in communicating with their first tier adequately in some cases. Therefore, they are at risk of implementing supplier development initiatives in an ineffectual way over the long term. Observations from the first tier suppliers corroborated these findings by consistently stating that they struggled to find resources to engage with the prime requirements for improvement.

4.1.9 Performance Management – First Tier Suppliers Perspective.

The questions used in the first tier semi-structured interviews on performance management were:

1. *Has your organisation ever been put into the prime's delivery or quality red flag as a result of poor metrics on the prime's balance scorecard?*
   1.1. *If so why and if not why not?*
2. *What are the specific metrics chosen by this organisation to ensure that long term chronic supply chain failure does not occur?*
   2.1. *Do / have they helped to prevent chronic long term failure from occurring?*
   2.2. *If so how, if not what happened?*
3. *What is the most common cause of customer rejection / failure with the prime?*

Table 4.5 shows the sub-themes captured from the performance management related interviews. The most discussed sub-theme throughout the performance management interviews related to the difficulties faced by all first tier suppliers in complying with the prime's quality standards.

Table 4.5 First Tier Suppliers – Performance Management.

Theme	**General Sub – Themes (Coding Level One)**
Performance Management	• Difficulties complying with prime's quality standards. • Ambiguous quality acceptance standards by the prime. • Erroneous errors such as incorrect serial numbers on parts. • Weekly demand schedule changes by the prime. • Poor planning capability throughout the supply chain. • Lack of adequate planning tools used by first tier suppliers. • Lack of lead-time adherence by the prime.

The quality standards were often labelled as ambiguous and were thought to perpetuate the risk of first tier suppliers failing to supply conforming products due to erroneous issues such as supplying products with incorrect serial numbers or incorrect accompanying paperwork. It was mentioned how all of these relatively minor issues could combine to dramatically result in a perception of consistent poor performance. Another cause of poor performance was identified as a lack of planning capability throughout the supply chain, also noted under the interviews in previous sections such as risk management. This deficiency was further exacerbated by a lack of adequate planning tools being used by first tier suppliers. The first tier participants described how their planning tools did not always coordinate effectively with the prime's planning tools, resulting in significant miss-matches to what was being seen by the first tier supplier versus what was being seen by the prime.

The first tier supplier participants attributed causes of failure to compliance related issues and focused on difficulties faced by suppliers in order to comply with the prime's quality management system. The reported issues revolved around ambiguity in acceptance standards, misinterpretation of the specifications provided by the prime, designs that did not match manufacturing capability as well as erroneous issues such as serialization errors. These are all essentially quality management issues hence the statement at the beginning of the Chapter that captured issues were related and inter-mixed. However, Participant BS / BO-B explained how they were currently struggling to achieve the agreed level of quality and delivery performance on a consistent basis: *"I know that we've had quality issues and I know that we've had 100% over checking bought in. I believe because of the quality it has affected our delivery so it has been a combination of both. It is not very good, it does not show supplier B in a particularly good state that we cannot achieve what they require (The prime) and we cannot achieve the quality that they require. I know internally that the key focal point across the business and from top down we need to halt this poor run of quality and delivery. The prime might choose to take the business elsewhere and supplier B in some ways might cease to exist".*

The supplier B participant acknowledges that they appear to contribute to creating issues or in some cases have been direct causes of supply chain failure. Many of the issues discussed by the first tier supplier participants during the performance management interviews were around planning and in particular how material demand requirements were managed by the prime. Some of the participants suggested that if a material schedule change was made by the prime, it was considered a direct result of the prime's deficiencies in areas such as poor planning, lack of adequate planning tools and a lack of lead time adherence. Participant BS / BO-B provided an interesting insight on this issue: *"I don't believe that we have any specifically good capacity measurement systems in place. We monitor pacing machines, we measure a lot of our ability to meet targets based on our output requirements. We kind of have a feel for what we can achieve based on value on what we can achieve in a month. In terms of real system* *tools that we use I think it is a lot more of a personal feel for it rather than a system that will give answers from the data that we put into it".*

Should the prime choose to make changes to supplier B's order book schedule at short notice there would be an increased risk of delivery failure. It was also reported that the supplier could still be penalised for late delivery against their agreed delivery targets irrespective of when changes in dates occurred. Participant PrM-D explains: *"In the majority of cases, from the schedule change perspectives then clearly as part of the Prime's Sales Order Review Board (SORB) there is an articulation of potential future demand changes. So we have the ability to respond. We have the ability to state to the customer whether we have the ability to cope with the changes. The prime will ask us if we can cope with a peak or trough in demand, even if we respond by saying we cannot, often the prime will update the schedule anyway, thus setting us up to fail".*

The presence of uncertain demand schedules being placed on first tier suppliers has meant that some suppliers have been forced into taking action to mitigate against the potential for material schedule changes that negatively affect their scorecard. Participant MD-D explained: *"We actually forward schedule onto the supply chain based on the supply chain quoted lead-times not through the planning rules that they [The prime] have on a plant by plant basis. So there is a discrepancy because obviously what we don't flow down for example is the build and manufacturing lead time of 84 days.''*

Captured narrative taken from the first tier suppliers suggests that the planning capability of each supplier is constantly being tested by the prime. The effect of uncertain material demand schedules appears to put the sub-tier supply chain under intense pressure. It was suggested that the changes occur because of poor planning throughout the supply chain. Therefore, regular changes in material demand requirements happen when the prime is looking to prevent disruption on key programmes. Participant BS / BO-B talked about the difficulty that frequent demand changes cause: *"The information that is given from the customer and the changes that they make ensures that the process is very difficult, certainly from the raw material point of view because the prime does seem to have a knack of making changes whenever they want and expecting us to basically say Okay, no problem".*

4.1.10 Performance Management – The Prime Perspective.

Questions used in the interviews held at the prime on performance management were:

1. *How is chronic failure defined by the prime in terms of performance management?*

   1.1 Can elements of that failure be attributed to the prime, if so what?
2. *Do the prime award new work to suppliers who been (historically or at present) put into delivery or quality red flag as a result of poor metrics on the prime's balance scorecard?*

   2.1 If so why and if not why not?
3. *Do you only award work that the suppliers are set up for and / or capable of doing? Or are there other factors that are taken into consideration?*

Table 4.5A shows the sub-themes captured during the performance management interviews held at the Prime.

Table 4.5A Prime Participants – Performance Management.

Theme	**General Sub – Themes (Coding Level One)**
Performance Management	• Ambiguous performance metrics being presented by the prime. • Immature performance expectations by the prime. • Different interpretations of performance across the prime's business. • Post event performance analysis / metrics used by the prime. • Uncertain demand signal passed onto suppliers. • Poor planning in the supply chain by the prime. • Lack of robust sourcing strategies by the prime. • Reluctance to invest within the supply chain.

All of the identified problems were attributed to issues regarding the understanding and interpretation of performance management between the prime and first tier suppliers. The findings highlight a general disparity between the management of performance metrics internally within the prime and with the first tier suppliers. There appears to be a difference in perception that each side of the dyad have on their performance level. Again, the lack of planning capability was highlighted as an issue in much the same way as it was by the first tier suppliers. In addition, the lack of investment and resources within the industry and its effects due to the economic volatility of the industry in recent times was also cited as a potential cause of failure.

The prime participants apportioned much of the causes of failure onto themselves and did not tend to redirect the blame for failures towards the first tier suppliers. Participant PPCM argued that the prime's performance management metrics were not sufficiently dynamic to improve the first tier performance due to infrequency with which each metric is updated. They suggested that the method of data capture means that key information is always generated post event, meaning that any failures have already happened before they are reported. This does not give the supplier time to react to any changes when notified by the prime. It was also suggested that the performance metrics are not coordinated across the supply chain, heightening the risk that they could be interpreted in different ways. Inconsistent methods can potentially cause pressure on the first tier suppliers if they are contracted to multiple supply chain units within the customer's business. Participant PPCM also believed that the continued use of the same metrics as a measure of performance highlighted the organisation's immaturity in performance management and slowed its ability to learn, develop and improve: *"Our business metrics that we use are around deliverables such as delivery, quality and cost performance. As a customer we are still immature on what we expect performance to be. We tend to be very reactive. We both ignore issues and then let them go chronic or we throw twenty people into something that probably doesn't need it. Across the business there is a lot of variability so you will get a different concept of what is considered a failure or is chronic. We seem to accept chronic failure a lot and seem to limit our thinking into believing that we don't really have any other options"*.

The participants from the prime generally agreed that they could contribute towards failure and actually pointed out where and how. Participant RPM confirmed that regular material demand signal changes made by the prime affected the supply chain; *"There is no doubt about it in terms of our demand signal volatility"*.

The prime participants consistently talked about a lack of capability and supply options due to poor commodity sourcing strategy [14] or lack of capacity in the first tier supply chain. This theme seemed to permeate throughout the responses given and was described as a key reason for a number of actions taken by the prime. The strategic thinking adopted for many of the prime's commodities appears to be constrained by the belief that there is limited supplier capability within the supply chain. Participant RPM also suggested that: *"Our strategies may not be as robust as they need to be. There are commodities where we are on a journey through transforming the supply chain or getting to grips with a supply chain. We have mature strategies and immature*

[14] Commodity Sourcing Strategy – *This is the process of defining the short, medium and long term direction / sourcing decision for specified material used to produce gas turbine engine.*

strategies. There is also a commercial negotiation element of it which puts you of track".

However, a supplier's performance could also be affected by actions taken by the prime. Participant RPM explained how common practices carried out by the prime could affect the first tier suppliers, the example given shows how quality management changes can affect supplier performance: "*Quality related issues, where we may have moved the goal posts regarding our expectations around quality. We reaffirm our standards so we do contribute to problems, significantly in some supplier's minds"*.

A notable difference between the first tier and the prime's observations was the subject of developing future sourcing plans / strategies for each product used to manufacture the end product. None of the first tier suppliers discussed the effects of strategy decisions on the supply chain. However, a number of the prime participants discussed how their ineffectual sourcing strategies could become a potential cause of supply chain failure.

4.1.11 Service Recovery – First Tier Suppliers Perspective.

Questions used in the first tier semi-structured interviews on service recovery were:

1. *What are the key factors that contribute towards supply chain failure?*
    1.1. *Can they be identified quickly?*
    1.2. *Can the factors that cause chronic long term failure be resolved in a timely manner so that they don't become chronic?*
2. *If there is an approval process, does it affect the speed at which key decisions are made delaying the ability to fix a problem?*
    2.1. *When a component is being consistently returned as a non-conformance, what steps do you take to resolve the problem?*
3. *Do you have direct collaborative communication with the customer?*
    3.1. *If so what are the benefits? If not, why not and what are the effects of this?*

Table 4.6 provides a consolidation of the sub-themes captured during the semi-structured interviews on the subject of service recovery at the first tier suppliers.

Table 4.6 First Tier Suppliers - Service Recovery.

Theme	**General Sub – Themes (Coding Level One)**
Service Recovery	• Incentives (Penalties) designed to prevent failure are rarely enforced.

	• Slow decision making at the prime reduces chances of quick recovery. • Perception that timescales for recovering from failure are different in the industry. • Prime has a tendency to become overbearing. • Major schedule changes by the prime make it hard for first tier suppliers to recover. • First tier suppliers actively develop strategy around IPR ownership.

A key sub-theme identified by the participants from the first tier suppliers was how commercial incentives (penalties) designed to ensure against failure from happening were rarely enforced by the prime. It was said that this was potentially due to a perception that decision making was slow, which reduced the chances of a quick recovery and also from the prime seeking compensation for failure. Another perception was that timescales for recovery within the aerospace industry were generally considered longer than those of other industries. That said, further narrative described the prime as often being overbearing towards first tier suppliers, which made the process of recovery difficult for suppliers to manage quickly and effectively. In order to mitigate the effects of failure, participants from the first tier described how they actively developed strategies around IPR ownership, which would eventually protect them against the ultimate punishment of supplier dissolution (Chen, et al., 2013) and resourcing components from alternative suppliers.

All of the participants suggested that failure to mitigate problems resulted in escalation and a subsequent reprimand from the prime's senior managers. Only participants from supplier D acknowledged that the consequences of repeated failures towards the prime usually resulted in serious measures such as supplier dissolution and components being re-sourced from elsewhere. However, due to issues with communication and seemingly slow decision making at the prime, the agreed penalties implemented to avoid failure were rarely enforced. The resultant effect was a perception that often nothing happens with the exception of perhaps a small financial penalty for cost of non – quality agreed between the prime and first tier supplier. Participant MD-E pointed out that an important method of resolving a failure is to clearly communicate with the prime in order to manage their expectations, otherwise they have a tendency to become domineering: *"A key measure taken was to ensure that this mind-set was changed. It is about working with the customer and making them understand that there* *are problems that need time and effort to resolve sometimes (managing expectations). We did not want customers intervening or second guessing any decisions that we made even if there was a delay. That disruption means that something else is not being managed. A hard message for the customer to take on board"*.

However, participant BO / BS-B suggested that the timescales for managing failure are far different in the aerospace industry than other industries. The participant suggested that time was actually akin to a commodity in its own right within the industry - you could in fact buy time. Furthermore, when asked about if making a full recovery from failure contributed to gaining more work from the prime, participant MD-E said: *"I don't think it was as a result of the way we recovered from the situation as much as the fact that we did recover the situation"*.

When asked if serious issues could be identified quickly so that preventative measures could be put in place, all of the participants said that potential failures could, in theory, be identified quickly. However, expedient containment would depend on the number of parts involved. Participant MD-D (who are managing over fifteen hundred part numbers for the prime), stated that the majority of their part numbers are classified as low volume and used on legacy engine platforms. That means demand may emerge only once every five years in some cases. However, participant MD-D said that they recorded the problem in the majority of cases except if the problem was caused by major material scheduling changes carried out by the prime. In these circumstances participant MD-D believed that they were not liable because they have the ability to state to the customer whether they could cope with the changes or not. The prime will ask Supplier D if they can cope with a peak or trough in demand. Even if Supplier E responds by saying they cannot, often the prime updates the schedule anyway, thus setting up Supplier E to fail. Understanding if repeat business occurred in the first tier supply chain irrespective of supply chain failure was an important aim of the research. Participant BO / BS-B suggested that they receive repeat business because of the fact that they own the design and IPR on their components in an industry where there are not many competitors, if any at all. Participant OM-B gave their view on how repeat business was gained: *"Business tends to be approved on the basis of who actually owns the design. A lot of products that we manufacture are design controlled by Supplier B. Returning business is mostly based on that but we do get business based on delivery, quality and price (obviously)"*.

As discussed earlier in this Chapter, there were comments made stating that suppliers actively develop strategy around intellectual property rights by focusing on design engineering. The intentions have been clearly stated to ‘corner the market’ for the particular product, assembly, or system, and become the sole source of supply.

4.1.12 Service Recovery – The Prime Perspective.

Questions used in the semi-structured interviews held at the prime on service recovery were:

1. *What are the key factors that contribute towards supply chain failure?*
   - 1.1. *How much responsible should the prime take when a supplier suffers from chronic long term failure, and why?*
   - 1.2. *Can they be identified quickly?*
2. *What impact does supplier failure have on the prime’s customers? Are there suppliers who respond better to failure than others?*
   - 2.1. *If this happens are the events recorded so that they prevent failure from happening in the future?*
3. *When a component is being consistently returned as a non-conformance, what steps are taken to resolve the problem?*
   - 3.1. *Are penalties / liquidated damage clauses enforced when failure occurs? Does this act as a deterrent?*
   - 3.2. *Has the prime ever awarded more business to a supplier as a result of recovering from a chronic long term failure?*

Table 4.6A provides a consolidation of the sub-themes captured during the semi-structured interviews on the subject of service recovery held at the prime. The overarching theme that was identified from the interviews was how the prime suffered from a lack of visibility throughout the supply chain, which often prevented a quick recovery.

Table 4.6A Prime Participants – Service Recovery.

Theme	**General Sub – Themes (Coding Level One)**
Service Recovery	• Lack of visibility in the supply chain caused by inadequate communication. • Identification of supply problems days / weeks after delivery from supplier. • Insufficient problem resolution by not establishing root cause of failure. • Concentrate / focus on non – conformance rather than lateness of delivery. • Providing engineering specifications that are not easily manufacturable. • Lack of commitment to improvement initiates in the first tier supplier failures. • Too much focus on short term failures and short term fixes by the prime.

It was mentioned how problems would often be identified only days or weeks after they had occurred, making a quick recovery very difficult to achieve. A cause of failure was attributed to insufficient problem solving by not establishing root cause of failure in the first instance. These issues would often recur, adding to pressure that is already affecting the supply chain. There was a perception that there was too much focus on resolving failures in the short term rather than looking to develop long term solutions. This was compounded by a further perception that there was a lack of commitment towards improvement initiatives at first tier suppliers, hampering recovery. This was further perpetuated by a belief that the prime put more effort into solving technical non-conformances rather than improving or recovering from poor delivery performance.

Again, rather than focusing on the first tier suppliers as a cause of failure, both participants identified and described problems caused by the prime. Participant BTL provided insights on how this may be perceived at the prime: *"There are a lot of factors that influence a suppliers' motivation to recover from failure. The suppliers' power is something that varies it. Suppliers who have more power than us are larger companies that don't depend on us and depend on other customers more. Therefore suppliers help depends on whether failure towards us has a negative effect on their bottom line. So I think it is completely varied. There are some suppliers that may be small to medium in size so recovering from failure for them is a way of getting future business. So it is completely varied".*

Another observation made during the interviews was how issues of lateness or non-conformance do not reach the buyer until it is too late to prevent consequences downstream, e.g. a production line stoppage. Participant BTL describes this as a potential weakness and one that could contribute to causing longer term disruption.

When asked if problems could be identified quickly participant BTL explained that invariably problems are not identified early enough.

A further finding from this research suggests that there is insufficient root-cause analysis conducted specifically in terms of assessing delivery failure. This appears to be more prevalent within the prime's quality organisation who seem to concentrate on non-conformances rather than lateness. However, participant BTL felt that the supply chain could learn a lot from the quality organisation in terms of root cause analysis of non-conformance and identification of why failure has occurred to help fix delivery problems. In addition, participant RPE explained the current position at the prime regarding failure: *"Have people got real control over what KPI's? Do we understand the underlying performance in the supply chain? Are we fixing root causes of the issues or just glossing over things? For quality I think first of all it comes down to, have we got an engineering specification that's manufacturable in the first place? Do we understand that well enough, in a lot of cases we don't"*.

Captured narrative suggests that it is the prime who commits time and resource to recovering and then developing the supplier rather than the reverse. The perception is that the prime leads the majority of problem resolution activities. The reality behind the perceived lack of activity can be attributed to strategic positioning. Again, participant BTL provided insight into the cause and effect of poor performance in the supply chain by suggesting that a lack of mature sourcing strategy is a key cause of eventual supply chain failure. Participant RPE also suggested that the prime focuses on the short term failures and short term fixes a bit too much, often losing focus of the real issues. Participant BTL went on to state that the prime should be tougher on the suppliers: *"We should be tougher on the suppliers instead of trying to help them by enforcing liquidated damages and get the suppliers motivated to fix the problems themselves"*.

However, the overall narrative from both participants interviewed suggested that a number of the causes of failure can be attributed to the actions conducted by the prime either at the present time or sometime in the past.

4.2 Empirical Evidence and its relationship with the literature.

This section compares and contrasts issues highlighted during the exploratory phase of the study with themes discussed in the research literature in supply chain management and related areas. Gaps in the literature are highlighted, leading to further analysis in

Chapter 5 (Causal Analysis) and contributing towards the development of causal loop diagrams.

In the interviews on the subject of Risk and Contingency Management, participants from the first tier supplier described how poor planning throughout the supply chain combined with regular material demand schedule changes carried out by the prime contributed to supply chain failure. Research by Kleindorfer and Saad (2005) examines risks associated with demand management. Their studies concentrated on how organisations manage disruption risks in their supply chains and identified risks associated with material demand planning errors, flexibility and robustness of supply chains (Flynn et al., 2016). This was also noted by participants from the first tier supply chain who described how fluctuations in demand places considerable pressure on the supply chain. Earlier, studies by Tang and Tomlin (2008) and Kerkkänen et al., (2008) examined how supply chain agility and resilience is closely related to demand risk (Govindan and Fattahi, 2017), which was also highlighted by participant OM-C who argued that there was a very real lack of planning capability throughout the aerospace supply chain.

4.2.1 Empirical Evidence and the Risk Management Literature.

Participants from the prime described how their risk management process was immature. The findings resonated with studies carried out by Zsidisin. His early research focused on the tools that organisations use to assess risk and identify whether they were being utilised effectively (Zsidisin et al., 2000). Observations from the exploratory phase indicate that the adoption of risk management tools and techniques were still relatively rare in the aerospace supply chain. The prime manufacturer had started to utilise risk management in order to seek an effective method of mitigating risks before a contract is agreed with a supplier. However, it was stated that suppliers are not usually asked to participate in the risk management process during the contract formulation process. Given the responsibility placed on them by the prime to manage their sub-tier suppliers, is clearly a weakness. Captured evidence also suggested that the supplier is only asked to participate once a failure has started to occur. These are issues that are not captured in the existing supply chain risk management literature.

4.2.2 Empirical Evidence and the Quality Management Literature.

Throughout the interviews on the subject of Quality Management, unclear specifications provided by the prime leading to non-conformances was frequently identified as a factor influencing supply chain failure and its persistence. Further to this, key steps that the prime organisation takes to ensure quality adherence, combined with a general lack of adherence were also highlighted. Some of the literature on supply chain quality management has focused on some of these areas. Studies by Power and Terziovski (2007), Yeung (2008), Basu (2014) and Quang et al., (2016) examined whether robust approaches to quality management lead to improvement in supply chain performance. Subsequent research studies found evidence to suggest that such approaches do lead to improved performance. However, evidence captured during the exploratory phase of this research also shows how achieving acceptable quality requires much more than just having a stringent quality system in place. How the prime applies and manages the quality management system with its first tier supply chain partners is equally important. For instance, the evidence captured during this study has identified how expedient communication of requirement changes is crucial rather than leaving the supplier to find out about changes themselves. First tier participants also indicated that refraining from making changes to requirements / specifications after a contract has been signed could help to reduce the risk of failure, i.e., having a stable design and set of requirements. Foster (2008); Zu et al, (2008); Han et al, (2011); Kim et al, (2012); Zhang et al, (2012) and Barouch and Ponsignon (2016) conducted exploratory examinations and analysis on the overall effectiveness of quality management practices adopted by organisations. The empirical findings from the exploratory phase supports the notion that the prime manufacturer is conducting supplier audits primarily to ensure compliance rather than to solicit improved performance. This backs up observations taken from the literature. A finding from the exploratory phase that corroborates some of the recent literature relates to the question whether the presence of a robust quality system reduces the risk of quality failure within the supply chain (Steven et al., 2014). Observations from both the exploratory phase and the literature indicate that the mere presence of a quality management system does not reduce the risk of supply chain failure.

4.2.3 Empirical Evidence and Power and Relationship Management Literature.

The main observations evident from the exploratory phase interviews on Power and Relationship Management concerned a general inconsistency in communication between the prime and its first tier suppliers. Similar to the captured observations regarding the communication of design / specification changes, a key aspect of the literature is the significance of effective communication between the first tier suppliers and the prime manufacturer. The literature highlights how its significance can be extended throughout the supply chain (Wadhwa et al., 2010). Jacobs et al., (2016) found that the way in which internal communication within an organisation was conducted could also facilitate positive communication with suppliers. Captured comments from the prime participants suggest that leverage can have an effect of developing more expedient information flow and overall responsiveness. This element is missing from the literature - the literature does not currently identify if increased leverage between parties in a dyad improves communication exchange.

Further issues captured from the empirical study described the effects of long term relationships. Participants from the prime appear to exercise caution when signing up to long term agreements due to negative experiences whereas first tier participants were very much in favour of long term relationships. The literature discusses two distinct approaches to relationship management that organisations adopt in order to examine how power affects the influence that one party can hold over the other. Evidence from this study indicates that first tier suppliers do favour the approach described by Håkansson and Ford (2002), which places high importance on developing long term relationships. Conversely, participants from the prime supported Cox's (2001) power perspective that seeks to understand methods of developing competence in procurement and supply management from a power perspective. The perspective on power suggests that buyer-supplier relations should always start from an understanding of the bases of supplier power and business strategy (Cox, 2001). This understanding should help gauge the type of relationship most likely to develop. Interestingly, participants from the prime cited how a lack of understanding of the relationship had led to dependency and ultimately was a factor influencing the persistence of supply chain failure. The potential for power / leverage to lead to dependency and the resultant negative consequences are not adequately addressed in the existing literature.

Cox et al., (2004, p.347) found that practitioners associate the identification of supplier positioning or the identification of leverage in a buyer supplier relationship on how important one is to the other in terms of turnover or spend. More recently, Jain et al., (2016) developed a model that attempted to quantify the power position of each player in the supply chain by linking specific procurement activities with buyer-supplier power asymmetry (Gnizy 2016). Krause and Ellram (2014) have suggested that the risk to the prime is perpetuated when the supplier is one of only a few sources able to supply the product. In corroboration with the findings from the exploratory phase, Krause and Ellram (2014) postulated that greater risk comes when the supplier is the IPR owner of the product. The first tier suppliers described IPR ownership as a source for competitive advantage whereas prime participants described it as being a risk and a potential cause of failure. Ultimately though, the literature describes studies that seek to identify who appropriates the most value from a relationship and the circumstances that surround relationships (Kähkönen and Tenkanen 2010). The findings from the exploratory stage have identified the effects of being on the weaker side of the buyer-supplier relationship. In support of the work conducted by Jain et al., (2016), the prime appeared to be weaker than some suppliers in some activities but in a more advantageous position in others.

4.2.4 Empirical Evidence and the Supplier Development Literature.

In the interviews on the subject of Supplier Development, participants from the prime described how supplier development initiatives were initiated and conducted. They also provided comments on how successful the methods adopted for implementation were with first tier suppliers. In depth studies by researchers such as Krause and Ellram describe how organisations adopt such methods with the intention of improving performance (Krause et al., 1997). However, the literature tends to focuses on critical success factors that lead to improved supplier performance (Routroy and Pradham, 2011). The literature does not investigate the effect of incorrectly managed implementations on first tier suppliers and how that can lead to minimal benefit and in some cases further disruption.

Participants from the first tier suppliers described how they found it difficult to resource supplier development initiatives, especially within their own supply chain in order to ensure adherence to the prime's quality system. These observations add to the recent research by Pulles et al., (2016) in their study on preferential resource allocation. They describe the significance of effectively securing supplier resource because customers could end up competing for this with competitors. Wagner (2006) discusses how in order to compete and survive in industries with few capable suppliers, prime manufacturers must seek to extract the maximum value through such relationships. However, evidence from the exploratory phase indicates that the prime manufacturer can often act too vociferously and monopolise a supplier's resources with only limited benefit to show for it in the end. The literature does not discuss the negative effects of a poorly managed supplier development activity.

4.2.5 Empirical Evidence and the Performance Management Literature.

Key findings from the exploratory phase relating to literature on Performance Management involved an examination of how the prime attempts to gain consistent adherence to their quality system throughout the supply chain. The literature focuses on the need for effective performance measurement and benchmarking (Koufteros et al., 2014). McAdam et al., (2008) identify that the outcome of such initiatives leads to the identification of successful performance management practices that organisations should adopt. However, findings from first tier and prime participants show a lack of consistency in this area. Narrative from the prime suggests a lack of identification and precision about how to use performance data to recover from failure and the first tier participants suggest that there was a distinct lack of visibility resulting in delays that often created the perception that the supplier was performing worse than they actually were and thereby creating unnecessary attention on suppliers. In the literature, Laihonen and Pekkola (2016) noted that companies have generally failed to maximise on the potential of performance management systems (Akyuz and Erken 2010). Pongatichat and Johnson (2008) described how, in the situation where managers are not provided with accurate information, their ability to align actual supply chain performance with agreed performance levels will be reduced. It can result in negative metrics being incorrectly interpreted and displayed against first tier suppliers. There is a risk that this can potentially create the perception that suppliers are perceived to be performing worse than they actually are (McAdam et al., 2008). The resulting effect causes the prime to make changes in demand scheduling in order to mitigate against the risk of delivery failure in the future. The negative impact of misaligned performance management systems is a topic that is discussed in the literature but has received limited attention. The evidence obtained from the study on persistent supply chain failure backs up that research to some extent. However, the risk of mishandling key information from a performance management system leading to unnecessary mitigation activities is not covered in the performance management or performance measurement literature.

4.2.6 Empirical Evidence and the Service Recovery Literature.

During the interviews on the subject of Service Recovery, participants from the first tier suppliers described how resolving and subsequently recovering from failure was key to retaining business with the prime. Comparable studies conducted by Craighead et al., (2004) within the service operations literature suggests that service recovery principally examines the effect that recovery can have on the customer / seller relationship. For example it has been observed that fulfilling specific recovery criteria can result in significantly positive effects for the seller (Augustus de Matos et al., 2007). This is referred to as 'the service recovery paradox', which originated from the work of McCollough and Bharadwaj (1992). They made the observation that effective recovery strategies can lead to a more favourable relationship than was in place before the failure (Tax et al., 1998 p.64). However, only two of the five first tier participant companies had actually managed to enjoy a period of stability with the prime after recovery from poor performance. Despite consistent periods of failure, all of the first tier suppliers managed to retain business with the prime. Participant BTL from the prime suggested that they spent so much of their time focusing on quick fixes and workarounds aimed at mitigating failures in the shortest period of time to even notice (Morrison 2015), let alone congratulate, suppliers who managed to fully recover from failure. The broader service management literature has many studies concerned with understanding how organisations regain customer satisfaction and confidence (Tax et al., 1998). However, the findings from this study indicated that the recovery paradox does not exist in an industrial supply chain management context. As suggested during the exploratory phase, it was found that the prime is much more likely to attribute recovery from failure towards how they managed the failing supplier rather than how the supplier managed themselves through the failure. This is an aspect of service recovery that the literature does not account for, i.e., the prime's perception of managing a failure.

Overall, there are a number of issues captured during the exploratory phase that legitimately back up observations from the literature covered during the study. However, there are also many important issues that are not covered in the literature. A key omission is the lack of research that examines the phenomenon of long term failures that organisations have failed to mitigate before they happen. The prime and first tier supplier then struggle to solve the problems in a short period of time, irrespective of efforts by both parties. The exploratory phase has captured issues that cover scenarios related to quality management, power, risk and contingency management and relationship management. It is clear from the empirical evidence that issues within each of these domains interact to cause longer lasting failures.

4.3 Exploratory Phase – Emergence of Persistent Failure.

The purpose of this section is to analyse the findings and observations from the exploratory empirical phase of the study and show how they can be further grouped together and categorised using a coding process (Hahn, 2008). The first part of the Chapter encapsulates level one coding and identifies key research themes and sub-themes. In order to categorize the data into dominant key themes and sub-themes and therefore move onto coding levels two and three (axial thematic coding) (Strauss and Corbin, 1990), a significant amount of recorded data taken from both first tier and prime participants has been analysed. Throughout the exploratory phase, it was identified that some failures occur persistently. The causes of failures that continue to persist were not very well understood by either the prime or first tier participants, although they recognised the phenomenon. Participant PPCM explained when asked during the interview if they ever awarded work to suppliers with a history of poor performance: *"We constrain our thinking to say that this is the only supply chain available to us. We don't put robust fixes in place to either fix that supplier or put the correct pressure to get them to up their game. There is an example of a supplier who were causing chronic failure seven years ago who we decided to exit at that time. However, we are now going back to them because we have not been able to find anybody else capable in the supply chain or manage the change. So we have now gone back to them with new business, even though we don't want to. So yes we do all the time".*

The findings indicate that there are certain causes of failure that the prime manufacturer struggles to mitigate against in the short term. Such failures then persist over time. They often start as reasonably small issues but eventually lead to serious supply chain failures that persist and consequently have a large effect on the prime and its ability to serve its customers adequately. The phenomenon is encapsulated in four dominant influencing themes related to four key literature domains as shown in table 4.7 below.

4.3.1 Summary of Key Identified Dominant and Sub–Themes.

Throughout the research process, categories of issues and dominant themes that were linked to potential causes of failure began to emerge. Each of the categories are related to themes evident somewhere in the research literature on supply chain management and related areas but rarely discussed in combination and never specifically related to supply chain failure persistence. Table 4.7 summarises the captured sub – themes and their related literature domains identified from the data captured during the exploratory phase that lead to the development of four distinct dominant themes.

Table 4.7 Exploratory Phase One - Summary of Key Themes and Sub - Themes.

Coding Level Two				
Literature Domain	**Supply Chain Quality Management.**	**Power, Leverage and Dependency in the Supply Chain.**	**Supply Chain Risk and Contingency Management.**	**Relationship Management in the Supply Chain.**
Dominant Theme	**Quality Adherence.**	**Dependency.**	**Risk and Contingency Management.**	**Relationship Management.**
Key Sub – Themes	• Adherence to Primes Quality System. • Short Term Quick Fixes versus Root Cause Analysis. • General Misunderstanding of Audits conducted by the Prime. • Ambiguous Performance Metrics. • Lack of Supplier Development Resource.	• Dual Dependencies in the Supply Chain i.e. the Prime Dependent on the First Tier Suppliers and Vice Versa. • Failure to manage spend with existing suppliers. • Immature strategy deployment resulting in a lack of supplier options.	• Material Demand Uncertainty generating frequent Schedule Changes. • Lack of Planning Capability throughout Supply Chain. • Immature Risk Management Processes.	• Inconsistent Communication throughout Supply Chain and Internally within the Prime. • Lack of relationship continuity throughout the supply chain between first tier and prime. • Lack of responsiveness and poor information flow between first tier and the Prime.

The sub-themes related to the Supply Chain Quality Management literature led to the development of the ‘Quality Adherence’ dominant theme. Both sides of the dyad appeared to struggle from a lack of adherence to the prime’s quality system, which was abundantly evident from the interviews on quality management. The prime participants reported suffering from the effects of a lack of compliance from the supply chain. The limitations of short term quick fixes were mentioned by both sets of participants as a result of being forced to resolve issues quickly and therefore reduce disruption expediently. However, this was carried out at the expense of conducting root cause analysis that could pinpoint the true cause of failure. Further to this, the justification and frequency of audits conducted by the prime was also seemingly misunderstood by both parties.

The identified sub-themes on performance management are related to ambiguous performance metrics alongside a lack of supplier development resource at first tier suppliers. These have been included under the Supply Chain Quality Management literature theme because of the effect the issues have on quality adherence. Participants from the prime described how their metrics were inflexible leading to the capture of potential failure 'post event'. Captured narrative from the first tier participants suggested that they were often confused with the metrics being used by the prime and described how their own metrics portrayed the performance differently to how the prime often presented it. To counter the effects of poor performance the participants from the prime discussed supplier development improvement initiatives and their effectiveness. However, the first tier participants described how they often did not have the resources to fully engage in the activities combined with having limited resource availability to adequately conduct supplier development within their own sub-tier supply chain.

The sub-themes related to Power, Leverage and Dependency in the Supply Chain literature led to the development of the 'Dependency' dominant theme. Both sets of participants described how they had become dependent on each other for the supply of products (often IPR owned) and subsequent turnover. It was noted how the lack of mature sourcing strategies had conspired to reduce the options available within the supply chain for the prime and meant that some first tier suppliers had dedicated virtually all of their business to the prime, leaving them very vulnerable and sensitive to the prime's performance in the market. Combined with a failure to manage spend with existing suppliers resulting in first tier suppliers having more business with the prime then they could effectively handle. This appears to be exacerbated by immature commodity sourcing strategies, which have resulted in a lack of supplier options for the prime.

The sub-themes related to Risk and Contingency Management in the Supply Chain literature led to the development of the 'Risk and Contingency Management' dominant theme. Material demand uncertainty and the resultant frequent schedule changes were regularly discussed by the first tier suppliers during the interviews on risk and contingency management. Despite having a fairly stable demand profile within the industry, the first tier suppliers reported that delivery dates could be changed on a weekly basis causing disruption throughout the upstream supply chain. Participants from the prime confirmed that this was happening and agreed that it could indeed cause disruption. Participants from the first tier attributed the regular changes in demand to poor planning capability at the prime and also discussed how this was extrapolated throughout the supply chain because planning capability was just as bad if not worse in the sub-tier. Immature risk management processes throughout the first tier supply chain are making potential issues more difficult for the prime to mitigate before they become persistent.

The sub-themes related to Relationship Management in the Supply Chain literature led to the development of the 'Relationship Management' dominant theme. Inconsistencies in communication throughout the supply chain, starting at the prime, was a theme regularly discussed by the first tier suppliers and participants from the prime during the interviews on power and relationship management. Participants noted how they regularly did not provide the first tier supplier with the potential demand figures for an entire programme, instead only giving them the volumes for the development programme. The prime participant acknowledged that this type of behaviour conspired to ruin relationships with first tier suppliers who would often refuse to quote for the work because of the unattractive potential of the business being offered. A picture also emerged of a lack of relationship continuity between key participants from the first tier supplier and the prime. This was caused by relationships being broken up due to mainly prime participants being moved into different roles on a frequent basis. A potential consequence of this was a lack of responsiveness between the first tier and prime participants combined with poor information flow within the supply chain. This was perceived as an antecedent to other issues, contributing to persistent supply chain failure.

4.4 Summary.

All of the key themes and sub-themes identified in Chapter 4 that have been consolidated in Table 4.7 demonstrate potential causes of persistent supply chain failure. They each affect different parts of an organisation and its supply partners and they appear to ultimately combine to cause persistent failures that are extremely difficult, time consuming, and costly to eradicate. In Chapter 5 a description of coding level two and level three will be given showing how variables and causal loops were developed from the sub-themes within the four dominant themes shown in Table 4.7.

Chapter 5: Causal Analysis.

The main outputs of the exploratory phase described in Chapter 4 were the identification of emergent dominant themes and sub-themes captured from the empirical study conducted on supply chain failure and why it may persist. Steps one and two, including coding levels one and two, were described in relation to the qualitative causal process shown in Figure 3.2 in the Methodology and Design Chapter. The exercise yielded preliminary categories that are linked to various literature domains discussed during the literature review section (Chapter 2). Multiple causes for persistent failure and the effect that these can have on the supply chain was provided throughout the exploratory phase. From the analysis in Chapter 4 (section 4.3.1) and summarised in table 4.7, four dominant themes emerged – Quality Adherence, Dependency, Risk and Contingency Management, and Relationship Management. Each of the identified variables and subsequent causal loops relate to these four dominant themes.

Chapter 5 begins the process of causal modelling using causal loop diagrams, which provide the principal mechanism used here to identify how variables interact in a cause and effect scenario. The discussion then moves on to show how the identified variables interact to form causal loops. This shows the effect that interacting variables can have on, and between, the prime and a first tier supplier which is the unit of analysis for the subject under study – persistence of supply chain failure. Justifications for how and why the variable names were chosen from the empirical evidence are given. At the end of this Chapter, the persistent supply chain failure model in its first iteration is presented along with a full glossary of terms (see Table 5.13 below) that provides a description and explanation of each of the variables created as a result of the empirical evidence analysed and categorized in Chapter 4. Finally, a description showing how each set of loops falls under one of the four dominant themes is presented. The final iteration of the causal loop model is presented in Chapter 6.

5.1 Validation of First Tier Supplier and Prime Interview Scripts.

As described during Chapter 3, in order to strengthen the development of the causal loop model, validation of all interview data captured during the exploratory phase was conducted with both first tier supplier and prime participants.

Findings from the first tier participants indicated in some cases that conducting business with the prime had gradually got worse since the start of the research in key areas. For example participant PrM-B described how the prime had subsequently reduced delivery lead time requirements on its first tier supply chain: '*A significant change over the intervening time period has been that the prime have now taken the further decision to reduce their lead time even further. So from what was the original material planning cycle of 84 days has been reduced down to 42 days. Therefore, the variability has actually increased rather than reduced. So were having to buffer for a worse situation from a customer demand fluctuation perspective'*. Participant PrM-D described how this change had increased the number of scheduled changes made by the prime: '*The main difference there is that the number of schedule changes per week has gone up per average'*. In addition participant QM-B mentioned how their overall supplier performance had got worse since the original interviews had been conducted: '*Our scorecard [Measuring Quality, Delivery and Cost] currently is probably the worst it's ever looked'*. Participant QM-B went on to describe why this had happened and how they were of the view that actions by the prime contributed towards the reduction in performance: '*Unfortunately we, I mean the bigger we [The prime], put people under pressure to try and push parts out of the door, so it is probably not as good as it was say two years ago. We've created that monster, well maybe in some respects it's joint with the customer. All the customer drawings are wrong, if you can't change them quick enough then it is a joint problem!'*

In general, participants from the prime reconfirmed their initial observations from the exploratory phase. The only addition to the findings was provided by participant RPM who also added that failure can be attributed towards the prime when providing first tier suppliers with poor drawings.

In summary, validation of the original interview scripts showed that since the original interviews were conducted during the exploratory phase, the prime was applying more pressure onto the first tier supply chain. This was being done by reducing required lead times on components and by making quality standards tougher for first tier suppliers to comply with.

5.2 Development of Causal Loop Variables.

The use of causal loop diagrams as a method of capturing and demonstrating the causes of persistent supply chain failure has been discussed in Chapter 3. Each diagram guides the reader to understand the particular characteristics of variables that cause problems over a period of time if they interact with other variables in a system. The aim of the following section is to highlight how the empirical data was coded and subsequently converted into pertinent variable names (Sterman, 2000) and how these variables interact, leading to causal loop development.

5.3 Quality Adherence.

Here we present and justify causal loops relating to quality adherence, disruption and sub-tier capability.

5.3.1 The Quality Adherence Loop.

Table 5.1 below shows how causes of failure were attributed to issues related to quality management topics and were linked to components consistently not meeting the prime's requirements. The evidence suggests that stringent quality requirements laid down by the prime and by aerospace industry regulations often make it difficult for first tier suppliers to achieve contractually agreed levels of quality performance. Failure to achieve requirements is registered as a supplier quality adherence failure by the prime. Figure 5.1 shows the quality adherence causal loop that has been constructed from the analysis of empirical evidence, which is explained below.

Table 5.1 Quality Adherence.

Themes (Coding Level 2)	Representative Empirical Findings (Coding Level 2)		Variables (Coding Level 3)
	First Tier Supplier	**Prime**	
Quality Management.	History of Failure. Chronic failure is the biggest impact.	Short Term Problem Solving. Lack of sub-tier supplier management by the first tier.	**Failure Persistence (From the Quality / Performance Perspective**
	Not being able to achieve what the customer wants (Specification issue). Meeting specification.	Moving the goal posts. regarding our expectations around quality. Misinterpretation of quality certifications.	**Quality Adherence**
	Men and money thrown at a problem. Seek help from the Prime if the issues become chronic in sub-tier.	Focus on the short term failures and fixes a bit too much. Lack of supplier development resource.	**Focus on Supplier**
	You need to build in your requirements with their requirements "do you want to be part of this game or not?". Reservations about throwing resources at a problem in the belief that this form of problem solving may well quickly resolve a critical situation in the short term but it won't necessarily identify the root cause of the problem increasing the probability.	Resource is limited. Heavy handed approach.	**Supplier Improvement Initiatives**

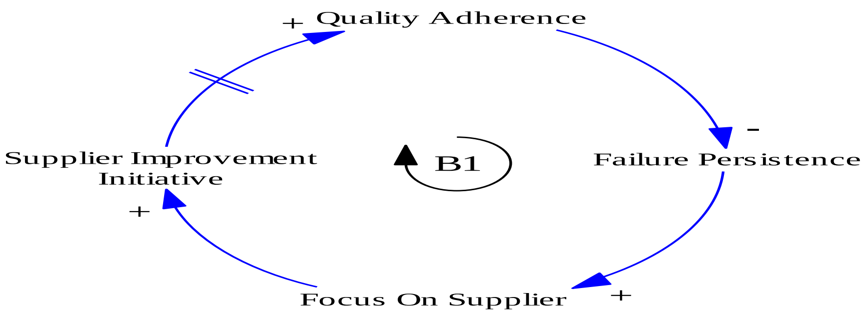


Figure 5.1 The Quality Adherence Loop.

A consistently discussed theme during the exploratory phase concerned how some quality failures appear to reoccur again and again, i.e. persistently. Evidence suggests that there are interactions between variables that result in the prime manufacturer struggling to eliminate such failures in the short term. Issues may often start off appearing reasonably innocuous but then develop into serious persistent supply chain failures if not addressed and eliminated quickly. Failure to quickly resolve such issues can eventually have a large effect on the prime and its sub-tier supply chain, hence the formulation and inclusion of the 'Failure Persistence' variable within the quality adherence sub-section[15].

All first tier suppliers who participated in the study stated that they try to align themselves very closely with the prime's balanced scorecard to ensure that problems do not become a cause of failure that attracts unwanted attention from the prime. This finding resulted in the inclusion of the 'Focus on Supplier' variable. By moving in a clockwise direction, the polarity between the two variables is shown as a positive sign to highlight how an increase in failure persistence results in an increased focus on the supplier by the prime because recurring issues have started to affect the prime's assembly and delivery schedules, which draws attention from senior managers at the prime.

The attention placed on a failing supplier resulted in the creation of the 'Supplier Improvement Initiatives' variable. There is a perception by the prime that more improvement visits result in a reduced risk of failure. The loop demonstrates how an increase in the focus on supplier has an increased effect on supplier improvement initiatives, influencing the number of development / improvement activities that the prime has going at any one time with a problem supplier in order to ensure quality issues do not disrupt future supply. The prime initiates improvement activities when failure persistence has the effect of causing disruption to the company. This extra focus placed on the supplier is seeking to mitigate against failure.

Further evidence presented in Chapter 4 indicated that failures related to quality issues are caused by a poor adherence to agreed quality standards as a consequence of problems in compliance with specifications. Quality management issues were frequently cited as a key cause of supply failure during the exploratory phase. The worst

[15] A full glossary of the model variables with definitions is presented in alphabetical order in Table 5.13 on pages 166-168.

case effect of a lack of quality adherence is the product failing to meet the specification that was agreed. These observations led to the development of the 'Quality Adherence' variable.

The loop shows how an increase in supplier improvement initiatives has the effect of increasing the supplier's ability to achieve quality adherence with the prime. Increased adherence happens over a period of time, captured by the time delay mark that sits between the two variables within the loop. The delay highlighted between the Supplier Improvement Initiatives and Quality Adherence variables captures oscillatory behaviour because the action of the prime, whose goal of is to improve quality adherence through the implementation of improvement initiatives, does not have an immediate effect on supplier quality adherence, resulting in further disruptions. The loop then continues to feedback and is completed by showing how the quality adherence variable then forms a linkage with the failure persistence variable. The polarity between the two variables shows a minus sign denoting a negative effect because an increase in quality adherence reduces failure persistence, i.e. the supplier is adhering to the prime's quality system which has the effect of reducing failure.

Overall, the quality adherence loop should have the effect of balancing or reducing causes of persistent supply chain failure if managed correctly. This is largely driven by additional focus on supplier and effective implementation of supplier improvement initiatives, which represent activities that the prime carries out in order to reduce the threat of failures from persisting or from happening in the first place.

5.3.2 The Disruption Loop.

Table 5.2 highlights variables created to show how quality issues relating to the highly complex specifications set by the prime can combine and lead to non-conformances and problems being encountered throughout a sub-tier supply chain. The interactions that have been identified between each of the variables led to the formulation of the disruption loop shown in Figure 5.2, as described below.

Table 5.2 Disruption.

Themes (Coding Level 2)	Representative Empirical Findings (Coding Level 2)		Variables (Coding Level 3)
	First Tier Supplier	**Prime**	
Quality Management	Inadequate Non-conformance process. Not being able to achieve what the customer wants. (Specification issue). Ambiguous quality acceptance standards.	Non-conformance to the process. Non-conformance, capacity (common causes of failure)	**Non Conformances**
	Calling out dimensions on drawings that are illegible can bring a stop to production. Inadequate planning.	Not pro-actively solving quality issues in the supply chain. Knowingly delivered non-conforming product.	**Disruption**
	Sometimes it takes that chronic failure before they actually do something.	If we don't fix the problem we will always go back to the fire-fighting. Lack of robust fixes in place to fix the supplier.	**Short Term Quick Fixes**
	Lack of PFMEA's. Poor tools for the job	Failure to identify the root cause of a problem Not getting to the root cause of failure	**Root Cause Analysis**

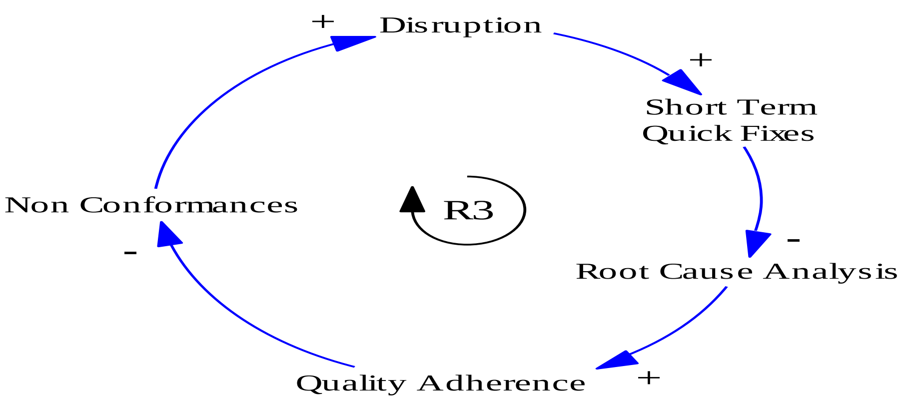


Figure 5.2 Disruption Loop.

Starting with the quality adherence variable, it was identified that the prime did not always entirely know what is required to correctly manufacture a component that is fit for its intended purpose. Specifications can be unrealistic or ambiguous, making the manufacture of components beyond the capability of the first tier supplier (or possibly any supplier). Captured issues also highlighted the complex industry standard requirements to which compliance is mandatory before being allowed to supply product into the aviation sector. Evidence from the exploratory phase has shown that the first tier suppliers and the prime struggle to achieve required standards on a consistent basis resulting in repeated non-conformances. Consequently, quality failures were commonly defined by both sets of participants as 'Non-Conformances' resulting in the inclusion of this variable in the model. The linkage between the quality adherence variable and non-conformances demonstrates how an increase in adherence to the prime's quality system has the effect of reducing the number of 'Non-Conformances' emanating from the supplier.

Disruptions occur when the flow of components to production is interrupted for a period of time. The extent of the non-conformance is often unknown when first identified and therefore needs to be quickly 'quarantined' to ensure that non-conformances are contained. Subsequent behaviour by the prime and the first tier supplier is influenced by the type of non-conformance and the scale of the disruption that is caused. However, the findings captured during the exploratory phase suggest that containing non-conformances to prevent or reduce disruption does not always happen sufficiently quickly to prevent repeat failure. This led to the inclusion of the 'Disruption' variable. The interaction between both variables demonstrates how an increase in non-conformances has the effect of increasing the 'Disruption' caused to the prime manufacturer.

It was also identified that when these further disruptions start to accumulate, the likelihood of the prime implementing a short term quick fix required to quickly resolve disruption is greatly increased. When a failure occurs, unless it is mitigated immediately there is a higher likelihood that both parties will abandon the possibility of conducting root cause analysis in favour of a short term fix. These observations led to the creation of the 'Short Term Quick Fix' variable. This results in a lack of robust 'fixes' being put in place with the supplier. Therefore, the interaction demonstrates how an increase in disruption can have the effect of causing an increase in short term quick fixes being adopted.

Conducting root cause analysis of persistent non-conformances is an approach that seeks to eliminate or mitigate a failure permanently. However, although conducting root cause analysis may reduce the likelihood of repeat disruption in the future it could take a long time and require more resources to get supply moving again. Hence, both the prime and the sub-tier supplier can become pressurised into favouring a short term quick fix in order to reduce the effects of a disruption. The findings also indicate that recognised tools used to conduct root cause analysis such as PFMEA[16] are still relatively immature within the first tier supply chain, although capability to adequately conduct PFMEA studies are slowly being implemented by the prime. This observation resulted in the inclusion of the 'Root Cause Analysis' variable. Therefore, the loop shows how an increase in short term quick fixes has the effect of reducing the amount of root cause analysis conducted in order to solve problems quickly.

Overall, the disruption loop demonstrates how the combination of the supply chain quality management sub-themed variables and the interactions between them feedback to reduce the level of quality adherence within the supply chain and reinforces the negative effects of failure. The cycle will self-propel, gradually reducing the effect of adherence, which will then increase the risk of failure persisting.

5.3.3 Sub-Tier Capability Loop.

A common strategy by the prime is to conduct audits that identify process deficiencies and seek to develop capabilities of the first tier supplier. Table 5.3 highlights variables that show the level of importance placed on quality adherence at the prime. In order to ensure adherence, audits are regularly conducted throughout the supply chain by the prime. The frequency of audits conducted by the prime on a first tier supplier depends on their ability to consistently supply products that conform to specified requirements. The interactions that have been identified between the variables led to the formulation of the sub-tier capability loop shown in Figure 5.3 and described below.

[16] PFMEA – *Part Failure Mode Effects Analysis. Methodology adopted to identify root cause of failures.*

Table 5.3 Sub-Tier Capability.

Themes (Coding Level 2)	Representative Empirical Findings (Coding Level 2)		Variables (Coding Level 3)
	First Tier Supplier	**Prime**	
Quality Management Supplier Development	Customer Auditing based on Spend. Audit programme based on problem / high risk suppliers.	Weak auditing of supply chain capability. Desktop auditing.	**Supplier Audits**
	Taking your eye of the ball during the process will result in a failure surfacing.	Processes that set the supplier up to fail. Lack of process understanding in supply chain.	**Process Compliance**

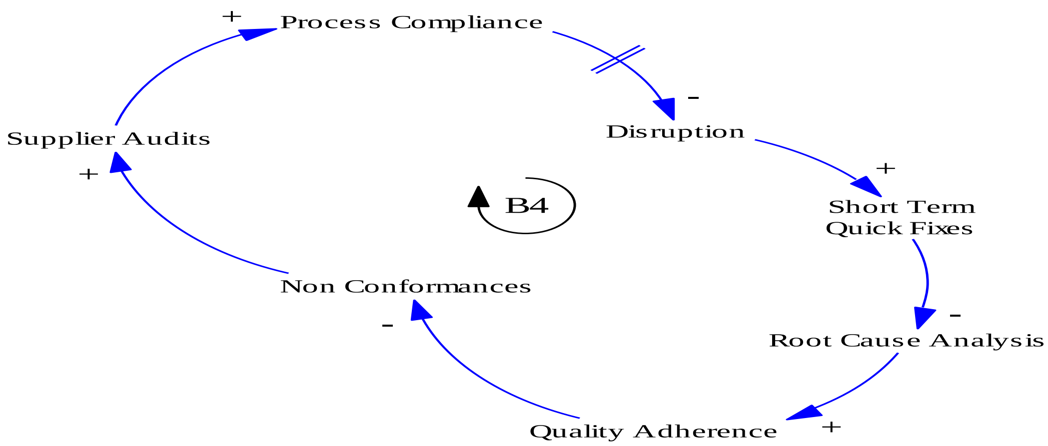


Figure 5.3 Sub - Tier Capability Loop.

The prime manufacturer conducts audits on first tier suppliers to prove the existence of ‘process capability’ within the supply chain and also to enhance that capability. Captured observations indicate that the sheer size of the prime’s supply chain combined with its geographic spread requires first tier suppliers to be compliant with the prime’s quality management system and explains why the prime requires each of its first tier suppliers to subsequently conduct audits on their own sub-tier suppliers. This resulted in the creation of the ‘Supplier Audits’ variable. The variable is designed to highlight the extensive importance that the prime places on supply chain capability to reduce non-conformances in pursuit of improved performance. Starting with the non-conformances variable, the loop demonstrates how an increase in non-conformances has the effect of increasing the number and / or frequency of 'Supplier Audits' being conducted by the prime on the failing supplier.

It was also described how there is a tendency to over-complicate systems and processes to such an extent that first tier suppliers can find consistent process compliance difficult to achieve. Process compliance is viewed as critical by the prime and is controlled by contractually agreeing performance metrics with all first tier suppliers. However, what constitutes acceptable levels of compliance appears to be more subjective within the supply chain. That led to inclusion of the 'Process Compliance' variable. The interaction between each variable shows how an increase in supplier audits has the effect of increasing process compliance. The supplier will then gradually become capable of adhering to the prime's quality system autonomously. The time delay mark has been added because it can take considerable time and effort by both the first tier supplier and the prime to achieve sustained compliance within the supply chain. The delay highlighted between the Process Compliance and Disruption variables demonstrates how the goal of achieving compliance is often delayed because of changes to requirements and standards, which causes oscillatory behaviour as disruptions continue to persist.

Further evidence from the exploratory phase shows that the supplier audit and process compliance variables represent captured sub-themes that the prime conducts to reduce or balance the effects of disruption in the supply chain. Without such mitigation activities, the loop will gradually reinforce over time to feedback in a continuous cycle of non-conformances and short term quick fixes until the system becomes so volatile that failure will become difficult to mitigate and supply chain failure will persist.

5.4 Dependency.

Here we present and justify causal loops relating to dependency, spend relationship and strategy mitigation.

5.4.1 The Dependency Loop.

Table 5.4 describes causal loop variables that interact to show how strategic decisions made by the prime can lead to a state of interdependency between the prime and a first tier supplier. The evidence relating to the interaction between all of the discussed variables led to the development of the dependency loop shown in Figure 5.4 and explained below.

Table 5.4 Dependency.

Themes (Coding Level 2)	Empirical Findings (Coding Level 2)		Variables (Coding Level 3)
	First Tier Supplier	**Prime**	
Power, Leverage and Dependency in the supply chain. Relationship Management.	Highly leveraged suppliers. Repeat business because of the fact that they own the design / IPR.	Sole sources of supply on rare complex commodities. Dependency effects recovery.	**Dependency on Supplier**
	Acceptance of poor performance due to lack of options. Selecting suppliers with a known history of chronic failure.	Lack of robust commodity strategies. We have limited options. We cannot go elsewhere so we are either forced to work with the supplier or force them to engage the one other source we have. Resourcing is a long process which is too long and too inflexible.	**Strategy Deployment**
	Slow decision making. Bureaucratic decision making structures.	Takes a while for this organisation to wake up and smell the coffee! Same as all large organisations. Breakdown at top level.	**Vacillation**
	Forcing suppliers to prioritise deliveries. Reduced their planned delivery time.	Not delivering on commitments. Putting all the delivery pressure on our suppliers before resolving our own internal pressures first. Not enough focus on the cost of non-quality and the cost of non-delivery.	**Delivery Arrears**

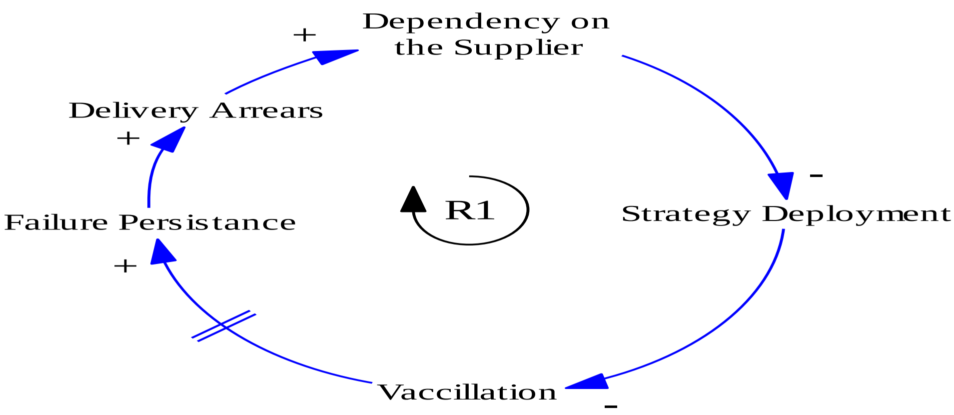


Figure 5.4 Dependency Loop.

The dependency loop highlights the effects of over-reliance on a single supplier because of a lack of sourcing options within the overall market. Participants from the prime mentioned how poor or immature commodity strategy development could contribute to situations whereby the prime becomes beholden to first tier suppliers. This is compounded by key suppliers who own the design rights on products that form a critical part of the prime's end product. The reverse can also happen if the majority of a first tier supplier's turnover is dependent on business with the prime. Obtaining the required industry certifications and approvals has become increasingly harder for all new entrants to the aerospace sector. The number of suppliers willing to enter the industry has reduced as a result, therefore reducing competition in the market. The effect of a lack of sourcing options led to the creation of the 'Dependency on the Supplier' variable.

Developing and deploying multi-sourcing commodity strategies is the prime's main defence against IPR and becoming dependent on critical suppliers. Sound commodity strategies are considered important because they identify options in the supply chain and highlight the existence of alternative suppliers. However, the evidence also points to the development and deployment of commodity sourcing strategies as being an arduous and lengthy process resulting in different levels of strategy maturity. In some instances reverting back to existing suppliers that have approvals already in place may be the only option available to the prime despite a history of poor performance by that supplier. Hence, 'Strategy Deployment' is included as a variable. This is the term used by the prime for examining and choosing supply options. The loop shows how an increase in dependency works to reduce strategic deployment activities and consequently the number of available options reduces when the prime focuses on only one first tier supplier. If that supplier starts to persistently fail, the prime then has no immediate options to quickly mitigate the failure. This is influenced by the volume of spend and / or number of parts that the first tier supplier supplies to the prime.

Observations that relate to poor commodity strategy development came principally from participants from the prime manufacturer who associated ineffective strategic sourcing decision making, combined with the inability to make required changes over time, as contributory factors causing supply chain failure to persist. This can occur when a manager has a lack of industry knowledge and supply options but most importantly, is under significant pressure to deliver a solution quickly. Indecision can prevent the prime from rapidly changing source when failures start to happen and subsequently persist. This effect has led to the inclusion of the ‘Vacillation’ variable in the loop. Vacillation is associated with decisions not being made in expedient time because of the tendencies of managers when faced with supply problems to either not know how to address the issue and / or swing indecisively from one course of action or opinion to another if not well informed. The loop shows how an increase in sourcing strategy deployment activities has the effect of reducing ‘Vacillation’ because more is known about the supply chain and the alternative options available to the prime. Over time, an increase in vacillation will lead to an increase in ‘failure persistence’, as highlighted by the delay mark. The delay mark inserted between the Vacillation and Failure Persistence variables captures the impact of management indecision and how it increases the effects of feedback on the loop. The resultant effect means that the prime are more likely to persist with existing suppliers for longer, which further increases dependency.

Even though the supplier is failing, a lack of viable options in the supply chain may prevent the manager from being able to stop failure from happening. Persistent failures that emanate from within the supply chain result in component supply being delayed, thus increasing delivery arrears. The prime monitors the supplier’s performance based on their ability to deliver to agreed schedules. Persistent delivery disruptions will be identified because of the risks to the prime and the critical implications for manufacturing and sales. Therefore, the ‘Delivery Arrears’ variable was included into the loop. The loop shows how an increase in ‘failure persistence’ has the effect of increasing ‘Delivery Arrears’. The loop moves on to also show how an increase in delivery arrears has the effect of increasing the dependency on the supplier because the prime is reliant on the supplier to catch up with their deliveries.

The dependency loop can be classified as an unfavourable loop because it combines to increase dependency on a failing first tier supplier with each cycle of the loop. This can result in decision making becoming very difficult for managers at the prime when all knowledge of available options within the market has evaporated over time. This loop drives a short term perspective because the prime’s supply chain management resources will spend more time trying to control and manage the supplier on which they are dependent rather than looking for alternatives.

5.4.2 The Spend Relationship Loop.

Table 5.5 introduces and justifies the creation of causal variables that show the effect of managing spend by the prime as a method of reducing dependency. The evidence relating to the interaction between these variables led to the development of the spend relationship loop shown in Figure 5.5 explained below.

Table 5.5 Spend Relationship.

Themes (Coding Level 2)	Empirical Findings (Coding Level 2)		Variables (Coding Level 3)
	First Tier Supplier	**Prime**	
Power, Leverage and Dependency in the supply chain. Relationship Management.	Supplier prioritisation based on spend. Customer dependency from the supplier.	There is only one source you can go to or they have got the contract for that product so you can't go anywhere else. There is a risk that we become beholding to suppliers who operationally haven't been a good performer.	**Supplier Growth**
	Level of Influence depends on leverage. Dealing with people (organisations) that we are not important too.	Supplier power effects motivation to recover. Cost is the driver. Lack of pressure on the supplier to get them to up their game.	**Supplier Influence**
	Lack of leverage cap. Limited competition in market.	Prime introducing a new supplier as a vendor does not happen terribly often for example within our particular team everybody within our supply base is established. Sourcing decisions do not force the assessment.	**Leverage**

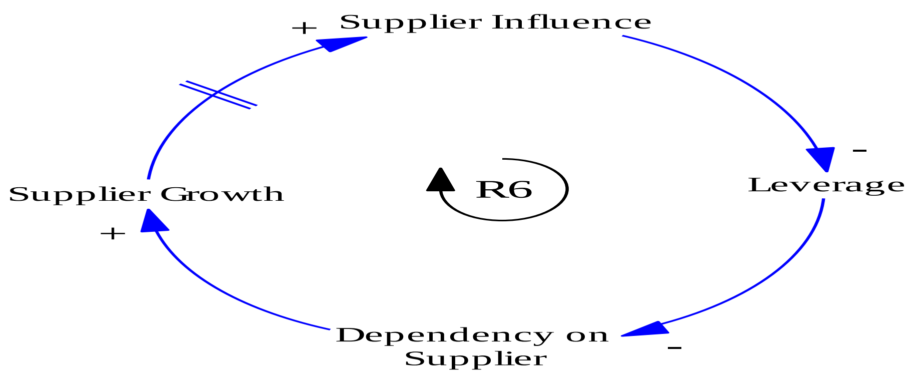


Figure 5.5 Spend Relationship Loop.

The prime spends large amounts of money in contracts with its extensive supply base. Evidence from the exploratory phase highlighted how some first tier suppliers explicitly target prime aerospace manufacturers that offer long term contracts. Aerospace contracts commonly cover both manufacturing and aftermarket requirements for long periods of time, sometimes up to thirty years. Winning a long term agreement has become central to the strategic objectives of many first tier suppliers. When entering into a long term contractual agreement, the intention for both parties is to generate revenue growth and prosper together over the duration of the contract. However, it was evident that the greater value of spend the prime has with a first tier supplier can correspond to an increase in interdependency over a period of time. Evidence captured from the prime suggests that such contracts are not always the optimal solution and can eventually result in operational and strategic problems. The more likely outcome of dependency on the supplier is that the prime systematically places orders irrespective of performance without thought or consideration of the potential future consequences. Increasing the amount of business with a first tier supplier has the positive effect of helping a supplier to grow but can also increase dependency. Hence, the 'Supplier Growth' variable was included.

In contrast to the prime, first tier supplier participants reported that they had a policy of retaining their sub-tier suppliers, even during the bad times. As a consequence of these actions, first tier suppliers are now stepping up their efforts to find alternative customers because re-sourcing activities conducted by the prime represents a major risk to future business. It has also exposed the extent of the prime's influence on the supply chain. The effect though, will eventually cause the prime to have a weakened influence in the market because first tier suppliers may find other customers. These observation led to the inclusion of the 'Supplier Influence' variable. This describes a supplier's power to influence decisions based on their ability and position in the market. The influence that a supplier has over the prime also corresponds with the increase in supplier growth over a period of time. The delay highlighted between the Supplier Growth and Supplier Influence variables captures how supplier influence is slowly reinforced over time as the first tier supplier gets more work from the prime. The system gradually becomes a closed feedback loop as the supplier's influence increasingly makes it harder for the prime to exit from that supplier as time passes by.

Therefore, the loop shows how an increase in supplier growth has the effect of increasing supplier influence within the relationship between the prime and the first tier supplier. Increasing the amount of work / expenditure with a supplier by continually awarding new business can develop into a key operational issue for the prime if not managed effectively. By increasing growth with key strategic suppliers, the prime runs the risk of effectively reducing their leverage over that supplier. Leverage in a relationship has the effect of increasing the power that the prime yields because the options that the prime has in order to take control in the relationship become greater than those of the suppliers. Factors that place a supplier into a position of power in the relationship often force the prime to increase the amount of repeat business with that supplier because of the cost and time required to transfer parts to an alternative and to find available capability in the market. This has resulted in the inclusion of the 'Leverage' variable. An increase in supplier influence has the effect of reducing the prime's 'Leverage', which captures the ability to act effectively in commercial negotiations in order to derive a favourable outcome. Over time, this can create a level of reliance on the supplier that can affect the prime's future supply flexibility.

Once the prime becomes heavily dependent on the supplier for the supply of goods, the risk of the loop causing persistent supply chain failure increases with every cycle, dynamically. The continual rise in spending with a single supplier has the effect of increasing dependency over time. Therefore, an increase in dependency on a supplier has the effect of increasing supplier growth. If action is not taken, then the effect of the loop will automatically increase until the prime is completely dependent and the supplier becomes the only source. Breaking the cycle by increasing the prime's leverage has the effect of reducing dependency on the supplier by the prime. An outcome of this can mean that the supplier suddenly goes out of business leaving the prime without a source of supply[17].

Overall, the loop is reinforcing because, when all of the variables link together, they increase the suppliers influence over the prime. The self-reinforcing nature of the loop is highly unfavourable to the prime in a commercial relationship as it increases dependency on supplier through increased supplier growth. This significantly increases

[17] *Was experienced directly by the author when supplier A went into administration leaving the prime without a supplier for critical components used on multiple engine products. The prime were forced to buy supplier A in order to maintain supply because of the lack of alternative suppliers.*

the leverage position of the supplier, which further enhances the effects of failure persistence.

5.4.3 The Strategy Mitigation Loop.

Strategy mitigation includes activities adopted by the prime to mitigate the effects of being dependent on existing suppliers. Table 5.6 identifies the variables that show how limited sourcing options within the supply chain can increase an existing first tier supplier's influence and reduce the resourcing options for the prime. A negative side effect of this happens because fully managed high risk source changes can and do take considerable time and consume valuable resources. The evidence relating to the interaction between these variables led to the development of the strategy mitigation loop shown in Figure 5.6 and explained below.

Table 5.6 Strategy Mitigation.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Suppliers	**Prime**	
Power, Leverage and Dependency in the supply chain. Relationship Management.	Difficult to resource IPR / Critical products due to the prime's source change process. Limited competition in market. Commercial Issues.	Cost - we get what we pay for. Restricted supplier base - decisions are made around capacity and not capability.	**Sourcing Options**

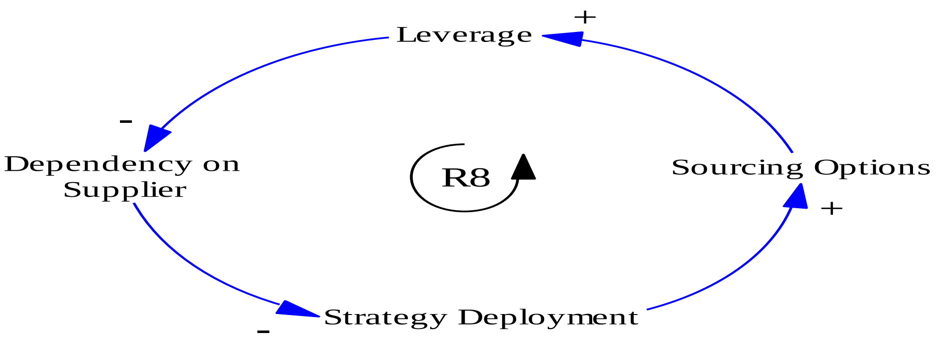


Figure 5.6 Strategy Mitigation Loop.

Starting with the strategy deployment variable, in order to counteract the effects of dependency on the supplier, the prime develops supply strategies for all of the relevant components. It does this in order to create options with the aim of preventing existing suppliers from becoming too powerful and influential within the supply chain.

The outcome of this causal linkage is that it increases the number of quality approved supply options available to the prime. This led to the inclusion of the 'Sourcing Options' variable. The loop shows how an increase in commodity strategy development and deployment has the effect of increasing the prime's sourcing options' as purchasing managers seek to establish control in the supply chain through greater leverage because of more supply options.

It was also reported that some of the participant first tier suppliers are currently performing below acceptable standards on delivery and quality due to long term supply chain failure but, significantly, it was noted that they are still being awarded work on major new product development programmes. As such, they still continue to grow their level of business with the prime and are frequently tendering for new business.

The loop is favourable because it demonstrates how an increase in sourcing options can increase the prime's leverage in the supply chain by introducing more competition into the market. The loop then shows how an increase in leverage reduces the prime's dependency on their suppliers because there is a greater choice of suppliers with which to contract.

5.5 Supply Chain Risk Management.

Here we present and justify causal loops relating to supply chain flexibility, demand planning and contingency risk management.

5.5.1 The Supply Chain Flexibility Loop.

Table 5.7 presents the variables relating to how a general lack of planning capability in the wider supply chain forces the prime to micro-manage suppliers because of the risk that failure represents to the prime. Interactions between these variables led to the development of the supply chain flexibility loop shown in Figure 5.8 and explained below.

Table 5.7 Supply Chain Flexibility.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Risk Management. Contingency Management.	Declining labour skills. Companies who cannot plan.	Limited supply chain capability. Poor planning in the supply chain.	**Supply Chain Capability**
	Lack of response / Urgency or understanding. Lack of trust towards customer resulting in poor relationship.	Micro managing suppliers. Lack of sub-tier control.	**Micro-Management**
	Poor planning in the sub-tier. Alien and Stranger demand (Legacy and low volume components).	Lack of load and capacity planning. Poor planning.	**Time to Plan**

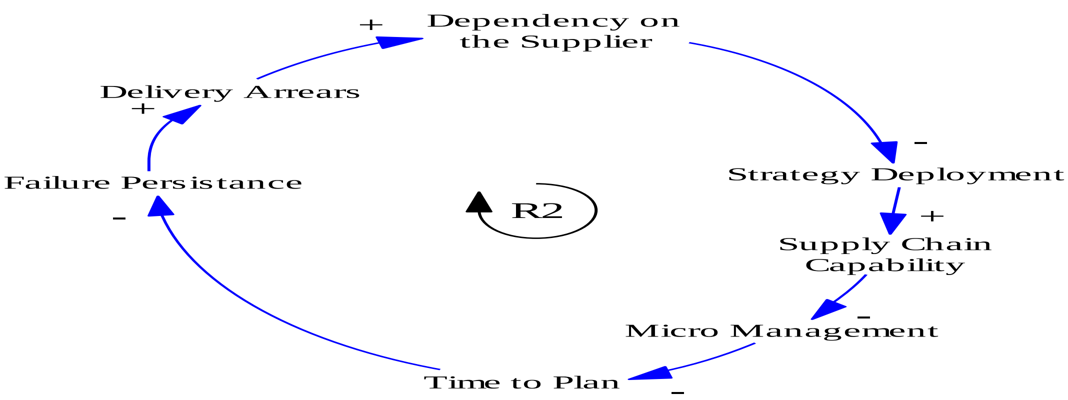


Figure 5.7 Supply Chain Flexibility Loop.

Greater awareness of capable suppliers within the supply chain enables the prime to be more proactive in sourcing. They can make more informed strategic and operational sourcing decisions in advance which helps the prime to reduce the risk of contracting with suppliers that do not have the capability to produce components to the required standard. This has created a significant risk to the prime because it has steadily become more dependent on the first tier supplier's general ability to identify and improve their overall capability. This has given rise to the inclusion of the 'Supply Chain Capability' variable. Evidence from the exploratory phase revealed how insufficient planning capability is considered to be a frequent cause of failure. The loop demonstrates how the strategic deployment variable has the effect of increasing supply chain capability as it results in sourcing from more capable suppliers

Further captured evidence suggests that the prime is forced to, or reacts by micro-managing first tier suppliers when they persistently fail to meet agreed levels of performance. As reported during the exploratory phase, the prime commits considerable resources to identify and resolve the causes of persistent supply chain failure, on occasion this involves 'parachuting' a team of supply chain personnel into the failing supplier to quickly establish and quarantine the cause of failure in order to ensure continuity of supply. However, the effectiveness of this heavy handed approach was questioned by a participant from the prime and first tier supplier. They both suggested that the short term approach didn't actually result in an improved supplier in the long term. Therefore, the 'Micro-Management' variable has been included. The loop demonstrates how an increase in supply chain capability has the effect of reducing the prime's need to micro–manage within the supply chain.

It was evident that some of the micro-management approaches adopted by the prime on high risk suppliers can be extreme, consuming valuable resources at both the prime and first tier suppliers. To prevent / mitigate failure, the distraction caused reduces the prime's planning time ahead of the forward production schedule. The more dialogue that the prime has to discuss problems with the supplier then the greater the chance that the supplier will attempt to resolve the issues themselves rather than standing back and letting the prime solve the failure. However, a lack of planning capability was cited as a cause of frequent schedule changes and that micro-management was an effect of the prime having reduced time to plan for future production requirements. These observations led to the inclusion of the 'Time to Plan' variable. The loop highlights how the micro-management variable interacts with the 'Time to Plan' variable to reduce the amount of planning time needed to adequately schedule future deliveries because the prime forces the first tier supplier to prioritize critically required components. The loop then shows how an increase in the time to plan variable subsequently has the effect of reducing failure persistence. An increase in failure persistence increases the effect of delivery arrears, which in turn increases the effect on dependency on the supplier. The loop is completed by the dependency on the supplier variable having the effect of reducing the strategy deployment variable as previously explained.

Overall the loop has a reinforcing effect on the supply chain because the greater the dependency on the supplier, the less resourcing activities are carried out by the prime. The number of parts that the prime has with one supplier determines whether it will be more susceptible to a reduction in planning time available for the supplier.

5.5.2 The Demand Planning Loop.

Each contracted first tier supplier is provided with a forecasted delivery schedule every week by the prime. The forecasted schedule is passed to first tier suppliers with the understanding that demand may change, despite the aerospace industry having a fairly stable demand profile compared to other sectors. The policy is put in place to protect the prime from potential cancellations by its customers and unplanned orders. Therefore, suppliers are incentivised to forward plan at their own risk. Table 5.8 presents variables that relate to the impact of material schedules changes on first tier suppliers. The evidence relating to the interaction between these variables led to the development of the demand planning loop shown in Figure 5.8.

Table 5.8 Demand Planning.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Risk Management. Contingency Management.	Number of schedule changes made by the customer. Demand is not fixed.	Treating the supplier inconsiderately with schedule demands and not listening when we don’t want to react to news we don’t want to hear. Demand signal volatility	**Rescheduling Disruption**
	Lack of lead-time adherence by the customer. Failure to identify the correct supply chain tools and lead times of products as part of planning.	Lack of time. Not supplying specifications on time and then condensing the suppliers lead time down.	**Lead time Accuracy**
	Schedule changes on a weekly basis. Number of Parts.	Forcing suppliers to prioritise deliveries. Lack of flexibility in sub-tier management.	**Supply Chain Flexibility**

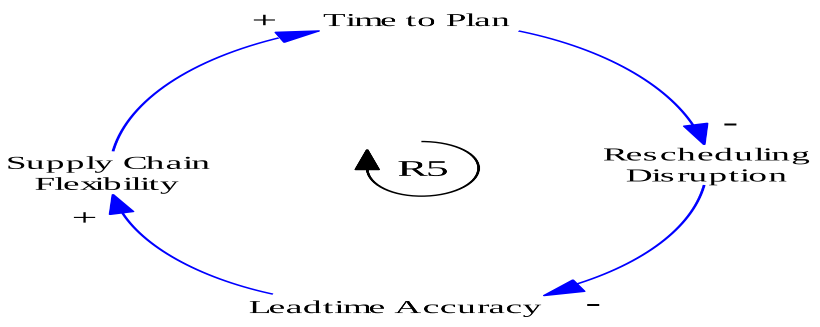


Figure 5.8 Demand Planning Loop.

Evidence from first tier suppliers highlighted how frequent material schedule changes can cause significant disruption to the suppliers if not planned adequately. It was noted that regular changes to demand schedules distributed to first tier suppliers was a cause of significant disruption to production plans at the supplier. These are tightly managed by first tier suppliers in order to meet the customers demand schedule. Suppliers find achieving adherence to their agreed delivery metric targets (set by the prime) much more difficult due to such frequent changes (called exception messages[18]). One supplier suggested that achieving a consistently good delivery score was almost impossible because of the changes and noted that this was reflected by a third party audit firm when shown the extent and frequency of the amendments. The evidence from the empirical study led to the inclusion of the 'Rescheduling Disruption' variable. Rescheduling disruption occurs due to persistent schedule changes by the prime despite a relatively stable demand profile overall in the aerospace market. The eventual effect is to reduce a supplier's resilience leading to persistent failure. An increase in the time available to plan has the effect of reducing the impact of rescheduling disruption.

Reducing the effects of disruption caused by regular rescheduling requires the specified lead-times to be achieved each time the loop feeds back. Planning at the prime uses fixed lead times. This should provide prior warning to the supplier and its sub-tier supply chain for planning and should require little effort by the prime to ensure that components are delivered on-time to the correct specification. However, the captured evidence has resulted in the inclusion of the 'Lead Time Accuracy' variable which relates to the accuracy in achieving a given lead time. The loop demonstrates how an

[18] Exception messages – *These appear in SAP to warn the prime that changes in delivery date requirements have changed.*

increase in rescheduling disruption has the effect of reducing a supplier's lead-time accuracy. Changes to material schedules are made by the prime in order to try and improve its delivery performance whereas the interaction between these variables demonstrates how it actually feeds back to reduce the first tier supplier's ability to deliver on time.

Due to the size of many sub-tier supply chains, the risk of first tier suppliers utilising unapproved sub-tier suppliers can increase. A lack of control within the first tier supply chain also reduces overall supply chain flexibility, effectively leaving the prime exposed to the risks of supply chain failure. Flexibility denotes the supplier's ability to manage their own internal production management system effectively in the presence of frequent demand change requests by the prime. The captured observations led to the development of the 'Supply Chain Flexibility' variable. The loop demonstrates how an increase in lead time accuracy by the supplier has the effect of increasing supply chain flexibility. An increase in supply chain flexibility helps the prime by increasing the time to plan because the supplier has the ability to manipulate their production plan, i.e. they can bring the delivery of parts forward or move them back without compromising the rest of their production plan.

Overall, the loop has been classified as favourable because the variable that causes the most issues for the prime and supplier, is rescheduling disruption. This variable is being counteracted positively by the other three variables. The loop reinforces to increase the prime's time to plan, which decreases failure persistence because the prime has more visibility and time to inform suppliers of upcoming changes in demand, giving them more time to react.

5.5.3 The Contingency Risk Loop.

It is often the case that orders for components need to be made months in advance because the raw materials required to manufacture them often have a long lead time due to high demand within the industry. Table 5.9 highlights and justifies variables that capture the effects of outsourcing and the need for adequate risk management processes within the first tier supply chain as a result. The variables that go into formulating the contingency risk loop have been created to capture the effect of outsourcing components from a supply chain that is widely dispersed geographically. This includes supply chains located in geo-political hotspots and / or in the vicinity of areas that are affected by natural disasters. The evidence relating to the interaction between these variables led to the development of the contingency risk loop shown in Figure 5.9 explained below.

Table 5.9 Contingency Risk.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Risk Management. Contingency Management.	Sticking to plan. Lack of Business Continuity Management (BCM).	Joint risk assessments not robustly in place. Willing to change. Unapproved sub-tiers.	**Supplier Resilience and Robustness**
	Poor or very bad supplier sourcing. Supplier doesn't see the need to perform or have the capability to perform.	Number of suppliers in high risk areas. Sourced IPR components in known global trouble spots. It is very difficult to transfer these out and takes a long time.	**Outsourcing**
	Weak auditing of supply chain capability. Lack of raw material availability.	There have been some very close calls in recent times. We have dodged bullets and this has woken people up to the realism. Unsure whether BCM is high on the list of priorities.	**External Material Supply**

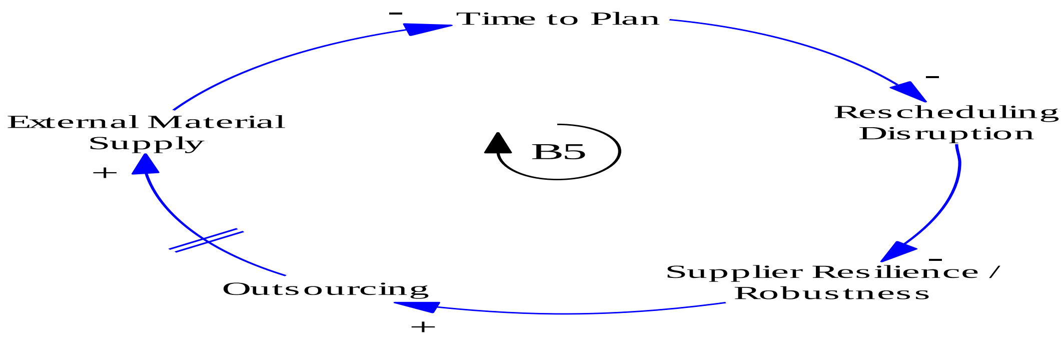


Figure 5.9 Contingency Risk Loop.

Throughout the exploratory phase it became clear that participant first tier suppliers operated at very different levels of competency when it came to identifying internal and external risks associated with sourcing components from their sub-tier supply chain. It was acknowledged by participants from the prime that failure to identify and manage key risks at critical stages in the contract formulation stage between the prime and first tier supplier, could contribute to persistent failure later on in a commercial relationship. The emphasis placed on risk management within the supply chain depends on the size of the supplier. The ability to successfully manage supply despite the effects of disruption led to the development of the 'Supplier Resilience and Robustness' variable. In this context it is defined as a first tier supplier's ability to recover from a failure and not cause any disruption to the prime. The loop demonstrates how an increase in rescheduling disruption has the effect of causing a reduction in supply chain robustness and resilience. Over a period of time, constant rescheduling will incrementally weaken the supplier's ability to react to changes creating further risks for the prime.

In contrast to observations made at the prime, captured perceptions by the first tier suppliers was that risk management was an area very much reserved for senior management with minimal information flowing down to the rest of the organisation. Some first tier supply participants said that they had started to hold discussions with the prime regarding the subject of risk management. They believed that in order to successfully outsource key components into the supply chain, management of risk is critical to ensuring persistent failures do not occur. These issues led to the creation of the 'Outsourcing' variable, reflecting the amount of effort made by the prime to capture risks when outsourcing components to globally dispersed supply chains. The loop shows how an increase in supplier resilience / robustness will have the effect of increasing the drive by the prime to increase outsourcing of components because the perceived risk of doing so is reduced.

Mitigating key identified risks is a significant issue for the prime because of events that have occurred in recent years that had caused extreme disruption to raw material supply in particular, hence the inclusion of the 'External Material Supply' variable. The loop shows how an increase in outsourcing has the effect of increasing external material supply. This is because a greater volume of parts are sourced from the first tier supply chain rather than produced in house. Therefore, greater effort is required by the prime to get the parts to where they need to be at the correct time. The key risk to the prime is that an increased use of a widely dispersed suppliers will cause a reduction in the level of flexibility within the prime's supply network and therefore reduces the amount of time available to plan at the prime because much of the time will be used to transport the components from the supplier to the prime. The delay highlighted between the Outsourcing and External Material Supply variables demonstrates how outsourcing product into the supply chain is a slow process. Therefore any problems with internally manufactured products will not be dealt with quickly. Increased planning time within the network feeds back to reduce the pressure on rescheduling disruption because the prime and subsequently first tier suppliers are given more time to manage demand changes within their production planning system.

Overall, this causal loop diagram is unfavourable to the system because it feeds back and reinforces to reduce planning time for the prime. The increase of both the outsourcing and external material supply variables increases the risk of delivery disruption to the prime by reducing the amount of time that the prime has available to plan for changes.

5.6 Relationship Management.

Here we present and justify causal loops relating to communication, relationship management and information delay loops.

5.6.1 The Communication Loop.

Table 5.10 presents variables identified relating to communication between the prime and the supplier and their impact on supply chain performance. The evidence relating to the interaction between these variables led to the development of the communication loop shown in Figure 5.10.

Table 5.10 Communication.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Relationship management	Dealing with people (organisations) that we are not important too. Seniors with own agenda.	Selective Communication. Miscommunication prompting capacity risk. We need to understand what the drivers of the relationship are.	**Dialogue with the Supplier**

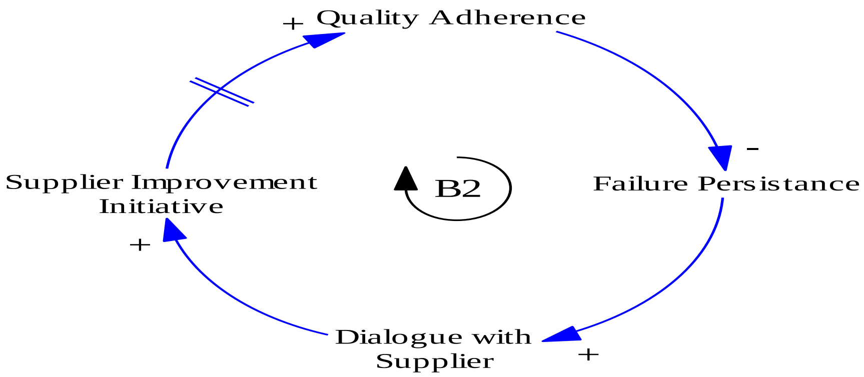


Figure 5.10 Communication Loop.

Captured evidence found that the quality of the relationships the prime has with first tier suppliers can affect the level of effort expended by suppliers, especially when personnel changes occur, changing the relationship dynamics and the type and mode of communication. These observations have led to the inclusion of the 'Dialogue with Supplier' variable. Starting with the failure persistence variable, the loop demonstrates how an increase in failure persistence has the effect of increasing dialogue with the supplier considerably, as a number of the supply chain functions within the prime urgently try to mitigate the failure and avoid further disruption.

The interaction shows how failure persistence stimulates the prime into increasing the amount of dialogue they have with the supplier in order to reduce or balance out the failure and increase quality and / or delivery adherence by implementing supplier improvement initiatives. The loop then cycles in a clockwise direction showing how an increase in the dialogue with supplier has the effect of increasing the number of supplier improvement initiatives. Persistent failures trigger a significant increase in dialogue with the supplier as the prime attempts to identify the cause of failure and quickly mitigate its effects. An increase in quality adherence then has the effect of reducing failure persistence, which reduces the continued disruption to the prime.

The communication loop has been classified as favourable because the system essentially combines to reduce the effects that cause failure persistence after each cycle of the loop. The reduced effect could be temporary as other loops continually reinforce to increase the pressure being placed on the prime. The loop also shows implicitly the existence of a reactive management style displayed by the prime because dialogue with supplier increases only when the prime is experiencing persistent failures. Dialogue with the supplier then becomes critical because both parties have to quickly identify where the failure is happening in the process before it becomes too difficult to contain.

5.6.2 The Relationship Management Loop.

Table 5.11 presents variables relating to communication and their effects on the buyer-supplier relationship. There is often a lack of understanding emanating from both the prime and supplier regarding technical specifications, forthcoming fluctuations in demand and changes to the quality management system. These issues have the effect of impairing the supplier's ability to understand what the prime actually wants in order to fulfil the requirement properly. The identified interactions between these variables resulted in the development of the relationship management loop shown in Figure 5.11.

Table 5.11 Relationship Management.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Relationship Management	Customer not clearly communicating what they want. Poor information flow / poor communication.	Vagueness around expectations. Lack of clarity of requirements.	**Understanding of Requirements**
	Not knowing what the customer wants. Poor information in load.	Sending out the wrong message. Internal communication issues at suppliers whereby senior people do not get given the real picture by middle management.	**Ambiguity**
	Lack of trust towards prime resulting in poor relationship. Poor communication.	Not viewed as long term partner. Relationship is broken.	**Commitment and Trust**

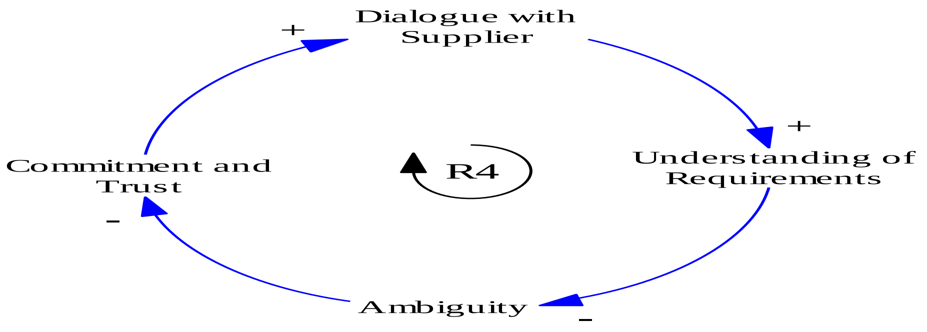


Figure 5.11 Relationship Loop.

Throughout the exploratory phase, a commonly identified theme was the negative effect on supply chain performance of a breakdown in the relationship between the prime and first tier supplier. The evidence indicates that a general lack of communication and poor relationship management practices could translate into delays in delivery and quality non-conformances, increasing the likelihood of persistent supply chain failure. New contacts may have a different agenda, scope, or responsibilities and this may result in inconsistent information flows and general frustration. The findings captured from the exploratory stage suggest that current relationships with the prime are far from consistent, heightening the risk of failure. These findings led to the development of the 'Understanding of Requirements' variable. Starting with the dialogue with the supplier variable, the loop shows how an increase in the dialogue with supplier has the effect of increasing the understanding of requirements by both the prime and the first tier supplier. This is simply because both parties will take the time to focus on and discuss the issues that are causing problems.

The evidence suggests that in practice these activities are not in many cases consistently maintained over the period of a commercial relationship because of issues with lack of personnel continuity. It was felt that vagueness came in the form of the prime sending out the wrong messages, resulting in a heightened level of ambiguity towards design requirements, especially during NPI projects. The evidence also suggests that failure to consistently communicate with a supplier can cause significant confusion, leaving suppliers not knowing how to work with the prime or what is expected of them. Therefore, 'Ambiguity' was included as a variable. The loop shows how an increase in the understanding of requirements has the effect of reducing ambiguity because queries from either party are dealt with in an understandable and, importantly, expedient way.

Evidence from the exploratory phase also indicates that a lack of trust by the supplier towards the customer could result in a poor relationship. Likewise, this situation arises when first tier suppliers feel that they are not viewed as a long term partner, resulting in efforts being directed elsewhere. Therefore, 'Commitment and Trust' has been included as a variable because the existence of trust between both parties is important to ensure that a relationship does not break down. The loop shows how an increase in ambiguity has the effect of reducing commitment and trust because the supplier quickly becomes frustrated when they do not know what is required and will be reluctant to proceed with the manufacturing of parts. Therefore, a reduction in ambiguity will increase cooperation and trust. An increase in commitment and trust then goes on to complete the feedback loop by increasing the level of dialogue with the supplier. The supplier and prime have greater motivation to contact each other on a more frequent basis because the interaction between the two is positive and easy to manage.

Overall, the loop is reinforcing in an unfavourable way because it is dependent on the prime's dialogue with supplier in order to create understanding of requirements and reduce ambiguity and foster commitment and trust. The frequency of communication with suppliers is done on a priority basis because of resource constraints, with suppliers who are already causing disruption receiving more attention. As the loop feeds back, it is the suppliers who have been largely ignored that potentially pose the greatest threat to the prime.

5.6.3 Information Delay Loop.

The literature highlights how the sharing of information plays an important role in developing strategic relationships. Similar observations were also captured during the exploratory stage of this study. Table 5.12 highlights variables that have been developed as a consequence of this evidence. The evidence relating to the interaction between these variables led to the development of the Information Delay loop shown in Figure 5.12 and explained below.

Table 5.12 Information Delay.

Themes (Coding Level 2)	**Empirical Findings (Coding Level 2)**		**Variables (Coding Level 3)**
	First Tier Supplier	**Prime**	
Relationship Management	Untimely response to questions (to the Prime). Lack of response / Urgency or understanding.	Wrong tactics / no engagement. Poor information flows. Ignoring issues.	**Responsiveness**
	Late material supply. Late specifications by the prime.	Risk of raw material availability. Failures are not identified quickly enough.	**Delays**

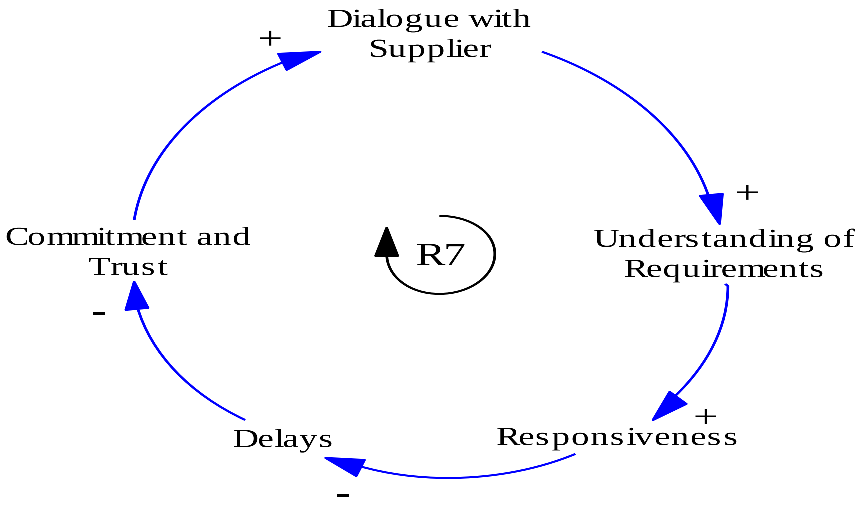


Figure 5.12 Information Delay Loop.

Potential causes of a relationship breakdown and contributors to persistent supply chain failure were attributed to issues concerning the responsiveness of either the first tier supplier or the prime for requests for information. This includes delays in responses to questions, or worse where one party continually ignores issues or requests for information. Responsiveness is the time it takes the prime to respond to a question in such a manner that any doubt regarding the answer to a query is clarified, thus enabling the process of manufacturing components to continue. Therefore, the 'Responsiveness' variable was added. Starting with the understanding of requirements variable, this was frequently cited as being a key interaction between the prime and supplier to ensure that the correct requirements are being satisfied. Therefore, the loop shows how an increase in understanding of requirements has the effect of increasing responsiveness between first tier suppliers and the prime.

In the context of the loop, delays can be caused due to requests for information from the first tier suppliers not being answered by the prime expediently. This could result in the first tier supplier halting production of the component until the required information is given by the prime leading to late deliveries. Equally, late specifications provided by the prime could cause 'Delays' hence its inclusion as a variable. All late deliveries affect the scorecard of a first tier supplier negatively irrespective of the cause. Therefore, any assistance given by the prime to mitigate potential delays will improve cooperation and trust between the two parties. The effect is that delays or the risk of delays can be reduced if the request for information is dealt with in an expedient way. The loop shows how an increase in responsiveness has the effect of reducing 'Delays'.

Evidence indicates that internal relationship management and in particular relationship continuity is a key antecedent to persistent supply chain failure. To some extent, this drives the way in which the prime manufacturer communicates with, and manages relationship issues with the external supply chain. The loop shows how an increase in delays has the effect of reducing commitment and trust between both the prime and the supplier. Subsequently, the loop shows how an increase in commitment and trust then has the effect of increasing dialogue with the supplier, which then increases the level of communication between the two parties. An increase in dialogue with the supplier subsequently has the effect of increasing understanding of requirements, which completes the loop.

The information delay loop is a favourable self-reinforcing loop because it feeds back to gradually increase the level of communication between the prime and supplier after each cycle. However, it often takes the prime a long time to build up a good level of communication with a first tier supplier. The difficult aspect of this for the prime is that it takes perseverance to build up a good relationship with a supplier which comes at a cost in the use of personnel resources.

5.7 The Core Failure Persistent Loop.

Figure 5.13 shows how a core loop made up of variables from four key loops discussed above (Quality Adherence, Dependency, Supply Chain Flexibility and Communication) is at the centre of the failure persistent model. This failure persistence loop has been developed by combining the effects of identified variables that interact to cause supply chain failure and the actions taken by the prime to try and mitigate those failures.

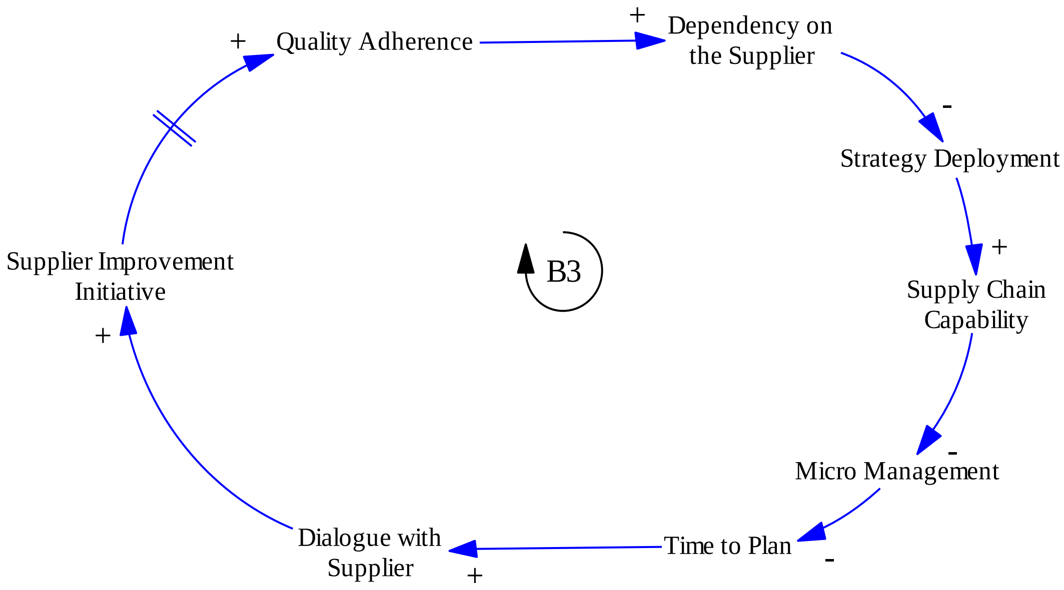


Figure 5.13 Failure Persistence Loop.

The failure persistent loop essentially captures events and activities that affect the prime's supply chain over time and either reinforce interactions between variables, leading to failure, or events and activities that are conducted to reduce the effect of persistent failure. Starting with the quality adherence variable, the loop shows how an increase in quality adherence has the effect of increasing dependency on the supplier because finding previously unknown or unused suppliers with all of the appropriate aerospace industry and specific customer approvals is very challenging. The prime does seek to develop new suppliers but this is a very costly and time consuming endeavour. Another option for the prime is to stick with existing suppliers that are already fully approved and currently supply products to the prime even though they have a history of failure and causing disruption.

Captured evidence indicates that existing suppliers are in a position of power because they already have experience and a working relationship with the prime and enjoy a level commitment through existing business. It is therefore perceived as being less risky by the prime to retain the incumbent supplier because they are already established. This does, however, leave the prime vulnerable to price changes as a result of commercial lock-in as alternatives are gradually diminished over time.

The next key interaction between the variables demonstrates how an increase in the dependency on the supplier has the effect of reducing strategic sourcing and deployment activities carried out by the prime. In theory persistent failure should result in an increase in sourcing activities rather than reducing it. However, participants from the prime talked about how preventing failure in the existing supply chain uses up considerable personnel resources and actually reduces the opportunity to investigate and deploy new sourcing strategies. Every sourcing strategy deployment activity should have the effect of increasing the prime's knowledge of the supply chain through the study and the identification of existing and new capability within alternative but related industries. The result of such activities were described as mixed, with some sourcing strategy deployment activities being more successful than others. Ideally, an increase in sourcing strategy deployment activities should increase the prime's supply chain capability through identification of capable suppliers. The loop demonstrates how successfully deploying new sourcing strategies should be a key part of the resourcing activity, although it was found that this is not always the case.

A greater awareness and holistic knowledge of what is happening within the prime's supply chain reduces the need for the prime to engage in micro-management of the supply chain. It was evident that a knock-on effect of micro-management of high risk suppliers is an increase in the amount of resource dedicated to prevent / mitigate failure. Conversely, an increase in supply chain capability has the effect of reducing micro-management. An increase in the amount of micro-management activity reduces the prime's time to plan against the production schedule. The loop shows how greater planning time available to the prime will enable an increase in dialogue with the supplier, which works in both directions. Greater discussion should provide both the prime and the first tier supplier with more time to react to changes in schedules.

The more dialogue the prime has available to discuss issues with the supplier then the greater the chance that the supplier will deliver parts on time. Hence, the loop demonstrates how an increase in the dialogue with supplier will increase the implementation of supplier improvement initiatives (even if it is only for a short period of time) in order to facilitate improvement in quality adherence. The core loop then moves on to show how an increase in supplier improvement initiatives will have the effect of increasing quality adherence. This is mainly due to the prime's quality system, which must be fulfilled in all sourcing deployment activities and subsequent production activities.

Overall, the core loop demonstrates how each of the variables not only interact with other variables within each loop, they also link with variables from other loops that relate to different themes. Therefore, the core loop shows that quality management, power / leverage, risk management, and relationship management are all inter-connected. Variables that sit within each of these areas can interact to cause an effect that results in persistent failure if not captured in the first instance or mitigated quickly once failure occurs. The loop shows the activities that are most likely to cause issues within the prime's supply chain and result in persistent supply chain failure if they are not identified and successfully addressed.

The core loop shows how key activities such as effectively monitoring the supply chain to ensure adherence to quality standards is critical in order to avoid repeat non-conformances. The difficulties faced by suppliers in adhering to the prime's quality management system are well known. Therefore, the prime should be actively working with suppliers to make this process much easier and not continually 'moving the goal posts' by changing requirements and specifications and failing to inform suppliers of the changes expediently. The prime should make the correct sourcing decisions and then control the level of spend they have with a supplier. These actions will help to reduce the effects of dependency and becoming beholden to a supplier. Informed strategic sourcing decisions should be made on what is known about the capability of a chosen first tier supplier rather than reverting to existing long term relationships. However, relationships should be cultivated and driven by the prime, which involves consistent and effective communication with all first tier suppliers.

5.8 Developing the Persistence Failure Model.

Figure 5.14 is titled "The Failure Persistence Model". It shows the full failure persistence model in its entirety and is the first iteration of the complete model. The model was subsequently reviewed and critiqued by participants from the prime during the workshop stage of the validation study. The findings of this workshop are presented in Chapter 6.

Figure 5.14 Failure Persistence Model.

Each loop is a visual representation of the interactions between each variable that develop over time at the prime and within the first tier supply chain. They are the end result of sustained activities conducted by either the prime or the supplier over a number of years. The loops are the result of cause and effect relationships that have influenced company sourcing strategy, and the approaches, philosophy and culture that have evolved over time.

Overall, it was identified that when the variables interact, they can manifest into a reoccurring failure that becomes increasingly hard to remedy (Sterman, 2001). Due to the sheer size and complexity of the prime's organisation and equally the size and complexity of its supply chain, it is difficult for managers to comprehend and capture the relationships between cause and effect of every decision that is made. Hence, the risk of persistent failure is present with every critical decision made by the prime.

5.9 Glossary Defining the Chosen Variables.

Table 5.13 provides a full glossary describing all of the variables included in the first iteration of the failure persistent model in alphabetical order. The glossary helps the reader further understand each interaction between the variables and how the polarities affect the loops.

Table 5.13 Failure Persistence Model Glossary.

VARIABLE	DESCRIPTION
"Ambiguity"	The first tier supplier does not know what is expected of them in some aspect of the commercial or operational relationship with the prime.
"Commitment and Trust"	A strong collaborative working relationship exists between the first tier supplier and the prime. Both the first tier supplier and the prime share joint goals in order to be successful.
"Delays"	Occur when requests for information or clarification from the first tier supplier are not answered by the prime expediently or specifications are not provided by the prime in sufficient time resulting in late deliveries.
"Dependency on Supplier"	Heavy reliance on a first tier supplier due to them either being a sole source, or there being limited alternative capability in the supply chain, or because the supplier has IPR ownership.
"Delivery Arrears"	The level of late deliveries from a supplier against the material delivery schedule specified by the prime.
"Disruption"	A supply failure emanating from a first tier supply chain that leads to interruptions to the prime's assembly line or build schedule.
"Dialogue with Supplier"	The interaction and communication between the prime and the first tier supplier.
"External Material Supply"	The complete supply chain from raw materials through to the assembly operations of the prime.
"Failure Persistence"	Supply chain failure that continues to happen despite multiple efforts by the prime and a first tier supplier to resolve it.
"Focus on Supplier"	The additional time and resource placed on a specific first tier supplier by the prime when they start to fail persistently.

“Lead-Time Accuracy”	A first tier supplier’s ability to accurately achieve a given lead time with the prime on a consistent basis.
“Leverage”	Either the prime or first tier supplier uses its resources to derive an advantage in a commercial relationship over the other, leading to a strong negotiating position for that party.
“Micro–Management”	A management style adopted by the prime where it closely monitors, observes or controls the work of the first tier supplier and/or its sub-tier suppliers.
“Non-Conformance”	Components supplied by the first tier supplier that do not meet the required specification as contractually agreed.
“Outsourcing”	Activities conducted by the prime to source components that were previously manufactured in-house from outside first tier suppliers.
“Process Compliance”	Consistent conformance to the prime’s quality management process and system.
“Quality Adherence”	Compliance to both industry regulations and the prime’s required specifications by the first tier supplier.
“Rescheduling Disruption”	The level of change in delivery schedules and / or date delivery date changes made by the prime to the first tier supplier’s existing delivery schedules.
“Responsiveness”	The amount of time taken by the prime to respond to a query / question by the first tier supplier.
“Root Cause Analysis”	Methodological analysis of a non-conformance to identify the main underlying cause of a problem, which aims to ensure repeat failures do not happen.
“Short Term Quick Fixes”	Non-conformances that are resolved in order to fix problems quickly but without investigating the underlying root cause of failure.
“Sourcing Options”	The number of viable alternative suppliers that the prime can contract with in the market for a particular component, sub-assembly or system.
“Supplier Audits”	Investigation and analysis of a supplier’s quality management system and its ability to meet requirements set by the prime.
“Supply Chain Capability”	A first tier supplier with strong production and sub-tier planning and management capability.
“Supplier Growth”	The increase in a supplier’s turnover due to the increase in the volume of orders being placed by the prime with the supplier.
“Supply Chain Flexibility”	A first tier supplier’s ability to deliver parts on time despite schedule changes imposed by the prime.
“Supplier Influence”	The influence that the first tier supplier has over the prime due to a specific capability that the first tier supplier posesses where there are limited alternatives for the prime.

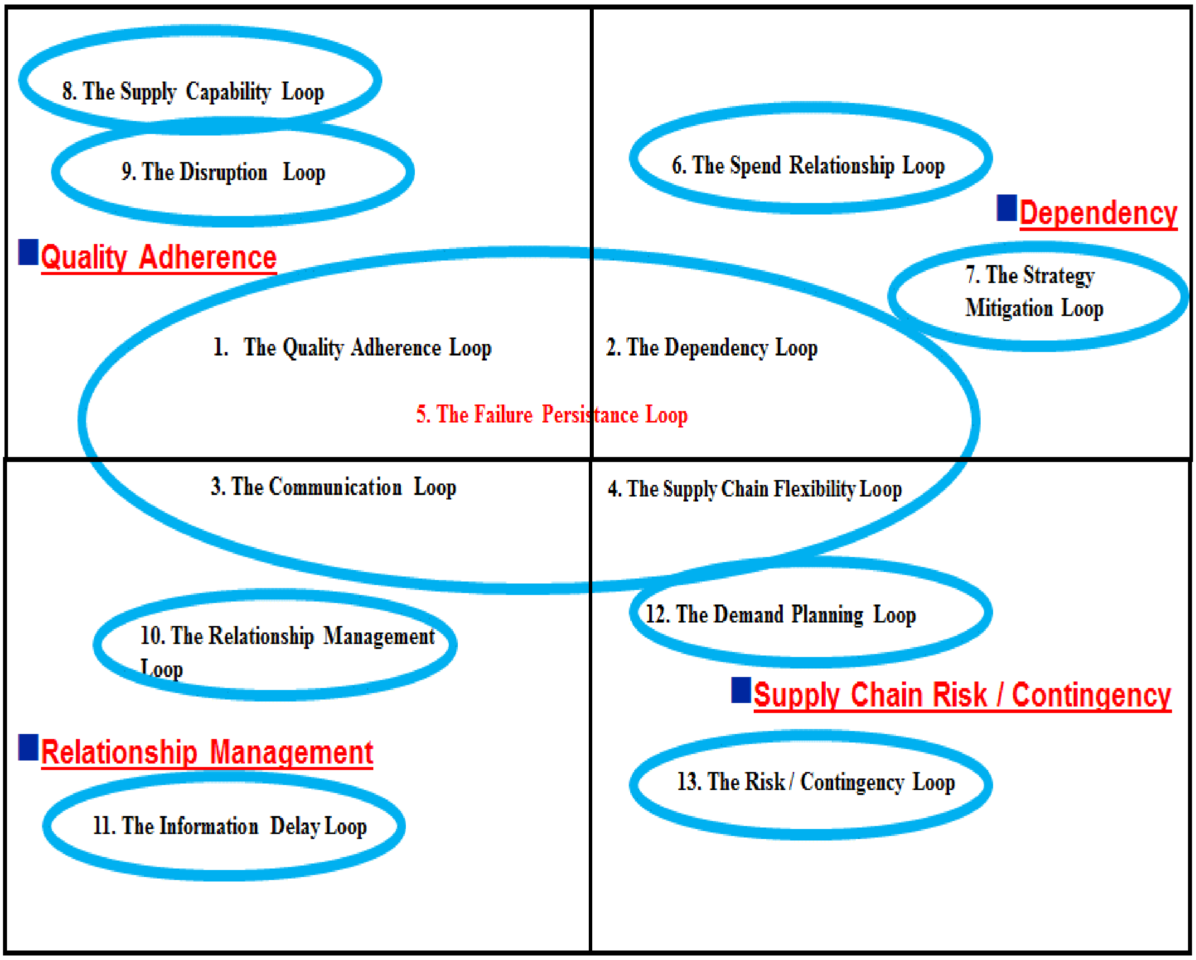
"Supplier Resilience / Robustness"	A first tier supplier's ability to recover from a failure and not cause any disruption to the prime.
"Strategy Deployment"	The term used to describe the development and use of sourcing strategies by the prime. Strategies involve identifying new or alternative suppliers and deciding what, from where, and when to source components.
"Time to Plan"	The length of time the prime has to plan material deliveries with the first tier supplier.
"Understanding of Requirements"	A first tier supplier's ability to understand a component specification given to them by the prime and then convert the requirement into a manufactured component.
"Vacillation"	The inability by supply chain managers at the prime to decide between different opinions or actions when faced with a failing supplier.

5.10 Chapter Summary.

The purpose of Chapter 5 was to show how the research evidence and findings were initially coded and then used to develop the first iteration of the causal loop model. Throughout Chapter 5, the data was gathered together, categorised and used to develop causal variables. Following on from the variable creation process, interactions between each of the variables were identified and analysed, culminating in the introduction of each of the causal loops. By conducting the coding process from step one through to step eight as described in Chapter 3, all of the semi-structured interview data from both sides of the dyad was analysed and captured. The loops were then formulated using variables developed from the findings made during the exploratory phase and used to highlight causes and effects that result in persistent supply chain failure. It was also found that all of the loops that made up the model could be placed within four dominant themes as shown in Figure 5.15.

As a consequence of a workshop conducted at the prime significant changes and improvements were made to the failure persistence model in order to develop a model that could be used by managers to define, understand interaction between variables and subsequently mitigate against persistent supply chain failure. The observations made by the workshop participants and the changes made are documented during Chapter 6.

Figure 5.15 Failure Persistence Model Key Themes.



Chapter 6 Causal Model Validation Phase.

The purpose of Chapter 6 is to analyse and review comments, observations and critique of the failure persistence model captured during the model validation workshop (described in Chapter 3) held at the prime's facility. The purpose of the workshop was to test the validity and applicability of the model and to seek improvements and refinements where justified. All causal loop diagrams must be robust and justifiable to achieve consensus of opinion (Morecroft, 2009).

The discussion and feedback highlighted throughout Chapter 6 serve to strengthen the methodological rigour of multiple case study research (Thomson and McLeod, 2015). A further aim of the workshop was to not only validate each individual loop, but also to guide the evolutionary development of the causal loop model towards becoming a tool that could be used to help supply chain managers identify, understand and mitigate failure. Once each of the failure persistent loops are examined and all of the comments and observations are discussed, a final iteration of the failure persistence model is presented along with a detailed description of the changes made.

For most of the participants, it was the first time they had been exposed to the concept of causal loop diagrams. Therefore a full explanation of the model was given prior to the workshop group sessions to ensure that the participants understood the basis for each loop. Below, the loops are presented individually following the same sequence used in Chapter 5. To further enhance the findings from the workshop, all of the captured comments relevant for a loop are included in a table accompanying that loop. Alongside these, each loop is labelled to indicate the position on the loop to which the observation relates and is matched to a corresponding position number in each table.

6.1 Prime Validation and critique of the Failure Persistence Model.

As discussed in Chapter 3 (Methodology and Design), the workshop was attended by nine supply chain professionals (here called 'the participants') representing multiple departments ranging from supply chain and operations to engineering functions. The workshop sought to identify those aspects of the model that truly reflected current reality and those that the participants found problematic or difficult to understand. To facilitate detailed analysis and critique the participants were divided into three breakout groups during the workshop, each led by one of the research team. Each of the observations presented in this Chapter originated from the group feedback sessions conducted during the workshop, which were captured on flip charts by each group as well as recorded with the use of Dictaphones. In summary, the agenda for the workshop was as follows:

- Introductions and Presentation of Workshop Aims – What is persistent supply chain failure.
- Workshop Part 1.
    - Group Session – Causal loop diagrams.
    - What are the causes of persistent supply chain failure? – validating the failure persistence model.
- Lunch Break.
- Workshop Part 1 Continued.
    - Causal Loop Diagrams.
    - Group feedback session.
    - Validation of the failure persistence model.
- Feedback session.
- Close.

Details of all comments and observations are presented below, one loop at a time, eventually leading to the development of the completed causal loop model. Table 6.1 provides a summary of the main issues with each loop as discussed by the workshop participants.

Table 6.1 Type of Issues Captured during the workshops.

Position	Type of Issue	Description
1	Naming convention	Identified issues with the name chosen for the variable.
2	Time Delay	Identified issues with the placement and usage (or lack) of time delay marks between variables.
3	Linkage	Identified issues with relationships / interactions between the variables in the loop.
4	Polarity	Identified issues with relationship / interactions between variables i.e. do the interactions have a positive or negative effect in the loop.
5	Directionality	Identified issues with the sequence of variables within each loop.
6	Missing Loop	Additional loops that were identified during the workshop as a result of captured observations taken from the feedback sessions.

6.1.1 The Quality Adherence Loop.

The quality adherence loop shown in Figure 6.1 was the first loop to be discussed during the feedback presentation session. The quality adherence loop was developed in recognition of the difficulties suppliers face when trying to adhere to the prime's quality management system.

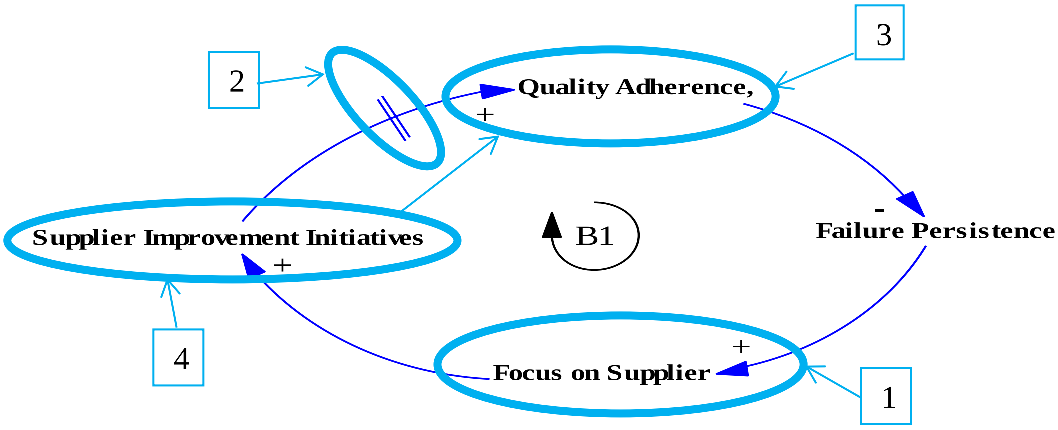


Figure 6.1 Quality Adherence Loop.

Table 6.2 Quality Adherence Loop Group Feedback.

Loop	Position	Type of Issue	Observation
B1	1	Naming convention	Focus on Supplier is it a positive or negative variable It is not positive dialogue
B1	2	Time Delay	Time delay conventions: Why applied only on a few?
B1	3	Linkage	Relationship between the Supplier Improvement Initiatives and quality Adherence - Dependency has an impact on this relationship. Question: would suppliers agree?
B1	4	Naming convention	Supplier improvement (activities)

The observations made regarding the quality adherence loop set the tone in terms of the language used to comment on each issue. Position 1 shown in Figure 6.1 and described in Table 6.2 was captured as a problem with the naming convention of the 'focus on supplier' variable and the polarity relating to it. The polarity between the 'failure persistence' and 'focus on supplier' variables was questioned. The problem was described by a participant: *"You've got that down as a positive [Failure Persistence increases Focus on Supplier]. It could be a negative, so it could be open to debate".* This was also the first indication of the significance placed by participants on using accurate naming conventions within each loop and the importance of polarities making intuitive sense. Each variable name and each polarity needs to be made crystal clear in a future iteration in order to facilitate understanding of the complete model. This will further improve the usability of the model.

The observation highlighted in position 2 also focuses on an issue that was to recur in the validation process – the implementation and interpretation of time delay symbols. It became apparent that time delays could be open to interpretation because their inclusion was mostly based on the mental models described by the participants (Groesser and Schaffernicht, 2012). Time delay placements need to be fully backed up with firm evidence, logic and reasoning, otherwise interpreting the model as intended could prove difficult. Being able to interpret the model is a critical factor (Morecroft, 2009) because each loop seeks to show contributory causes of persistent failure over time.

The issue highlighted in position 3 relates to comments regarding the ‘quality adherence’ variable and its relationship with the ‘dependency on supplier’ variable. It was noted that the relationship between supplier improvements and quality adherence can be context specific and could depend on the circumstances surrounding the relationship between the prime and the supplier (Kähkönen, 2014). The example given was that a supplier’s willingness to participate in improvement activities can rely on how dependent they are on the prime. Captured comments also hint at some issues with the directionality of the sequence of events in the loop.

The issue highlighted in position 4 relate to a debate regarding the naming convention of the ‘supplier improvement initiative’ variable. The workshop participants argued that the naming convention ‘supplier improvement initiative’ seems to imply the prime will effectively push suppliers for an improvement. This narrative was met with disapproval by some workshop participants who suggested that improvement was a joint activity between the prime and first tier supplier. The loop was subsequently amended in order to reflect the observations made (see full description of changes later within the Chapter).

6.1.2 The Disruption Loop.

The disruption loop shown in Figure 6.2 generally gained approval from all of the participants and the discussion involving the interactions between variables within the disruption loop validated the link between disruption and short term quick fixes.

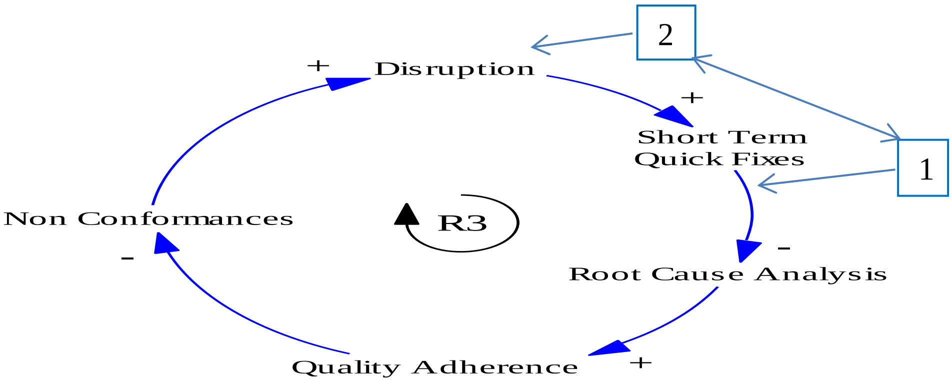


Figure 6.2 Disruption Loop.

Table 6.3 Disruption Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R3	1	Time Delay	Time delay conventions
R3	2	Missing Loop	New loop suggested - Disruption increases short term quick fixes therefore short term quick fixes increases the effect of disruption which is a closed reinforcing loop.

The participants described this loop as closely reflecting actions and consequences experienced by the prime: *"We reflected on the fact that with the Loop R3 we recognise a lot of short term fixes versus root cause and proper fixes. So loops B1 [Quality Adherence] and R3 resonated a lot in terms of the prime's behaviour".*

As per Table 6.7 (described later), discussions revolved around the removal and subsequent adding of alternative variables to the loop and incorporating a time delay mark combined with the possibility of adding an extra loop. This was suggested in order to acknowledge how the interaction between variables evolve slowly (denoted by position 1). These issues were debated by the participants in relation to position 2: *"If we look at loop six, we were debating between supplier audits and process compliance - was there actually a supplier improvement initiative in that loop? So what actually drives from the audit to actually get compliance? There's obviously something happening and that would be an improvement activity. Again, the time delay and then we are drawing a link, also creating another link for yourself which was linking process compliance right round to root cause analysis on R3".*

However, findings from the exploratory phase and comparable comments made during the workshop suggest that this is more of a desired outcome by the prime, rather than a reflection of reality. Although there was a suggestion that the prime was actively working on initiatives to reduce disruptions through conducting root cause analysis. However, the empirical evidence indicates that current reality and practices are less optimistic for persistently failing suppliers. A more realistic representation of the actual sequence of events that occur would see a link from ‘disruption’ to ‘short term quick-fixes’ and then back again. Therefore, a vicious reinforcing cycle is created, i.e. an increase in disruptions causes more short term fixes, because the driving imperative for the prime is that it always needs to supply parts to production and assembly operations. Resources tend to be dedicated to mitigating disruption rather than implementing an initiative and having the luxury of spending time trying to understand the root cause of the problem, which contributes to repeat failures happening. The loop was subsequently amended based on the observations provided.

6.1.3 Sub-Tier Capability Loop.

The main issue of debate during discussion focusing on the sub-tier capability loop 6.3, was whether an increase in the number of ‘non-conformances’ had the effect of triggering more ‘supplier audits’ and more generally influenced the purpose of audits.

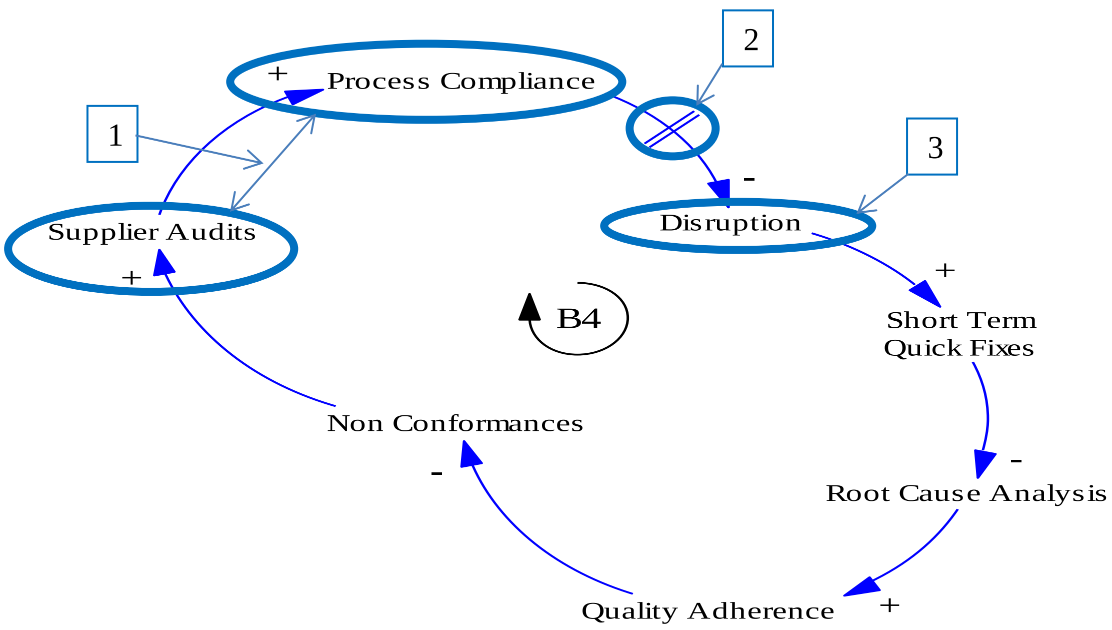


Figure 6.3 Sub - Tier Capability Loop.

Table 6.4 Sub-Tier Capability Loop Group Feedback.

Loop	Position	Type of Issue	Observation
B4	1	Directionality	Supplier Audits - Adds improvement before compliance?
B4	2	Time Delay	Time Delays
B4	3	Missing Loop	Link Process compliance into RCA as a positive variable

The frequency of audits is often prescribed by industry standards. The focal point of the discussion centred on the number of industry requirements that go into developing an audit plan. However, it was acknowledged that non-conformances do play a part in deciding the frequency of audits at suppliers although they are not the determining factor as highlighted in position 1: *"I think that's perhaps the supply chains view of what is happening. So I think there is a misconception driven by the supply chain in terms of does non-conformance drive supplier audits? Non-conformances probably increases the frequency of the prime's audits as we recognise a high risk supplier so rather than going I'll touch these guys every two years or every three years with a full blown Sabre audit, the audits will take place every year".*

The linkage between these variables highlights the perception by the prime that a greater number of audits will increase process compliance and therefore reduce the level of disruption. The inclusion of the time delay variable was questioned as indicated in position 2 because it was felt that disruption could occur at any time. However, despite the number of audits any given supplier will have to undergo, frequent audits do not seem to stop disruptions from happening. Again, the resulting observations made by the participants resulted in the loop being subsequently amended.

Participants also reported that the amount of supplier development initiatives had also dropped off in that period. The participants did, however, recognise how the prime's quality function operates in relation to loop B4 and how it interacts with the rest of the business and the supply chain as per position 3: *"There's a third party coming into that environment and our quality and engineering teams are moving right to the top of the B4 cycle, in terms of conducting supplier audits, process compliance, process audit. That's where the team's going. So we're pushing ourselves right to the top of that quadrant".*

6.1.4 The Dependency Loop.

The participants then discussed the dependency loop shown in Figure 6.4 during the feedback session. Dependency is defined as an over-reliance on a single supplier because of a lack of sourcing options. Conversely, the supplier may also have an over-reliance on the prime due to a high percentage of its turnover emanating from the prime.

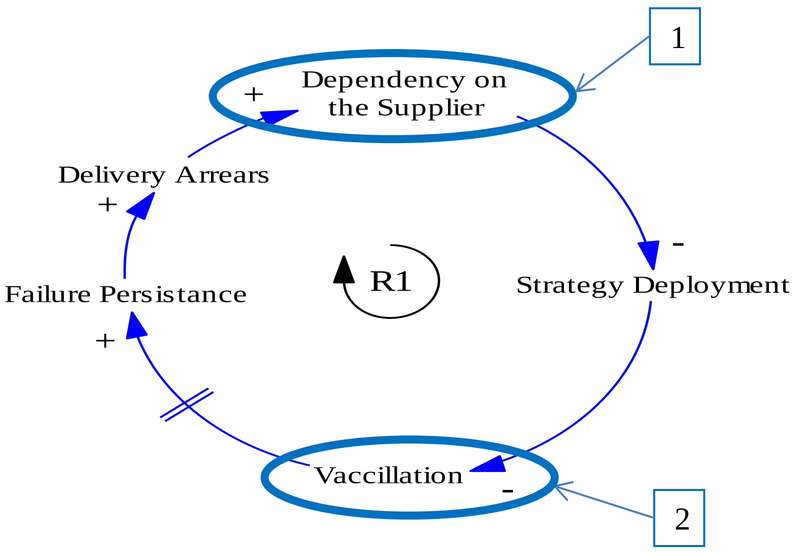


Figure 6.4 Dependency Loop.

Table 6.5 Dependency Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R1	1	Polarity	Dependency on supplier reduces strategy deployment - other way around? You would move to reduce dependency.
R1	2	Naming convention	A tick indicating agreement with the vacillation variable

Position 1 in Table 6.4 concerns the polarity of the link between the ‘dependency on supplier’ and ‘strategy deployment’ loops, which has been captured with a minus symbol, i.e. indicating a reduction in the amount of strategy deployment work that the prime needs to conduct if the prime is dependent on the supplier. The thinking behind this interaction also took into consideration the resources available at the prime. Findings from the original interviews conducted at the prime suggested that increased dependency on one supplier meant that development and subsequent deployment of strategies was reduced because the prime’s resources were locked into providing the supplier with support to get out of a failure scenario. However, according to some workshop participants: *“If we see a dependency on a supplier, in most commodities we’ve actually got a strategic position that’s trying to reduce that dependency*”.

The comment suggests that the link between the variables in reality could also be shown as a plus sign because the linkage has the effect of increasing the number of strategy deployment activities rather than reducing them. The comment also implies that resources needed to conduct such activities are thought to be available. It may also be the case that buyers at the prime are meant to increase strategy deployment activities if dependency becomes too high to reduce supplier dependency risks. The evidence obtained from this study, however, indicates that the deployment and success of this policy is in reality somewhat different, particularly with persistently failing suppliers.

Position 2 concerns a naming convention issue raised about the use of the word 'Vacillation'. Although there was agreement by participants that vacillation was a contributory cause of failure, it became apparent that not all potential users of the model will be able to understand the terminology. The resulting observations made by the participants resulted in the loop being subsequently amended as part of the next iteration of the model.

6.1.5 The Spend Relationship Loop.

The participants then discussed the spend relationship loop shown in Figure 6.5. The Spend Relationship Loop highlights how spending with a single supplier (i.e. increasing the number of parts allocated to a supplier) increases supplier influence and reduces the prime's leverage in a relationship.

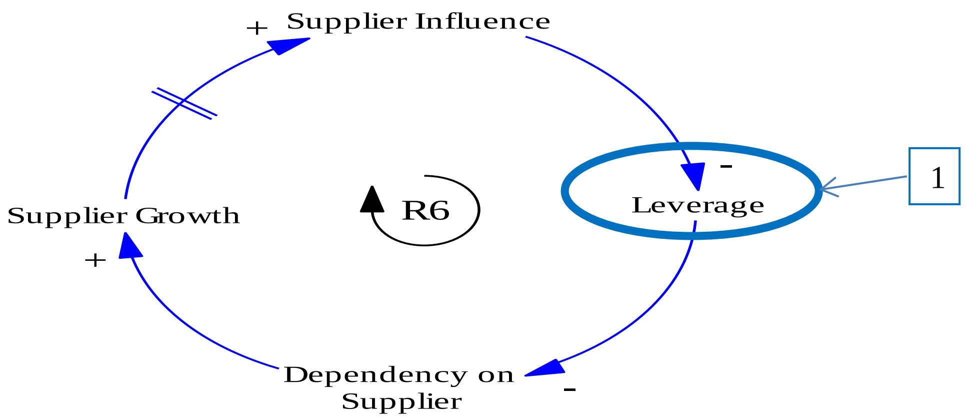


Figure 6.5 Spend Relationship Loop.

Table 6.6 Spend Relationship Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R6	1	Naming Convention	Leverage variable should be more explicit i.e. buyer's leverage

The only problematic issue concerning the spend relationship loop was the chosen variable name as indicated in position 1. However, some participants identified further issues with the loop resulting in more discussion: *"The first observation in R6 is the linkage between supplier growth and supplier influence, we raised the question; is it really supply growth that is linked to supply influence or is it something else? What* *we tend to find is that we have suppliers who have a lot of influence because of specific capability they have, not necessarily because they are growing".*

If a supplier becomes dependent on the prime, it might be because a supply contract with the prime represents a significant amount of turnover for the supplier's business. Type of parts will fall into one of two categories (1) technologically advanced parts with few suppliers (possibly IPR owner and / or design to order) or (2) low technology components equating to a large number of parts (mostly make to print parts). Irrespective of who is dependent on whom, the prime will still run the risk of disruption because of either a lack of alternatives or through having to conduct a large scale source change to move the parts to another supplier. The participants discussed linkages with the dependency on supplier variable at some length in order to identify if they agreed with the interactions between variables: *"Yeah, there was a long discussion on the dependency on supplier, whether quality adherence always leads to dependency. If everyone is a hundred percent quality adhering, then it won't lead to dependency, it is very context dependent. Only if you're in an environment where most or at least significant portions aren't performing then one supplier's quality adherence would create dependency".*

Again, the captured observations made by the participants resulted in the loop being subsequently amended.

6.1.6 The Strategy Mitigation Loop.

The main observation made regarding the strategy mitigation loop shown in Figure 6.6 was captured during discussion of the R1 loop. The strategy mitigation loop highlights activities that the prime conducts in order to reduce supplier dependency and increase the prime's leverage in the supply chain. Discussion during the validation workshop sought to identify if the participants agreed that more consistency in strategy development and deployment activities would help to increase the prime's overall leverage in the supply chain.

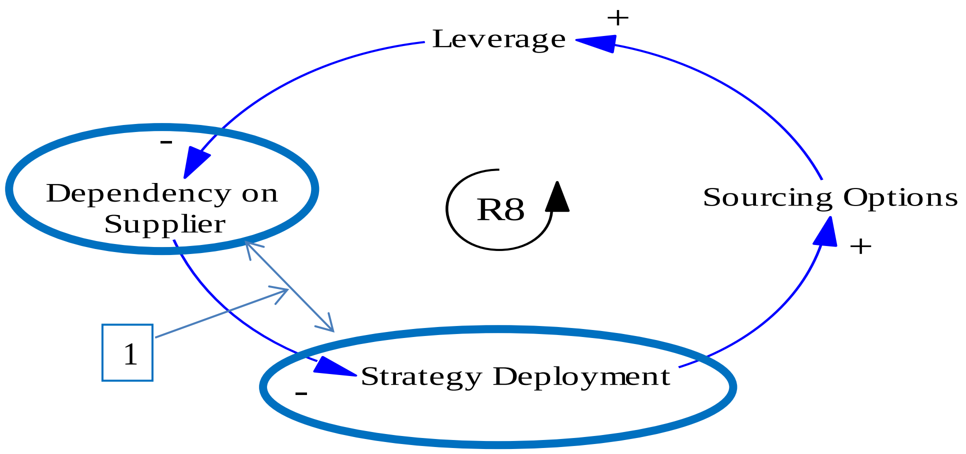


Figure 6.6 Strategy Mitigation Loop.

Table 6.7 Strategy Mitigation Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R1	1	Polarity	Dependency on supplier reduces strategy deployment - other way around? You would move to reduce dependency.

Position 1 concerns the issue of the polarity between the ‘dependency on supplier’ variable and how it links with the ‘strategy deployment’ variable, which has been shown as a plus (positive) relationship in the loop. Discussion occurred because there was a feeling by some that the relationship could actually stimulate a greater drive for strategy deployment rather than having the effect of reducing it. Another issue with the naming of the ‘leverage’ variable in loop R6 was that it needed to be more explicit to facilitate greater understanding, for example ‘buyers leverage’ was suggested. Overall, the participants agreed that more consistent strategy development and deployment would help to increase their overall leverage in the supply chain. Therefore, the loop was subsequently amended.

6.1.7 The Supply Chain Flexibility Loop.

The purpose of this causal loop diagram is to demonstrate how resourcing activities can enhance the prime’s supply chain flexibility. A question mark regarding the placement and absence of time delays was the only aspect documented regarding the supply chain flexibility loop Figure 6.7.

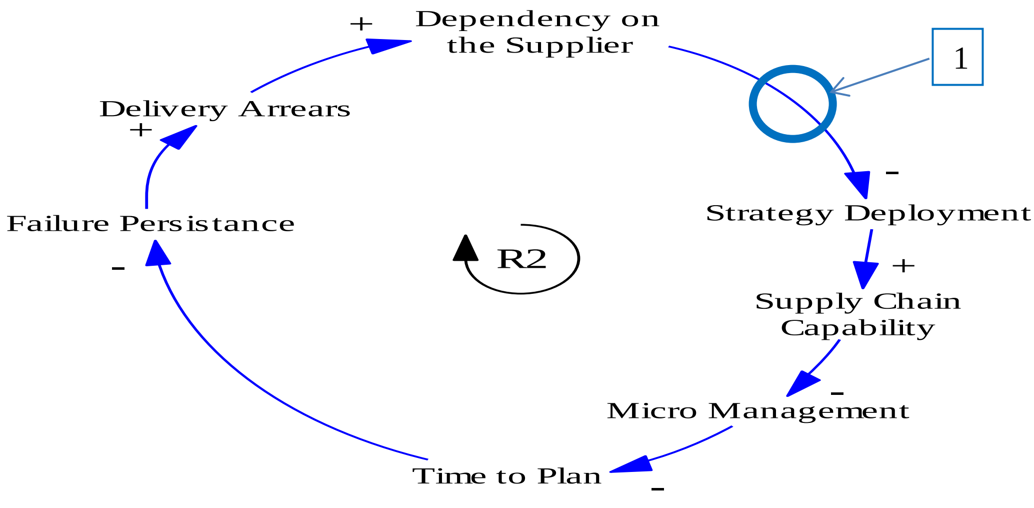


Figure 6.7 Supply Chain Flexibility Loop.

Table 6.8 Supply Chain Flexibility Group Feedback.

Loop	Position	Type of Issue	Observation
R2	1	Time Delay	Should the loop contain more time delays as the effects between each of the variables take time to develop?

The discussion regarding Position 1 concerned the participant's belief that each negative interaction between variables took time to develop into significant issues for the prime, therefore a time delay mark should have been included. However, the actual discussion and debate surrounding the loop went into much greater detail. The major talking point was around the understanding of how 'supplier dependency' occurs in reality and what the actual effects are on the prime. The participants went on to suggest that it could manifest itself in a number of ways depending on the type of commodity that the supplier traded with the prime: *"Moving from delivery arrears into dependency on supplier question mark. We have why? Because, depending on where we are commodity wise, it could be a negative. It could actually reduce our dependency because we've already got options to go and move from supplier A to supplier B and it forces them into taking our options. However, we've been engaging in risk and revenue sharing on really complex components. In this case the polarity is a positive because we've got no options capability-wise or options commercially"*.

Further comments made by the participants went on to suggest that there are different levels of dependency: *"It's a realisation that you're dependent on a supplier and you can take various actions depending on that supplier. If it is risk and revenue, their options are limited. If it is a C class supplier, you've got more options available"*.

However, what was made less clear was the distinction between the categories most of the persistently failing suppliers fall into. Evidence from exploratory phase one findings indicate that there are issues with both risk and revenue and C class suppliers irrespective of commodity types. Despite the discussion during the workshop, no changes have subsequently been made to the R4 loop.

6.1.8 The Demand Planning Loop.

The demand planning loop in Figure 6.8 sought to capture how rescheduling disruption can reinforce to feedback and affect the overall supply chain. Observations captured during the exploratory phase suggested that changes were frequently being made by the prime leading to a reduction in the first tier supply chain's ability to achieve their agreed lead-times. Therefore, the aim was to identify if the workshop participants agreed that regular changes had a detrimental effect on the first tier supply chain.

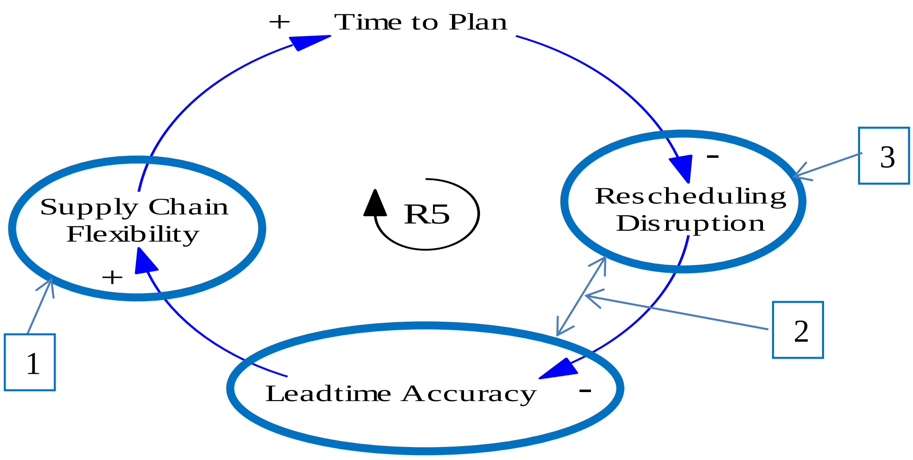


Figure 6.8 Demand Planning Loop.

Table 6.9 The Demand Planning Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R5	1	Naming Convention	Supply chain flexibility or agility - discuss?
R5	2	Naming Convention	Leadtime, capacity or operational efficiency?
R5	3	Directionality	Link between rescheduling disruption and leadtime accuracy - other way round i.e. first leadtime accuracy then rescheduling disruption.

Evidence suggests that the main contributory factor that makes the loop feedback and potentially develop into a vicious circle is the frequency of demand changes made by the prime. The issue noted in position 1 refers to the use of the term 'flexibility', which was challenged by the participants. They suggested that the correct term should be 'Agility'. Rescheduling disruption affects the prime in two ways, (1) by consistently changing delivery dates, the prime can effectively make the supplier become a persistent cause of delivery disruption, and (2) when the prime needs some flexibility, it does not exist in their supply chain because they have systematically weakened the supplier's capability. The described sequence of events was recognized by all the workshop participants. However as can be seen from the issues raised in Table 6.7, positions 2 and 3, there were some queries regarding the naming conventions, placement of the variables and directionality of the loop: *"It came bouncing back down to lead-time accuracy, is it lead time accuracy or is it actually capacity? Customers actually indicating it probably started with capacity, you know through iterations affects lead time. It's the naming convention. We might actually get back to capacity on this, or is it actually operational efficiency that sits there, so not lead time accuracy or capacity but actually operational efficiency? So rescheduling disruption makes your operational efficiency lower"*.

In addition, the participants suggested that perhaps the 'rescheduling' variable was too general because planning problems could occur in parallel to rescheduling of items for example by the prime forgetting to order parts in the first place and then chasing them up with an unsuspecting supplier: *"We're talking about this loop of rescheduling disruption. Question, should it be rescheduling or just scheduling? Classic case this morning, we've had a cock up where we've assumed a supplier is meant to be supplying a part. They don't think they're supplying the part. We've now got a major disruption on one of our programmes because there is no schedule on them. That's not rescheduling, that's just scheduling not happening.*

These comments also highlight an interesting issue with regards to the R5 loop. It assumes that all of the schedules are in place, therefore limiting the risk of disruption. The feedback received suggests that there could be a number of internal oversights including those which lead to orders not even being placed. For instance, it might transpire that a specific component was not even ordered. Therefore, the loop was subsequently amended to reflect the captured observations.

6.1.9 The Risk / Contingency Loop.

The next loop to be discussed was the risk / contingency loop shown in Figure 6.9 during the feedback session. The purpose of the loop is to acknowledge that sourcing components from widely dispersed supply chains has the effect of increasing risk of delivery failure either because of process or first tier supplier capability in certain regions of the world. A further reasons could be because of issues that are out of the control of the supply chain managers such as political factors or natural disasters in a region. It was hoped that this loop would stimulate the workshop participants to reveal their true opinions on the topics and to see if they agreed with what the loop demonstrates.

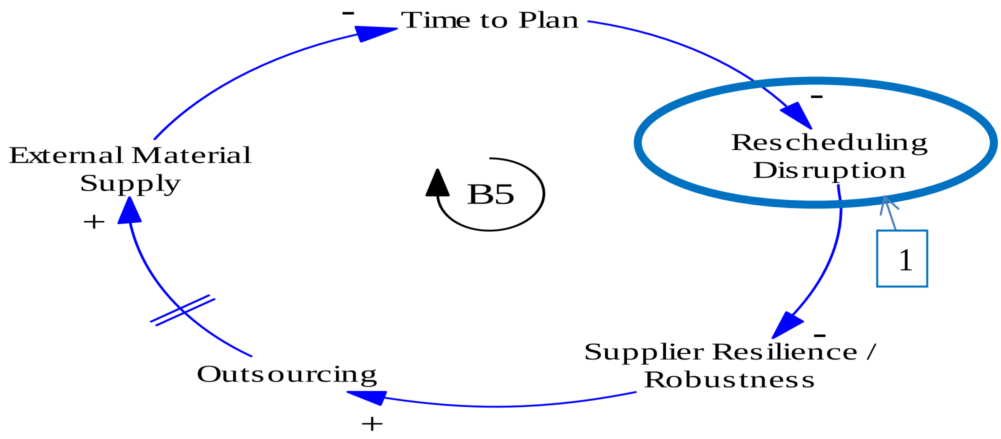


Figure 6.9 Risk / Contingency Loop.

Table 6.10 Risk / Contingency Loop Group Feedback.

Loop	Position	Type of Issue	Observation
B5	1	Naming convention	Supplier Resilience = Supply Chain Resilience

Aside from the issue discussed earlier concerning the naming convention for the rescheduling disruption variable the only other aspect that stimulated further debate was the naming convention adopted for the supplier resilience / robustness variable shown by position 1. The debate centred on whether the terminology should be supply chain resilience rather than supplier resilience? The justification for this thinking was that if a supplier in isolation is resilient and robust, then that does not necessarily mean they would have a positive impact on the rest of the supply chain and be able to prevent persistent failure. The supply chain in its entirety would need to be resilient in order to reduce the impact of failure in the loop.

Again, the captured observations made by the participants resulted in the loop being subsequently amended.

6.1.10 Communication Loop.

The next set of observations discussed during the feedback session involved the communication loop shown in Figure 6.10. The purpose of the communication loop is to illustrate the causal relationship between performance and level of communication between the prime and first tier suppliers. Opinions were sought from the workshop participants as to whether they agreed that communication with first tier suppliers played on important role in reducing the causes and the effects of persistent supply chain failure.

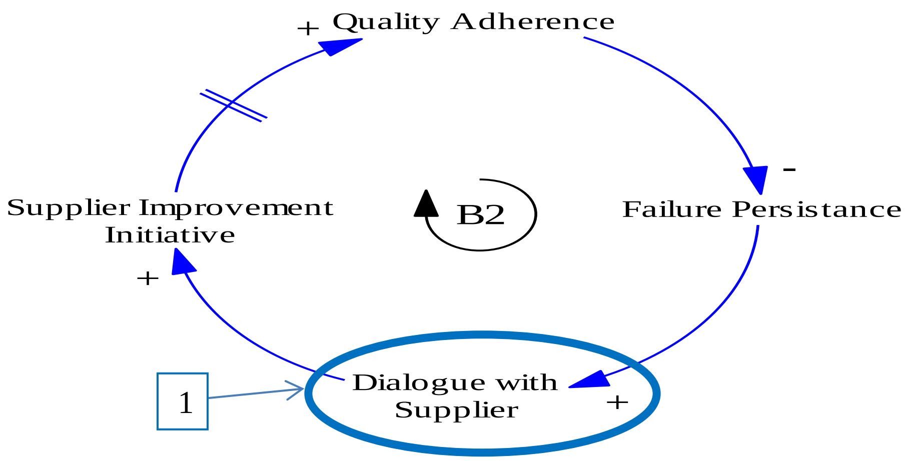


Figure 6.10 The Communication Loop.

Table 6.11 Communication Loop Group Feedback.

Loop	Position	Type of Issue	Observation
B2	1	Naming Convention	Dialogue with supplier needs to be more explicit to the client i.e. (Optimized) dialogue with supplier

The issue raised in position 1 of Table 6.10 highlights one of the variables that generated much discussion and debate by the whole group. The participants had trouble linking the variable with causing an increase in 'supplier improvement initiatives': *"We weren't too sure whether the link between dialogue with supplier and supplier improvement initiatives was particularly good because, depending on the relationship you have with the supplier and where the power may be, you may not get any improvement initiatives out of that dialogue. So that's where we started to think of the term optimized dialogue"*.

The observation supports the notion that the polarity is context specific. If 'dialogue with the supplier' is not good enough then there is a greater possibility that supplier improvement initiatives could be implemented in such a way that it leads to the chance of reduced quality adherence. There were no comments however, regarding the link between failure persistence causing an increase in dialogue with supplier. The debate centred on the quality and frequency of the communication and whether it leads to greater cooperation with the supplier. The captured observations made by the participants resulted in the loop being subsequently amended.

6.1.11 Relationship Loop.

The next loop to be discussed was the relationship loop shown in Figure 6.11. Findings from the exploratory phase highlighted how there is often a lack of understanding emanating from both the prime and first tier supplier concerning actual requirements needed to satisfy demand. The aim of this discussion was to identify whether the workshop participants agreed with the loop and could see the association between problems with technical specifications, forthcoming demand fluctuations and changes to the quality management system and relationship management.

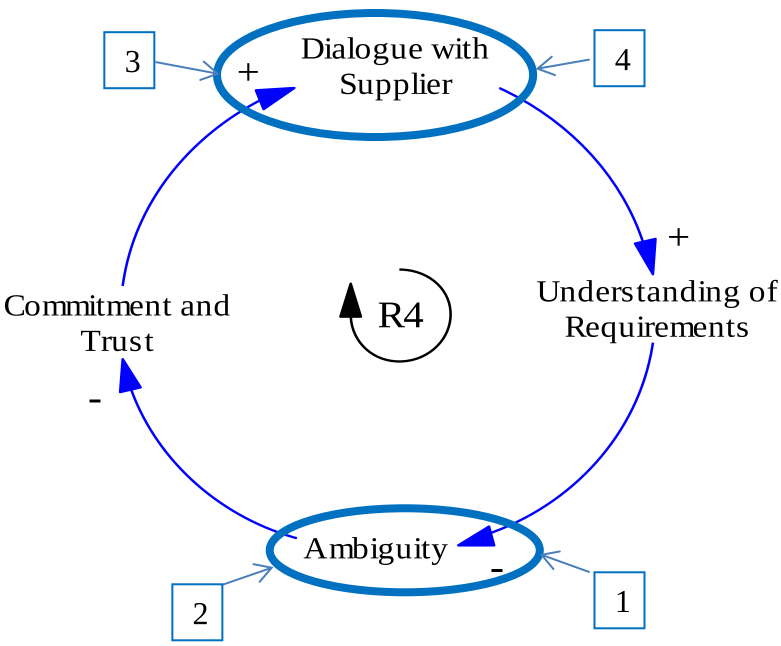


Figure 6.11 Relationship Loop.

Table 6.12 Relationship Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R4	1	Naming Convention	Ambiguity reduces commitment and trust - terminology needs to reflect information. Is this always the case? Could it (Ambiguity) be left out?
R4	2	Linkage	Suggested added variable - Understanding of requirements leads to increased validation which then reduces ambiguity?
R4	3	Naming Convention	Dialogue with supplier - quality and appropriatness of dialogue Forward / Targeted dialogue with supplier.
R4	4	Naming Convention	Dialogue with supplier needs to be more explicit to the client i.e. (Optimized) dialogue with supplier.

As highlighted in Table 6.11 the issues raised in relation to position 1 involved discussions concerning the 'ambiguity' variable and the desirability of removing it. Participants felt that the ambiguity variable had somehow become redundant because of the linkage between 'understanding of requirements' and 'commitment and trust'. An alternative was proposed as per position 2, which suggested an additional variable and linkage should be created to better reflect the sequence of events and reality. As per position 3 and 4, one group of participants mentioned that the 'dialogue with supplier' variable should be amended and be more explicit: "*In terms of R4, starting again with optimized dialogue (the groups earlier suggested alternative to dialogue with supplier) we accepted that this did increase the understanding of requirement. If it is not optimized, it may actually reduce. So I think that was good. If you have an understanding of your requirements then we recognise that there will be a reduction in ambiguity. We weren't entirely sure ambiguity had to be there. If you improve your understanding of requirements you will increase your commitment and trust".*

Further insightful comments were also provided on the R4 loop. These comments however, did not touch on ambiguity directly but it did give some insight into the possibility that the participants found the concept and 'understanding of requirements' variable to be problematic. The concern behind the observation is perhaps because there was an almost automatic assumption that the variable only applies to the supplier when in fact it was meant to apply to the prime as well: *"We're not very good necessarily at communicating within our own organisation and therefore we may have lots of dialogue with the supplier but it may not be consistent and therefore we don't drive better understanding".*

The participants suggested a connection between quantity of communication with the supplier and the quality of information: "*Yeah, I think a later conversation we had was around quantity of dialogue with supplier or quality? Because if it's quality,* *that fits nicely, we'd agree with that".* As a result of the feedback, the R4 loop was subsequently amended.

6.1.12 Information Delay Loop.

The final loop to be discussed during the feedback session was the information delay loop shown in Figure 6.12. The aim of this discussion was to identify whether the workshop participants agreed that a reduction in dialogue with the supplier throughout the supply chain has the effect of causing a lack of understanding of requirements within the supply chain. The overall effect is subsequent delays in delivery.

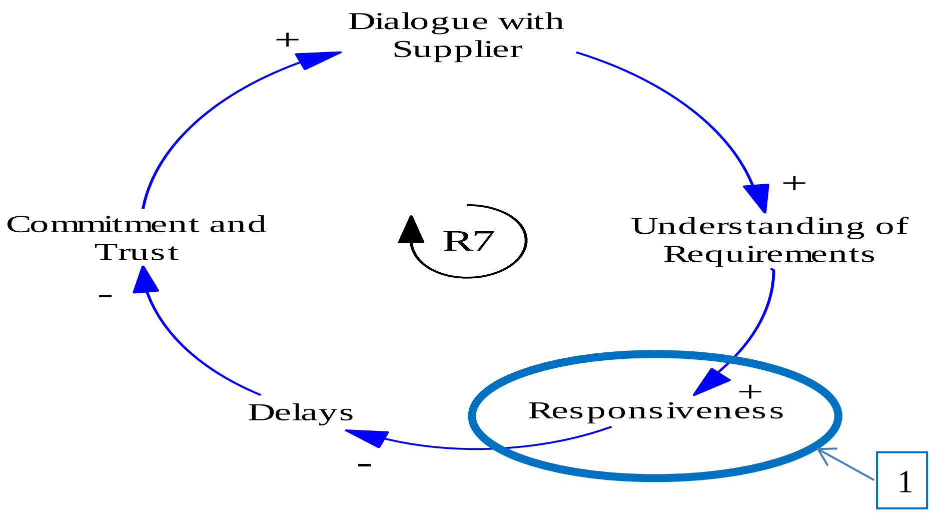


Figure 6.12 Information Delay Loop.

Table 6.13 Information Delay Loop Group Feedback.

Loop	Position	Type of Issue	Observation
R7	1	Naming Convention	Responsiveness needs to be more explicit to the client i.e. (supplier) responsiveness.

The issues raised regarding position 1 highlights how the main talking point regarding the information delay loop was the interpretation and actual effect of the 'responsiveness' variable: *"So then in R7 from understanding of requirements it increases responsiveness. We had a little bit of a delay around this. Understanding of requirements, I can make it very clear to you what I need, but it doesn't mean you can deliver it. What it does mean is you can give me a message immediately that say's no I can't do that but this is what I can do. So we changed that to say supplier responsiveness in the sense of their ability to respond to your request".*

The 'responsiveness' variable was meant to be applicable for both the first tier supplier and the prime based on findings from the exploratory phase. The responsiveness variable indicates that suppliers will not proceed with producing a part until they understand exactly how to produce to the correct requirements, hence 'understanding of requirements' increases responsiveness. A requirement is something that conforms to the prime's production parts approval process (PPAP) process, which was mentioned during the workshop. However, some of the suppliers seem to suggest that when they requested such information from the prime, often there would be a significant delay before they received a response. The resulting effect would be a delayed part. Other potential effects could lead to commitment and trust issues as a consequence of persistent failure in terms of delivery. The concept proved problematic with all of the participants who took part in the workshop. They noted that it depended on the type of parts: *"That is what I was trying to sanitize, where it was coming from in the model? I might expect it to come out in the bottom half of the model, in terms of the relationship and the risks like planning aspects. I'd expect probably a real negative vibe from our supply chain. Top left, I'd expect it to be positive. Top right, which is about the strategy, it depends where the supplier sits in our strategies".*

Again, the captured observations made by the participants resulted in the loop being subsequently amended.

6.1.13 Failure Persistence Loop.

The main purpose of the failure persistence loop shown in Figure 6.13 was to demonstrate how all of the loops, when combined, result in the effect of increasing failure persistence, along with the counter-balancing activities that the prime conducts in order to reduce the effects and the persistence of failure. Again, participants were invited to provide feedback because the loop encompasses all four dominant themes that represent key aspects of the model that interact to cause persistent supply chain failure.

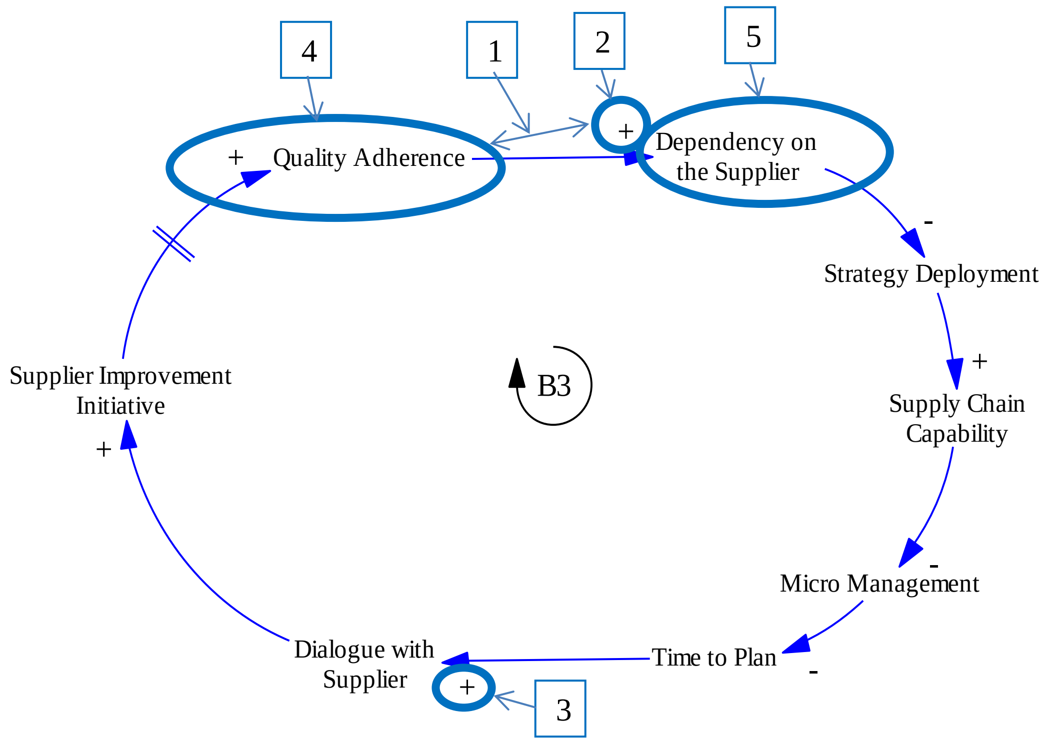


Figure 6.13 The Failure Persistence Loop.

Table 6.14 Failure Persistence Loop Group Feedback.

Loop	Position	Type of Issue	Observation
B3	1	Linkage	Question mark against the link between quality adherence and dependency.
B3	2	Polarity	Also a question mark against whether this increases dependency on supplier.
B3	3	Polarity	A question mark against whether time to plan increases dialogue with supplier.
B3	4	Linkage	Comments on the Link between quality adherence variable and dependency on supplier - Context dependent not universal. Only if performance is unique, if everyone performs it does not lead to dependency.
B3	5	Naming convention	Quality adherence increases supplier attractiveness.

The combined loops show the feedback effect of failure persistence, resulting in a vicious cycle, which becomes very difficult to stop. The main problematic issues that were pointed out earlier were revisited here for further validation, as indicated in positions 1 and 4 in Table 6.14. Position 5 highlights a naming convention that was suggested by the group because it was thought that the description 'supplier attractiveness' was more appropriate than 'dependency on supplier'. The suggested change in variable name was because there was a general consensus between the groups that if a supplier adheres to the quality management system they would therefore become more attractive because of good performance. The likely effect of this is that the prime becomes more inclined to load the supplier with more business, which ultimately has the effect of increased dependency on the supplier. Position 3 highlights observations made by the participants concerning the polarity between the 'time to plan' variable and 'dialogue with the supplier': *"If you have time to plan, does that increase your dialogue with supplier? Would it not reduce the dialogue with the supplier?"*

It was then communicated to the participants that the linkage was trying to convey the effect of compressed timescales on the prime's ability to supply on time to the agreed schedule date. The resulting conversation led to the following acknowledgement: *"If we put time to plan in the context of a material requirements planner (MRPC) role, when we said time to plan, we mean go and have dialogue with your supplier about your order book. That's what we are actually saying. Order book reviews are a formal sit down with a supplier".*

The linkage between the 'time to plan' and 'dialogue with the supplier' variables is aimed at demonstrating how by having more time to effectively plan the workload there should be an increase in the amount of dialogue between the prime and first tier employees. Participants also mentioned that more and better communication can prevent failure from happening: *"From a communication point of view, rather than delivering, because if you double your demand overnight, it's not going to happen, but they [First Tier Supplier] will tell you what they can do and when they can do it immediately. That will then reduce any delay in communication and reduce the delays in delivery".*

6.2 Section Summary.

The overall reaction to the model and the strong level of engagement and participation combined with the level of interest and enthusiasm shown throughout the day were very encouraging. Given the thorough critiquing of the model, the captured narrative indicated strongly that the participants were able to relate the model to their working experiences as purchasing and supply chain executives and to 'the way things happen' in terms of the prime's engagement with their first tier supply base. This was viewed as a significant achievement by the research team. A participant provided a summary of the applicability of the model in relation to their current operations: *"We see a lot of what we do today [at the prime] in the model and therefore in a lot of the loops I think we agreed with the kind of content that was in there".* That comment was echoed by the rest of the participants. Therefore, the general construction and the identified dominant themes / quadrants that the model fits within were viewed as largely accurate. The overall outcome from the validation workshop suggests that the model is relevant, topical and did not require radical change (see further observations below): *"You're* *clearly recognizing what we're doing relates to a theoretical model that says, actually, theory and practice have come together now and it's actually joined together and there's a sense, if you look at the quality adherence quadrant, it's very much what we're doing today, very much how we actually do business today and how we react today. I think we're actually seeing that maturity and quality is something that we've been talking about for years in terms of failure and it's very low on the radar now, quality within our business, because it's a given and we've got a robust, mature model that looks like that model, I think. Not a lot of debate around that. If you look at the feedback, it was just about the timings and actually do you put that, the improvement activity, in between supplier audits and process compliance? The model itself is actually now driving into identifying where that comes in our supply chain. So that feels like it is representative, that's what we're used to seeing".*

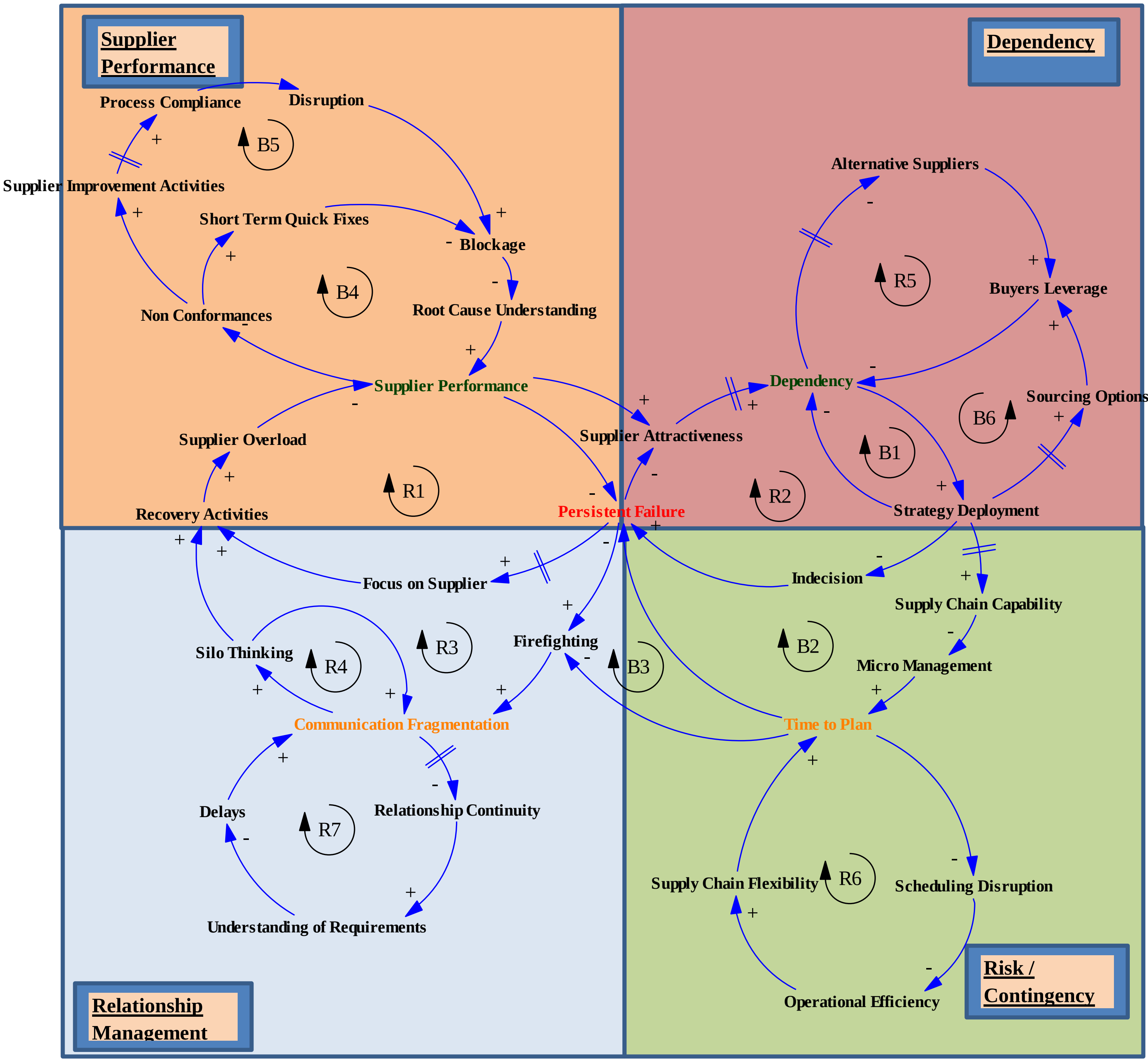
From an evaluation of all the comments, feedback, discussions and critique received from the workshop participants, it was clear that the next iteration of the model should concentrate on developing the following areas:

- Clarifying and strengthening the naming conventions to make them more immediately understandable.
- Re-evaluating some of the linkages / relationships between variables based on new observations and critique provided during the workshop.
- Re-thinking polarity designation within each loop based on comments from the workshop.
- Placement of time delays within each loop based on comments from the workshop.
- Ensure that the cause and effect of persistent failure is more explicit for the target audience within the model.
- Introduce a colour coding scheme into the model to make it easier to follow.

6.3 Post Workshop Persistent Failure Model.

The output of all captured observations and insights from the validation workshop have been brought together to create a revised causal loop model. The updated causal loop diagram model is now entitled the ‘Persistent Failure Model’ and is shown in Figure 6.14 below. The name has been changed from ‘Failure Persistence Model’ in order to be more understandable to the end user.

Figure 6.14 Persistent Failure Model



6.4 Post Workshop Persistent Failure Model.

Throughout the next section we take a critical realism approach (Easton, 2010) to describing the key aspects of the persistent failure model and how it evolved from the original failure persistence model, created as a consequence of findings from the exploratory phase. As with the previous version of the model, Table 6.15 shows how the persistent failure model is divided into four dominant themes / quadrants.

Table 6.15 Post Workshop Persistent Failure Model.

Table 6.15 Post Workshop Persistent Failure Model			
Supplier Performance		**Dependency**	
Loop No.	**Name.**	**Loop No.**	**Name.**
R1	The Supplier Performance Loop	R2	Dependency Loop
B4	Sub Tier Capability Loop	B1	Sourcing Strategy Loop
B5	Disruption Loop	R5	Spend Relationship Loop
		B6	Strategy Mitigation Loop
Relationship Management		**Risk / Contingency**	
Loop No.	**Name.**	**Loop No.**	**Name.**
R3	Communication Loop	B2	Supply Chain Capability Loop
R4	Silo Mentality Loop	R6	On Time Delivery Loop
R7	The Relationship Management Loop		
Persistent Failure Loop			
B3	Consolidation of loops R1,R2,R3,R4,B1 and B2		

The loops have been identified to show (1) activities that the prime carries out in order to counteract the effect of failure that is being caused by reinforcing loops within each dominant theme / quadrant (i.e. B1, B2, B3, B4, B5 and B6), and (2) the issues that perpetuate the reinforcing loops by variables interacting to cause failure to persist (i.e. loops R5, R6 and R7). Key variables from loops within each of the dominant themes have been highlighted / coloured (Supplier Performance, Dependency, On Time Delivery, and Communication Fragmentation). The final version of the model has, in comparison to the first iteration, seven reinforcing loops as opposed to six balancing or goal seeking loops. The second iteration of the model also demonstrates how there are more interactions that reinforce to result in persistent failure. Despite a comprehensive set of processes, procedures and improvement tools available to supply chain personnel at the prime, persistent failure continues to happen. A greater number of time delays were added to the updated Persistent Failure Model based on validation of the original findings from exploratory phase one and further insights captured during the workshop. The time delays added to reinforcing loops show how these loops feedback over time eventually developing into vicious cycle loops if not identified and mitigated expediently by the prime. The time delays that feature within the negative feedback structures represent myopic behaviour by the prime which can result in oscillation of the loop because goal seeking activities being conducted by the prime are delayed or not actioned quickly enough. Therefore persistent failures continue to affect the prime.

6.4.1 Changes to the Quality Adherence Loops.

The first significant change to the persistent failure model is the amendment to the quality adherence loop (B1), which was developed and renamed as the 'Supplier Performance Loop' (R1). Using the term 'quality adherence' implies conformance is about meeting the specification of a component only. However, adherence should mean all aspects of delivering a component to the correct specification at the right time. This is followed by a naming convention change i.e. the quality adherence variable changed to 'Supplier Performance'. It was noted during the workshop that overall supplier performance is of greater concern to the prime than quality adherence, which is considered mandatory. Using the terminology 'supplier performance' had greater resonance with the participants from the workshop. This is because it can result in the supplier becoming a more attractive proposition for the prime in terms of awarding further business: A participant from the group session provided an explanation: *"If we have a good performing supplier, what do we do, we put more work in, and then they rapidly become a poor performing supplier probably down to resource capability, a whole range of stuff. So we take a good performing supplier over time to become a poor performing one"*.

Corresponding to the name change of the complete model, the failure persistence variable was also changed to 'Persistent Failure' to be more understandable to the end user. Further to this, a time delay mark has been added between the 'Persistent Failure' and 'Focus on Supplier' variables to highlight how the variables interact dynamically over a period of time, gradually increasing the focus placed on the failing supplier by the prime as the knock-on effects of failure worsen. The next update of the adherence loop shows how the 'Supplier Improvement Initiatives' variable has been changed to 'Recovery Activities'. The change was made because greater focus on the supplier typically occurs due to a build-up of failures. Therefore, the prime instigates activities that seek to help the supplier to recover from a failure situation rather than improve performance. Supplier improvement initiatives are used by the prime to balance out the effects of failure in the long term whereas the adherence loop portrays reactionary activities carried out by the prime when persistent failures are already reinforcing to reduce supplier performance. The final change to the adherence loop was the inclusion of a new ‘Supplier Overload’ variable. This was added due to comments from participants during the workshop (and also the first tier participants during the exploratory phase) about how the prime often misinterpreted the need for improvement at a failing first tier supplier and subsequently committed unnecessary amounts of resource in order to quickly mitigate problems. This is also symptomatic of comments made by the participants during the workshop about how the prime was good at turning a good performing supplier into a poor one and then mismanaging the recovery effort. Overall, the loop has changed from initially being one with interactions that conspired to reduce the effects of persistent failure to one that actually reinforces failure as a consequence of overloading the supplier.

The next set of improvements to the model was to rearrange the sub-tier capability loop (B4) around with the Disruption Loop (R3). In the final persistent failure model they are now displayed as a Sub-Tier Capability Loop (B4), which has changed from a reinforcing loop to a balancing one and a Disruption Loop (B5), which remains a balancing loop. The changes were made because it was deemed necessary to link the ‘Disruption’ and ‘Process Compliance’ variables together. This resulted in the disruption loop effectively changing places with the sub-tier capability loop in the model including a number of the variable interactions. As a consequence, the sub-tier capability loop now demonstrates how the ‘non-conformances’ variable interacts to increase short term quick fixes. The change was made to show how a greater number of failures places pressure on the prime to identify quick solutions in order to prevent blockages in production. This resulted in the ‘Blockage’ variable being added to the loop in order to show how short term quick fixes reduce blockages. The resulting effect reduces ‘Root Cause Understanding’, which is a naming convention change made to the original terminology of root cause analysis. The name was changed because understanding root causes of failure helps the prime to identify causes of failure and therefore increase supplier performance. The original ‘Root Cause Analysis’ definition implied that investigations take place but does not necessarily suggest that causes of failure will be established.

Further improvements to the disruption loop are the introduction of a new ‘Supplier Improvement Activities’ variable. This variable was included because it shows an interaction that seeks to increase process compliance over time. Process compliance then has the effect of reducing the disruption to the prime. The disruption variable has the effect of increasing blockages, which then reduces root cause understanding because the prime will concentrate efforts on quick mitigation because of the blockage.

Overall, the Adherence themed loops attempted to convey how short term quick fixes feedback to reduce supplier performance, whereas identifying the root cause of failure over time has the effect of increasing supplier performance. An increase in supplier performance then has the cyclical effect of reducing persistent failure after each feedback of the loops. The general feedback from the participants of the workshop was that they viewed supply chain adherence to the prime’s quality management system as a given and first tier suppliers would not have received approval to supply product if they could not prove adherence to the quality system. The main area of focus for the prime was the performance of the supply chain and in particular the performance of first tier suppliers. Therefore, in addition to changing the name of the quality adherence loop to supplier performance, adherence was replaced by ‘Supplier Performance’ as a dominant theme.

6.4.2 Changes to the Dependency Loops.

The first significant amendment made to the dependency series of themed loops describes how the supplier dependency loop (Originally R1) was changed to the ‘Dependency Loop’ (R2). In addition, the dependency on supplier variable was changed to ‘Dependency’ because this can apply for both the prime and / or first tier supplier, i.e. the prime can become reliant on the first tier supplier for components whereas the first tier can be dependent because of the high proportion of its turnover with the prime. Therefore, if there are limited supply options, the prime will attempt to identify alternative suppliers in order to reduce the effects of dependency. It was also discussed during the workshop and during the exploratory phase that the prime’s supply chain management function is continually seeking to reduce the risk of dependency by trying to identify and develop new supply chain capability as shown in loop B1 (Sourcing

Strategies). These efforts are a continuous supply chain management activity and seek to increase buyers' leverage within the supply chain with the goal of reducing dependency. Participants noted how there are multiple sourcing strategies being conducted at any time and each can be described as being at different levels of maturity. However, the prime is not quick to use gathered intelligence from within the supply chain and often awards more business to suppliers who are providing immediate benefit. In addition the 'Vacillation' variable was changed to 'Indecision' because, although there was agreement regarding the inclusion of the variable and its effect on the loop, it became apparent that not all potential users of the model immediately understood the terminology. The next change in the dependency loop was to replace the delivery arrears variable with 'Supplier Attractiveness' because there was a general consensus amongst the workshop participants that an increase in supplier performance is more likely to result in the prime rewarding the supplier with more business. The effect of this will eventually result in an increased dependency on the supplier. The 'Sourcing Strategy Loop' (B1) was added to the persistent failure model in order to acknowledge that the prime seeks to reduce dependency in the supply chain by managing sourcing strategies more effectively. No connection was made between delivery arrears and dependency during the workshop. Therefore, the delivery arrears variable was removed from the loop.

Changes to the spend relationship loop (R5, Originally R6) involved the removal of the 'supplier growth' variable because it was suggested that supplier growth was stimulated through attractiveness based on performance rather than the supplier's dominance in the market. The participants did not generally believe that growing a supplier by increasing the amount of business led specifically to greater supplier influence. The perception was that this is more related to a supplier's general performance. In addition, the next change involved removing the 'supplier influence' variable and replacing it with 'Alternative Supplier'. Again, this was changed because the participants did not agree that supplier growth has the effect of increasing supplier influence. The participants felt that influence was created because of the specific capability that suppliers have and not necessarily because they are growing. Therefore, the inclusion of the 'alternative supplier variable' acknowledges how reducing dependency involves increasing competition in the market.

Finally, a slight adjustment was made to the loop by changing the leverage variable to 'Buyer's Leverage'. This was done to be more explicit about which party needs to increase leverage in the supply chain and to facilitate greater understanding of the model and the interactions between the variables. A consequence of the amendments means that the strategy mitigation loop has changed from being a reinforcing to a balancing loop as is evident by the summation of polarities.

6.4.3 Changes to the Risk / Contingency Management Loops.

The first significant amendment made to the risk management series of themed loops involves changes to the supply chain flexibility loop R2. This has been changed to the supply chain capability loop B2. The loop was amended to show that 'Micro Management' caused an increase in 'On Time Delivery' a change from the time to plan variable, changing the loop from reinforcing to balancing. The alteration was made because future planning of material demand can become restricted as the first tier supplier is forced to focus on delivering items that are already late. Therefore, reduced time to plan is an effect rather than a cause of failure, whereas 'on time delivery' can either cause a reduction in failure when it increases.

The demand planning loop (R5) has been changed to the 'On Time Delivery Loop' (R6) in order to highlight the effect of rescheduling by the prime and how it affects delivery performance in the supply chain. In addition, rescheduling disruption has been changed to 'Scheduling Disruption' based on comments made during the workshop concerning how disruptions can occur irrespective of late delivery or capacity. Mistakes as simple as the prime not placing orders for the component in the first place can occur. Fluctuations in demand can always happen but if the orders are not placed in the first instance then the prime is not going to receive the component on time. The on time delivery loop demonstrates the fine line between achieving supply flexibility and maintaining supply chain control in an uncertain environment. A workshop participant explains the risk to suppliers: *"You have to look at the supply chain or the network. There's a lot of unwanted rescheduling disruption and it's not necessarily anyone's fault. It just happens".*

The next amendment made to the on time delivery loop is the change of the 'Lead-time Accuracy' variable to 'Operational Efficiency'. The change was made because of debate evident within the groups indicating that lead time accuracy is the effect of issues with capacity, which can reduce 'operational efficiency'. Therefore, as a consequence, the ability to deliver components to the specified lead time is affected due to scheduling disruption. The final change within the risk management themed loops was the removal of the Risk / Contingency Loop (B5 in the original model). The feedback from the workshop indicated that it was not capturing a true effect or causal relationship and was therefore not adding value to the model.

6.4.4 Changes to the Relationship Management Loops.

The first significant amendment made to the relationship management series of themed loops involves the Communication loop. The loop was originally balancing (B2) but has now been changed to reinforcing (R3) because it was found that the effects of poor communication drives persistent supply chain failure if not managed correctly. This stems from the dialogue with supplier variable being changed to 'Communication Fragmentation' because it was noted by the participants that the prime has difficulty communicating effectively and consistently with first tier suppliers and internally. It was reported that communication significantly increases when the urgency of getting parts delivered on time increases. However, communication does not occur on a consistent basis. In addition, the need to get parts delivered on time increases the risk that designated communication protocols get ignored because multiple employees from various levels of the prime's organisation feel pressurised into contacting first tier suppliers for status updates. The effect can cause the fragmentation of established communication protocols.

Communication fragmentation then forms a linkage with a newly included 'Silo Thinking' variable. The variable was added following critique and insights from the workshop to show how functions / departments in the prime that are immediately affected by a failure seek to act individually rather than act as one 'joined up' company. Therefore an increase in communication fragmentation has the unwanted effect of increasing silo thinking. In addition, silo thinking within the prime causes problems with first tier suppliers because they do not know what, which and when to prioritize workload. A participant from the workshop explains the disparity between divisions and functions of the prime's business: "*Often, there isn't a linkage internally within the prime that we are talking to each other, so particularly in the buying world we're doing the day to day stuff with commercials; the strategic team are also doing their own thing".*

As a result of these observations the ‘Silo Thinking Loop’ (R4) was added as a new reinforcing loop to show how silo thinking within an organisation can interact to cause communication fragmentation. The effect can reinforce into a vicious cycle until communication is completely fragmented, significantly contributing towards causing persistent supply chain failure. Further to this the 'Firefighting’ variable was included to show how management behaviour intensifies towards first tier suppliers when persistent failure occurs. The effect of delivery arrears, can result in the supply chain being in a constant state of ‘catch up’ in order to fulfil engine build line schedules, which has ramifications for the entire supply chain. Hence, firefighting activities intensify.

Due to further captured observations during the workshop, changes have been made to the relationship management loop (R7 originally R4). The understanding of requirements variable was rearranged to show how ‘Relationship Continuity’ has the effect of increasing understanding of requirements. The changes were made because relationship continuity was perceived as a way to consistently manage issues with chosen suppliers rather than dissolve or terminate relationships. Maintaining relationship continuity should improve or resolve problems through increasing first tier suppliers’ understanding of requirements. This is meant to show how the prime mitigates the negative effects of communication fragmentation. The ‘Ambiguity’ and ‘Commitment and Trust’ variables were removed from the loop because they were deemed redundant by the workshop participants due to a perception that the interaction between these variables does not actually result in reduced dialogue with a supplier so the proposed linkage was considered subjective. The ‘Delay’ variable was subsequently added to the relationship management loop to show how understanding of requirements has the effect of reducing delays. Therefore, the Information Delay Loop (R7 in the original loop) was removed from the model and consolidated into the Relationship Management Loop.

It is important to note that each of the loops in the final model are designed to show what does happen in the context of persistent failure, not what should happen. The final updated model provides key decision makers at large industrial prime organizations that manufacture highly complex products with the understanding and visibility of the supply chain management activities where negative interactions between variables can and do reinforce to cause persistent supply chain failure. It identifies and demonstrates where and how the balancing activities conducted by the prime are ineffective at halting the persistence failure cycle. Thus, when confronted with persistent failure, organizations such as the prime may appear to conduct rational reactive activities but overall behave irrationally. The implications of this are discussed further in Chapters 7 and 8.

6.4.5 Post Workshop Persistent Failure Model – Glossary.

The Persistent Failure Loop Glossary Table 6.16 provides the reader with an explanation of the updated terms and meanings of each variable described within each of the persistent failure model loops. They are iterations of the variables developed in Chapter five and follow the same naming convention rules (Morecroft, 2009).

Table 6.16 Post Workshop Persistent Failure Model Glossary.

VARIABLE	DESCRIPTION
"Alternative Suppliers"	Number of alternative suppliers available to the prime in different commodity groups.
"Blockage"	Occurs when components stop production because they are either late being delivered or do not meet the required specified.
"Buyers Leverage"	When the buyer from the prime identifies their key resources to derive an advantage in a commercial relationship over a first tier supplier, leading to a strong negotiating position.
"Communication Fragmentation"	Dialogue between prime and first tier supplier becomes uncontrolled with different personnel from the prime making contact with first tier suppliers who are not authorised to do so.
"Delays"	Occur when requests for information or clarification from a first tier supplier are not answered by the prime expediently or specifications are not provided by the prime in sufficient time resulting in late deliveries.
"Dependency"	Either the prime or first tier supplier is overly reliant on the other due to them being a sole source or the only customer.
"Disruption"	A supply failure emanating from a first tier supply chain that leads to interruptions to the prime's assembly line or build schedule.
"Focus on Supplier"	The additional time and resource given to a specific first tier supplier when they start to fail persistently.
"Firefighting"	The prime is under pressure to solve problems with first tier supplier in a short period of time. This becomes the focus for the prime instead of normal day to day activities.
"Indecision"	The inability by supply chain managers at the prime to decide between different opinions or actions when faced with a failing supplier.

"Micro Management"	A management style adopted by the prime where it closely monitors, observes or controls the work of the first tier supplier or sub-tier.
"Non-Conformance"	Components supplied by the first tier supplier that do not meet the required specification as contractually agreed.
"On Time Delivery"	Consistent delivery by a first tier supplier 'on time' according to contractually agreed timeframes.
"Operational Efficiency"	Occurs when first tier suppliers are able to deliver components precisely to the scheduled delivery date irrespective of changes in demand signal received from the prime and / or rush order requests.
"Persistent Failure"	Supply chain failure that continues to happen despite multiple efforts by the prime and a first tier supplier to resolve it.
"Process Compliance"	Consistent conformance to the prime's quality management system.
"Recovery Activities"	Activities or initiatives conducted by the prime to help a first tier supplier recover from failure.
"Relationship Continuity"	The interaction between the prime and the first tier supplier. This includes the continuity of the relationship between the prime and the supplier in line with the protocol of a single point of contact philosophy.
"Root Cause Understanding"	Occurs when the main cause of non-conformance is identified and solved so that repeat failures are prevented.
"Scheduling Disruption"	The prime consistently makes changes to the first tier supplier's component delivery schedules, irrespective of quoted lead times and capacity constraints.
"Short Term Quick Fixes"	Non - conformances that are resolved without investigating the cause of failure in order to fix problems quickly.
"Silo Thinking"	Occurs when departments within the prime do not share information or knowledge and act as if they are in competition with other departments within the organisation.
"Sourcing Options"	The existence of a number of viable alternative suppliers that the prime can contract with in the market for a particular component.
"Sourcing Strategy"	Activity conducted by the prime to identify new or alternative suppliers and then deciding what, where and when to source components.
"Supplier Performance"	How well a first tier supplier performs to the level of quality and / or delivery performance originally specified and expected in an agreed contract.
"Supplier Improvement Activities"	The activities conducted by the prime to improve performance of a first tier supplier.
"Supplier Overload"	Occurs when there are too many supplier improvement activities going on at first tier supplier, affecting resources and taking up capacity.
"Supplier Attractiveness"	A first tier supplier is perceived as being more capable of performing a task or function than other suppliers to the prime. The prime will therefore tend to give that supplier more business often in a short space of time.
"Supply Chain Capability"	A first tier supply chain that contains a first tier supplier with strong production and sub-tier planning capability.
"Supply Chain Flexibility"	A first tier supplier capable of delivering conforming components on time despite internal or external disruption to ensure continuity of supply.

“Understanding of Requirements”	A first tier supplier’s ability to understand a component specification given to them by the prime and then convert the requirement into a manufactured component.

6.5 Chapter Summary.

This Chapter has presented the observations, insights and critique captured during the workshop that examined the failure persistence model. As a consequence of the feedback, comments and critique, a refined ‘Persistent Failure Model’ has been presented. The purpose of the updated model is to identify and clarify the interactions between variables that can combine to cause persistent supply chain failure. The model also shows how responses and improvement activities intended to reduce the effect of persistent failures can result in the converse effect, essentially acting to reinforce the cycle.

The most apparent mitigation activities that are carried out by the prime is to identify root cause of failure, increase individual sub-tier capability, increase the capability of the entire supply chain and develop strategy mitigation activities such as increasing the number of sourcing strategies. All activities involve the prime and first tier suppliers committing to very labour intensive work streams. The evidence, analysis and models presented during this and previous Chapters will be discussed further in the subsequent discussion Chapter (Chapter 7). This encapsulates how inter-relationships between loops (and not just variables) also drive persistent failure.

Chapter 7 – Discussion.

The concept of persistent supply chain failure and a causal loop model describing the phenomenon have not been considered or presented in the literature to date. Each variable and loop in the persistent supply chain failure model developed in this study are based on new empirical evidence. In this Chapter a thorough discussion of the model is given in the context of the existing literature and current state of knowledge. The discussion examines whether the causal loops within each dominant theme add to the literature, supports it, or refutes existing thinking. Where the literature is currently silent on issues that were captured in the study is highlighted. The Chapter therefore shows where and how the model adds to existing knowledge.

The work has important implications for practice. The Chapter discusses managerial and business implications of the persistent failure model. It examines the relationship between each of the main themes and describes the principal implications of each loop and how the complete model can be used to help managers understand and mitigate against failure. The implications section provides a review of the model in relation to current knowledge and practice. The Chapter concludes with a discussion of how each of the study's research questions have been addressed as a result of this research.

7.1. Supplier Performance.

The supplier performance loop (R1) as shown in figure 6.14 in Chapter 6 was developed in order to demonstrate the challenges faced by a first tier supplier seeking to achieve consistent performance. Ebrahimi and Sadeghi (2013) highlighted how quality management is a major driver of performance in supply chain management. Following on from these observations, Barouch and Ponsignon, (2016) identified how quality management systems are often implemented in an inconsistent way due to a lack of understanding of quality management methods. The findings from this literature is supported by observations captured during the exploratory phase. Participants often described how a lack of consistency in quality management requirements could negatively influence their performance measurement scores. As a result, if a first tier supplier's performance consistently falls below agreed performance levels, the prime increases its focus on that supplier because they are a source of persistent failure. The loop shows how additional focus will lead to recovery initiatives being deployed by the prime. If the failures are not being mitigated quickly enough and continue to happen then the recovery initiatives will become more intensive, potentially resulting in overloading the affected supplier. This is the result of the prime placing too much focus and attention on that first tier supplier. The loop shows how such an increase in recovery activities enacted by the prime can cause failure to persist if utilised incorrectly or too vigorously.

The contemporary literature does not investigate the connection between how an increase in recovery activities can have the effect of unnecessarily overloading a supplier. Existing quality management literature contains numerous studies that examine whether the adoption of quality management systems by organisations can lead to improved supply chain performance (Flynn and Flynn 2008; Yeung, 2008; Quang et al., 2016) or can act to reduce the risk of failure in supply (Ebrahimi and Sadeghi, 2013). Flynn and Flynn (2005) sought to identify whether the existence of a quality management function within an organisation improves supply chain management performance. They found that organisations form a symbiotic relationship with their supply chain that recognises how each contributes to the others success, describing this as the 'Horizontal Effect', which is encouraged by the adoption of quality management practices (Flynn and Flynn 2005). Seldom does the literature consider whether the existence of stringent quality processes required to achieve adherence to a prime's quality management system could result in reducing the performance of a first tier supplier. In addition, rarely does the literature identify how processes and specifications may in some cases be too stringent for first tier suppliers to consistently adhere to, therefore contributing to reduced performance. Evidence from the empirical research indicates that for first tier suppliers to achieve consistent performance requires a vast amount of collaborative effort from the prime and the first tier supplier (Barouch and Ponsignon 2016). The literature does not investigate how such efforts can be affected by regulatory bodies[19]changing the industry quality requirements on a regular basis in order to increase product safety. Frequent changes to the quality management system can cause a decrease in performance, despite work conducted to ensure consistent adherence by both the prime and first tier supplier.

The interaction between the focus on supplier and recovery activities is supported in the literature to some extent. Some existing research has investigated how

[19] NADCAP – *National Aerospace and Defence Accreditation Programme. Industry managed approach to conformity assessment of special processes.*

organisations aim to mitigate against instances of failures. The literature highlights how factors such as senior management involvement and alignment of strategic goals between the buyers and suppliers are important for success in supplier development initiatives leading to recovery from poor performance (Humphreys and Chan, 2004). Findings from the exploratory phase add to the literature by identifying and highlighting the importance of managing recovery initiatives in an appropriate way. Efficient and effective methods need to be deployed in initiating mitigation activities with a failing supplier taking into account the benefits that can be derived. This includes carefully deciding on the intensity of the effort and the most effective number of personnel to be deployed.

The sub-tier capability loop (B4) demonstrates how non-conformances in the sub-tier affect a first tier supplier's performance with the prime. The loop highlights activities that are conducted to reduce disruption and keep blockages in production to a minimum. This is either through short term quick fixes for an expedient resolution or through long term resolution by conducting root cause analysis. Repenning and Sterman (2001) reported that despite a number of tools and techniques widely available to an organisation on how to improve product quality and therefore reduce non-conformances, there had been little improvement in the ability of organisations to incorporate these innovations into their daily activities.

There is very little literature that analyses the long term effects of favouring short term quick fixes instead of establishing the root cause of non-conformances on supplier performance. The literature focuses on understanding quality management practices and concepts, providing descriptions of how they seek to prevent failure from happening in the first instance (Robinson and Molhotra, 2005). Morrison (2015) did however recently conduct research aimed at establishing why organisations carried out 'workarounds' in order to quickly fix problems, which is reflected in the effects captured in the loop showing how short term quick fixes reduce blockages. The research found that workarounds happen due to a lack of available resources needed to quickly mitigate failures. There is currently no literature that investigates this link other than Morrison's (2015) study. Therefore, the loop adds to the literature by showing that an increase in short term quick fixes reinforces blockages because the same problems have to be fixed repeatedly. This is because a root cause and an effective change or mitigation strategy have not been established.

The disruption loop (B5) was developed to show how interactions between variables can also have a balancing effect in the persistent failure model. It demonstrates how the prime seeks to improve supplier performance through reduction of non-conformances by increasing the number of supplier improvement initiatives being conducted, therefore increasing process compliance. The loop supports current literature that seeks to address ways in which buying organisations utilize improvement initiatives to improve performance (Nagati and Rebolledo 2013). This includes research by Wagner (2010) who described a scenario whereby an increase in non-conformances reduces process compliance and subsequently increases the amount of disruption experienced by a prime. The findings support existing literature that examines the use of supplier development initiatives and their positive effects on the supply chain but it also highlights how achieving increased performance as a result of supplier development initiatives can be dependent on the context of the failure and the methods adopted to implement initiatives. The research also investigated how buyers manage improvement initiatives in the event that both parties fail to mitigate against disruption in the short term or if failure persists despite improvement initiatives being instigated. The findings back up research by Arroyo-López et al., (2012) who identified that a major issue with supplier development initiatives is the tendency for buying organisations to abandon them too early in the process if implementations do not result in an immediate improvement. Their research identified how initiatives that take longer to complete may prove to be less successful (Arroyo-López et al., 2012). A further gap in the literature comes with the identification of whether supplier development initiatives can actually cause increased problems for the intended recipient over a period of time should an initiative prove unsuccessful.

Overall, the disruption loop highlights how the prime manufacturer seeks to ensure that the first tier supplier does not pose a risk to continuity of supply and therefore reduce the likelihood of causing disruption to the wider organisation and ultimately the customer (Chopra and Sodhi, 2004). This supports previous studies that sought to identify the characteristics of supply chains in relation to frequency of disruption (e.g. Choi and Krause, 2006; Craighead et al., 2007), although these studies have tended to focus on how external issues can cause disruption in geographically dispersed supply chains. In contrast, the disruption loop examines how repeat non-conformances result from a lack of understanding of the root cause of a problem when they first occur.

7.2 Dependency.

The dependency loop (R2) was developed in order to illustrate how close long term relationships between buyers and suppliers can lead to a state of interdependency if not managed proactively by the prime, exacerbating the effects of persistent supply chain failure. The type of dependencies reported in the literature tend to focus on the supplier being dependent on the prime or larger suppliers demonstrating opportunistic behaviour (Hou et al., 2016). However, this work shows that the causes of dependency can vary greatly, ranging from issues concerning volume of spend, lack of sourcing options, and strategic decisions to supplier influence and IPR. The dependency loop points to a key interaction between variables that moves the prime towards becoming dependent on a supplier or vice - versa. It was found that dependency can occur in either direction, i.e. the prime can become reliant on the first tier supplier if the supplier is the design owner of key components and / or has a large portfolio of parts that the prime finds difficult to source from elsewhere. Conversely, the first tier supplier can become overly reliant on the turnover generated by having a contract to supply with the prime. Makkonen et al., (2015) found that, as a result of good performance, the prospect of awarding the supplier with more work increases with attractiveness in the relationship between the prime manufacturer and supplier. When this happens much of the leverage transfers to the supplier. In an earlier study, Kähkönen (2014) found that the power dynamic within the relationship between buyer and supplier influences the amount of collaborative working. The loop shows that an increase in supplier attractiveness leads to an increase in dependency and shows how the prime can lose the power balance in a relationship by continually awarding work to an attractive supplier. The findings support the study by Kähkönen, (2014) who observed that relationship collaboration reduces if the actors do not have balanced power positions.

An alternative, but equally relevant perspective to how commercial relationships can play a significant role in the understanding of persistent supply chain failure is the work conducted by the International Marketing and Purchasing (IMP) group starting in the early 1980s. This research suggested that the type of buyer-supplier relationship is an inevitable outcome from the nature of business and hence beyond the complete control of either participating company (Vaaland and Hakansson, 2003). The dependency loop demonstrates how long term relationships can result in both the prime and first tier suppliers becoming complacent if allowed to feedback and reinforce over time. If the prime is in a position of dependency then this represents a genuine risk because they cannot readily change the source of supply if performance consistently falls below the agreed levels and the relationship turns sour, resulting in persistent supply chain failure. The dependency loop supports the concept of power regimes identified by Cox et al., (2001) because it demonstrates how dependency can occur on both sides of the dyad if there are no alternatives for the prime or the supplier only has one substantial customer. The dependency loop does not support the work by Håkansson and Ford (2004) because it shows how long term relationships can result in either the buyer or supplier becoming complacent if one party becomes dependent on the other over time. The prime can forfeit a position of power (Pazirandeh and Norrman, 2014) by giving the first tier supplier more business. Sourcing decisions made by purchasing managers at the prime are driven by current circumstances. However, the loop demonstrates how constantly awarding a first tier supplier with more business can have serious effects later on. There is no literature that currently investigates this phenomenon.

The sourcing strategy loop (B1) was included in the final persistent failure model in order to capture how the prime seeks to reduce dependency in the supply chain by managing sourcing strategies more effectively. Caniels and Gelderman (2007) noted in their work on power and interdependence in buyer-supplier relationships that even satisfactory partnerships can be dominated by the supplier. The findings from some of our case studies lend support to Caniels and Gelderman’s (2007) observation because of the lack of substitute manufacturers. Even if the prime is in a position of influence and strong leverage within the Kraljic matrix (1983) at the time of contract award, agreements in aerospace can last for up to thirty years. Tacit knowledge will eventually transfer to incumbent suppliers making it more difficult to challenge them with the existence of competitors. As a result, first tier suppliers to the aerospace industry can become very difficult to replace over time. This is an observation that the current literature rarely touches upon. The literature mainly focuses on identifying different elements of power in relationships and how buyers and suppliers need to understand where the power dynamic is currently placed (Lacoste and Johnsen, 2015) rather than looking at the dynamics of power over time. Rarely does the literature identify and investigate strategies that prime manufacturers can conduct in order to prevent and mitigate against dependencies from occurring in the supply chain over time. The sourcing strategy loop demonstrates how this is a continual activity for the prime albeit the outcome is not currently very successful.

The spend relationship loop (R5) has been created to illustrate how a limited number of alternative suppliers can reduce the amount of leverage that can be exercised by the buyer. By actively identifying a greater number of alternative suppliers in the market, leverage for the prime can be increased. The loop shows how increased leverage will help the prime to reduce its dependency on existing suppliers. The work by Cox (2004) examined whether there was a correlation between the ability to improve the performance of suppliers and the power circumstances that exist between buyers and suppliers. Cox (2004) found that buyers are able to improve the performance of suppliers if they can identify whether they are in a position of power / or dominance within the supply chain. Much of the literature that advocates power / interdependence brings up the same or similar conclusions as Cox's et al., (2004) work, which suggests that buyers are able to get suppliers to improve performance if they are in a position of power or dominance. However, the variable and the sequence of effects in the loop is based on evidence provided by the research participants, which suggests that supplier growth was caused by consistently good performance by a first tier supplier rather than their position / dominance in the market. This is minimised if one party exercises more power over the other in the relationship (Kähkönen 2014). However, the participants did not generally believe that holding a greater influence over a supplier specifically led to improved performance by the supplier, even if this could result in an increase in the amount of business they received from the prime. It was also suggested by a participant from the prime during the exploratory phase that reactivity to supply chain failures was dependent on the importance that the first tier supplier placed on the prime's business or how much disruption they would themselves incur as a result of the failure. The spend relationship loop goes further and seeks to understand the factors that generate leverage in a relationship and identifies the behaviour of the parties involved and the effect it has on performance over time. The factors include the number of alternative suppliers available to the prime in different commodity groups. Fewer available suppliers has the effect of increasing the prime's dependency on a first tier supplier. This influences the buyer's leverage, which has an effect on performance in the supply chain. Research including that by Zhao et al., (2008) tends to examine the effect that influence and leverage have on the power position as a combined effect on performance rather than just leverage and seeks to understand who actually holds the power in the relationship and why (Benton and Maloni, 2005). This does not take into consideration the dynamic aspect of leverage, whereas the spend relationship loop highlights how leverage is not static and can change over time if not managed effectively.

The strategy mitigation loop (B6) was included in the model in order to demonstrate how increasing available sourcing options should be a key method used by the prime to mitigate the effects of being dependent on existing suppliers. The loop works in tandem with the sourcing strategy loop (B1) in order to further balance out the effect of dependency within the supply chain. Crook and Combes (2007) discuss how even weak members of a supply chain can often gain by switching to alternative customers and leveraging supply chain management outside of the focal supply chain, which suggests that suppliers do not have to focus on just one customer or even one industry. The strategy mitigation loop supports those observations as the loop attempts to show how the prime should focus resources on identifying alternatives for first tier suppliers that have been identified as strong members of the supply chain. Therefore, in order to mitigate against the dominant first tier supplier the prime should attempt to increase their leverage by developing more sourcing options over a period of time.

The literature contains few studies that seek to investigate the effects of being on the weaker side of a relationship. However, Chen et al., (2014) studied the impact of supply chain power structures on firm's profitability. They found that if the prime manufacturer is the most powerful organisation in the supply chain then profit is usually at its highest for the prime. The study focuses on relationships within the supply chain that result in the greatest amount of profit being generated such as sub-tier suppliers joining forces in order to mitigate the power held by the prime manufacturer. The Chen et al., (2014) study does not investigate the effects of being on the weaker side of the relationship.

In challenging circumstances if a buyer does not hold leverage with a supplier and does not appropriate any value from the relationship then the situation can become hostile for the buyer. In many industries it is possible they will seek to end the relationship and go elsewhere (Benton and Maloni, 2005). However, because of a lack of options, this can be difficult to achieve within the aerospace industry, and generally cannot be done quickly.

7. 3 Risk / Contingency Management.

The supply chain capability loop (B2) illustrates the potentially negative effects of contracting with suppliers across a widely dispersed supply chain. This supports the observations of Bode and Wagner (2015) who identified a relationship between geographical spread and the frequency of supply chain disruptions (Bode and Wagner, 2015). They identified how organisations that operate through complex supply chains are subject to increased risk of supply chain disruptions. Much of the literature on supply chain risk management focuses on identifying techniques, processes, and procedures conducted by organisations to capture risks in order to prevent failures from happening (Swink and Zsidisin, 2006). The limitation within the risk management literature is the lack of studies that seek to identify what organisations should do to manage risks when supply chain failure persists.

The literature typically describes how organisations should define the issues or scenarios that are likely to cause problems or impact negatively on supply chain operations if not mitigated and / or managed in a proactive manner (Wu and Olson, 2010). The supply chain capability loop contributes to the literature by highlighting specifically how a lack of planning capability within the supply chain can cause problems if not addressed effectively before failure occurs. In addition, the supply chain capability loop also shows how a lack of planning capability increases pressure on the prime to micro-manage their supply chain. Conversely, this research also found that micro-management by the prime of first tier supplier activities has internal effects such as an increase in reporting that middle managers are required to carry out in order to satisfy senior managers. These observations back up studies that have identified that prime manufacturers often intervene in all aspects of the supplier's activities in order to solicit an improvement in performance (Villena et al., 2011). The supply chain capability loop shows how such micro-management can lead to an increase in on-time delivery performance due to intervention but this may not reflect a positive situation for the prime because of the resources it employs to achieve this. The literature identifies how the adoption of risk management activities in small manufacturing enterprises is relatively low (Zsidisin et al., 2004). This was strongly supported by the findings from the exploratory phase based on observation from the first tier suppliers.

The on-time delivery Loop (R6) was included in the model to capture how uncertain demand can affect material rescheduling and demonstrates the negative effect on the supply chain that it can cause. The literature contains numerous studies that investigate and explain risks related to uncertain demand and their effect on performance (Pereira et al., 2014; Kerkkännen et al., 2008). There is little or no literature that identifies the effect of limited planning capability with on-time delivery performance within the supply chain. The loop demonstrates how this is an important theme in persistent supply chain failure because it is an operational phenomenon that can affect the entire supply chain. This supports the literature that investigates the effect that changes in demand have on the supply chain from the customer through to the raw material producer (Wen–Ho and Fang, 2013; Flynn et al., 2016). The loop shows how frequent rescheduling disruption places considerable pressure on the supply chain and reduces operational efficiency.

A number of studies concentrate on how organisations manage the risk of external disruption within their supply chains (Kleindorfer and Saad, 2005; Bode et al., 2011; Bode et al., 2015). The literature on risk management also identifies how large, typically multinational organisations, have developed whole departments dedicated to identifying and managing risks. The literature also describes how organisations implement initiatives to manage supply risk by reducing the likelihood of a detrimental event (Zsidisin et al., 2004) or its impact (Tang, 2006). The focus of research on risk has tended to be principally geared towards understanding how failures can be prevented from happening before they happen whereas the on-time delivery loop shows how the prime needs to identify robust and flexible suppliers who have the capability to plan and manage effectively in scenarios when adverse events occur.

7. 4 Relationship Management.

The communication loop (R3) illustrates the causal relationship between the prime's supplier performance requirements and inadequate communication with a first tier supplier. When the prime fails to adhere to strict communication protocols, this can cause confusion because employees of the prime may not know what other functions / divisions within the business are doing. This also has the effect of disrupting suppliers within the supply chain. The findings support the research by Forslund and Jonsson (2009) who found that a lack of consistent communication between first tier suppliers and the prime seriously hinders supply chain management performance. Forslund

(2014) recently went on to identify a correlation between logistics performance and the type of relationship between buyers and suppliers. The communication fragmentation variable in the model lends support to these research findings because it demonstrates how poorly managed communication can become a contributory cause of persistent supply chain failure. The quality and frequency of inter-personal communication and the subsequent management of relationships throughout the supply chain has an effect on supplier performance. Villena et al., (2011) in their study on the ‘dark side’ of supplier / buyer relationships found that contrary to the ‘bright side’ of buyer and supplier relationships, which benefits the buyer because of greater collaboration, if the relationship becomes too open then the supplier is more likely to demonstrate opportunistic behaviour. The findings from the exploratory phase show that when communication appeared to be inconsistent between the prime manufacturer and the first tier supply chain, the supplier would be at greater risk of poor performance because the prime seemed less likely to give them the information required to successfully manufacture and supply components on time.

The silo mentality loop (R4) was incorporated into the model in order to further highlight the significance of internal relationships / communication within the prime on supply performance. The loop lends support to the findings of Yates (2006) who in her study found that positive levels of internal communication within large multinational companies transferred over to result in greater financial performance. Comments made by participants during the exploratory phase and workshop suggested that many of the prime’s departments and functions are working in isolation and may appear to be in competition with each other. These observations also relate to the recent findings made by Jacobs et al., (2016), who found that positively perceived internal communication within organisations also facilitated positive communication with suppliers, whereas poor internal communication is reflected by the organisation sending out mixed signals into the supply chain because communication is not coordinated between functions / departments.

The relationship management loop (R7) was included in the model to show how communication and the type of interaction between the prime and first tier supplier was a factor that could perpetuate the causes of persistent supply chain failure. Much of the literature that investigates communication in buyer-supplier relationships identifies how supply chain relationships are important in improving performance (Choi et al.,

2002) so the inclusion of relationship continuity variable supports this general theme in the current literature. Relationship continuity was perceived as a way to improve or resolve problems through the forming of coalitions with the prime (Bastl et al., 2013). Carr and Kaynak (2007) found that traditional communication and internal – external information sharing improves performance in the supply chain. The literature rarely investigates how inadequate or hostile relationships can have negative effects on supply chain performance. Parallel to these findings is the literature that suggests successful performance based on improved relationship management can be characterised by win–win collaborations such as the alignment of organisational goals, cultural fit, embedding information systems and resources into both parties' organisations (Wilding and Humphries, 2006). The narrative from participants in this study indicated clearly that deficiencies in these areas are a key cause of material delivery delays, which then increase communication fragmentation as managers from the prime are placed under greater pressure for parts to be delivered. The evidence taken from the first tier suppliers in this study was that communication tended to became more frequent when delays had started to cause significant disruption to the prime and not before. There appears to be no research that directly investigates these issues. Therefore, the interactions shown within the relationship management loop adds to the current literature.

7.5 The Persistent Failure Model.

The persistent failure model adds to and provides new and fresh insights to current knowledge and literature by providing a fundamentally new chain of interactions that explains the phenomenon under study. Each loop within the model provides the related literature with new insights, confirmation or further insights relating to previous studies conducted on similar or related topics. A number of the interactions highlighted within the model refute some studies in the current literature. However, most importantly, the model demonstrates how the current contemporary literature is silent on the issue of persistent supply chain failure. The use of causal loop diagrams is rarely used in the supply chain management literature as a method of presenting findings from case study research (Adamides et al., 2012). Furthermore, and irrespective of the extant operations and supply chain management literature being well represented with examples of failure, none of them directly addresses the issue of persistent failure nor do they attempt to model the phenomenon as a sequence of interactions that results in such failure, as done in this work.

As the data collection process during this study on persistent supply chain failure was heavily focused on semi-structured interview and recorded workshop data, causal loop diagrams are seen as a robust method of presenting the findings in order to facilitate an understandable way of testing the data (Meredith, 1998). Despite comprehensive research that has utilised System Dynamics to model supply chains, articles written within the project and programme management literature and risk / contingency management literature represent the closest identified research studies with this study (Zsidisin, 2003; Chopra and Sodhi, 2004; Sterman and Dogan, 2015). Project management research covering topics such as causes of cost and time scale overruns on large scale and mega projects have used System Dynamics and causal loop diagrams to highlight the characteristics of these failures (Howick and Eden, 2004).

The persistent failure research adds to the literature on System Dynamics by presenting the model through dominant interacting themes. In addition, another interesting element of the persistent failure model is how a combination of literature subject areas are used to identify and support causality and the effects of causality on the system. Therefore, managers can pinpoint areas of risk and also develop strategies for mitigation within the same model. Only rarely are there studies that use a cross pollination of literature topics in supply chain and operations management and show how they relate to each other to result in failure.

The model also adds new knowledge to each of the principal literature domains that have been reviewed. None of the literature domains analysed throughout the study attempt to demonstrate how topics and activities link together to create either a positive or negative effect on the supply chain. Furthermore, none of the literature domains covered have been formulated into a model that practitioners can use to visually identify causal relationships between variables. Nor has a model been created previously that shows the effect on organisations if problems are not treated in an expedient way can reinforce to cause persistent supply chain failure.

7.6 Managerial and Business Implications.

Throughout the duration of this research project and more specifically during each of the defined phases and stages of the research, many insights have been identified that have managerial and business implications, not least concerning the behaviour and actions of managers and organisations participating in the supply chain. The persistent failure model captures the outcome of such actions and the effect of strategic sourcing decisions made by the prime's organisation over a number of years. The implications of this research project do not just affect managers from the target research sample. They also have implications for purchasing and supply chain managers and their employing organisations in other related high tech manufacturing industries. The model is presented as a tool that can support managers in relevant functions at both the prime and first tier suppliers to understand and mitigate against failure.

7.6.1 Implications of the Supplier Performance Loops.

The prime's quality management system is a combination of internal quality system requirements and industry regulations. Being able to achieve the industry regulations is considered a standard entry requirements for all first tier suppliers in the industry. Failure is not tolerated in the aerospace industry because of safety issues for good reasons - if a prime manufacturer cannot readily find substitute suppliers they have a duty of care to ensure existing supplier's products meet the required standards. As a consequence, each of the loops that are related to adherence to the prime's quality management system portray the effort required to achieve improved supplier performance in order for first tier suppliers to consistently meet agreed targets. These activities are not mutually exclusive and are as much the prime's responsibility as the first tier suppliers. The most important implications for businesses and managers of the Supplier Performance Loops are:

- The prime should fully ensure that the first tier supplier is capable of achieving agreed targets before a contract is agreed and trading is commenced. Reducing the risk of future non-conformances involves close collaboration and communication throughout the early stages of the buyer / supplier relationship and effective decision making by the prime on a supplier's true capabilities.
- Changes to industry regulations are inevitable and cannot be avoided. Therefore, potential updates should be anticipated and factored into project plans. Both the prime and the first tier supplier need to adequately plan for such eventualities rather than attempting to manage the effect of making changes retrospectively. By doing so, when a change to the quality management system occurs, the effect on supplier performance can be minimised. However, given the structure of this kind of industry the primary responsibility for this process is likely to rest with the prime organisations.

- Poor alignment of performance management systems between the prime and first tier suppliers affects supplier performance by increasing disruption and consequently the frequency of audits required to ensure that non-conformances are minimised. Therefore, the prime should work with their first tier suppliers to ensure they have the best possible understanding of the supplier's performance before increasing the frequency of audits.
- When failures start to persist, the pressure that is applied to the managers responsible for a supply chain engenders the tendency to favour quick fixes or workarounds in order to reduce current disruption. However, short term resolution of problems may not be sustainable. Developing 'workarounds' to solve a problem in order to quickly alleviate blockages is likely eventually to feed back to cause persistent failure. These observations are particularly important for managers at both the prime and the first tier suppliers because they build up over time and so are difficult to identify until it is too late. A strong message reflected by the supplier performance themed loops is that managers need to avoid resorting to short term solutions for failures and concentrate on identifying the root cause and sustainable problem resolution. Otherwise, the failure is likely to become persistent.

7.6.2 Implications of the Dependency Loops.

The Dependency themed loops show how high performing first tier suppliers can become so attractive to the prime that it results in procurement managers increasing spend at a rate that neither the prime nor the first tier supplier can manage effectively. Problems then occur when the first tier supplier's performance falls below contractually agreed levels. The most important implications for businesses and managers of the Dependency Loops are:

- If an increase in spending with a sole supplier is not controlled, then the risk of persistent failure is increased should the supplier be unable to cope with the extra volume. It was found that procurement managers need to be especially cognisant of suppliers if (1) the first tier supplier is one of a few companies that has all of the approvals and certifications required to supply product to the industry, (2) supply a large portfolio of parts to both the prime and its competitors, and (3) is an IPR owner on components used on prime's end product. Changing a supplier that demonstrates any, some, or all of these characteristics during periods of poor performance will result in the need to either re-design the part or find an alternative supplier. Therefore the prime needs to (1) recognise the emergence of 'lock – in' and thus dependency and (2) take avoiding action.

- The identified factors that increase dependency are strongly influenced by complacency and / or indecision. The outcome of complacency and / or indecision may be extremely difficult to mitigate against because first tier suppliers have switched their effort to other competitors or alternative industries. Therefore, the prime's influence is reduced. The prime needs to consider identifying more sourcing options capable of operating as a dual source solution in order to increase its buying leverage rather than focusing on a single supplier where possible.
- In the event that a poorly performing supplier is a sole source, the prime must pursue supplier development initiatives in a collaborative, but also assertive manner in order to establish the root cause of the failure instead of leaving the first tier supplier solely responsible for the recovery.
- First tier suppliers can become dependent on the prime for the majority of their turnover. This represents a risk to the prime because if there is a situation where demand drops considerably in the industry, then this could potentially send a first tier supplier out of business. This can have serious implications for the prime because they risk losing a readily available source of supply. The evidence has highlighted how moving from one source of supply to another is a very time consuming activity.
- The core message portrayed by the dependency themed set of loops is that if a consistent approach to developing sourcing options is not fostered and pursued, it will invariably result in a lack of supplier options and will reduce the buying party's leverage within the supply chain, potentially pushing up costs but also reducing performance. To counter this, managers at the prime must commit to a long term strategic view and develop options that create competition in the market.

7.6.3 Implications of the Risk Management Loops.

The Risk Management themed set of loops highlight how uncertain demand schedules can be a contributory cause of persistent supply chain failure. The effects of poor planning capability throughout the supply chain can further exacerbate the problem. The most important implications for businesses and managers of the Risk Management loops are:

- Rather than behaving reactively, the prime should refrain from requesting first tier suppliers to reschedule production of components once the original demand schedule has been submitted and accepted by the supplier. Frequent changes to demand places significant pressure on the planning capability of first tier suppliers, which increases the likelihood of persistent supply chain failure, especially throughout a widely dispersed sub-tier supply chain.
- The loops also show how a lack of capable suppliers within the supply chain places considerable pressure on the prime to micro-manage existing suppliers. There is a general lack of planning capability throughout the supply chain, which has resulted in the prime micro managing suppliers who represent a risk to achieving on time delivery. It is the prime and first tier supplier's inability to plan for material requirements adequately that sits behind many delivery failures and resultant shortages. The evidence highlights the need for an agile supply chain with a coordinated approach to demand planning and management.
- Supply chain flexibility is achieved by suppliers who have considerable experience of the prime's processes and procedures and have a proven track record of achieving agreed on time delivery targets. The on-time delivery loop shows managers that operational efficiency must be achieved on the supply of existing components before the first tier supplier is considered for new business. First tier suppliers who are new to the industry must be given adequate time in order to achieve and demonstrate operational efficiency. Problems occur when new suppliers are hastily awarded more work in order to mitigate issues with existing first tier suppliers.
- The core message portrayed by the risk management set of loops is that both the prime and first tier supplier need to take joint ownership of a problem to mitigate against persistent supply chain failure. Managers at the prime need to strike a balance by persisting with long term strategies and developing sourcing options within the supply chain but also must help existing suppliers to improve operational efficiency on the components they already supply.

7.6.4 Implications of the Relationship Management Loops.

The relationship management series of themed loops highlights how the effect of poor communication throughout the supply chain can contribute to persistent supply chain failure. A lack of information often prompts first tier suppliers to stop proceeding with production until satisfactory answers and guidance are provided by the prime. The prime is often slow to respond to queries from the first tier suppliers causing a detrimental ripple effect through the first tier's sub-tier supply chain that eventually feeds back to affect deliveries to the prime. The quality of communication is also a very important factor, not just the frequency. The most important implications for businesses and managers of the Relationship Management loops are:

- The relationship management themed loops demonstrate to managers at the prime how relationship management issues can contribute to causing persistent supply chain failure just as much as failing to adhere to quality procedures.
- The communication loop shows managers at the prime how a reduction in adequate and properly managed communication can lead to a reduction in supplier performance resulting in persistent failure. The prime has fewer processes and procedures for relationship management than for processes ensuring quality adherence or sourcing strategies. The prime has a 'one-size-fits-all' relationship management process that is currently being used by supply chain employees across the globe. As a consequence of cultural differences between employees in a multi-national company, the process of communicating with suppliers is being managed independently between sites, leading to inconsistencies in the way processes and procedures are presented to international suppliers.
- The communication loop shows managers how an uncoordinated / fragmented approach to communication can lead to 'silos' developing in different parts of the company. Fragmented communication protocols can lead to a reduction in relationship continuity. To mitigate against the effects of reduced relationship continuity greater collaborative working between the prime and first tier suppliers from the very beginning of the relationship, including collaborative working during the design phase, should be considered. Early engagement would establish closer relationships and more effective communication structures.

- The findings have wider managerial implications because they highlight the existence of a general lack of coordination between internal functions, which is exacerbated by internationally based departments / functions within the prime. Poor communication within the prime feeds back to result into poor communication throughout the first tier supply chain. When failures persist, a risky culture of firefighting emerges as employees from across the organisation ‘progress chase’ on behalf of the part of the organisation they represent. Silo thinking permeates throughout the organisation until firefighting becomes the sole focus for managers at multiple levels from different functions of the business.
- The core message portrayed by the relationship management themed loops are that in order to improve supply chain relationship management and communication the prime must examine current communication processes and established protocols within the organisation and then coordinate with the first tier suppliers. A complete review of all processes and procedures related to relationship management needs to be conducted and administered globally throughout the organisation to establish continuity and just as importantly, some regional flexibility where justified.

7.6.5 Implications of the Persistent Failure Model.

Based on the findings of this research project, the phenomenon of persistent supply chain failure is just starting to be appreciated and its implications understood. New contributions and significant insights come from having a real understanding of the causes of persistent failure, which the persistent failure model provides for the first time. A key purpose for the development of persistent failure model was to create a comprehensive visualisation tool that could be used by businesses and by purchasing and / or supply chain professionals to help mitigate failure. The model pinpoints interactions between key variables that link and eventually reinforce to cause supply chain failures to persist if not treated effectively and expediently. The model shows these as unfavourable linkages between variables that can develop into reinforcing loops. The model also demonstrates how causal loops feedback to cause vicious cycles that if not mitigated can result in serious disruption. The model also highlights activities / variables that are implemented by the prime and first tier suppliers to counteract the negative effects of reinforcing interactions and loops. These include expediently informing suppliers of a change in regulations, developing a consistent approach to sourcing with suppliers and continually monitoring the supply market for alternative sourcing opportunities. Additionally, and in order to avoid confusion the model also prompts the prime to refrain from changing a supplier's demand schedule in order to prioritise production of components because of delays and to maintain a consistent approach when communicating with the supply chain.

The core messages communicated by the model in its entirety is that the prime needs to recognise the emergence of a persistent failure scenario and use the model to help identify and focus on developing both avoidance and recovery strategies that help organisations to mitigate against long term failures by demonstrating how short term thinking and reactive strategies combine to create unfavourable situations in the long term if not managed correctly.

7.6.6 Using the Model to Mitigate against Persistent Failure.

A key output of the research on Persistent Supply Chain Failure is to inform key decision makers / supply chain professionals how to identify and mitigate against failure. This can be achieved by using the Persistent Failure Model as a tool to identify the potential to break loops, turn reinforcing loops from vicious to virtuous, and reduce the delays that cause overshoot in balancing oscillatory loops.

For example the Supplier Performance Loop – R1 demonstrates to key decision makers how overzealous recovery activities reinforce to increase supplier overload because the resource availability of the first tier supplier needed to commit to and support recovery activities and therefore increase performance levels, are seldom taken into consideration by the prime, which can lead to a reduction in the performance and effectiveness of these activities. Preventing this loop from becoming closed is critical to improving supplier performance. Therefore the loop can be used to show supply chain professionals how interactions between variables need to be closely examined before increasing the focus on the supplier and injecting additional resources in order to break the loop and mitigate against it becoming a closed reinforcing loop that becomes more vicious to the organisation after each oscillation.

The Sub Tier Capability Loop B4 and the Disruption Loop B5 both demonstrate activities being conducted by the prime that seek to reduce the effects of failure and increase supplier performance. The Sub Tier Capability Loop B4 illustrates how the interaction between the non-conformance and supplier improvement initiative variables has a critical effect on process compliance which drives supplier performance. Equally, the disruption loop B5 can be used to inform supply chain professionals that improving process compliance reduces disruption. Loop B5 also demonstrates how initiatives that are implemented with the goal of improving process compliance can become delayed unless supplier improvement activities are managed effectively resulting in continued failure.

The Dependency Loop R2 was developed based on findings from both the exploratory phase and then comments captured during the workshop highlighting how consistently giving an attractive supplier more work can feed back to increase dependency which can conspire to make both the first supplier and the prime over reliant on each other. To counteract this, the Sourcing Strategy Loop B1 demonstrates to supply chain professionals how persisting with sourcing strategies is an effective method of reducing dependency on both sides. In addition, the Strategy Mitigation Loop B6 shows how consistently pursuing further sourcing options helps the prime to increase their leverage within the industry and can help to break the dependency loop by reversing the reliance that both the first tier supplier and the prime have built up.

The Communication Loop R3 is an example highlighted in the model of how to help supply chain professionals identify interactions between variables that can turn reinforcing loops from vicious to virtuous. In conducting the empirical research and also in discussions in the workshop, it became apparent that efforts for improvement were focused more on quality management in order to increase supplier performance. It was identified that the way in which communication was managed throughout the supply chain could perpetuate a lot of the failure, especially if suppliers were regularly being ignored. The Silo Thinking Loop R4 in the model highlights how communication fragmentation is driven by departments at the prime having a tendency to work in silos. The lack of a co-ordinated approach feeds back to turn the communication loop into a vicious cycle which if not mitigated quickly can drive the mismanagement of recovery activities causing capacity overload at the first tier supplier and ultimately reduced performance. Through highlighting these negative interactions, the model can be used to reverse and prevent the effects of poor communication within the supply chain by motivating the prime to place greater emphasis on establishing appropriate supplier communication protocols throughout the organisation. The desired effect is to minimise firefighting and silo thinking at the prime, which will consequently help the loop to become virtuous by contributing to more efficient and better informed recovery activities that the first tier supplier is able to manage effectively.

A number of the loops, both balancing and reinforcing are highlighted within the Persistent Failure Model as being impacted by time delays. The delays have been included to acknowledge and highlight the empirical findings that show the prime's goal of improving aspects of failure within their system are being delayed resulting in oscillatory behaviour. Thus, the model illustrates to supply chain professionals where resources can be positioned in order to prevent recovery initiatives highlighted within balancing loops from demonstrating oscillatory behaviour.

Overall, the intention of the Persistent Supply Chain Failure model is to give supply chain professionals at the prime the visibility to identify and understand how key variables interact within each theme forming closed loops that can interact negatively to result in persistent failure. Each theme, demonstrates loops that are an effect of failure and show how they interact with loops that cause failure. Variables that interact with the goal of reducing the effects of failure are also highlighted to enable the development of action plans that seek to ensure that reinforcing effects of failure are reduced. Initiatives can also be put in place to prevent further disruption by time delays which can occur if goal seeking initiatives are not managed correctly.

7.7 Research Conclusions.

This study's research questions have been satisfactorily answered by developing and validating the persistent failure causal loop model. The empirical research has been exploratory in its methodology (McCutheon and Meredith, 1993), adopting a critical realism perspective (Adamides et al., 2012). The research has also facilitated theory development (Borgström, 2011) and has direct relevance for practice (Piekkari, 2010).

The methodology and research design for this study was influenced by Yin's (2009) multiple case study protocol. However, in order to enrich the findings and to ensure methodological rigor, various innovations have taken place to ensure that informative answers to the research questions were captured (Pratt, 2009). The practice was an essential element of the research project as new and rich insights emerged, culminating in the development of the persistent failure model. Due to the very limited amount of supply chain and operations management literature focusing explicitly on persistent failure, the research phase was by definition 'exploratory' as new areas of interest and methods of displaying findings emerged. Summarised below are the major conclusions to each of the research questions drawn from the research process, the empirical evidence, the persistent failure model, and the overall findings of the study.

7.7.1 Addressing Research Question One.

The initial motivation for the study was to understand why first tier suppliers could be allowed to persistently fail on agreed deliverables during the contract period with the prime manufacturer. This led to investigations being carried out in order to answer the first research question for this research:

RQ1 'What is persistent supply chain failure and how can it be understood?'

Why is persistent supply chain failure allowed to happen? The evidence captured during the study and presented in Chapters 4, 5 and 6, describes how specific failures can feed back to eventually cause supply problems that cannot be easily or quickly remedied or effectively managed by the prime due to a number of factors including a lack of substitutes with adequate design and manufacturing capability or capacity, and very time-consuming and high switching costs. The research has found that failures become persistent when different variables interact over time creating volatile relationships and ineffective relationship management processes that result in highly negative effects for the prime. The effects include reduced supplier quality and delivery performance, interdependency between the prime and first tier supplier, and communication fragmentation between the prime and the first tier supplier and throughout the sub-tier supply chain.

The identified influencing factors and effects of failure have been consolidated into four principal themes / quadrants, i.e. Supplier Performance, Dependency, Risk Management, and Relationship Management. The identified variables that sit within each of these themes can interact to ultimately cause persistent failure within the supply chain. As demonstrated within the persistent failure model, the variables form linkages that develop into feedback cycles, which can escalate into vicious cycles that become very difficult to remedy (or balance out in causal loop terms). It was also found that deficiencies in any of these four domains can result in a type of supply failure that becomes very difficult to eliminate or successfully mitigate quickly.

The literature highlighted some examples of high profile failures at manufacturing companies including large scale disruptions within the automotive industry over the past fifty years (Hammond, 2013) and the characteristics of those scenarios. The literature was also replete with theories and studies devoted to examining ways of helping manufacturing companies to avoid failure or escape from it happening in the first place (Zsidisin and Smith, 2005). However, the specific topic of why a supply could be allowed to fail persistently was absent from the literature.

Answering RQ1 involved identifying and describing how each variable and interaction could influence the phenomenon of persistent failure. Ultimately, persistent supply chain failure as captured in the model is the effect of the prime and a first tier supplier not identifying and subsequently managing interactions adequately between key variables that can develop into recurring causes of failure over time, allowing the relationships to exacerbate the effect of failures to the point whereby they cannot be easily mitigated or resolved quickly.

7.7.2 Addressing Research Question Two.

The purpose of research question two was to understand the processes / interactions that could explain why persistent failures occur. The key gap in the literature was the lack of research that sought to evaluate failure that continues to disrupt prime manufacturing organisations in some industries over a period of time. This led to the second research question for this study:

RQ2: 'What factors drive persistent supply chain failure and what are the interrelationships between them?'

Findings from the study have enabled the development of a model that captures and illustrates multiple factors that interact to contribute to persistent supply chain failure. The model captures and describes prominent variables that drive failures, causing significant effects on the first tier supplier, ultimately affecting its ability to deliver successfully to the prime. The variables and interactions are highlighted within the Supplier Performance loop (R1), Dependency Loop (R2) and the Communication Loop (R3). Interactions that are likely to reinforce failures if not treated expediently are shown in the Silo Mentality Loop (R4), On Time Delivery Loop (R6) and the Relationship Management Loop (R7). The model also captures how the variables can interact with loops based on other themes shown in the Persistent Failure Loop (B3) to balance out persistent failure providing the oscillatory behaviour of time delays is avoided.

The model encapsulates how inter-relationships between loops (and not just variables) also drive persistent failure, for example, the Supplier Performance loops can interact with the Dependency loops to create a form of lock-in, resulting in the prime being unable to resource components quickly even when failure persists. Interactions between the Dependency and Risk Management loops develop as the prime lacks capability and options in their supply chain resulting in the need to micro-manage suppliers, preventing time to forward plan.

Instigating a risk management process using the persistent failure model either at the very start of a commercial relationship or at key points within a relationship can be a mechanism to capture and record all of the issues / potential risks. For instance, the Relationship Management loops highlight how inadequate communication between key stakeholders within the supply chain exacerbates the risk of supply chain failure throughout the model. All of the loops interact to perpetuate the causes and effects contributing to persistent supply chain failure. The insights are underpinned by the Persistent Failure Loop (B3), which is a consolidation of all the key loops that drive and also seek to balance out the effects of failure.

Observations from the validation workshop justified the use of causal loop diagrams to provide a clear and concise method for answering research question two. The method proved valuable for capturing the dominant variables that interact to cause persistent supply chain failure, and show why and how they interact.

7.7.3 Addressing Research Question Three.

The purpose of research question three was to gain insight into how the prime and first tier suppliers could tackle supply chain failure. This led to the third and final research question:

RQ3: 'What supply chain recovery strategies can be adopted to help resolve different types of persistent failures effectively?'

The identification of the key causal relationships can demonstrate to managers how organisations are at risk of suffering significant disruption if they fail to identify and manage potential risks of failures early in a contractual relationship. In order to help managers at the prime resolve persistent supply chain failures effectively the persistent supply chain failure model highlights the need for managers at the prime to concentrate on identifying the root cause of a failure rather than consistently repeating short term solutions in order to fix problems quickly. Although they can take longer to establish, sustainable resolutions to problems must be identified and pursued in order to avoid persistent failures from reoccurring.

In addition, the model demonstrates how the prime must remain committed to long term strategic plans by developing alternative supply options that create competition in the market. The model demonstrates this by highlighting how interdependencies between the prime and first tier supplier can lead to commercial lock in if not managed correctly. In order to successfully mitigate against interdependencies that have formed overtime, managers at the prime need to establish the correct balance between persisting with long term strategies and developing sourcing options within the supply chain.

In order to help existing first tier suppliers to improve operational efficiency on the components they already supply, the prime needs to minimise the amount of material rescheduling requests made once schedule requirements have been accepted by the first tier supplier. The model highlights how adoption of this strategy by the prime reduces scheduling disruption and improves existing planning capability throughout the first tier supply chain. The need for the prime to micro-manage the supply chain will also be reduced.

The model also highlights how deficiencies in the prime's current communication processes and established protocols feeds back to exacerbate the risk of developing internal silos, which in turn contribute to persistent failure. The model highlights to managers how relationship management / communication is equally as important to improving supplier performance as process compliance for example and therefore must be effectively managed in order to reduce the causes and effects of persistent supply chain failure.

7.8 Chapter Conclusions.

The purpose of Chapter 7 was to critically discuss the persistent failure model in relation to the current state of knowledge and related literature and identify the implications for business and management. The contributions made to the literature of individual loops have been discussed and the unique contribution of the complete model is highlighted. Business and managerial implications of the model were then assessed providing clear guidance to managers at prime industrial organisations with directions on how to avoid persistent supply chain failure with a first tier supplier. Key contributions pertaining to where and how a prime needs to focus its efforts in order to firstly resolve persistent failure and secondly mitigate against reoccurrences in the future was provided. Finally, it has been demonstrated how the research questions have been successfully addressed during the research project. This highlights a significant contribution to existing literature on supply chain and operations management.

Chapter 8: Conclusion.

From the beginning, the ultimate goal of this research project was to address a critical business problem by performing new empirical research and generating insights that would contribute to solving the problem. Upon commencement of the project, it was identified that some literature talked about a perceived gap between management research and the practitioner world (Teece, 2007). There have been many comments made about how far apart the two worlds appear to be (Meredith, 1998). Despite there being a multitude of research studies, there is a debate within the operations / supply chain management field around the usefulness of the research literature for practitioners (Stuart et al., 2002 pp. 419). A challenge that researchers face is being able to convert developed theories into practical uses for practitioners. This background motivated the approach taken to the empirical study in this work - the best way to extract rich insights and tacit knowledge was to discuss issues directly with practitioners themselves through multiple case studies. The research captured a real life topical management problem and sought to present the findings in the clearest possible way using a model based on interacting causal loops. A brief summary of how each stage was conducted and presented is provided here.

The background and motivation for the study was introduced in Chapter 1. A brief discussion of previous literature studies that sought to investigate supply chain failure along with a description of the supply chain management literature to be reviewed was given and research background was then provided followed by an examination of key research topics. This was followed by an introduction to the research aims, objectives and expected contributions. The research questions were then introduced to highlight key issues that needed to be explored and addressed. This was done in order to illustrate subject areas that would be investigated throughout the study. Finally, an overview of the research methodology and design was given.

A comprehensive review of literature relevant to the study of persistent supply chain failure was provided in Chapter 2 (Literature Review). Key gaps in the contemporary literature were identified, justifying the research questions proposed in Chapter 1. In order to develop a set of robust research questions that could address gaps in the literature and adequately justify the study of the phenomenon of persistent supply chain failure, a wide breadth of literature needed to be investigated covering a number of related domains. Finally, the principal research themes that guided the research design and methodology Chapter were identified and discussed.

In Chapter 3, Methodology and Research Design, the research protocol that was developed and followed throughout the study was described in detail. This included a detailed description of the structure for the research approach, which included information about the selection of companies and the managers within these organisations that would participate in the study. In addition, a description of the data gathering process and protocols for each set of participants was given. In order to illustrate how categories and themes were developed from the data, commentary was provided detailing how the coding process was conducted followed by a description of causal loop diagrams and analysis of how they are constructed and what they can show. Finally, a review of the steps taken to validate the research findings was provided to ensure that the methods applied were rigorous, robust and are repeatable.

In Chapter 4, Qualitative Analysis, the most consistently identified causes of failure highlighted in the study by the target groups were presented and then organised into specific categories and themes. Throughout the Chapter, key observations and findings were documented and analysed. This included empirical evidence and narrative descriptions captured in the exploratory phase. The emergence of the phenomenon of persistent supply chain failure was then described, followed by a review of the empirical evidence and its relationship with the literature.

Chapter 5, Causal Analysis, focused on providing justifications for how and why variables were developed from the empirical evidence that was analysed and categorized in Chapter 4. An explanation of how each of the variables interact to form causal loop diagrams was then described in detail along with the presentation of each developed loop, culminating with the introduction of an initial complete model of persistent failure for the first time. The Chapter ends with a glossary of terms that provided descriptions and a brief explanation of the individual variables.

Chapter 6, Validation, described and analysed observations and critique of the failure persistence model given by participants in a model validation workshop held at the prime’s facility. This was preceded by a pilot study testing of the model. The workshop held at the prime’s facility involved a thorough critiquing and validation of the failure persistence model. Every observation and comment captured regarding each loop was presented and discussed during the workshop. This led to a further developed iteration of the causal loop model, now entitled the 'Persistent Failure' model to help in identifying, understanding and mitigating against persistent supply chain failure. Analysis and review of the updated persistent supply chain model was given along with a description of the updated variable definitions.

In Chapter 7, Discussion, each causal loop model was discussed in relation to the existing literature and current state of knowledge culminating in a review of the completed and newly developed model. Whether each causal loop confirmed, added to, or refuted existing thinking was examined. In addition, an identification of whether the literature is currently silent on each captured issue was given, clarifying where and how the model adds to existing knowledge. The Chapter then discussed the managerial and business implications of the persistent failure model. A review and justification of how the research questions had been addressed as a result of the research project was then provided, demonstrating the key findings presented in the persistent failure model.

Finally, here in Chapter 8, Conclusions, we summarize the formulation, validation and development of the persistent failure model. The limitations and an examination of potential further areas for research are discussed. Elements of the research methodology and design that could be further developed are indicated. Ideas for further research that have emerged during the course of the project are also presented.

8.2 Limitations of Multiple Case Study Research.

As the theory of persistent supply chain failure was being developed, a large portion of the research process required an element of innovation (Piekkari et al., 2010). As a consequence of the practical realities of conducting research in the real world, a number of things did not go to plan. Also, reflecting on the study, there are a number of issues that could be further developed in future research. The limitations of this type of study and the further opportunities that have emerged are noted here.

Persistent supply chain failure can occur due to a multitude of reasons, issues, influences, and negative interactions over a period of time. This research project was guided by the philosophical approach of critical realism based on the opportunity to gather and interpret data from a large prime manufacturer and a number of first tier suppliers with a history of failure, an opportunity that perhaps others may not have had. Five first tier suppliers participated in the study. They represented a good blend due to their differing characteristics and history with the prime. A significant number of supply chain professionals from both first tier suppliers and the prime participated. Although the study is large in comparison with many published empirical studies in supply chain management, in the development of the research design and methodology it was hoped that a larger number of participants would take part in interviews across a larger sample of first tier suppliers. The sensitivity of the topic did prove to be challenging. This included the potential bias in responding, particularly the first tier supplier participants who had a tendency to blame the prime's strict quality management system and subsequent behaviour for contributing to persistent failure. However, this was mitigated by the guarantee of anonymity and through conducting research with both parties, i.e. conducting case study research on the prime in order to gain their perspective on causes of persistent failure. In addition to the sensitivity of this emotive subject area, other obstacles and practical constraints were inevitably experienced, in particular the time available to collect data.

As with all qualitative studies, the key issue is saturation (Mason, 2010) - how many interviews does it take to gain sufficient knowledge that underpins the theoretical propositions required to satisfactorily answer the research questions? There are a number of literature responses that attempt to address this question (e.g., O'Reilly and Parker, 2012), although it is generally considered to occur when participants start providing insights and observations that have already been captured. A strong indication that the number of interview participants who contributed to the semi-structured interviews during the exploratory phase was sufficient was that the participants from both the first tier suppliers and then the prime repeatedly discussed the same issues.

All of the participants in this study were from the UK, although the supply chains they managed were globally dispersed with sub-tier supply chains based in Far East (China and Japan) and also in Central Eastern Europe (Poland). Although this was not necessarily a limitation, future research opportunities could investigate first tier suppliers and prime manufacturers from other countries. A further limitation of this work is that only one industry was investigated, i.e., the aerospace industry. Other complex high-tech manufacturing industries could also be studied such as Automotive, Rail, Marine, and Power Systems because they contain similar high quality standards, complex planning and production processes and often share suppliers across supply chains due to the utilisation of similar components and technology.

Reviewing a large literature spectrum was required to identify potential domains of relevance and identify gaps in the literature with regard to the phenomenon of persistent supply chain failure. Research that was related to the phenomenon was spread across a myriad of different literature topics. The search criteria for this project brought up literally tens of thousands of books, academic journals and practitioner journals. Focusing the literature and then identifying a potential gap that would lead to a contribution to knowledge was an extremely time consuming endeavour because such searches are never fully exhaustive. The most directly relevant domains were used to underpin this research. However other theory domains in business and management such as agency theory (Zu and Kaynak, 2012) might also have been explored if time had allowed.

A further potential limitation of the research project was the use of only two methods of research, i.e. a qualitative study using multiple case study research, followed by causal loop modelling. Due to the size and overall complexity of the study alternative methods were precluded but could be considered. Adopting a 'triangulation' approach in the empirical research methodology, i.e. data collected in two ways such as directly interviewing key members of staff and issuing questionnaires sent to a pre-determined sample of participants within the organisations selected. Data derived from each approach could then be grouped together using coding in order to establish trends and a specific data set per each research question. In order to ensure that the information attained was uniform across all six organisations (including the prime), the data could then have been collected and coded in exactly the same way demonstrating a method for reliability. However, this would have been much more time consuming and the success of this activity may have been questionable due to the sensitive subject of the research, i.e., participants may have been unwilling to record negative issues in a survey that might reflect badly on them, their business function, their superiors, or their organisation. Thus, a justification for not using quantitative style questionnaires is that they may have proven too be too limited.

In this research it was decided that qualitative research alone was the most efficient method to identify why failures occur within the sub-tier supply chain management process. By conducting semi-structured interviews, in view of the philosophical standpoint, and obtaining data from a real life setting from supply chain professionals, it was felt that this would provide a greater opportunity for richer data with more depth. Quantitative research surveys might not have provided a picture of the dynamic element of a relationship between buyers and suppliers or the interaction of influential variables since the original contract formulation. Interpreting interview data with the use of coding by asking structured questions that were specifically designed to identify cause and effect of failure proved to be an effective method to adopt.

Finally, this study did not run simulations or test the model through simulation as is often done in System Dynamics research. The purpose of the study was to define persistent supply chain failure and to understand the cause and effect of variables within each of the loops and how they contribute to persistent supply chain failure. Therefore, developing simulations in order to test the model was outside the scope of the study.

8.3 Opportunities for further research.

Due to the nature of this research project, the sheer number of literature domains considered and the case studies conducted, a number of other issues emerged that would justify further examination. The methodology and postulated theory development of persistent failure provides a myriad of opportunities for further research. Below are noted some of the opportunities that could enhance academic research in this area and add value to operations and supply chain management theory and practice:

(i) *Conducting simulations and testing the model* – The next stage in the development and evolution of the model is to test the effectiveness of the persistent supply chain failure model by simulating a real life scenario at the prime and demonstrating the cause and effects of failure dynamically over a period of time. The model could pinpoint potentially negative interactions between variables enabling supply chain managers to put mitigation activities in place in time to either reduce the effect of failure or prevent failures from occurring in the first instance. The big challenge for such a study is the specification of the time lags that occur between causes and effects in the model. This would be a major research project in itself requiring further empirical research.

(ii) *Agency Theory* (Prosman et al., 2016) – could be used to analyse the 'principal–agent' relationship between the prime and first tier supplier as this approach was not investigated in the study. Using an agency theory perspective could be especially pertinent in further understanding the supplier performance set of loops. For example, does the principal act in the best interests of the supplier? Conversely with the dependency theme i.e. does the supplier act in the best interests of the principal at every opportunity (Bosse and Philips, 2017)? More specifically, self-serving behaviour within the relationship by either the prime or the first tier suppliers was not examined, which could add greater insight into the causes of persistent supply chain failure (Bosse and Philips, 2017). A further question that could be examined concerns whether one of the parties generates value at the expense of the other party even if it can become detrimental to both parties in the long term?

(iii) *Identifying the effects of changes over a period of time* – Tracking the effectiveness of interventions made to the system. This could be done by developing a System Dynamic Model and then evaluating the effect of sudden changes in policy by the prime on the supply chain and how this affects persistent supply chain failure.

(iv) *The effects of Risk and Revenue Partnerships on Persistent Supply Chain Failure* – These types of partnerships (Ghadge et al., 2017) are formed in order to spread the cost and risk of new product development into the supply chain. As a result, the supplier invests in the project and takes a percentage of the engine sale. They are by definition long term. What are the effects on the prime if such a supplier begins to cause persistent supply chain failure?

(v) *Enabling managers to visualise the effects of external factors* – The area of research focus could be on the first tier and sub-tier supply chain. Changes to industry regulations and the effects caused could be measured to see how they affect supply chain performance.

(vi) *Highlighting the effects of poor relationship management* – This could study the effects of the prime continually changing the personnel who interact with a first tier supplier. Evidence from the exploratory stage shows how the prime regularly changes personnel who act as the point of contact to first tier suppliers. Participants from the first tier suppliers reported how this activity caused them disruption because relationships had to be continually re-established wasting time and effort on their part.

(vii) *Implementation of a new visual tool for management* – Taking advantage of being able to condense large amounts of information into one model, managers can use the model and the research methodology that has been created to develop supply chain recovery strategies. Also, the prime could use the model to make internal process and protocol design changes.

(viii) *Substitute or additional value stream mapping* – The causal loop diagrams show network cause and effects, i.e. they identify potential outcomes of supply chain designs rather than just identifying the component parts of a supply chain or a process. The causal loop model could provide managers with visibility of interacting variables that could cause failure before the failures are allowed to happen. The model could also show how quickly solving a problem in one part of the system can potentially cause a problem in another area.

(ix) *Identification of the implications on decisions - internal organisational structures and strategy*. The effects of the organisation of individual departments having their own purchasing functions such as the aftermarket function could be explored.

The aforementioned areas for further research are some of the potential opportunities that the persistent supply chain model represents to industry.

8.4 Wider Application of the Persistence Failure Model.

As development of the model progressed from being an initial concept, through to validation, further potential applications emerged. The persistent failure model could be utilised by prime manufacturers and wholesalers in a number of industries as a way of visualising their supply chain management and identifying where risks may occur in the future. Persistent failure is tolerated far less in industries such as Automotive and FMCG industries but significant failures do still happen. For example, the automotive industry regularly suffers from high profile supply chain failures resulting in mass recalls (Marksberry, 2012). The fast moving consumable goods (FMCG) sector such as food retail, can be relatively complex and advanced in terms of preparation and packaging and is also sensitive to supply chain failure (Lambert et al., 2016). The horse meat scandal (Premanandh, 2013) highlights why leading supermarket chains need to have control and visibility of their supply chain. The electronics industry is another market with often large and complex sub-tier supply chains (Cooper et al., 1997). In recent years this industry has been affected by unpredicted events caused by natural disasters and industrial accidents. Another threat for these companies is obsolescence[20] and disruptive technologies[21]. In some of these industries there will be an opportunity to switch suppliers more quickly than in aerospace. By adopting a causal loop diagram methodology, such manufacturers could identify and link key variables together from their respective markets and use the model as an early warning system by identifying which variables could interact to reinforce possible future failure.

[20] Obsolescence – *The process of components or manufacturing techniques becoming outdated and therefore no longer required. These are usually superceded with new technology or improved processes.*

[21] Disruptive Technologies' – *Technology that renders rival products or processes as obsolete.*

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Appendix 1 – Draft Pilot Case Study Protocols

1.1 Overview of Pilot case study project.

This pilot case study is being conducted in order to investigate, analyse and evaluate the phenomena of persistent supply chain failure. In persistent supply chain failure a chosen sub-tier supplier consistently fails to provide the level of quality and delivery performance originally expected or specified within an agreed contract. The work is a major element of a PhD research project at the University of Nottingham aimed at analysing and defining the concept of persistent supply chain failure.

The key outcome of the research is to:

- Define persistent long term failure.
- Understand and document how organisations manage persistent long-term failure.
- Identify and document how organisations recover from persistent long term failure.

The criteria for case study selection are explained below:

1. Poor performing suppliers to the prime.
2. Low tech suppliers (Example: Machining) to the prime.
3. High Tech suppliers (Electronics) to the prime.

1.2 Project Objectives, Purpose and Auspices.

The key objectives of this case study protocol document is to create a plan of action to be used and followed when conducting research at the site of a chosen participant supplier, and to ensure that the correct procedures are followed. This methodology is required in order to ensure a systematic replicable study that can be repeated throughout the project on all participating suppliers. It is also a key objective to keep the threat of bias to a minimum and protect the rights of the participants asked to be involved in the study. The aim of this pilot case study protocol document is to develop standardised procedures to obtain information to support the research project on persistent supply chain failure. Systematic processes and procedures will be created and tested during this pilot study research and the findings and experiences will be utilised to develop the most efficient protocols to use during the official case study research. The following activities will drive the research process;

- Interview questions. The questions will be drawn up to answer the research questions. These questions will then be tested to see if they yield responses to support the study. It will be here that the relevancy of the interview questions in line with persistent supply chain failure will be validated.
- Structure and format. The semi-structured interview sessions will be developed and tested. The experiences and observations gained here will show whether the structure adopted is flexible enough to deal with sudden changes in the itinerary and behaviour of the employees being interviewed.
- Data collection. The ability to obtain information from other sources within the organisation will be tested and built into the protocols of the official case study research. The ability to observe events going on in a real life environment and ask relevant questions accordingly will help develop flexibility into the overall plan
- Develop field procedures. A process will be developed that is firstly, repeatable and will be the format that is followed for every case study. This will include developing an introduction letter explaining the purpose of the research and the contribution that the organisation will make to research. A process for the protection of interviewees will be developed and tested along with basic procedures such as structure of interview process. This will include functional employees to be interviewed, the time and location of interview, for how long, process for reporting findings back to organisation to make them feel that they have benefitted from the process.

The overall outcome of the pilot case study research project is to develop a set of robust protocols to be used in the main multiple case study research. The experiences gained at the chosen pilot case study organisation will enable a streamlining of the process so that data can be collated and grouped in a systematic way. Data from all case study suppliers will be sorted into groups and categorized into themes. When all of themes are identified, they will be compared against the research questions to establish whether any trends occur that highlight characteristics of performing suppliers versus consistently failing suppliers. This will show what activities each supplier is engaged in and should identify successful practices in comparison to problematic practices. Therefore, the pilot case study will test the initial study design.

1.3 Field procedures.

In order to present credentials to case study participants (Organisations) a standard letter template has created that details the following:

- Introduction from the lead investigator and the institution they represent.
- Outline who the letter is directed at within the organisation and detail their importance within the process.
- Provide brief information on the aims and objectives of the study.
- Provide brief information on the questions that require answering.
- Outline the potential benefits that the research investigation will bring.
- Re-iterate the fact that successful co-operation will provide important and critical research findings.

1.4 Justification of the selection of the pilot case study.

The pilot case study organisation has been chosen on the following basis;

- Convenient location.
- Direct supplier to the prime.
- Direct supplier to other aerospace OEM's.
- Supplier with a long term contract with the prime.
- History of poor performance.

Access to the pilot case study site has been gained through the use of networking and prior knowledge of the organisation. Through the researcher's previous experience of working for the prime in Derby, a counterpart was contacted via email and asked whether they would

1.5 Language pertaining to the protection of interviewees.

For interviewing key persons, you must cater for the interviewee's schedule and availability, not your own. The nature of the interview is much more open ended, and an interviewee may not necessarily cooperate fully in sticking to your line of questions. Similarly, in making observations of real life activities, you are intruding into the world of the subject being studied rather than the reverse; under these conditions, you are the one who may have to make special arrangements, to be able to act as an observer (or even as a participant-observer). As result, your behaviour, and not that of the subject respondent – is the one likely to be constrained (Yin, 2009 pp. 85). As part of the protection for employees at each case study site the following activities are going to be conducted to ensure that special care and sensitivity towards human subjects is given. These considerations go beyond the research design and other technical considerations:

- Informed consent will be obtained. All persons who may become part of the case study will be notified of the nature of the research. They will be formally soliciting their willingness to volunteer in the study.
- Protecting those who participate in the study. All participants will be protected from harm, including avoiding the use of deception in the study.
- Privacy and confidentiality. This will be carried out with all those who choose to participate in the study so that they will not be unwittingly put in any undesirable position.

1.6 Sources of data (Data collection plan).

The following table (Table 1 data collection protocol) highlights the adopted process for collecting data at each of the first tier suppliers.

Table 1 Data Collection Protocol.

DATA COLLECTION PROTOCOL		
Evidence	Type	Approach
Semi Structured Interview questions	Primary	Arrange interviews with pre-selected personal from identified job functions – This will done 1 month in advance of being on site. Interviews should take no longer than 1 hour. Build in flexibility in-order to capitalize on potential new information i.e. interview employee from a different function.
Observation	Primary	Observe all events that are going on and be aware of

		what employees are actually trying to say. Continually ask questions that are pertinent to SCR throughout the entire time I am onsite.
Support documentation	Secondary	If it is ok to do so request the following documentation: • Sub-tier performance metrics. • Customer performance metrics. • Sub-tier sourcing specifications i.e. quality, delivery and commercial requirements. • Organisation strategy, goals and vision.

1.8 Pilot case study questions.

Formulation of the case study questions has been guided by Yin's 'levels of questions'. The questions in the case study protocols are different depending on who they are aimed at i.e.

- Level 1: questions asked of specific interviewees.
- Level 2: questions asked of individual case (these are the questions in the case study protocol to be answered by the investigator during a single case, even when the single case is part of a larger, multiple case study).
- Level 3: questions asked of the pattern of findings across multiple cases.

(Yin, 2009 pp. 87)

The questions asked at all levels are designed to answers and further understand the research questions formulated as a result of the systematic literature review study.

Research question one (RQ1): *What is persistent supply chain failure and how can it be understood?*

Research question two (RQ2): *What factors drive persistent supply chain failure and what are the interrelationships between them?*

Research question three (RQ3): *What supply chain recovery strategies can be adopted to help resolve different types of consistent failures effectively?*

Appendix 2 – Level 1: questions asked of specific interviewees

1. Performance Management Questions.

PARTICIPANT INFORMATION		
Function:	Operations / Engineering	
Job Title	**Responsibilities**	**Justification for Interview**
Operations Manager	Accountable for production, manufacturing quality and delivery to customer.	Can provide overall picture of organisational performance in line with the future direction of the organisation i.e. quality / manufacturing improvements and efficiency programmes. They should be aware of best practice / standards within industry and within alternative industries.

Question Number	Research Question	Question	Literature	Interviewee Response
1	1	How is your organisation measured by the Prime?	Performance	
2	2	Do you review internal capacity constraints vs. the customer demand profile when tendering for business? If not why not?	Performance	
2.1	3	If not why not, how do you know that you have enough resources to meet demand and quality requirements	Performance	
3	1	How often do you review performance?	Performance	

4	2	Do you only accept work that you are set up for and capable of doing? If not why not?	Performance	
5	2	Has your organisation ever been put into delivery or quality red flag as a result of poor metrics on the Primes' balance scorecard?	Performance	
5.1	3	If so why and if not why not?	Performance	
6	2	What are the specific metrics chosen by this organisation to ensure that long term chronic supply chain failure does not occur?	Performance	
6.1	3	Do / have they helped to prevent chronic long term failure from occurring?	Performance	
6.2	3	If so how, if not what happened?	Performance	
7	2	If quality and delivery performance are being affected because of capacity constraints in times of high demand, are customers prioritized?	Performance	
7.1	1	If so how? If not why not?	Performance	
7.2	2	Does your organisation increase shifts to cope with additional demands?	Performance	

7.3	2	Do you get suppliers to increase shifts to cope with additional demands?	Performance	
7.4	2	Does your organisation prioritise production runs when capacity is constrained? If not why not?	Performance	
8	3	Does your organisation align its business goals with the customer?	Performance	
9	3	When a failure is reported by a customer, how quickly do you have to respond to that failure in-order to prevent it from being classed as a chronic long term failure?	Performance	
9.1	2	If it takes longer than a week to react, why?	Performance	
10	2	Do you have a planning department? Is this considered a key organisational function? If not why not?	Performance	
11	3	What containment measures do you put in place to prevent the failure from turning chronic?	Performance	

12	1	What is the most common cause of customer rejection / failure with the Prime?	Performance	
13	3	What measures could take place to solve problems earlier in the event of chronic long-term failure	Performance	
14	3	In the event of chronic long-term failure are teams assembled and empowered to resolve the problem?	Performance	
15	2	What are the key factors that contribute to failure through performance management?	Performance	
16	3	What initiatives (if any) have been put in place to improve performance management?	Performance	
16.1	2	Are they customer or supplier led?	Performance	
16.2	3	If so, how successful are the initiatives, if not why not?	Performance	

2. Quality Management Questions

PARTICIPANT INFORMATION	
Function:	Quality Department

Job Title	Responsibilities	Justification for Interview
Quality Manager	Owner and gatekeeper of organisations quality process.	Should provide perspective on current sub-tier / market quality capability in line with company standards and alternate industry capabilities

	Research Question	Question	Literature	Interviewee Response
1	1	What would you describe as a ‘quality’ failure?	Quality	
2	2	What are the key factors that contribute to quality failure within the organisation?	Quality	
3	1	Is your organisation ISO 9000 certified?	Quality	
3.1	3	Does the existence of the ISO certification mean that quality failure (Long-term) are less likely to occur?	Quality	
4	1	Does your organisation have a robust quality system that can quickly identify, improve and control quality failures?	Quality	

4.1	2	How can you identify that the system is robust and can control a failure by preventing it from becoming chronic?	Quality	
5	2	What is the process from managing a reoccurring failure?	Quality	
6	3	Does your organisation conduct process failure mode effects analysis PFMEA to ensure repeat problems don’t occur?	Quality	
6.1	3	Is this part of your sub-tier selection criteria to control potential failure from occurring down the supply chain?	Quality	
6.2	2	Were you asked to provide evidence of a PFMEA process when tendering for business from the Prime?	Quality	
7	1	Does your company employ gage r&r measurement techniques?	Quality	

8	2	Does your IT system support the quality requirements for each manufacturing process? Are you audited by your customer on this system?	Quality	
8.1	3	If so, how often?	Quality	
8.2	2	How often do you audit your sub-tiers quality systems?	Quality	
8.3	3	If you not, why not?	Quality	
9	3	In the case of long term chronic failure, How quickly does it take to identify the problem and put containment measures in place?	Quality	
10	3	Do you review processes regularly? How often do you update and train people on improving processes?	Quality	

3. Relationship Management Influences and Leverage (Power) Questions

PARTICIPANT INFORMATION		
Function:	Sales	
Job Title	**Responsibilities**	**Justification for Interview**
Commercial Manager	Commercial link between procurement and sales within the organisation	Detailed knowledge of customer requirements vs supply chain capability. Should understand where the organisations strengths and weaknesses lie within their supply chain management function and how it affects their ability to be competitive within the markets they serve.

	Research Question	**Question**	**Literature**	**Interviewee Response**
1	2	What are the key factors that can contribute to chronic long-term failure for the organisation?	Power	
2	1	What is your organisations current credit rating?	Power	
2.1	2	Does your performance have an effect on the credit rating of the company?		
3	3	On what criteria does your company select its potential customers?	Power	

3.1	2	Does your organisation select suppliers who have been known to have been involved in chronic long term supply chain failure in the past?	Power	
3.2	3	If so why? If not why not?	Power	
4	1	Do you have favoured / non-favoured customers?	Power	
4.1	2	If so what is the criteria for this, how do you decide what who is a favoured customer as opposed to a non-favoured customer?	Power	
5	1	How does your organisation differentiate itself from other competitors within aerospace sector?	Power	
5.1	3	Do you think these core competencies give you more time to recover if a failure starts to become chronic? If so why? If not why not?	Power	
6	3	If a chronic long-term failure occurs under what circumstances would the failure be allowed to become chronic, i.e. go on so long?	Power	

7	2	Do you have a maximum leverage cap with your customers and suppliers? If so what is it and why?	Power	
8	2	Do you ensure that supplier protection clauses are incorporated into the contract with the customer to protect you against: • Fluctuations in customer demand (Customer has to pay for WIP parts and raw material if demand is cut within leadtime). • Expectations (I.e. cardinals defining who is responsible for what, where and when and what are the parameters) • Quality disputes (Innocent before being proved guilty through joint investigation) • Other	Power	
8.1	1	Are these flowed down to your customers?	Power	
9	3	Do you encourage long standing relationships with suppliers? If so do you think it reduces the likelihood of chronic long term supply chain failure from occurring?	Power	

9.1	2	How quickly and easily can you re-source if a supplier is not performing thus effecting you performance?	Power	

4. Supply Chain Failure and Recovery Questions

PARTICIPANT INFORMATION		
Function:	**Senior Management**	
Job Title	**Responsibilities**	**Justification for Interview**
Sales Director	Accountable for all sales and new business development	Knowledge of market trends and future business potential

	Research Question	Question	Literature	Interviewee Answers
1	1	What are the key factors that contribute towards supply chain failure?	Service Recovery	
1.1	2	Can they be identified quickly?	Service Recovery	
1.2	3	Can the factors that cause chronic long term failure be resolved in a timelier manner so that they don't become chronic?	Service Recovery	
1.3	3	If this happens are the events recorded so that they prevent failure from happening in the future?	Service Recovery	

2	2	What are the key factors that have contributed to recovery from failure for the organisation?	Service Recovery	
2.1	3	Are these identified factors recorded and used to improve existing processes thus reducing the likelihood that failures will happen again?	Service Recovery	
3	1	Are teams or individuals at all levels given the authority to resolve problems with customers or suppliers autonomously or is there a hierarchical approval process?	Service Recovery	
3,1	1	If there is an approval process, does it affect the speed at which key decisions are made delaying the ability to fix a problem?	Service Recovery	
4	2	When a component is being consistently returned as a non-conformance, what steps do you take to resolve the problem?	Service Recovery	
5	1	Has your organisation managed to win more business as a result of recovering from a chronic long term failure?	Service Recovery	

6	1	Does your organisation have an established process for handling quality failures or late delivery with customers and suppliers?	Service Recovery	
6.1	3	How is this improved in the event of a long term failure?	Service Recovery	
7	1	Do you have direct collaborative communication with the customer?	Service Recovery	
7.1	2	If so what are the benefits? If not, why not and what are the effects of this?	Service Recovery	
8	2	Do you have an agreed time in which to mitigate a failure / close an NCR?	Service Recovery	
8.1	3	Does your customer measure you on this?	Service Recovery	

8.2	2	What is the outcome with your customer if you fail to mitigate / identify the problem within the specified time?	Service Recovery	
8.3	3	Does your organisation flow this rule / time down to your customers?	Service Recovery	
9	3	Are their agreed penalties for non- conforming parts and late deliveries?	Service Recovery	
9.1	3	Do these penalties ensure that greater attention is placed on achieving agreed quality and delivery targets with contracted customers?	Service Recovery	
9.2	1	Are these requirements with the customer ambiguous? If so how and what effects does this have on your ability to deliver on time and to the correct specification?	Service Recovery	

5. Risk Management Questions

PARTICIPANT INFORMATION		
Function:	Senior Management	
Job Title	**Responsibilities**	**Justification for Interview**
Managing Director	Accountable for the organisation	Knowledge of organisational performance and competitiveness in the

		market. Knowledge of future vision and strategy of the organisation in line with customers’ strategy and future market forecasts.

	Research Question	**Question**	**Literature**	**Interviewee Response**
1	2	What are the key risks that contribute to failure for the organisation?	Risk	
1.1	3	Are risk assessments carried out to ensure these issues are identified and managed before they can contribute towards chronic long term failure scenario	Risk	
2	3	Can failure to identify and manage key risks at critical stages in a contract contribute to long term chronic failure? If so how and when?	Risk	
3	1	Who is considered responsible for your organisations identification and management of risks?	Risk	
3.1	2	Are these identified risks flowed down to other members of the organisation / project teams etc.	Risk	

4	3	What mechanisms are used within the organisation to identify potential risks?	Risk	
4.1	2	Once identified, how are the risks managed / controlled?	Risk	
4.2	3	Has any of these initiatives helped the organisation recover from chronic long term failure? If so how?	Risk	
5	3	Does your organisation conduct joint risk assessments with customer / suppliers prior to key milestones during the contract formulation process?	Risk	
5.1	3	If so how? If not why?	Risk	
6	2	Does your organisation conduct risk assessments when selecting new potential customers /suppliers and when manufacturing new components?	Risk	

6.1	1	If so, do you think it has contributed to mitigating chronic long term failure?	Risk	
7	2	How regularly are risk assessments updated and managed during a contract with a customer / supplier?	Risk	
8	3	When it is identified that chronic failure is occurring (i.e. repeated NCR's and component returns) do you instigate a risk assessment process?	Risk	
8.1	2	Has this contributed to resolving the problems and has it prevented the problem from occurring again?	Risk	
9	3	Do you have regular meeting concentrated on risks or are potential issues identified during day to day meetings?	Risk	
9.1	3	If so, how effective are the meetings at identifying the issues?	Risk	

6. Business Continuity Management (Contingency) Questions

PARTICIPANT INFORMATION		
Function:	Senior Management	
Job Title	**Responsibilities**	**Justification for Interview**
Managing Director	Accountable for the organisation	Knowledge of organisational performance and competitiveness in the market. Knowledge of future vision and strategy of the organisation in line with customers' strategy and future market forecasts.

	Research Question	**Question**	**Literature**	**Interviewee Response**
1	3	What in your opinion are the key macro-economic factors that can contribute towards long term chronic supply failure?	Contingency	
1.1	3	What actions (If any) do you put in place to protect your organisation from this causing chronic long-term supply failure?	Contingency	
1.2	1	If you have no actions / initiatives in place in place, why not?	Contingency	
2	2	To mitigate against the risk of events happening that are out of your control, what initiatives do you have in place to insure continuity of supply?	Contingency	

3	1	Who is considered responsible for your organisations management of BCM?	Contingency	
3.1	3	Are these initiatives flowed down to the rest of the organisation?	Contingency	
4	1	Do BCM issues drive business strategy I.e. supplier selection?	Contingency	
5	1	Does your organisation request a BCM from all prospective suppliers?	Contingency	
6	2	In the event of a supply failure caused external events, how quickly can the organisation react?	Contingency	
7	2	When long term chronic failure occurs, are BCM issues reviewed and included in a mitigation plan? If not why not?	Contingency	

8	2	Is raw material / finished stock held on site or is it stored in warehouses in multiple locations?	Contingency	
9	3	Do you identify potential external risks on an on-going basis i.e. watch the news, keep track of the markets etc.	Contingency	

7. Supplier Development Questions

PARTICIPANT INFORMATION		
Function:	Supplier Development	
Job Title	**Responsibilities**	**Justification for Interview**
Supplier Development Manager	Is accountable for all supplier improvement projects in line with company business process deployment plan	Can provide overall picture of supplier improvement projects in line with the future direction of the organisation i.e. supplier selection criteria vs existing supplier improvement programmes. They should be aware of best practice / standards within industry and within alternative industries.

	Research Question	Question	Literature	Interview Response
1	3	Do supplier development initiatives contribute towards preventing long term failure for the organisation?	Supplier Development	

1.1	2	If so how? If not why not?	Supplier Development	
2	2	In the event of chronic long-term supply chain failure within your supply chain, do you deploy people into your supplier's in-order to facilitate recovery?	Supplier Development	
2.1	3	If so how quickly? If not why not?	Supplier Development	
3	3	If periods of sustained under performance occur, how much extra resource is dedicated to resolving the problem?	Supplier Development	
3.1	3	Do you think extra / dedicated resources can help to mitigate chronic long term supply chain failure?	Supplier Development	
3.2	3	If so why, if not why not?	Supplier Development	

4	1	Have improvement initiatives were implemented by your customers and / or suppliers in the event of periods of chronic failure? If so what are they? Have they helped to improve chronic long term failure?	Supplier Development	
5	1	Are you currently still involved in any customer led activities that were started during chronic supply chain failure?	Supplier Development	
5.1	3	If so has it been beneficial i.e. has it stabilized and / or improved performance?	Supplier Development	
6	3	Do you embrace knowledge and support from your customers and suppliers?	Supplier Development	
6.1	3	If so how and why? If not why not?	Supplier Development	
7	2	During times of chronic supply chain failure do you deploy personal from your organisation into problem suppliers? if so, for how long?	Supplier Development	

7.1	3	Did it improve the situation?	Supplier Development	
8	3	How many, customer supplier development personal have there been within your organisation during times of chronic supply chain failure?	Supplier Development	
8.1	3	Do you think it helped to improve the situation? How?	Supplier Development	

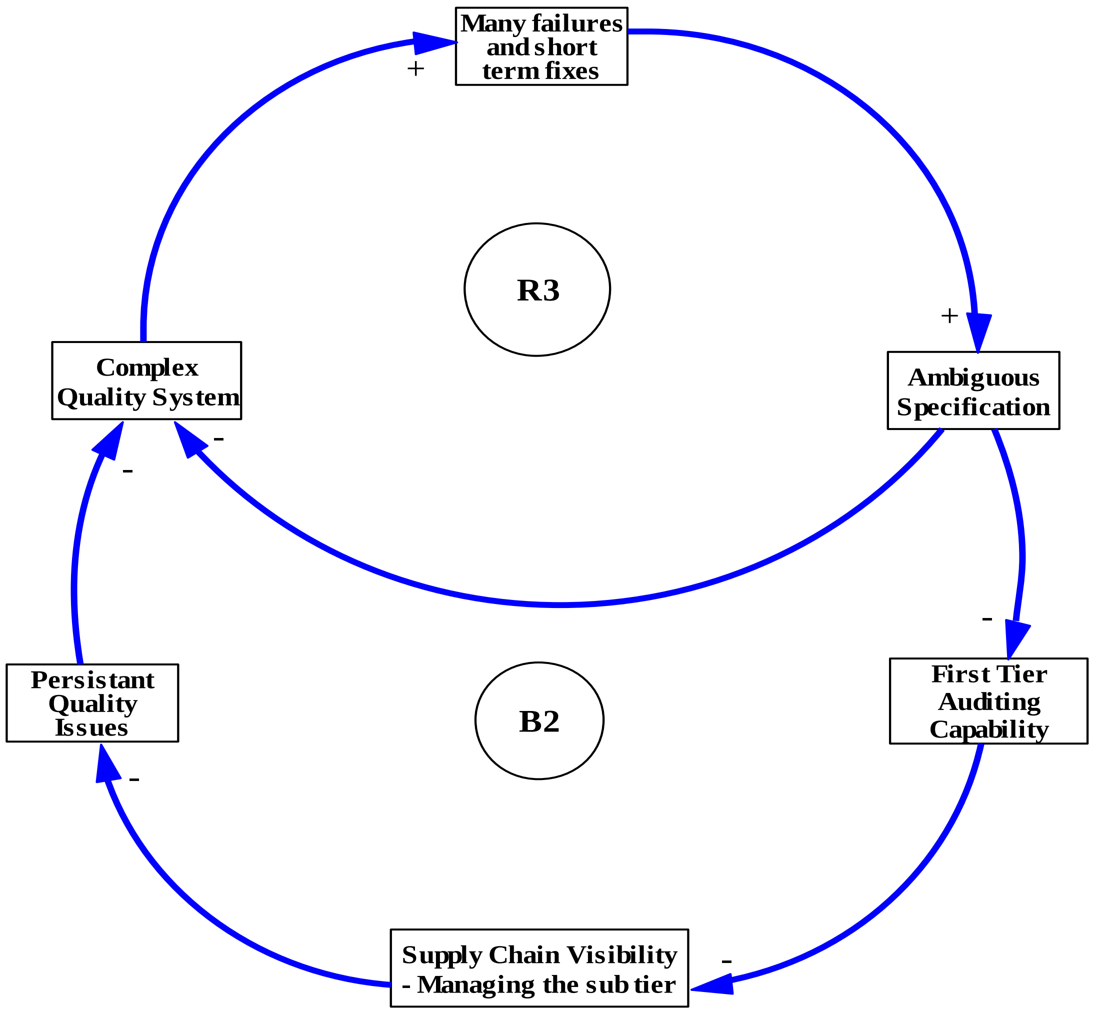
Appendix 3 – Summary of the Coding File Findings.

Interview Topic	Company A	Company A Validation	Company B	Company B Validation	Company C	Company C Validation	Company D	Company D Validation	Company E	Company E Validation	
Performance	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Interviewee Response	Interviewee Response	Key Findings
Power	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings
Service Recovery	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings
Risk	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings
Contingency	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings
Supplier Development	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings
Quality	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Validation	Interviewee Response	Interviewee Response	Key Findings

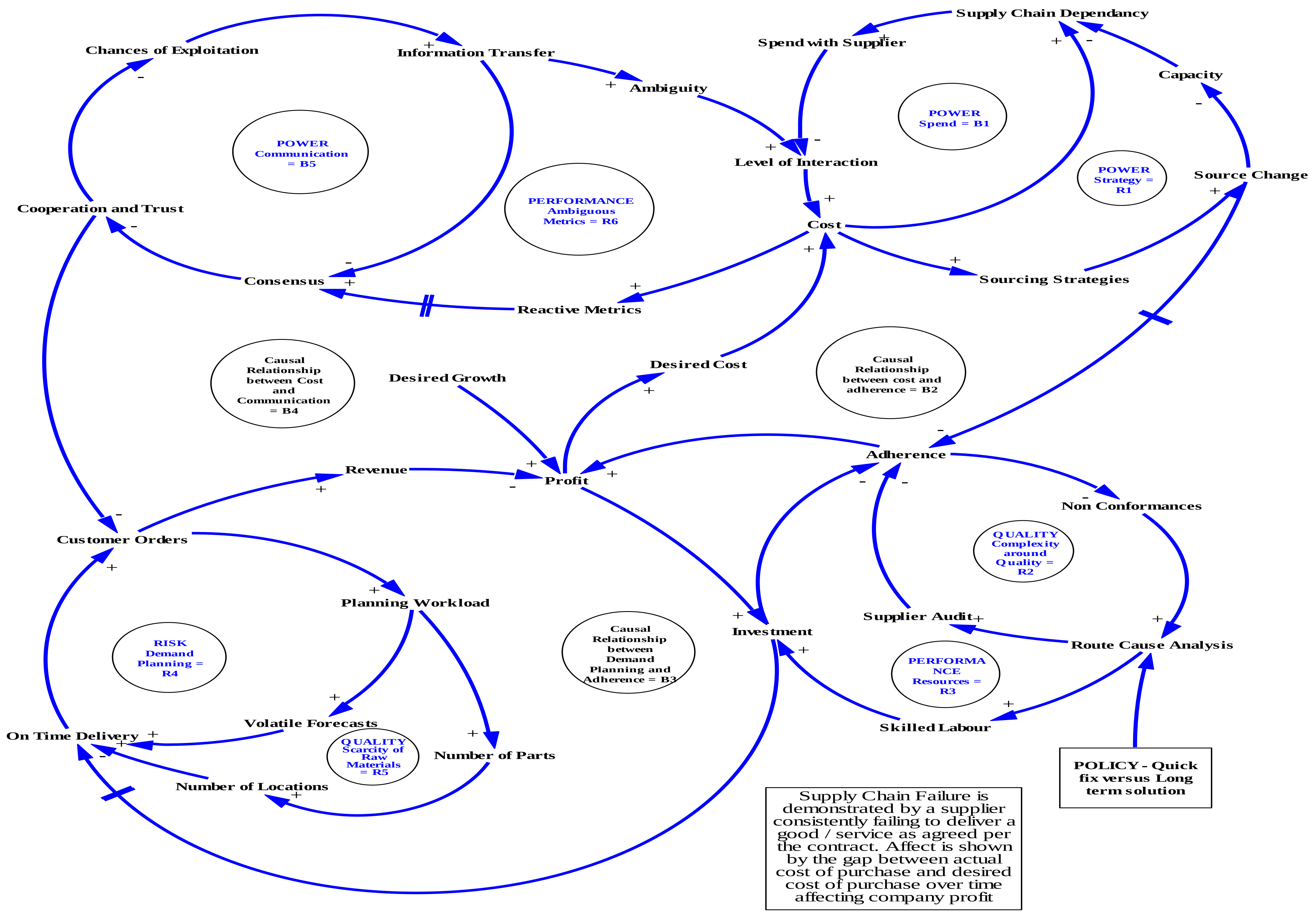
Interview findings – Example of Coding Level 1.

Risk	Risk	Quality	Quality	Relationship Management	Power	Power	Power	Performance	Performance
Demand Planning	Contingency Risk	Complexity Around Quality	Scarcity of Raw material	Communication	Spend	IPR	Strategy	Resources	Ambiguous Metrics
Demand signal Volitility1c Lack of load and capacity planning1c Lack of load and capacity planning1c Inaccurate forcasts1c Forcing suppliers to prioritise deliveries1c Poor planning in the supply chain1c Lack of Adequate Planning Tools1s Poor planning1s Schedule changes on a weekly basis1s Lack of leadtime adherence by the customer1s Sticking to plan1s Demand is not fixed1s Inadequate planning2s Late material supply3s Late specifications by the customer3s Poor planning in the sub tier3s Failure to identify the correct supply chain tools and lead times of products as part of planning3s Number of schedule changes made by the customer.3s Companies who cannot plan3s Putting all the delivery pressure on our suppliers [illegible]	Number of suppliers in high risk areas3c There have been some very close calls in recent times. We have dodged bullets and this has woken people up to the realism.3c Unsure whether BCM is high on the list of priorities.3c Lack of BCM3s	Moving the goal posts regarding our expectations around quality1c Lack of sub tier supplier management by the first tier1c Lack of robust fixes in place to fix the supplier1c Lack of process understanding in supply chain1c Complexity of Parts1s Specification ambiguity1s Ambiguous quality exceptance standards1s Serialization errors1s Knowingly delivered non conforming product2c Process Capability2c Non conformance to the process2c Anything that doesn't meet the specification2c Vagueness around expectations2c Lack of clarity of requirements2c Processes that set the supplier up to fail2c Very high quality standards2c Waivers in the quality process2c Misinterpretation of quality certifications2c Not getting to the route cause of failure2c Re-actively not pro-actively solving quality issues in the [illegible]	Number of Parts1s Alien & Stranger parts made out of exotic materials1s Lack of raw material availability1s Material Issues2s Issue with rare or exotic materials3s Raw material input6s Rare Raw Material6s	Poor information flows2c Culture2c Poor communication2s That is beginning rather than that is in place, we are beginning to share risk management activity with the suppliers.3c Joint risk assessments not robustly in place3c Assessments are based on fairly high level understanding of risk3c Risk assessments conducted on an annual basis.3c We are 12 months in on the journey. So we still have a long way to go in-order to have that full understanding at our fingertips.3c It takes times and it will be a journey of several years before we can say that we have mitigated all the risks3c Untimely response to questions (to the customer)3s Poor information in load3s	Supplier prioritisation based on spend1s Cost - we get what we pay for2c Cost is the driver2c Customer Auditing based on Spend2s Recessions (Economic restriction)3s Support it depends on the level of volume you have and with the vendor.5c Takes a while for this organisation to wake up and smell the coffee! Same as all large organisations.5c Level of Influence depends on leverage5s Not viewed as long term partner4c Focused on mainly strategic relationships4c Supplier relationships Yes / No depends on commodity and in some cases emotional response from suppliers.4c Customer dependency from the supplier4s Commercial Issues4s Dealing with people (organisations) that we are not important too.4s Supplier power effects motivation to recover.6c Dependency effects recovery6c	Restricted supplier base - decisions are made around capacity and not capability1c Sourced IPR components in known global trouble spots3c Sole sources of supply on rare complex commodities4c We end up engineering that single source onto our platforms which makes it difficult to go elsewhere. There is a risk that we become beholding to suppliers who operationally haven't been a good performer.4c We have limited options. We cannot go elsewhere so we are either forced to work with the supplier or force them to engage the one other source we have.4c It is very difficult to transfer these out and takes a long time4c Repeat business because of the fact that they own the design / IPR6s	Lack of robust commodity strategies1c You need to build in your requirements with their requirements "do you want to be part of this game or not"?5c Selecting suppliers with a known history of chronic failure4s Acceptance of poor performance due to lack of options4s Highly leveraged suppliers4s Lack of leverage cap4s Lack of strategy6c Limited competition in market6s	Lack of resources1c Lack of skills and knowledge regarding supplier validation1c There is an aversion in terms of investment in manufacturing1c Antiquated manufacturing processes1s Poor equipment1s Declining labour skills1s Lack of Investment1s Finite resources2c Limited supply chain capability2c Human error2s Poor training2s Poor tools for the job2s Supply chain capacity3c Resource / growth availability in the supply chain3c Lack of required resources at the required time3s Extreme rapid growth (Economic retraction)3s Companies not being able to get adequate funding from the banks3s Cashflow issues at suppliers3s You have got to have a staff of over 150 to 200 people before you start thinking about supplier development otherwise you cannot sustain it.5c Lack of sub tier control.5c Lack of supplier development resources5s Level of resource depends on criticality5s [illegible]	Ambiguous Performance Metrics1c Immature Performance Expectations1c Different Interpretations of performance across the business1c Post event perfomance analysis / Metrics1c History of Failure1s

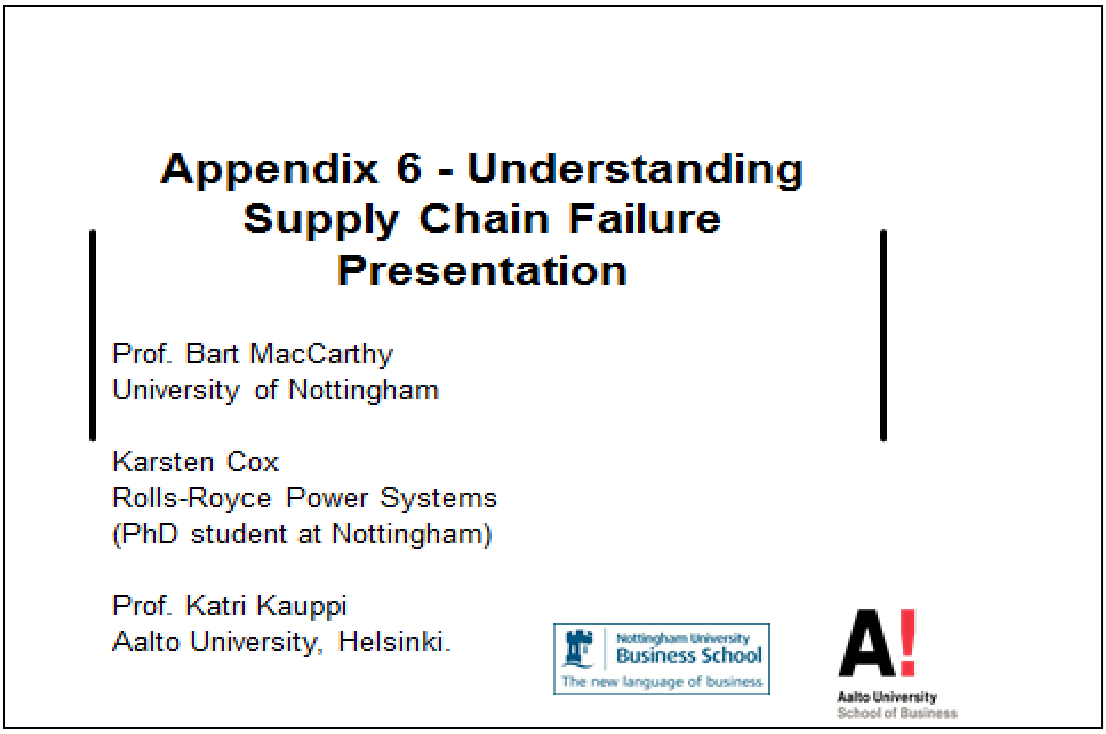
Appendix 4 – First Quality Causal Loop Diagram.



First Iteration of the Causal Loop Diagram Model.



Appendix 5 – Understanding Supply Chain Failure Presentation.

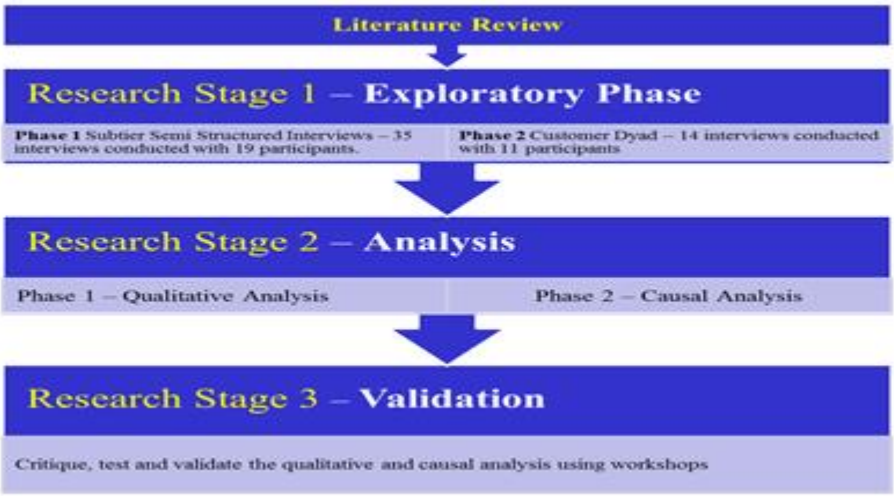


Agenda

- **Introductions & Presentation of Workshop aims – What is persistent supply chain failure.**
- **Workshop Part 1**
  - **Causal Loop diagrams**
  - **What are the causes of persistent supply chain failure by validating the failure persistence model.**
  - **Top level view of the relationship persistence model**
- **Lunch Break**
- **Workshop Part 1 Continued - Causal Loop diagrams – Group feedback session – Validation of the failure persistence model.**
- **Closing feedback session**
- **End**

3

Research Design



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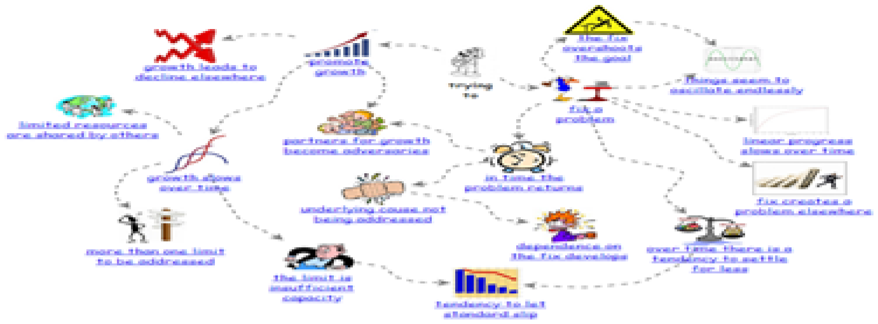
The Dynamics of Supply Chain Failure

Workshop Presentation

Explanation of the Failure Persistence Model



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Key characteristics of CLD behaviour

- **Reinforcing loops** – Demonstrate exponential growth within a system caused by a single feedback loop.
- **Balancing loops** – Demonstrate goal seeking behaviour i.e. the organisation has a defined target. However, there is a gap to achieving the target so the organisation set out to reduce the gap.

The purpose of this research is not to create a perfect model that replicates the real world situation in every detail. Rather it is to engage in a learning process using the model as an instrument for investigation, clarification and discovery.

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Key Identified Themes

Quality Adherence (Process and Product)	**Dependency** (Supply Chain)
Relationship Management (Dyadic)	**Supply Chain Risk / Contingency** (Internal and External)

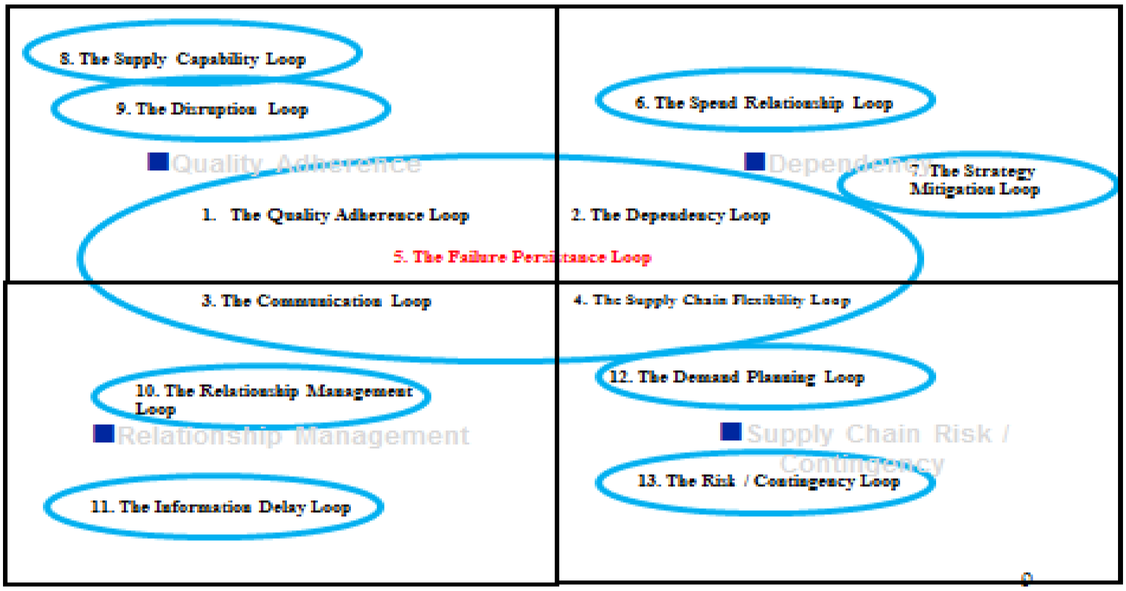
Failure Persistence Model CLD Headings

The Failure Persistence Model aims to show the cause and effect of Persistent Supply Chain Failure using CLD's – The title of each loop is listed below:

1. The Quality Adherence Loop
2. The Supplier Dependency Loop
3. The Communication Loop
4. The Supply Chain Flexibility Loop
5. The Failure Persistence Loop
6. The Disruption Loop
7. The Relationship Loop
8. The Demand Planning Loop
9. The Spend Relationship Loop
10. The Sub Tier Capability Loop
11. The Information Delay Loop
12. The Strategy Mitigation Loop
13. The Risk / Contingency Loop

Why does the prime persist in the relationship with a consistently failing supplier? This model aims to demonstrate the cause and effect of failure persistence on supply chain failure. 8

The Failure Persistence Quadrants



The Failure Persistence Model

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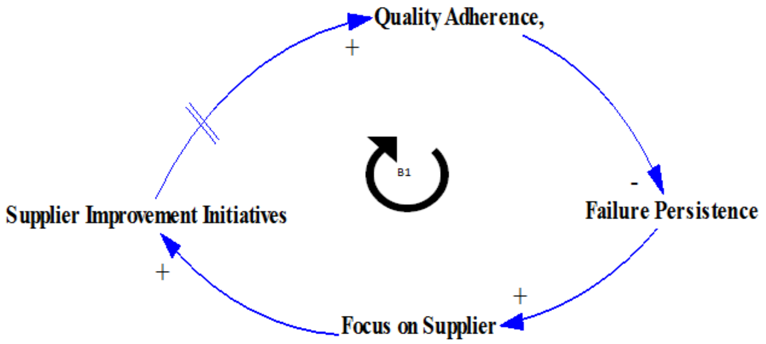
Constructing the Failure Persistence Model

Loop 1

The Quality Adherence Loop (balancing no.1)



Example – Balancing Loop:

- The goal is to reduce failure persistence by increasing quality adherence.
- The gap can be measured by the difference between current performance and the target level set by the organisation.

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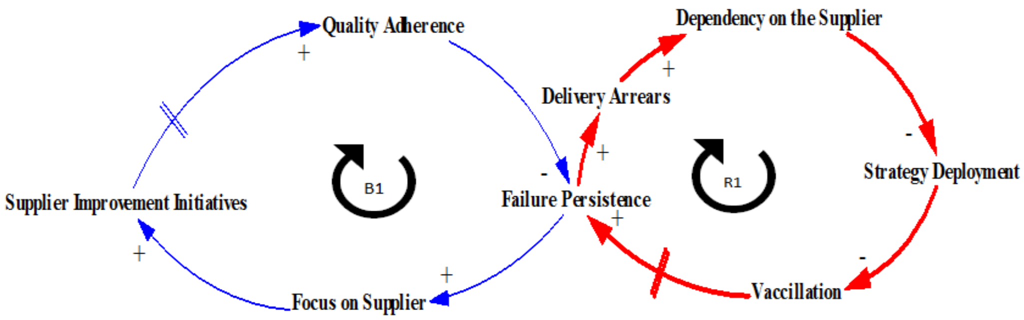
Loop 2

The Loop highlighted has red linkage arrows between each variable

The Dependency Loop (reinforcing no.1)



Example – Reinforcing Loop:

- Exponential growth in dependency on the supplier after each feedback .
- When the problem is identified it is usually too late to mitigate against it. Therefore in this case the prime is already dependent on the supplier to a certain degree.

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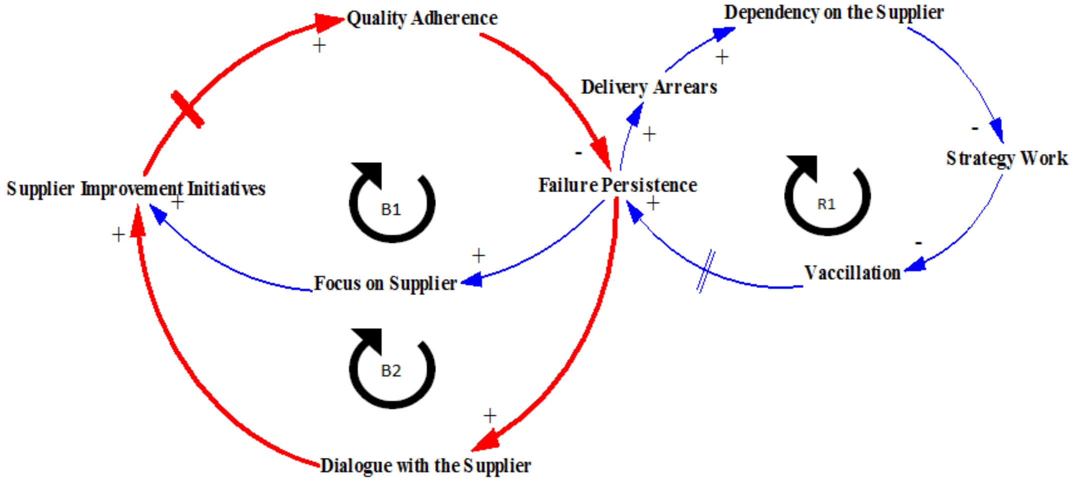
Loop 3

The Communication Loop (balancing no.2)



Example – Balancing Loop:

- The goal is to reduce failure persistence by increasing dialogue with the supplier.
- The gap can be measured by the difference between current levels of communication with a supplier and the target level set by the organisation.

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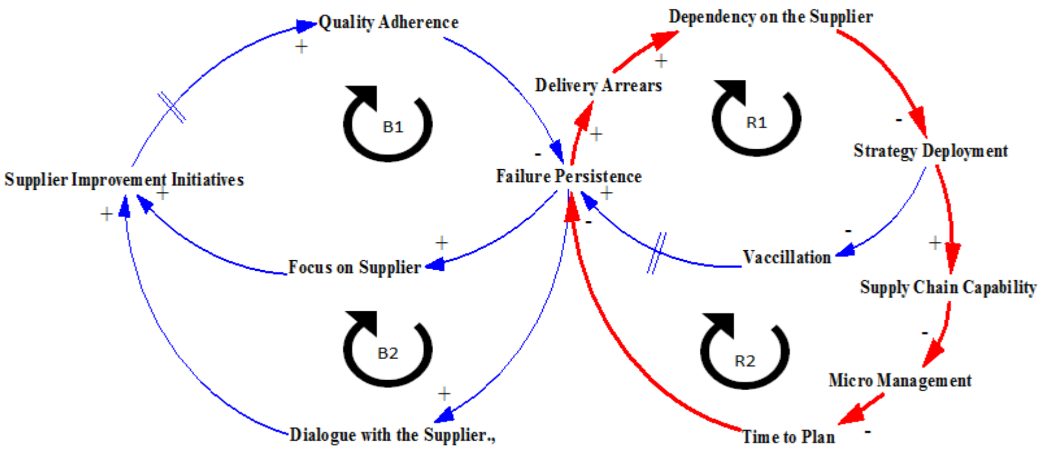
Loop 4

The Supply Chain Flexibility Loop (reinforcing loop no.2)



Example – Reinforcing Loop:

- Exponential growth in the supply chain flexibility loop after each feedback .
- Despite the existence of activities aimed at reducing dependency on the supplier and increasing time to plan. The flow of new customer orders continually increases the pressure on the primes and their supply chain.

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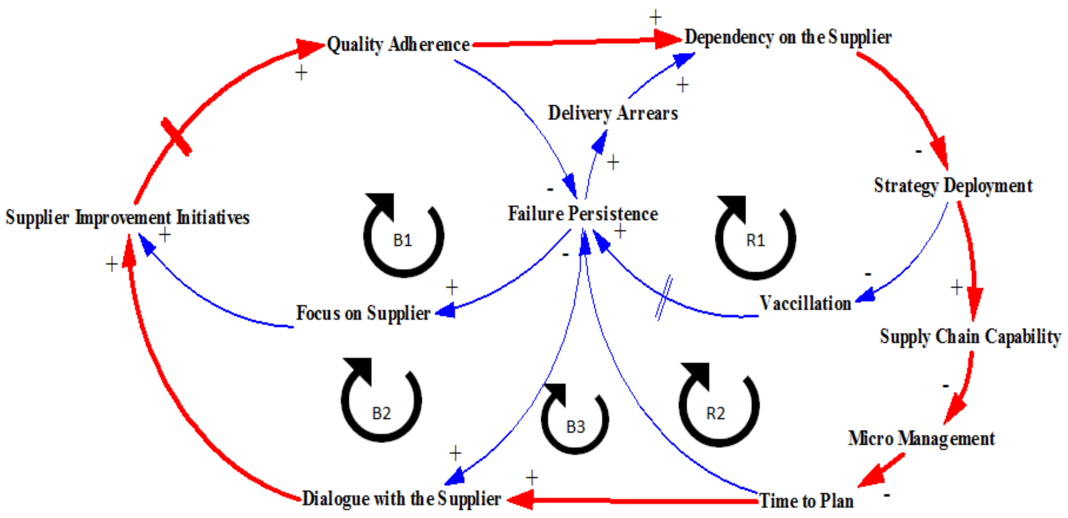
Loop 5

The Failure Persistence Loop (balancing no.3)



Example – Balancing Loop:

- The goal is to reduce failure persistence by increasing quality adherence, dialogue with the supplier, time to plan and by reducing dependency on the supplier.

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Key Causes of Failure Persistence

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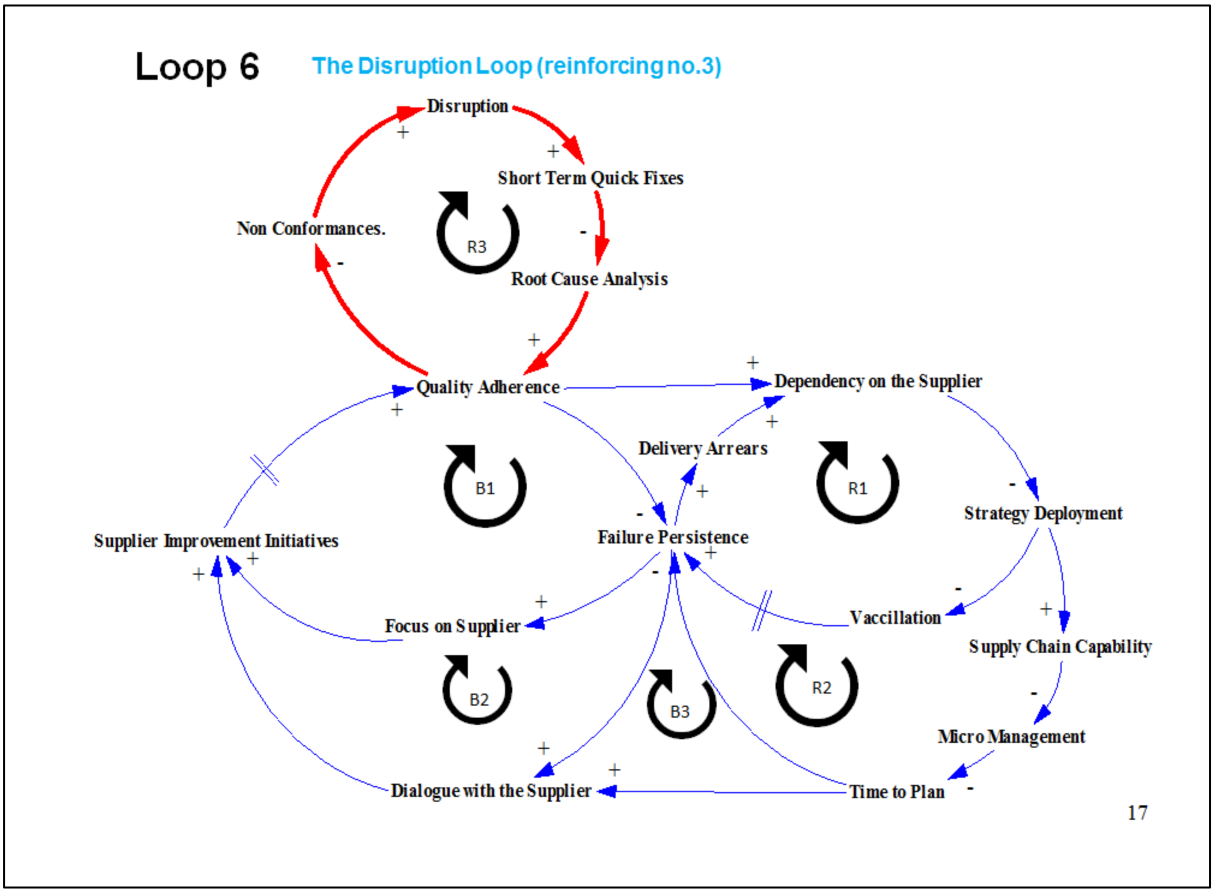
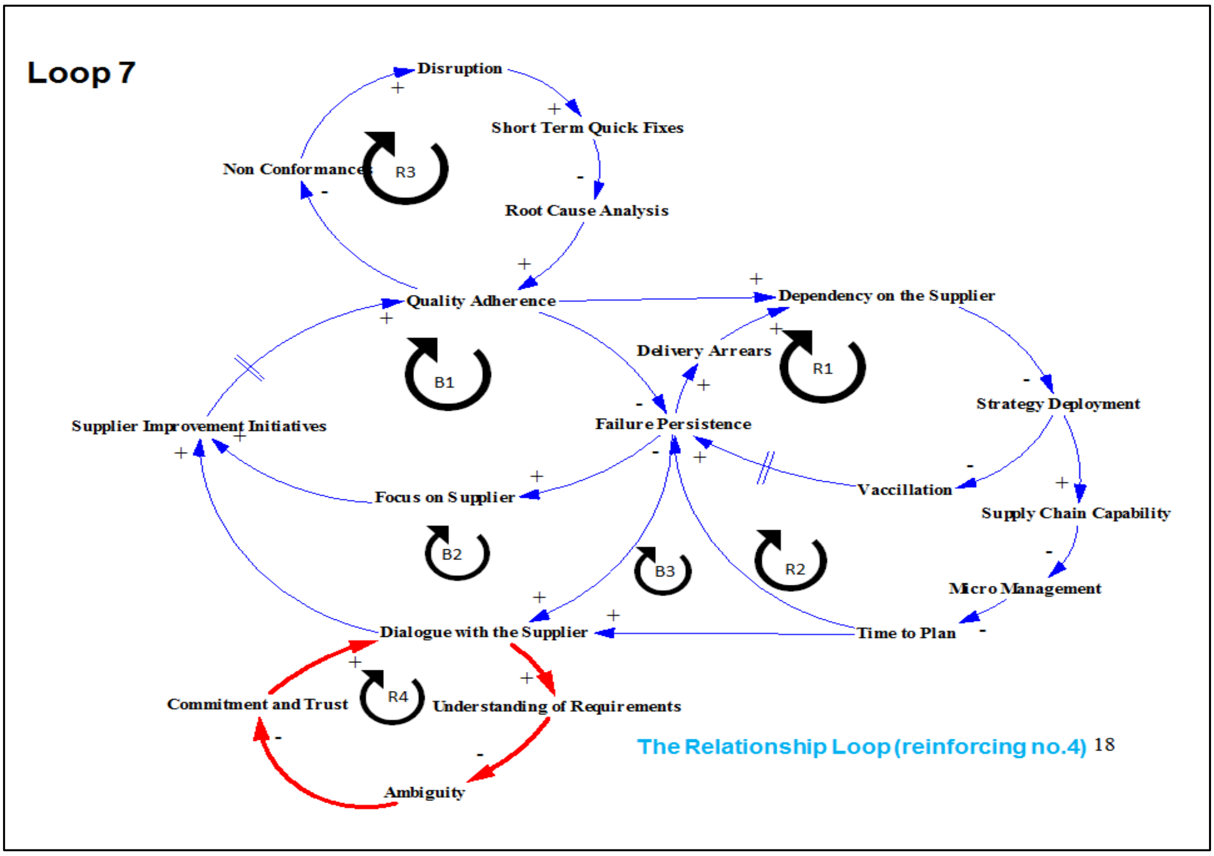
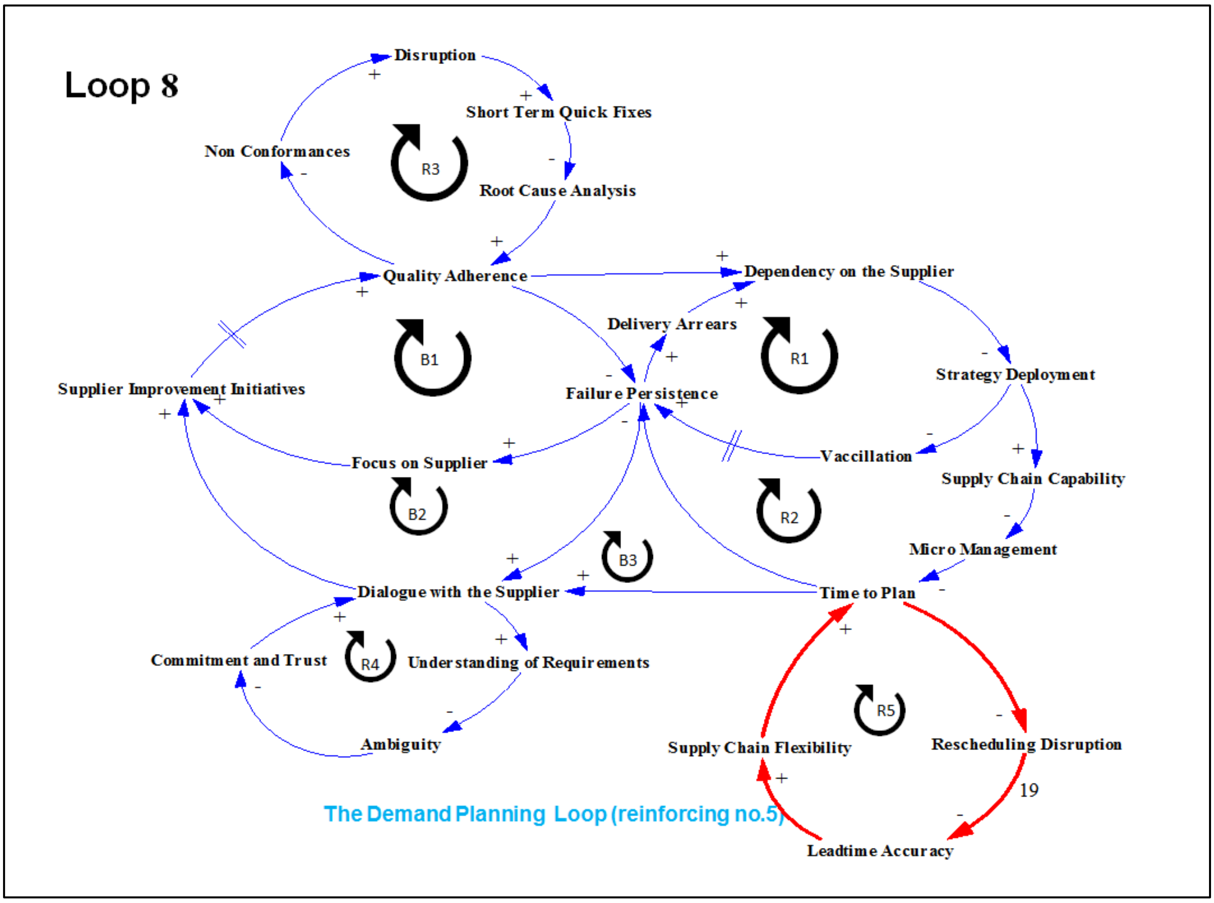
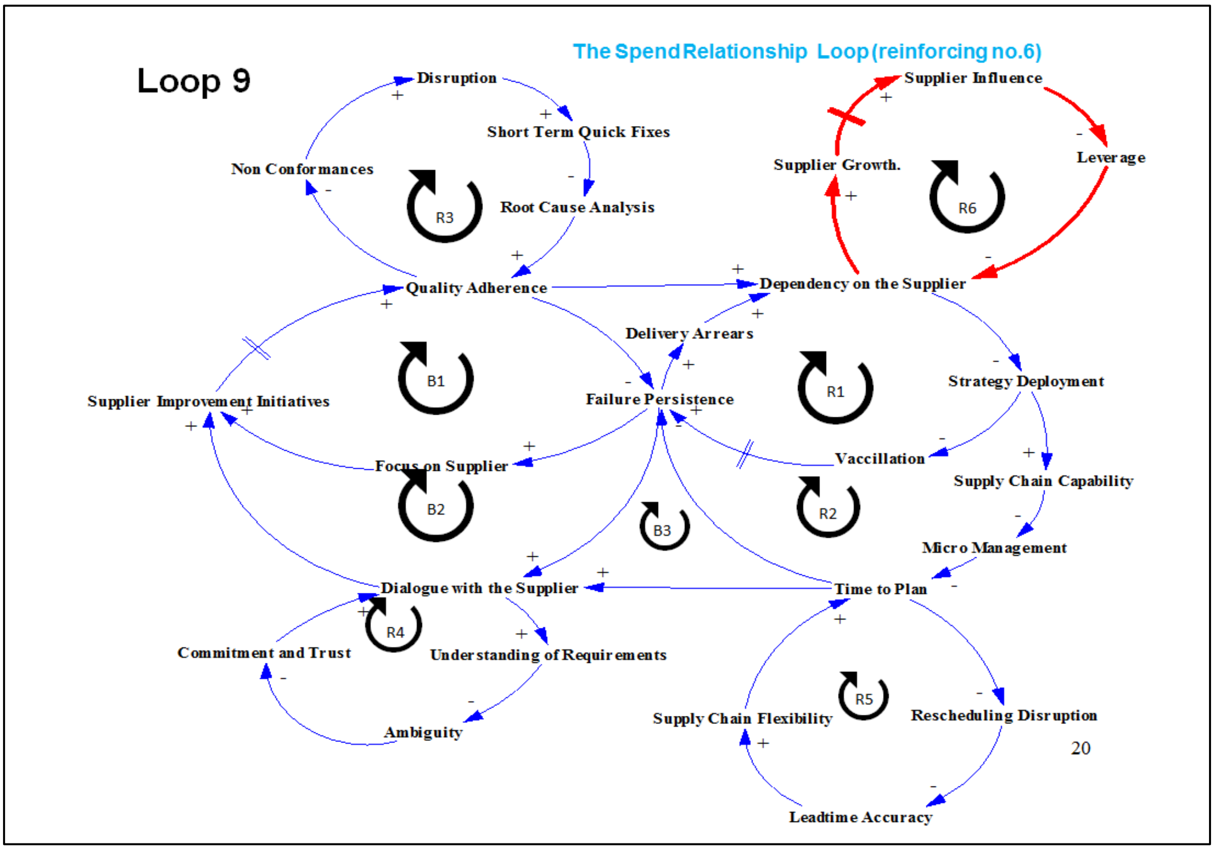

Loop 6
The Disruption Loop (reinforcing no.3)
Disruption
Short Term Quick Fixes
Root Cause Analysis
Non Conformances.
Quality Adherence
Dependency on the Supplier
Delivery Arrears
Strategy Deployment
Supplier Improvement Initiatives
Failure Persistence
Vaccillation
Focus on Supplier
Supply Chain Capability
Micro Management
Dialogue with the Supplier
Time to Plan
R3
B1
R1
B2
B3
R2
17


Loop 7
Disruption
Short Term Quick Fixes
Non Conformances
Root Cause Analysis
Quality Adherence
Dependency on the Supplier
Delivery Arrears
Strategy Deployment
Supplier Improvement Initiatives
Failure Persistence
Focus on Supplier
Vaccillation
Supply Chain Capability
Micro Management
Dialogue with the Supplier
Time to Plan
Commitment and Trust
Understanding of Requirements
Ambiguity
The Relationship Loop (reinforcing no.4)
R3
B1
R1
B2
B3
R2
R4
18


Loop 8
Disruption
Short Term Quick Fixes
Non Conformances
R3
Root Cause Analysis
Quality Adherence
Dependency on the Supplier
Delivery Arrears
B1
R1
Supplier Improvement Initiatives
Failure Persistence
Strategy Deployment
Focus on Supplier
Vaccillation
Supply Chain Capability
B2
R2
Micro Management
B3
Dialogue with the Supplier
Time to Plan
Commitment and Trust
R4
Understanding of Requirements
R5
Ambiguity
Supply Chain Flexibility
Rescheduling Disruption
19
The Demand Planning Loop (reinforcing no.5)
Leadtime Accuracy


The Spend Relationship Loop (reinforcing no.6)
Loop 9
Disruption
Supplier Influence
Short Term Quick Fixes
Leverage
Non Conformances
Supplier Growth.
R3
R6
Root Cause Analysis
Quality Adherence
Dependency on the Supplier
Delivery Arrears
B1
R1
Supplier Improvement Initiatives
Failure Persistence
Strategy Deployment
Vaccillation
Focus on Supplier
Supply Chain Capability
B2
R2
B3
Micro Management
Dialogue with the Supplier
Time to Plan
R4
Commitment and Trust
Understanding of Requirements
R5
Supply Chain Flexibility
Rescheduling Disruption
Ambiguity
20
Leadtime Accuracy

Strategies to Mitigate Causal Effects

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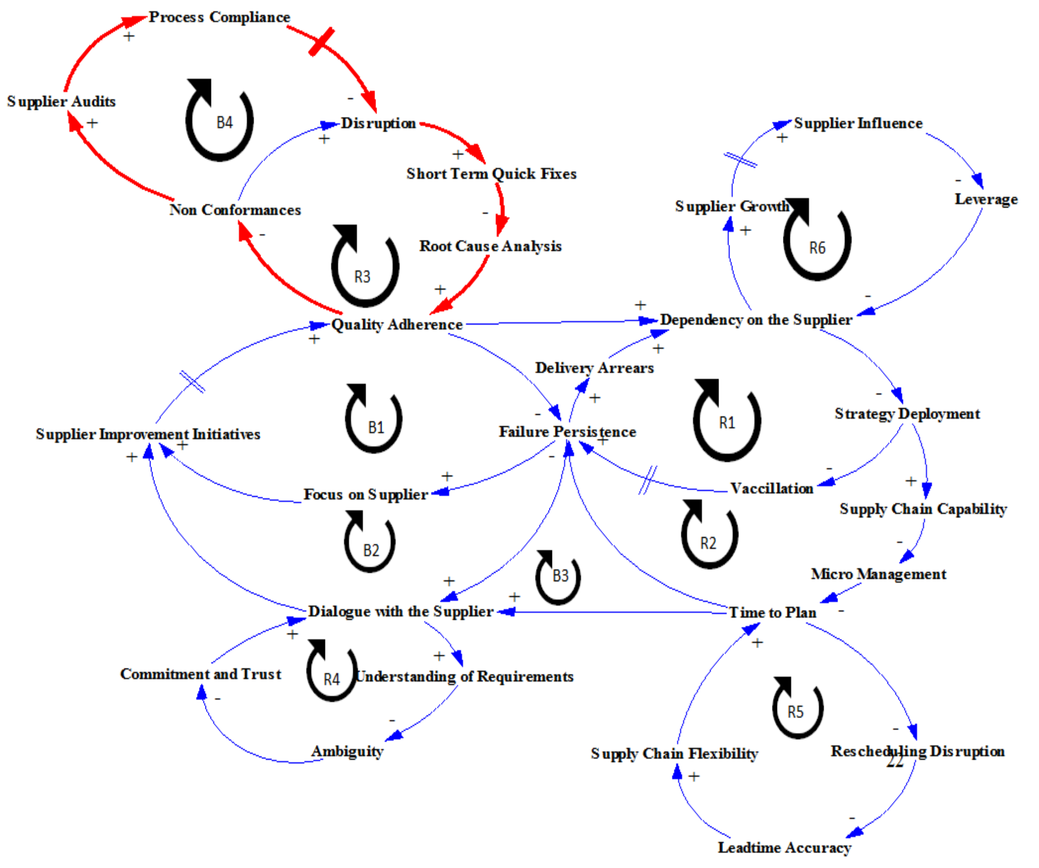
Loop 10

The Sub Tier Capability Loop (balancing no.4)



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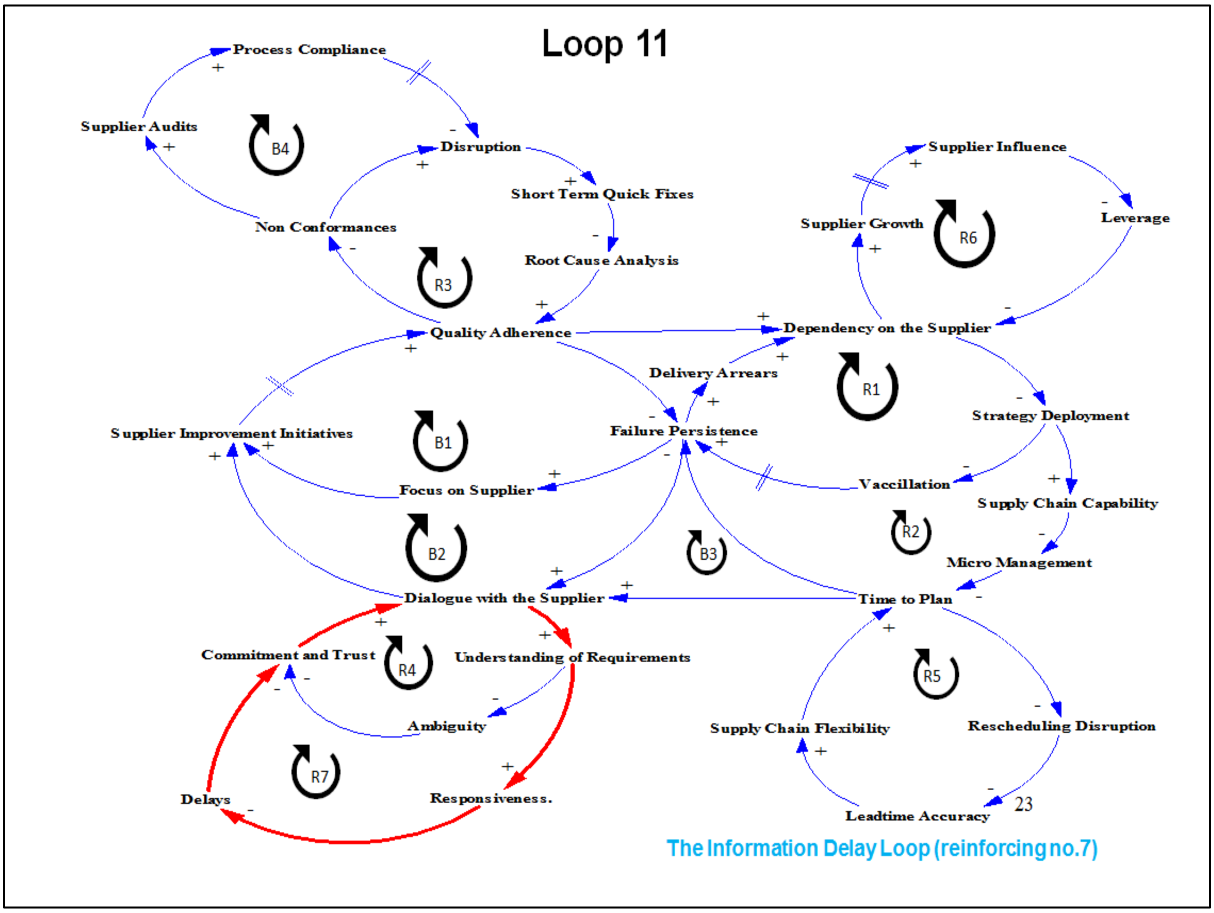
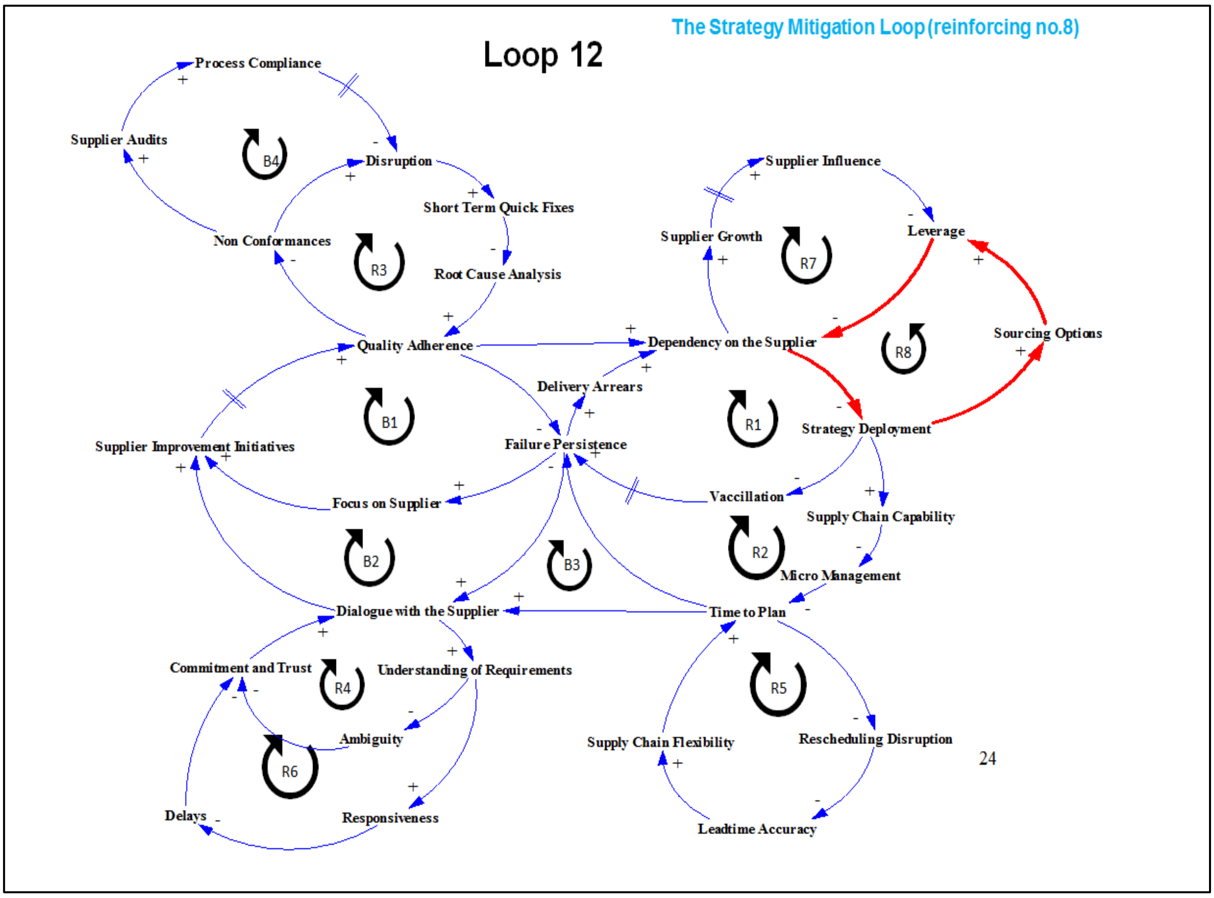
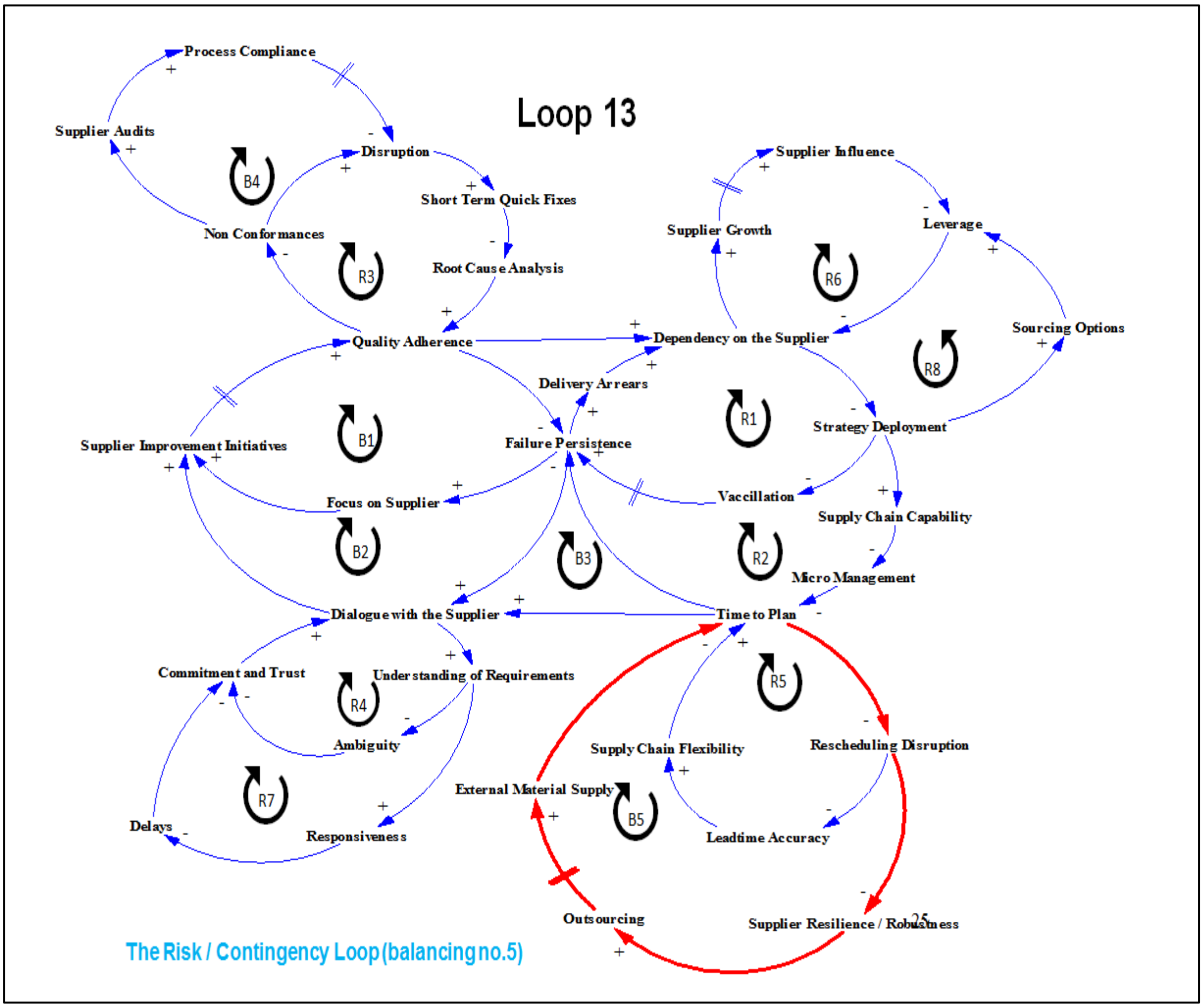

Loop 11
Process Compliance
Supplier Audits
B4
Disruption
Short Term Quick Fixes
Non Conformances
R3
Root Cause Analysis
Supplier Influence
Supplier Growth
R6
Leverage
Quality Adherence
Dependency on the Supplier
Delivery Arrears
R1
Supplier Improvement Initiatives
B1
Failure Persistence
Strategy Deployment
Focus on Supplier
Vaccillation
Supply Chain Capability
R2
B2
B3
Micro Management
Dialogue with the Supplier
Time to Plan
Commitment and Trust
R4
Understanding of Requirements
R5
Ambiguity
Supply Chain Flexibility
Rescheduling Disruption
R7
Delays
Responsiveness.
Leadtime Accuracy
23
The Information Delay Loop (reinforcing no.7)


The Strategy Mitigation Loop (reinforcing no.8)
Loop 12
Process Compliance
Supplier Audits
B4
Disruption
Short Term Quick Fixes
Supplier Influence
Non Conformances
R3
Supplier Growth
R7
Leverage
Root Cause Analysis
Quality Adherence
Dependency on the Supplier
R8
Sourcing Options
Delivery Arrears
B1
R1
Strategy Deployment
Supplier Improvement Initiatives
Failure Persistence
Focus on Supplier
Vaccillation
Supply Chain Capability
B2
B3
R2
Micro Management
Dialogue with the Supplier
Time to Plan
Commitment and Trust
R4
Understanding of Requirements
R5
Ambiguity
R6
Supply Chain Flexibility
Rescheduling Disruption
24
Delays
Responsiveness
Leadtime Accuracy



Failure Persistence Model

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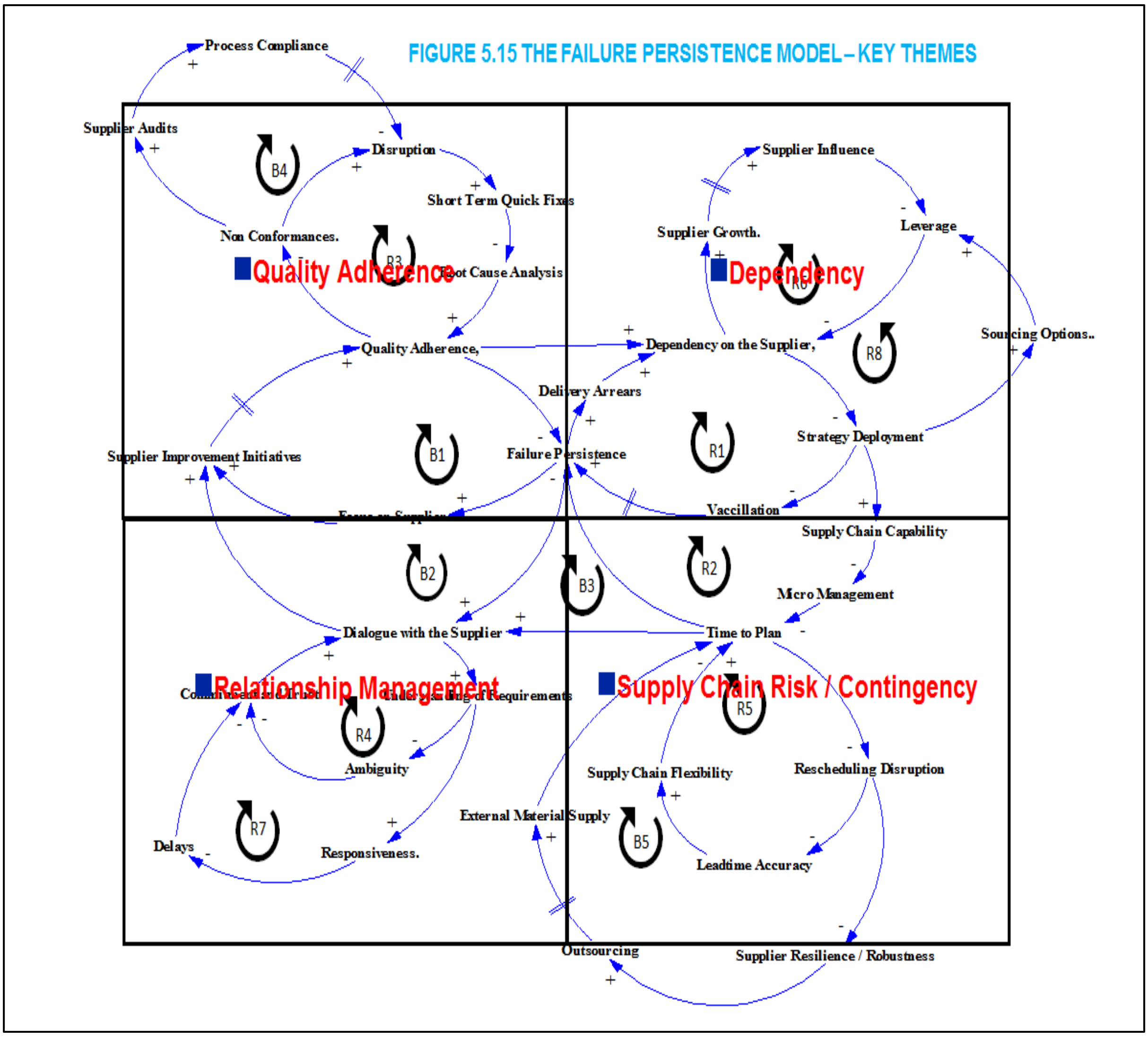

FIGURE 5.15 THE FAILURE PERSISTENCE MODEL – KEY THEMES

Highlights

- All variables have been created from themes evidenced from the empirical data.
- Polarities have been constructed using a combination of empirical data and mental modelling – This requires validation.
- Loops have been constructed using a combination of empirical data and mental modelling – This requires validation.
- Time delays have been included based on evidence from empirical data.
- Favourable versus non favourable loops have been identified – this helps to identify the cause and effect of each loop on the system.
- Linkages to literature (through literature themes) for each loop has been identified. This strengthens the research findings
- The model can be used to show managers why persistent supply chain failure happens and will help them to focus on where improvements need to be made.

Key Statistics:

- 1 Model
- 13 Causal loops
- 8 Reinforcing Loops / 5 Balancing
- 30 Variables
- 43 Links
- 7 Favourable loops / 6 Unfavourable

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Appendix 6 – Research Stage 3 Validation Design.

Workshop Strategy Research Design Proposal

Introductions & Presentation of Workshop aims – What is persistent supply chain failure.

Introduction – All three researchers to briefly introduce themselves to the group

Step 1 – Bart to introduce the research. The starting gambit will be to read out our definition of persistent supply chain failure. Then move onto discuss the aims and objectives of the research and also the aims and objectives for the workshop. Then briefly and tactfully discuss the key issues identified during the research.

Step 2 – Katri to discuss the methodological framework of the research i.e. the three stages of research design and to highlight the importance of methodological rigor. In other words highlight the importance of this workshop to the research.

Step 3 – Karsten to go through the model creation process. This will be done by firstly identifying the key themes of the research. Then we will run through the presentation highlighting each loop step by step. Until the entire persistent failure model is constructed. During the presentation the following information will be extrapolated to consist of the following:

- What is the causal loop trying to show?
- How is it constructed?
- What is a variable? What are the rules for creating a variable i.e. use of nouns, are the variables measurable etc.
- What are the rules for linking one variable to another?

(Note: if time starts to become tight it is ok to suggest we speed things up!)

Step 4 – All of the participants will be asked if they understand / agree with the definition of persistent supply chain failure. This will be recorded either with the use of a Dictaphone or camcorder depending on permission.

Workshop Part 1 - Causal Loop diagrams – What are the causes of persistent supply chain failure by validating the persistent failure model.

Step 5 – split the workshop into the three groups – The aim of this session will be to assign the participants in each group a theme from the persistent failure model (Ideally a dominant literature theme i.e. Quality Management, Dependency and Relationship Management.) and then ask them to critique that loop

Each group will be tasked with verifying the variables and linkages within the loop. If there is a general disagreement with the sequence / construction of the loop then within their groups they will be asked to explain why and tasked with providing an alternative sequence. They will also be free to add or amend the wording of the variables. In addition to this they will be asked to answer the following questions:

- What does the loop highlight?
- What is the unseen key determinant – Ceterus Paribus (The hidden constant)?
- What are the key characteristics? Long term / short term, favourable / unfavourable?
- How does it contribute to the persistent failure model?

Each one of us will individually facilitate a group and capture the comments / observations made by the participants regarding the models. The comments will be captured on a flip chart by the facilitator. The key idea is to get the participants to speak freely in the same manner as a semi structured interview and too make comments about the failure modes (variables) and how they form interdependencies (systems) at the prime. It will also be important to split the groups between functions, job roles and seniority. The purpose of this is to maintain a good spread of participants but it is mainly to stop having all of the seniors in one group.

<u>12.30pm Lunch Break</u>

Workshop Part 1 Continued - Causal Loop diagrams – Group feedback session – Validation of the persistent failure model.

Step 6 – each group will then be asked to provide feedback on their specific loop to the rest of the group. All of the workshop participants will be encouraged to comment and ask questions at this point. The goal of this session will be to gain a general consensus on whether (1) the model accurately highlights key variables associated with the causes of persistent failure at the prime (2) the loops accurately or closely capture the interdependencies / linkages between the variables that combine to create reinforcing or balancing loops (3) that the loops show the cause and effect of persistent failure at the prime in an understandable way. The key thoughts / comments that emerge from the discussion will be recorded either with the use of a Dictaphone or camcorder depending on permission.

Step 7 – The desired conclusion to this session will be to get the participants to ask questions on the persistent failure model in its entirety. For example does this model on persistent failure reflect reality? If it does why, if it does not, why not. The information captured here will help to decide if the model adequately captures the systems that link together to cause either an increased or a reduced effect on failure.

Workshop Part 2 – Beneficial uses of the persistent failure model.

Step 8 – With the involvement of all participants we will ask the question to the group “How can the persistent failure model be used to prevent persistent failure in the organization” We will display the model on the projector and record all suggestions on a flip chart. This session will also be recorded either with the use of a Dictaphone or camcorder depending on permission.

Closing feedback session

Step 9 – To further back up and increase the validity of the findings, for approx. 30mins at the end of the afternoon session each participant will be provided with a workshop feed-back form that will simply ask if the participant agreed with the construction, layout, content and assertions of the persistent failure model. The form will then ask the participants to provide comments as to why they agree with it or to explain why not. They will also be asked to list any limitations with the model and the research in general if applicable. The participants will then be asked to date the form rather than sign in-order to retain anonymity to further enhance the reliability of the data. This is standard practice at the prime after every training session so hopefully the participants will be familiar with this process and complete the form.