# Supply Chain Innovation: An integrating framework and Aerospace cases from China

by

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# ABSTRACT

The relationship between supply chain management and innovation has been fragmentedly explored in the literature. Relevant arguments have been generally formulated around issues of resources, coordination and learning in supply chain management. Important arguments include engaging suppliers in buyers' research and development processes, especially in the early stage of new product development, which helps to leverage suppliers' expertise but may also lead to inevitable risks. Another fragmentation is that there is no unifying framework explaining how the activities along the supply chain can systematically impact on the buyers' innovation performance. In this context, this research develops an integrating framework of supply chain innovation (SCI) to reveal how the supply chain capabilities influence a firm's innovation performance.

This research adopts a multiple case study approach to collect empirical data for two main reasons. Firstly, the process of identifying the relationship between supply chain capabilities and innovation performance is a theory-building process (Eisenhardt, 1989). Therefore, case study provides description and exploration to serve the aim of theory-building. Secondly, implementing case study approach is more suitable to serve the research objective to collect qualitative data that focuses on exploring in depth rather than breadth (Denscombe, 1998 and Eisenhardt, 1989). Because case study "focuses on instances of a particular phenomenon with a view to providing an in-depth account of events, relationships, experiences or processes that are occurring in that particular instance" (Denscombe, 1998).

We have conducted 37 intensive interviews and secondary data from 8 aerospace manufacturers in China. The case companies were selected via theoretical sampling method, and there are five case selection criteria: firstly, the case companies must be involved in manufacturing in the aerospace industry; secondly, the company must be engaged in at least one type of innovation performance; thirdly, the researched companies must come from either the manufacturer and supplier side of the supply chain; last but not least, the company must be at the higher tier of the complex aerospace manufacturing supply chain (at least tier 1-2). The data were analysed by following Yin's (2018) guidelines and thematic analysis methods (Braun and Clarke, 2006) to explore the relationship between supply chain capabilities and innovation performance.

The main contribution of this research is that it extends the existing literatures to provide an integrating framework of SCI that incorporates discussions from different aspects of operations theories. It provides case studies from eight companies from China, including two leading enterprises in the aerospace manufacturing industry in the domestic market. The research looks from both the manufacturers' side and suppliers' side, aiming to provide a more comprehensive framework and explains how innovation performance can be enhanced through SCI.

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# ABBREVIATIONS

| | |
|---|---|
| **ASCI** | aerospace supply chain innovation |
| **JV** | joint venture |
| **M&A** | merger & acquisition |
| **NPD** | new product development |
| **OEM** | original equipment manufacturer |
| **QA** | quality assurance |
| **R&D** | research and development |
| **RBV** | resource-based view |
| **SC** | supply chain |
| **SCI** | supply chain innovation |
| **SCM** | supply chain management |

# Chapter 1 Introduction

## Research Background

The conceptualisation process of Supply Chain Innovation has initially been developed based on the traditional theory of innovation that "…innovation is an economic/business sense" accomplished with the first commercial transaction involving a new product, a process" (Freeman and Dosi, 1988; Flint et al, 2005). In this context, "…SCI refers to tools that can improve firm process directed for efficient supply chain management through seamless integration with suppliers, manufacturers, distributors and customers" (Lin, 2008; Mandal et al, 2016). Theories of Supply Chain Innovation also indicate that the effects of supply chain management are not only on improving the process but also on innovation performance (Austry et al, 2008). However, other than the traditional conceptualisation, the discussions around theories of supply chain management and innovation have been fragmentedly explored. The internal resources and capabilities of organisations have been studied by Smith and Transfield (2005). They looked at supply chain management and innovation, respectively as in relation to the resource deployment inside the organisations. They summarised two contradictory schools of thoughts on arranging resources to supply chain management and innovation. It has been proposed that the lean supply chain is not only about eliminating waste but also it has implications for innovations (Lamming, 1993). As standardisation and vertical integration with mass production may discourage innovation, lean supply chain may provide scope for changing dynamics of innovation as vertical disintegration can release the innovation capability for suppliers (Lamming, 1993). On the other hand, it has been mentioned that SCM may have the opposite effect on innovation because it has taken away all the energy and resources of an organisation and left no more for innovation (Bruce and Moger, 1999). Smith and Transfield (2005) have studied cases in the aerospace industry but found in favour of Lamming's theory with only two exceptions that cannot be generalised. Moreover, the aerospace industry has developed and changed a lot since 2005; the standability of Smith and Transfield's findings needs to be re-tested accordingly. But the findings have certainly raised the attention of the resource deployment in an organisation to manage supply chain and innovation. Another capability generated by SCM is through supplier integration in product development. One of the main reasons for firms involved in supplier-coordination in early product development is to gain the access to information by leveraging the supplier's expertise (Petersen et al. 2004).

Proactively involving suppliers in innovation systems can result in significant benefits (Bozdogan et al., 1998). Such significant benefits are: "long-term commitment to suppliers, collocation, joint responsibility in design and configuration, seamless information flow, and retaining flexibility in defining system configuration" (Bozdogan et al., 1998). This involvement will require the firms to consider the supplier's innovation capability at the supplier selection and decision-making stage. Moreover, the supplier's culture is also an essential factor of consideration that would fundamentally impact on firms' ability to interact with the supplier effectively (Petersen et al., 2004).

In SCM theory, information sharing with suppliers is also essential for effective supply chain management, but it is also important to innovation. Sharing information will increase the knowledge base that is required to stimulate innovation. The need for both internal and external information sharing to innovation (new product development), and especially in the high technology industry has been identified (McAdam et al., 2008). The authors went on further to suggest incorporation and codification of internal and external knowledge using both organisational and IT-based approaches with appropriate organisational and management support, to utilise the knowledge (McAdam et al. 2008).

## The research question

This research will focus on the resources along the supply chain that can be deployed and combined, the integration process and information sharing methods to achieve innovation performance. Though discussions around the relationship between supply chain management and innovation performance have been mentioned all the time, there is no comprehensive answer that establishes how the activities along the supply chain can systematically result on firm’s innovation performance. Therefore, this research aims to provide an integrating framework that answers to the relationship between supply chain resources and innovation by establishing the Supply Chain Innovation framework. The research question is: “***How do aerospace manufacturer’s enhance innovation performance through SCI?***”

## The Research Objectives

The discussions around the relationships between supply chain management and innovation have been fragmentedly explored in recent literatures. There is no comprehensive answer to how supply chain management can benefit innovation nor a theoretical framework establishing how the activities along the supply chain can systematically result on a firm's innovation performance. Still, the influences on supply chain management and innovation are inevitable.

This research aims to contribute through establishing an integrating theoretical framework of how to deploy supply chain capabilities that can enhance a firm's innovation performance. This research also aims to provide practical implication for firms in this industry to develop and improve innovation-oriented supply chain capabilities. Such kind of capabilities helps firms to break through innovation bottlenecks and also provides financial incentives through suppliers' investment in resources. Suppliers can also become more stable and gain more bargaining power through actively engaging in the development of innovation-driven supply chain capabilities of their customers.

## The Scope of Research

### *Scope of Industry: Aerospace Manufacturing Industry in China*

Aerospace manufacturing has become one of the most important development agenda for the global aerospace industry. The global aerospace manufacturing industry has special characteristics that include: high-value adding activities, intensive technology, intensive innovation, high investment, long payback period and high level of government regulations and controls (Jagtap et al., 2010). The traditional Aerospace Supply Chain used to be vertically integrated and it remains under the "make-to-order" system (Chang et al., 2010). Under such make-to-order system, the level of work-in-progress and inventory is significantly reduced (Dyer et al., 1998). The traditional objectives of Aerospace Supply Chain Management (ASCM) were more about safety, quality, delivery time, cost, durability, etc.; whereas the effects of ASCM on innovation were very little mentioned. The ASCM has evolved in recent years and disintegrated vertically. As suggested by Chang et al. (2010), Tier 1 aerospace manufacturers, such as Boeing, Airbus, etc., keep the high value-adding and technology-intensive activities in-house while outsourcing low-value adding and labour-intensive activities to aerospace manufacturing suppliers (Tier 2 and Tier 3 manufacturers). Prime contracts become extremely important in this industry and 70% of the final value of an aircraft is associated with the contributions of prime contractors (Williams et al, 2002). Niosi and Zhegu (2005) have suggested that the implication of cluster and regional innovation systems has identified the inevitable knowledge spillovers. It is implied that knowledge can be transmitted without distortion within the clusters, and more knowledge deployment channels have been identified. Within the aerospace industry, international knowledge spillovers mostly occur between tier 1 and 2 manufacturers; and local knowledge spillovers occur in tier 2, 3 and 4 suppliers that are geographically close to each other (Niosi and Zhegu, 2005).

Traditional Aerospace Supply Chain Management objectives have relatively lightly focused on improving, coordinating or facilitating innovation, but in practice, the linkage between ASCM and innovation plays a vital role in this sector and thus requires more research; and because the nature of this industry is fundamentally different from traditional manufacturing industry, the doubts of standability of the traditional theories within this industry have been raised. Aerospace manufacturing has become one of the prime focuses of China's development agenda, and the industry's recent performance has been phenomenal. The fact that SCI is taking place in China's aerospace manufacturing industry makes it a great case to examine how SCI takes place and the decision making processes for managers to engage in SCI. Therefore, this research examines cases in China to establish the framework of Aerospace Supply Chain Innovation.

## Research Approach

This research implements a multiple case study approach to collect empirical data. The researcher has extracted the following supply chain capabilities through exploratory studies and literature reviews: resource development that includes R&D investment, R&D personnel, R&D equipment and infrastructure (Smith and Transfield, 2005); direct knowledge and technology transfer (McAdam et al, 2008; Irwin et al, 2007 and Niosi et al, 2005); supplier coordination and information sharing (Petersen et al 2004). We have examined the effects between all the supply chain capabilities on both product and operational innovation performance in the case studies to build up the integrating framework of SCI. 37 intensive interviews and secondary data from 8 aerospace manufacturers in China have been collected. The researchers started the case selection process with a full list of the aerospace manufacturers in China released from China's Network of Industrial Information website (www.cnii.com.cn), which is governed by the Ministry of Industry and Information Technology of People's Republic of China. The researchers then conducted explorations of secondary data of the companies about histories, locations, types of ownership, main product categories, etc. Then the researcher started to reach out to the companies. After a pilot study of 3 Chinese aerospace manufacturers, 8 companies were visited for data collection. One case has been built up for each company. These companies come from different levels on the aerospace supply chain. The case selection logic followed guidelines by Yin (2014) and the same data collection method has been replicated for 8 times, to identify the results from different case scenarios and find out how the relationship between capability and performance has been affected within such different case situations. Following the guidelines of case study research by Yin (2014), this research's data analysis process was inductive.

## Research Findings and Contribution

When establishing the relationship between SCI capabilities and innovation performance, three main SCI capabilities have been identified: resource, integration and information sharing. This research focuses on explaining in details about how different resource strategies, integration methods and information sharing methods affect innovation performance that suppliers contribute to manufacturers in an SCI relationship. The research question is answered that the aerospace manufacturers can enhance the innovation performance through effective management of both internal R&D resources and external resources and expertise extracted from suppliers by implementing specific integration methods and information sharing methods. This research contributes through establishing the theoretical connection between supply chain integration and innovation in the aerospace manufacturing industry with the framework. This research also provides practical implication for firms in this industry to develop and improve innovation-oriented supply chain capabilities to break through innovation capability bottle-necks. For the suppliers in the aerospace manufacturing industry, engaging in the co-development of their customers in the innovation-driven supply chain can increase bargaining power and improve relationship with customers.

This research also suggests directions to conduct future research in different industries, different countries, and in a large quantity, for theory testing.

## Outline of the Thesis

The thesis is followed by Chapter 2, which contains the literature review that builds the theoretical background of Supply Chain Innovation. It starts with definitions of specific terms used, key theoretical developments of SCI and the development of the theoretical framework in Chapter 3. Chapter 4 presents the philosophical background of the research design, the research methodology implemented, and the details of data collection processes. Chapter 5 presents the case description, results from case studies and cross-case analyses. Chapter 6 establish the connection between the most critical three findings in this research, which are: resources, integration and information sharing, in relations to the current theories to answer the main research question. Chapter 7 presents the conclusion as well as the contribution of this research, and it also contains limitations and future research implications.

# Chapter 2 Literature Review

## 2.1 The term of Supply Chain Innovation (SCI)

The term of Supply chain innovation has been used in the literatures to present two concepts. The first meaning for supply chain innovation refers to “complex processes that deal with environmental uncertainty and respond to customer needs by using new technologies to improve organisation processes in new ways” (Wong and Ngai, 2019). Simply speaking, it means process innovation on the supply chain itself. The other meaning for supply chain innovation focuses on the innovation capability along the supply chain. The second meaning combines the notion of supply chain collaboration, and integration. The supply chain collaboration means “sharing of people, resources, knowledge along the supply chain to create synergies for competitive advantage” (Fawcett et al, 2008) and to “manage value-added processes to better serve customer needs” (Adams et al, 2014). The supply chain integration looks from the manufacturing firm’s perspective to integrate suppliers to achieve competitive advantage (Birasnav and Bienstock, 2019). This research develops from the second meaning of SCI to combine these concepts and view SCI as the process for manufacturers to integrate suppliers in their R&D stage to enhance the manufacturers’ innovation performance.

## 2.2 Definitions and Backgrounds

### *2.2.1 Definition of supplier*

Supplier is defined as “external organisations that deliver services or goods to a buyer”; and it is also known as “vendor, service provider or contractor” (Chartered institute of Procurement of Supply, 2017). Therefore, this research implements the wide interpretation of the term “supplier” that does not limit to companies providing physical goods, but also companies, organisations or research institutes that provide intangible products such as services or knowledge to their customers.

### *2.2.2 Relevant Theoretical Developments of Supply Chain Management*

Operations and process management is about how organisations create goods and services and it can strategically impact on businesses in four ways: cost, revenue, investment and capabilities (Slack et al, 2012). Supply chain management is closely associated with the “deliver” principle of operations management, meaning “an operator’s ability to deliver products or services to customers is fundamentally influenced by how its supply chains are managed” (Slack et al, 2012).

The term supply chain management was originally used in the early 1980s (Oliver and Webber, 1992; Bales, Maull and Radnor, 2004), to refer to the “managerial materials across different functional departments within an organisation”. Later the definition has extended to include “upstream” production chains and “downstream” distribution channels outside the firm (Womack et al, 1990; Womack and Jones, 1996). Supply Chain management was reviewed as the “best practice” in the search for improved value for money and relationships with suppliers (Cox et al, 2003). Supply Chain was then defined with the structural scope, that supply chain equals “series of organisations and activities that are required to convert raw materials and deliver them as finished products to the final user” (Davis, 1993). The theory went on further to describe supply chain management as the material and information flowing, value-adding, transforming and supplying (Davis, 1993).

The origins of the term “chain” implies a linear structure (Brown et al, 2000; Kim et al, 2011). However, in operations management, supplier management is more than a mere upstream and downstream linear structure that the relationship is rather more of a web/network structure (Harland, 1996; Brown et al, 2000). Various terms of supply chain were listed due to its inter-organisational relationships and structures. The terms he listed are: “value nets”, “supply webs”, “e-networks”, etc. (Hewitt, 2001). Therefore, due to the fact that the implied inter-relationship has been replacing the simple linear notion of supply chain management. Two important views of supply chain management have been proposed and supported by various academics: inter- and intra- organisational views (Saunders, 1995; Cox, 1997; Croom, 2000).

Supply Chain Management was then distinguished from logistics management in 2000s (Lambert and Cooper, 2000). 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, finances, and/or information from a source to a customer” (Mentzer et al, 2001). The definition of supply chain management was drawn as the “integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders” (Lambert and Cooper, 2000). They have also gone on further to draw a normative supply chain. As noted in the title of this research, this research only focuses on the interactions between suppliers and manufacturer along this supply chain; customer and consumer/end-customer will not be looked in this research. Lambert and Cooper (2000) has also drawn attention to cross-functions implications between supply chain management and other business functions. The level integration of supply chain management with other business functions is determined by the need of each process (Lambert and Cooper, 2000).

Development of supply chain management goes further to more contemporary issues: sustainable supply chain management. Tamošaitien et al (2014) looked at sustainable supply chain management and extended the concept to include increasing concerns in environmental issues, sustainable growth, and regulatory concerns, rather than merely focusing selecting suppliers based on the traditional criteria of quality, cost, flexibility and delivery goals. They have also proposed to implement supplier selection methods---"Multi-attribute decision-making methods" in the sustainable supply chain management (Tamošaitien et al, 2014).

The supply chain management theory has further developed by (Gligor, Esmark and Holcomb, 2015) with the proposal of a combination of agility and lean management. Recent researches on the traditional operations management theories have discussed the new approach in achieving operational efficiency or effectiveness through being either agile or lean. Agility is now one of the most salient issues in contemporary supply chain management (Gligor and Holcomb, 2012a). It is all about taking advantage of being fast and flexible (Gligor et al, 2015; Jennings and Haughton, 2002). However, little research links the firm agility with financial performance (Swafford et al, 2006). Gligor, et al (2015) found very little researches have addressed the relationships between these two sets of theories. Gligor et al (2015) seek to find out relationships between customer effectiveness, cost efficiency and firm supply chain agility, and they have come up with a better understanding on how to achieve financial performance through firm supply chain agility. Therefore, supply chain management theory has gained a new achievement by being proven to be not only efficient but also cost-effective.

The supply chain management framework was extended and explored in greater depths since the 2000s. Firm's internal business functions are coordinated across different business divisions and managed across multiple companies; therefore, corporate success requires integrating supply chain activities into the management of other business functions (Blackstock, 2005; Lambert and Enz, 2017). Building from the framework established by Lambert and Enz (2017) the most relevant functions relating to this research are manufacturing flow management, product development and commercialisation. The cross-function approach evaluates and coordinates the strategic resources of manufacturers and it indicates implications for supply chain management in innovation and achieving manufacturing excellence.

Because of the characteristics of cross-functional divisions that supply chain management has, the notion of supply chain has developed into the concept of network which is more complex and involves different players interacting with one another (Bellamy et al, 2014). The interlinked supplier network involves suppliers, customers, third party service providers, partners in alliance, etc. (Bellamy et al, 2014). Initially, a traditional linear concept of supply chain between the suppliers and manufacturers has been implemented, but each manufacturer has a set of different supply chains that interact with one another. Therefore, in the contemporary theories and practices of supply chain management, no matter which term is used, the scope of supply chain management should involve managing inter-organisational relationships. Moreover, though suppliers interact with different players in a more complex network, the focus of this research remains on the contribution of supplier into the manufacturers' innovation capabilities. Therefore, this research looks at a more comprehensive concept of supply chain that integrates the traditional dyad linear relationship between suppliers and the manufacturers as well as their inter-organisational relationships rather than the entire supply network or capabilities generated from the network.

### *2.2.3 Supply Chain Design at strategic level*

Supply chain management has different perspectives and areas of focuses, whereas this research mainly focuses on the strategic level of supply chain management. A supply chain is a continuous process that can be extended or reduced to adjust to the internal capabilities and strategic decisions and external changes in demand, market, suppliers, etc. (Govil and Proth, 2002). Summarised by Govil and Proth (2002), at the strategic level of supply chain management, five major decision-making activities take place: buy, make, move, store and sell. In a supply chain relationship, it does not matter if supply chain partners are competitive to each other or not, firms associate together through cooperative arrangements (Govil and Proth, 2002). Therefore, the success and failure of one firm are inevitable transferrable to another. At a strategic level, the goal is to "guarantee fair cooperation between the partners" (Govil et al, 2002). In order for firms to cooperate with each other, the most important element is ensuring the flow of information and materials (Slack et al, 2012). Cooperation activities can include: research, technology development, human and physical resources sharing, inventory management, quality management, cost management, etc. (Govil et al, 2002).

The goal of strategic supply chain management is to develop “efficient and highly profitable supply chain” (Hicks, 1999). Strategic supply chain integration has two areas of focuses: the information technology, that is to provide a collaborative plan of sharing information between suppliers and customers; and quantitative analysis of logics problems (Hicks, 1999; Power, 2005). This research focuses on the first area of strategic supply chain integration focus: information sharing at a strategic level, as the integrating value chain differentiates from the traditional strategy and such strategic decision leads to competitive advantage (Porter, 2001; Power, 2005).

Successful supply chain integration strategy avoids the problems of vertical integration for two reasons (Power, 2005). Firstly, for certain industries, it takes a long time and a series of strategic decisions for a firm to convert from vertical integration to disintegration; and it creates waste and unprofitability for a firm to return to its original status before disintegration. Secondly, implementing supply chain integration instead of vertical integration enables firms to avoid managing too many departments, business functions while keeping the core competence and receiving information from suppliers/customers (Power, 2005). According to Porter’s (2001) theories of competitive advantage, developing distinctive value chains that cannot be easily copied enables manufacturers to generate competitive advantages.

### *2.2.4 Definition of Innovation and Innovation Performance*

The discovery of theories of innovation can date back to Schumpeter (originally in 1912, translated and published in English in 1934), about the notion of “new”. Freeman (1982) suggested innovation “is an idea, a sketch or a model for a new improved device, product, process. However, these inventions do not necessarily lead to an innovation.” Freeman and Dosi (1988) went on further to explain that “innovation is an economic/business sense” that is accomplished on with the first commercial transaction involving a new product, process…” In the manufacturing industry, the adoption processes of innovation are divided into five stages: awareness, interest, evaluation, trial and full adoption (The institution of production engineers, 1987). The sources of innovation in practice come from the customer, legal requirement, competitors, market research, financial constraints, research, technology transfer, depleted resources, personnel and trade unions, production designs and interactions between company functions (The institution of production engineers, 1987). Ettlie (1988) summarised the linkage between technological innovation and administrative innovation as: the more radical the new technology is, the more radical administrative change is; and the link between administrative innovation and technology innovation is stimulated through competitive environment and a more demanding technological environment. Lundvall (1992) expanded the theory to “the ongoing process of learning, searching and exploring which result in new products, new techniques, new form of organisation and new markets.” Tidd et al (2005) has broadened the theory by describing “innovation involves the exploration and exploiting of opportunities for new or improved products, process or services based on advances in technical practice, or a change in market demand, or a combination of the two…” therefore, in the innovation theory, there are four key characteristics: the first characteristic is about the notion novelty, which can be new technology or first introduced into the area or a combination of existing knowledge with new learning; secondly the forms of innovation can be technological, organisational and social; thirdly, invention does not automatically equal to innovation, it only becomes innovation when first involving in commercial transaction; the last element is that innovation involves ongoing process of learning.

The level of novelty is a key distinguishing factor of whether the innovation is radical or incremental (Woschke et al, 2017). Radical innovation involves significantly new technology or ideas (McDermott et al, 2002). Radical innovation also involves breakthrough in technology that has completely altered customer's prior experiences with existing products (Chandy and Tellis, 2000; Menguc et al, 2014). Incremental innovation can be any minimal improvement in the existing routine, operations and knowledge (Menguc et al, 2014). The level of novelty is also associated with the "unit of adoption", meaning "to whom" the innovation is new (Johannessen et al, 2001). Innovation can be both new to the market and new to the firm (Cooper, 1993; Johannessen et al, 2001). The notion of "new to the firm" that the innovation is adopted aligns with the category of incremental innovation (Tidd et al, 2005; Zanello et al, 2016).

This research takes the view of incremental innovation and the notion of "new to the firm" as the definition of innovation. Because the selected cases come from China, which is a developing country with technology developed slower than the developed countries, it is critical to determine what the researcher believes as the concept of innovation in terms of developing countries at the beginning of the research. The concept of whether innovation should be new to the world or new to the firm is not an answer to the right or wrong question. It associates with the level of novelty in terms of the outcomes of innovation. Therefore, in this research, the researcher has taken a view of incremental innovation as the main concept of innovation that does not necessarily need "new to the world" technology to determine whether a country has been innovating or not. Additionally, this research focuses more on the process of obtaining innovation, i.e. the R&D processes, process of knowledge creation and communication, the coordination and development of existing knowledge ongoing process of learning, etc., rather than measuring the level of the newness of innovation in the selected industry.

### *2.2.5 Innovation Capabilities*

The capability of an organisation is "the ability to deploy and combine resources to achieve a specific goal…" (Amit and Schoemaker, 1993). Capabilities are conceptualised in the Operations Management theories as the "intended or actual operational strengths contributing to an organisation's competitive performance…" (Hayes and Wheelwright, 1984; Slack and Lewis, 2002; Voss, 2005; Zhang et al, 2016). Moreover, in the concept of the resource-based view (RBV), firms need to have resources and capabilities that are scarce, unique, durable, inimitable and non-substitutable (Grant, 1991; Huang et al, 2016). Theories of RBV have been proven that resources, assets and capabilities can lead to market advantage (innovation, market positioning, etc.) which ultimately result in firm's success in performance (Day et al, 1988; Mengus et al, 2014). It is also believed that firms and organisations cannot obtain targeted performance merely through capability itself, but through the application and use of these capabilities instead (Porter, 1991; Stalk et al, 1992; Lin, 2013). Therefore, in the RBV concept, the concept of capability mainly focuses on how firms allocate and deploy internal resources.

In this research, the interpretation of innovation capability has been extended to the integration and coordination of both internal and external resources of a firm to enhance innovation performance. In the context of this research, Supply Chain Innovation (SCI) capability is innovation-oriented, and it is a capability that has a purpose of obtaining/enhancing innovation performance through combining, coordinating, cooperating and integrating the resources pooled together along the supply chain (Zhang et al, 2016; Zhang and Zhu, 2016).

Additionally, the capacity to innovate is proven to be the key driver to firm's success (Francis and Bessant, 2005; Kallio et al, 2012; Saunila, 2016). Innovation capability depends on the ability to processing and deploying knowledge (Delgado-Verde et al, 2011; Saunila, 2016). Innovation capability is one of the most important dynamics that enables a firm to achieve competitiveness within both the domestic and international markets (Saunila, 2016). There is no single way to define innovation capability (Saunila, 2016). However, the innovation capability can be grouped into two categories: technical and managerial innovation (Tuomiene and Hyvonen, 2004; Liao et al, 2007; Saunila, 2016). This research looks at both groups and have implemented the wider approach of viewing innovation capability as new product, new operational process, new type of service, marketing, etc. (Saunila, 2016).

Summarised by Iddris (2016), the measurement of innovation capability has been developed through measuring the product, market and process innovativeness (Lawson and Samson, 2001); creativity, motivation, leadership etc. (Saunila and Ukko, 2012); technological and product development capability (Vicente et al, 2015). However, these developments are confined to the result of firm-level and internal capability (Iddris, 2016); whereas this research goes beyond firm-level and looks at the contribution to manufacturer's innovation capability through supply chain activities.

### *2.2.6 Supply Chain Management and Innovation*

Competition, global changes and product life cycles have determined that a firm cannot merely rely on existing products to make money through achieving economies of scale (Govil et al, 2002). There are a lot of strategic decisions available based on their objectives in supply chain management or other marketing strategies (Boston Consulting Group) for businesses to achieve competitiveness. Firms that have broader access to knowledge from suppliers and customers within the (global) innovation network will receive access to both market and technical information (Schwald, 2008). Urban and Hauser (1993) has proposed that one way to achieve competitiveness is through product development. Product development is mainly internal, but it also relies heavily on external participants. As customer is not considered in this research, supplier is the main unit of analysis in this research. Therefore, supply chain management needs to be able to facilitate product development and innovation (Govil et al, 2002).

Product development may result in changes in the targeted market and subsequent strategic decisions, regarding to investment and also corporate strategy; it also affects the supply chain management as current design of supply chain and supplier relationships need to adapt to innovations (Govil et al, 2002). Therefore, it is very difficult to manage innovation without considering supply chain (Zairi, 1999), because effective innovation management needs to coordinate elements from supply chain perspectives: logistics, production and physical distribution. Zairi (1999) went on further by discussing the effective model of supply chain management to facilitate effective innovation is through partnerships. Within such partnerships, firms start with recognising common strategy and mutual benefits; then they set up the partnership, manage and assess (Zairi, 1999). Due to the importance of the linkage between supply chain management and innovation, this research seeks to look further on the current applications and practical developments of these relationships in the specific industry so as to establish the systematic framework of how to improve innovation performance through effective management of supply chain integration.

There are increasing interests in exploring supplier's/supply chain's contribution to innovation capability in the recent years (Swink, 2006; Storer and Hyland, 2009; Ferrer et al, 2011; Delbufalo et al, 2015; Iddris, 2016). These studies started with addressing the importance of customer's sensitivity as major dimension of supply chain management (Van Hoek et al, 2001; Iddris, 2016); it went further to address the influences in supply chain relationship from innovation capabilities by sharing competence, flexibility in responsiveness with suppliers and customers (Ferrer et al, Delbufalo et al, 2015; Iddris, 2016); and focused on establishing the framework of building collaborative innovation capability through supply chain to remove organisational barriers (Swink, 2006; Iddris, 2016). Existing literatures have established the positive relationship between integrating supplier into focal buyer firm's innovation process and innovation outcome, the benefits and implications of such relationships, but the process of how to integrate suppliers in the innovation process has been under-examined. Additionally, because of the benefits of supply chain integration in product innovation, industries have realised the importance of supplier and started to collaborate with suppliers more in their R&D stages. The under-examined research area has inspired the researcher to explore further underneath the current phenomenon and to establish a theoretical framework on supply chain integration in the innovation of the focal industry.

## 2.3 Supply Chain Innovation

### *2.3.1 Resource deployment view*

In order to establish the framework of supply chain integration in innovation, the underpinning relevant theories need to be considered. The aerospace industry has been restructured since the 1990s that the manufacturers in the US and Europe are vertically disintegrated (Brown, 2000; Smith and Tranfield, 2005). Due to the cost and resource capacity concerns and a variety of complex contextual factors, companies may not be able to facilitate all the processes of production, they outsource sub-process to suppliers; and the outsourcing is not limited to locations (Lamming, 1996; Pawar et al, 2019). The restructuring has created more collaboration between customers (manufacturers) with suppliers in the aerospace industry rather than vertical integration (Brown, 2000; Smith and Transfield, 2005). Moreover, the role of suppliers has been changed since the restructuring and it is now extended to include providing training to customers, technical assistance, sale of specialised equipment (Brown, 2000; Smith and Tranfield, 2005). Different from the traditional model of mere product supply, the new responsibilities suppliers undertake come from the fact that the industry is now vertically disintegrated. Due to the vertical disintegration, external suppliers work closer with customers in assembly operations (Krafcik, 1988; Smith and Tranfield, 2005).

However, there is an increase in the debate about the effects of supplier on innovation from the resource deployment view. The optimistic side of the view is about positive impacts from supply chain to innovation. Lean supply chain is found not only about eliminating waste, but also implications for innovation (Lamming, 1993; Smith and Tranfield, 2005). Lamming (1993 and 1996) believes that standardised mass production omits suppliers' ability to innovate in product/technology. Suppliers are competing through price, quality and delivery time, other than innovation. Therefore, it is not beneficial for the overall advancement of technology. However, vertical disintegration creates closer integration between suppliers and customers, and it releases innovation capability and responsibility to suppliers (Lamming, 1993; Smith and Tranfield, 2005).

On the pessimistic side of debate, Bruce and Moger (1999) believe that supply chain integration has negative effects for innovation based on the fact that the amount of resources of organisations are limited. If the managers of organisations focus too much on managing the supply chain, it will leave no time/resource/effort/energy for innovation management (Bruce and Moger, 1999). Moreover, collaboration hinders suppliers' absorptive capacity in learning (Bruce and Moger, 1999; Smith and Tranfield, 2005). This view is also related to the resource dependence view that all resources are scarce and limited, and a company cannot have all (Pfeffer and Salancik, 2003). Unlike the view of resource dependence that encourages collaboration, Bruce and Moger (1999) regard collaboration and supply chain integration as a method of deviating (human and physical) resources from managers, and leave insufficient for innovation (Smith and Tranfield, 2005).

In the later research by Smith and Tranfield (2005), the two case companies from the British aerospace manufacturing sector found in favour of the optimistic view. They found that the more demand in innovation in the market and the higher number of new projects available, the more engaged the case companies are engaged with suppliers (Smith and Tranfield, 2005). They have also found that the case companies were able to assimilate external development through the internal capacity to pursue innovation (Smith and Tranfield, 2005). Although it was difficult at the time of the research to generalise the results based on findings from only two companies, the research identifies a research field worthy of attention and potentials for future research. The later developments in supply chain integration and innovation focuses more toward other theoretical fields than resource deployment as the theoretical findings lean more towards the supplier's involvement in new product development and resource dependence aspect. This research develops from the optimistic view of involving suppliers in product innovation not only based on the findings from Lamming (1993) and Smith and Tranfield (2005), but also backed up the series of findings introduced in the following sections.

### *2.3.2 Involving supplier in new product development (NPD)*

Due to the increasing intensity of competition because of globalisation, there is a growing trend for companies to search for external resources for technology to drive innovation (Chesbrough, 2003a; Yeniyurt et al, 2014). Two of the most common external resources a firm can assimilate into internal innovation capability are customers (Griffin and Hauser, 1992; Menguc et al, 2014) and suppliers (Ragatz et al, 2002; Wynstra et al, 2003; Yeniyurt et al, 2014). It is very common for user-centric firms to seek for innovation inspiration from customers for increasing market acceptability in new products (Menguc et al, 2014). Suppliers can contribute to buyers' innovation through providing resources that facilitate innovation and insight, knowledge and expertise of innovation (Ragatz et al, 2002; Menguc et al, 2014). However, this research investigates technology-centric firms; therefore, supplier involvement is a more important external source for increasing innovation capability (Ragatz et al, 2002; Wynstra et al, 2003; Yeniyurt et al, 2014).

Wynstra et al (2003) defines supplier involvement as the "resources (capabilities, investments, information, knowledge, ideas) that suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part process or service for the benefit of a buyer's current or future product development projects." This research focuses on the supplier's contribution in innovation capability, which fits perfectly in the definition of supplier involvement by Wynstra et al (2003); and the purpose of involvement is for the buyer to gain innovation capability.

Integrating suppliers into NPD is desired to take place at the possible earliest stage (Petersen et al, 2005). Because suppliers have the product knowledge of production, and they have more realistic information about the feasibility of certain design (Petersen et al, 2005). The information supplier can provide does not limit to cost of production, but also feasible weight, size, application, development time, etc. (Petersen et al, 2005). Such knowledge and information also help buyer to reduce cost and time wasted on producing unrealistic design.

Petersen et al (2005) have also given an example of Japanese firms visiting suppliers before innovation to assess the possible cost and quality level of current and expected technology. It also gives the buyer a chance to assess the supplier's ability to become its partner at later stages. Researchers have found in favour of improved performance when integrating suppliers into NPD (Wasti and Liker, 1997; Petersen et al, 2005). The supplier integration in NPD results in "better products at a lower cost, with improved features and higher financial performance" (Petersen et al, 2005). Moreover, technology uncertainty can be mitigated with supplier involvement (Tatikonda and Stock, 2003).

Supplier involvement in innovation process provides insight, knowledge, experience and resource that the buyer lacks (Ragatz et al, 2002; Menguc et al, 2014). However, information sharing is not the only benefit that can be brought by supplier's involvement in innovation. Proactively involving suppliers in innovation systems can result in significant benefits (Bozdogan et al, 1998). Such significant benefits are: "long-term commitment to suppliers, collocation, joint responsibility in design and configuration, seamless information flow, and retaining flexibility in defining system configuration" (Bozdogan et al, 1998). This will require the firms to consider the supplier's innovation capability at the supplier selection decision-making stage.

The ability to manage and attract supplier's contribution in providing information or taking responsibilities in innovation creates unique value for manufacturer to achieve competitive advantage (Menguc et al, 2014). Involving supplier in NPD also implies reduction of cost and time for innovation (Petersen et al, 2005); access to information that the manufacturer previously lack (Brown and Eisenhardt, 1995); better understanding in technology (Song et al, 2008); increase in financial performance (Monczka et al, 2010); and improved quality (McDermott et al, 2000; Petersen et al, 2005; Menguc et al, 2014). The product and process knowledge suppliers can provide is the main reasons for integrating suppliers in early new product development. However, the current literatures are more about the application of technology information, rather than generating technology. This research focuses on both supplier's knowledge on the application of technology and the ability to generate new technology.

However, supplier involvement in NPD also creates risks for manufacturers. The first risk is the increase in supplier reliance of the same supplier (Petersen et al, 2005). Involving supplier in NPD creates stronger supplier reliance. As well as receiving information and resources from supplier, difficulty, cost and opportunity cost of switching supplier have also been increased. The second risk is the ability to replicate manufacturer's success (Ketchen et al, 2007; Salge et al, 2013). Involving supplier in NPD can create unique competitive advantage (Menguc et al, 2014). However, for the competitiveness to sustain, the resource and capability need to be unreplicable (Porter, 1980). Supplier involvement creates risks of other firms receiving insights of how the manufacturer is able to turn resources into innovation performance (Salge et al, 2013). Previously, such know-how information is kept confidential internally, but it is now accessible between partners and this increased risk of replicability. The third risk is unintended knowledge spillovers. Supplier involvement in NPD requires close collaboration and information sharing. However, the level of sharing makes it almost inevitable for unintentional knowledge leakage (Roy and Sivakumar, 2011; Salge et al, 2013). The fourth risk lies with the manufacturer's capability to convert resources into values. As discussed earlier, competition nowadays is more about the capability to assimilate resources instead of the resource itself (Menguc et al, 2014). Transferring (tangible/intangible) resources from suppliers to customers does not automatically turn into innovation capability (Petersen et al, 2005). Therefore, it is still the manufacturer's internal innovation capability and management decisions that are crucially important to gain competitive advantage; and there is a risk of failing to obtain innovation performance regardless of the levels of contribution from external sources.

The debate is still going on with regard to the benefits and risks of supplier involvement in NPD. Moreover, the previous researches tend to focus more on hypothesising testing of the relationships between the relevant theoretical construct of supplier involvement and performance, and most of the literatures found in favour that supplier involvement leads to improvement in innovation performance (Petersen et al, 2005; Monczka et al, 2010; Menguc et al, 2014, etc.). But the processes of how to involve/integrate suppliers in the buyers' innovation process have been under-investigated. Therefore, this research focuses on establishing the process rather than testing the hypotheses relationship that has already been tested by numerous previous researches.

### *2.3.3 Effects of buyer's innovation strategy on suppliers*

Previous literatures have discussed supplier's efforts in providing resources and suppliers to facilitate product launch (Fynes et al, 2015) and the importance of supplier's contribution as external source of innovation (Henke and Zhang, 2010; Jajja et al, 2017). Moreover, supplier innovation capability directly reflects on the end product (Azadegan et al, 2008; Jajja et al, 2017). There is still scarcity on how buyers leverage supplier's innovation capabilities (Arlbjørn and Paulraj, 2013; Jajja et al, 2017).

Theories have suggested that it is also the other way around that buyer's innovation strategy can change innovation focus of suppliers: buyers focus on innovation motivates suppliers to innovate (Jajja et al, 2017), or sometimes discourages suppliers from innovating (Lamming, 1993). Buyer's innovation incentives are encouraging suppliers to increase innovation capability by investing in R&D, developing technology competence, improving technological advancement, and increase in diversity in knowledge and skills (Hagel, 2002; Jajja et al, 2017).

With the development of supplier's technology level, there is also a potential for the buyer to access to supplier's newly developed technology (Ellis et al, 2012). But the access to new technology is not the sole purpose for buyer's influence on the increase of supplier's internal innovation capability. Motivating supplier to innovate may not even be intentionally from the buyer's side as such motivation derived from the core of innovation-focused companies. Additionally, the notion of autonomy has also been discussed. Choi et al (2001) pointed out that the level of autonomy that the supplier has is associated with the level of innovation capability the supplier can obtain. The higher the autonomy, the higher innovativeness the supplier will have. But there is also the risk of creating too many unstructured behaviours by leaving too much autonomy at the supplier's discretion (Dooley and Van de Ven, 1999; Choi and Krause, 2006). Although, it is important to consider the mutual impacts on innovation capabilities of both suppliers and buyers, this research mainly focuses on the buyer's angle as a target of the investigation. This research starts from the angle of the buyer as manufacturer and looks at its interactions, cooperation and collaboration with suppliers in the R&D process and the contribution from suppliers in its innovativeness. Therefore, the reverse impacts from buyer's innovativeness on suppliers are not examined in this research, but they are still worthy of intention and have the potential that calls for further research.

### *2.3.4 Resource dependence view*

The meaning of resource dependence view is: "organisations lack all the resources and abilities needed to achieve desired outcomes", and organisations are inter-dependent between one and another (Pfeffer and Salancik, 2003). Exchanging knowledge between buyer and supplier has proven to have a positive impact on innovation (Thomas, 2013; Jajja et al, 2017). As an organisation lacks all the resources and abilities they need, collaborations are necessary in the resource dependence view. Collaborations with universities, suppliers, customers as well as competitors help the manufacturer to gain access to knowledge that supports innovation (Un et al, 2016). Because suppliers possess technological know-how, spillovers, knowledge gained through practices and experiences over time, integrating suppliers in buyers' innovation process does not only help the firm to benefit from suppliers' manufacturing capabilities but also their key learnings (Bellamy et al, 2014). Involving suppliers make the supply chain more responsive to changes in customer requirements, and involving suppliers is proven to have greater impacts than universities (Un et al, 2016; Jajja et al, 2017).

### *2.3.5 Resource dependence view: interdependency*

Supply chain integration in buyer's innovation process creates interdependence between suppliers and customers (Takeishi, 2001; Yeniyurt et al, 2014). The more integrated the suppliers and buyers are, the less likely switching suppliers will take place. The increase in dependence on the supplier is created by the supplier's involvement in the supply chain integration in NPD (Yeniyurt et al, 2014). Moreover, the increase in supplier's dependence on the customer is also inevitable with the high level of involvement and investment in the buyer's firm. The situation of interdependence between buyer and supplier creates uncertainty (Pfeffer and Salancik, 2003). The uncertainty results in focal firm's (/manufacturer's) inability to predict the actions of suppliers (Jajja et al, 2017). The uncertainty also goes against the purpose of engaging supplier in NPD to reduce uncertainty (Petersen et al, 2005). Moreover, there is a risk of a high cost to switch supplier (Petersen et al, 2005). High level of supplier involvement also implies the risk for the supplier to exploit this relationship for its unilateral advantage (Monczka et al, 2000). When the buyer dependence increases, the supplier's willingness to invest is expected to decrease (Yeniyurt et al, 2014); and the supplier's dependence on buyer may increase supplier's willingness to contribute in buyer's NPD (Takeishi, 2001; Yeniyurt et al, 2014).

Theories have suggested that innovation-focused firms engaging with suppliers can mitigate uncertainty and increase predictability suppliers through developing collaborative relationship (Martins and Terblanche, 2003; Hoegl and Wagner, 2005; Jajja et al, 2017); integrating suppliers (Yang et al, 2013; Yeniyurt et al, 2013); to improve product/process and delivery (Soosay et al, 2001; Flynn et al, 2010; Lau, 2011; Roh et al, 2011); and to develop communication channels (Liker and Choi, 2004). Therefore, the overall benefits of integrating suppliers in buyers' innovation process still outweigh the risks and uncertainties it carries, and such risks and uncertainties are evitable and mitigatable.

#### *2.3.6 Buyer-supplier relationship*

Supply chain integration in innovation creates a strong relationship between buyer and supplier (Lamming, 1996; Smith and Tranfield, 2005); and it is a mutually beneficial relationship that between relationship also enables long-term collaboration (Pfeffer and Salancik, 2003; Wagner and Bode, 2013; Jajja et al, 2017). As supplier relationship encourages cooperation and collaboration and minimises opportunism, it is also viewed as one important source of inter-firm learning and innovativeness (Dyer and Singh, 1998; Chesbrough, 2003; Cheng and Huizingh, 2014; Mitregea et al, 2017). When selecting suppliers, buyers nowadays view both hard skills and soft skills of suppliers (Wagner and Hoegl, 2006; Mitregea et al, 2017). Benefiting from the supplier relationship requires networking channels that facilitate knowledge and information transfer (Choi and Krause, 2006). Such channels constitute part of "soft skills" that have impacts on technical innovation in focal buyer firms. The long-term agreement between buyer and supplier reflects in a longer relationship (Lamming, 1993). The relationship is often established at the early product development stage (Ragatz et al, 2002; Petersen et al, 2005). Buyers must establish a long-term relationship with suppliers in order to gain access to suppliers' technology. Moreover, Pfeffer and Salancik (2003) have also argued that it is more likely for buyers to establish a long-term relationship with suppliers when they feel they have control over the relationship.

Coordination helps suppliers to understand better, and it helps to reduce suppliers' uncertainty by aligning its capabilities to meet buyers' needs (Martins and Terblanche, 2003). Suppliers also tend to establish a long-term relationship in supply chain integration process as they have the anticipation of long-term return and the long-term relationship makes the supplier indispensable (Yeniyurt et al, 2014). Under the long-term relationship, suppliers are more willing to share information and invest even if the changes arise from innovation would disrupt its current operations (Wagner and Bode, 2013; Jajja et al, 2017).

Therefore, the supplier relationship facilitates knowledge and information transferring, cooperation and collaboration on knowledge creation and resource synergy (Mitregea et al, 2017). It helps manufacturers to configure internal resources and external resources and capabilities transferred from suppliers into its own internal innovation capabilities (Mitregea et al, 2017). Supplier relationship management creates mutual benefits to both buyers and suppliers (Lambert and Enz, 2017). Moreover, collaboration in innovation also strengthens the relationship (Yeniyurt et al, 2014)

### *2.3.7 Supplier's willingness to contribute*

Supply chain integration in innovation cannot happen unless all the parties have agreed on the expected benefits as well as the costs and risks (Petersen et al, 2005). The enabling factors that have influences on the successful formation of cooperation and collaboration between suppliers and buyers include supplier's attitude toward co-innovation (Monczka et al, 2000; Yeniyurt et al, 2014), supplier's level of responsibility (Petersen et al, 2005), information sharing (Griffin and Hauser, 1992; Paulraj et al, 2008; Yeniyurt et al, 2014), and trust between suppliers and buyers (Autry and Golicic, 2010; Corsten et al, 2011; Yeniyurt et al, 2014).

Supplier's attitude toward co-innovation is critical to supply chain integration in buyer's innovation process as it provides foundations to integration. Supplier's attitude toward co-innovation is also influenced by its anticipation of long-term return through the joint NPD (Yeniyurt et al, 2014). The benefits of collaborative projects are usually long-term than short-term; thus, suppliers with anticipation of long-term return are more willing to join SCI in buyer's innovation projects (Yeniyurt et al, 2014). Collaborations enable suppliers to plan and develop long-term processes of the utilisation of resources to meet buyer's needs (Yeniyurt et al, 2014). Moreover, when the supplier's anticipation of long-term return increases, it is more likely for them to participate in closer integration with buyers and invest more in buyer's assets (Monczka et al, 2000).

The level of responsibility that supplier takes affects supplier's involvement in manufacturer's innovation (Petersen et al, 2005). There are three types of involvement: white box (supplier has minimum responsibility), black box (the design is supplier-driven), grey box (formal/informal joint development between buyer and supplier) (Petersen et al, 2005). The level of integration is measured through the level of information sharing (Petersen et al, 2005). The black box type reports the highest level of integration as suppliers take the highest responsibility. It has been proven that in the black box integration, suppliers do not only complete the product R&D design but also set out technical objectives that are critical to "effective project team decision making" (Petersen et al, 2005).

### *2.3.8 Information sharing*

Firms innovate through generating internal knowledge, but organisational learning also comes from external partners, i.e. customers, suppliers, third-party service providers, etc. (Yli-Renko et al, 2001; Bellamy et al, 2014). Therefore, information sharing is critical for joint development of innovation (Petersen et al, 2005; Yeniyurt et al, 2014). Communication and information sharing enables both buyers and suppliers to better understand each other (Griffin and Hauser, 1992; Yeniyurt et al, 2014). Information sharing needs to be timely and honest and it is critical to any cooperative projects (Paulraj et al, 2008; Yeniyurt et al, 2014). Information sharing itself, directly and indirectly, affect supply chain integration in NPD. The level of accessibility in supply chain is important to manufacturers and directly relates to the level of accessibility to knowledge and learning (Bellamy et al, 2014). This level of accessibility in the supply chain is also related to geographic distance, speed of knowledge transfer, level of cooperation and tier of suppliers (Bellamy et al, 2014). Therefore, integrating supplier creates higher innovation output by generating information-based advantage to manufacturers that help them to compete against their competitors (Bellamy et al, 2014).

Information sharing impacts directly on facilitating and sustaining cooperation, and it is indirectly influencing the SCI in NPD through the supplier's willingness to contribute (Paulraj et al, 2008). Sharing information increases the knowledge base that is required to stimulate innovation. McAdam et al (2008) have identified the need for both internal and external information sharing to innovation (new product development), and especially in the high technology industry. The authors went on further to suggest incorporation and codification of internal and external knowledge using both organisational, and IT-based approaches with appropriate organisational and management support, to utilise the knowledge (McAdam et al 2008). As communication provides suppliers with transparent information for decision making (Yeniyurt et al, 2014), it will be more likely for the supplier to contribute to its buyer's innovation.

In order to sustain a long-term collaborative buyer-supplier relationship, trust between the two parties needs to be established (Spekman et al, 2006; Yeniyurt et al, 2014). Trust is even more important for innovation related integration (Yeniyurt et al, 2014), and mutual trust is extremely in technology-intensive industries (Dyer and Singh, 1998). High level of trust enables high level of information exchange which ultimately results in higher asset investment from the supplier into buyer (Corsten et al, 2011) and increase in supplier's willingness to provide customers with access to technology (Ellis et al, 2012; Yeniyurt et al, 2014). Trust is the fundamental enabling factor that creates foundations for supply chain integration in product development, literatures have also shown improved operational performance to be the outcome of high level of trust in buyer-supplier relationships (Autry and Golicic, 2010; Yeniyurt et al, 2014).

### *2.3.9 Other Context factors*

Innovation performance and competitive advantage are not enhanced through merely gathering resource itself, but the capability to turn resources into internal assets (Petersen et al, 2005; Menguc et al, 2014). However, the capability may be affected by other context factors so that the results in performance differ. These context factors are: location, government interference (support/regulate/control, etc.) and strategic decisions (Roberts, 1995; Petersen et al, 2005; Yeniyurt et al, 2014; Lambert and Enz, 2017). These factors affect the integration side but also the performance side on the relationship between supply chain integration and buyer's innovation performance.

On the supply chain integration side, collaboration is not limited to the location (Lamming, 1996), but the location factor is infused with location benefits. The efforts of government and strategic decisions of either party of the integration do not directly affect supply chain integration in innovation, but indirectly through influencing williness to engage in the collaboration (Roberts 1995; Yeniyurt et al, 2014). Moreover, not only the supplier's capacity but also its cultural compatibility is also important for supply chain integration (Petersen et al, 2005).

On the innovation performance side, the location factor and government control and support factor relating to innovation performance are relevant to systems of innovation. The national systems of innovation focus on national organisation and institutions

(Fagerberg, et al, 2005); the regional systems of innovation focus on regional clusters of firms and innovative institutions (Cooke et al, 2004); and the sectoral systems of innovation: analyses systems on the basis of technological, industrial or sectoral characteristics (Malerba, 2004). As this research investigates innovation in the firm and industry level, this research will focus on the sectoral system of innovation. Within these categorisations, the term "system" refers to "complexes of elements or components, which mutually condition and constrain one another, so that the whole complex works together, with some reasonably clearly defined overall functions" (Fleck, 1992 in Edquist ed., 1997). Location advantages or cluster advantages imply the ease of open innovation. As suggested by Chesbrough (2006b) that business thrives under the environment of innovation through open innovation and open business models.

Firm's innovation level is also associated with an institutional partnership. As integrating suppliers in manufacturers innovation process can also be viewed partnerships and collaborations, suppliers can be either/both private or/and public organisations. As proposed by Azadegan et al (2013), the influence of partnerships on innovation capability differs between private research partnerships and government research partnerships. Such partnerships involve technological alliance and strategic alliance in R&D, R&D joint venture, etc., that may result in cost saving), knowledge and technology transfer and risk sharing (Stiglitz and Wallsten, 1999; Buson, 2008; Azadegan et al, 2013). As R&D partnership creates an increase in innovation capabilities, there may be a positive outcome in innovation (Azadegan et al, 2013). In the research conducted by Azadegan et al (2013), they found a positive link between private research partnerships and innovation outcomes as well as government research partnerships. They have also found out that the more government ownership the manufacturer has, the less innovation outcome it will benefit from private research partnerships due to different institutional characteristics (Azadegan et al, 2013). Therefore, institutional partnerships are also one of the important factors to consider that may influence the relationship between supply chain capabilities in firms' innovativeness.

Additionally, the open innovation requires sharing human resources, knowledge and information, collaborative R&D and offering unused technology outside the firm. Proposing the notion of open innovation does not mean the in-house R&D becomes completely obsolete (Chesbrough, 2006a). The new logic of innovation indicates companies structuring themselves to "leverage this distribution landscape of knowledge" (Chesbrough, 2006a) and the new logic will exploit diffusion of knowledge. However, internal R&D should take into account of the "wealth outside the firm", as suggested by Chesbrough (2006a); and he went on further explaining that "the role of identifying and accessing external knowledge in addition to generating inside R&D changes the path of R&D firms". Moreover, with regard to intellectual property, Chesbrough (2006a) has suggested considering the level of "openness" to maintain the key intellectual property at a strategic level. Moreover, as information is crucial in the core of supply chain management, companies have already been engaging in open innovation logic to a certain degree; and the new trend of information sharing, such as big data, has pushed the innovation logic to a more open state. Morevoer, Niosi and Zhegu (2005) have suggested that the implication of cluster and regional innovation systems has identified the inevitable knowledge spillovers. It is implied that knowledge can be transmitted without distortion within the clusters, and more knowledge deployment channels have been identified. Within the aerospace industry, international knowledge spillovers mostly occur between tier 1 and 2 manufacturers; and local knowledge spillovers occur in tier 2, 3 and 4 suppliers that are geographically close to each other (Niosi and Zhegu, 2005).

Concerning the strategic decision, firms strategic decision affect its ability to turn external resources into internal innovation capability, and the strategic decisions also have impacts on innovation performance through: investment decisions for R&D (Roberts, 1995; Collins et al, 2017), organisational culture and management style (Roberts, 1995), resource deployment decisions (Bruce and Moger, 1999), incentives to innovate (Ferreira et al, 2014); decisions on investing human capital in innovation (Sun et al, 2017).

### *2.3.10 Industry sector background and Corporate Governance*

The aerospace industry includes civil aircraft, military aircraft and aircraft maintenance (Chang et al, 2010). The civil aerospace manufacturing industry is high value-added and technology-intensive (Chang et al, 2010). Due to the fact that the investment is high and payback period is long in this industry, this industry still implements the “make-to-order” system (Chang et al, 2010). Therefore, under such make-to-order system, the level of work-in-progress and inventory is significantly reduced (Williams et al, 2002). The industry also has special characteristics that include: high value-adding, technology-intensive, innovation-intensive, high investment, highly regulated and vertical disintegrated (Chang et al, 2010). Tier 1 aerospace manufacturers, such as Boeing, Airbus, etc., have only kept the high value-adding and technology-intensive activities in-house while outsourcing low-value adding and labour-intensive activities to aerospace manufacturing suppliers (Tier 2 and Tier 3 manufacturers) (Chang, et al, 2010). Williams et al (2002) pointed out that within the aerospace supply chain, prime contractors are very important. They are the "platform assemblers and system integrators" who have traditionally played a dominant role in coordinating the value chain from top to down. 70% of the final value of an aircraft is outsourced and the prime contractor plays a leading role in such supply chain (Williams et al, 2002). However, the prime contractor also handles responsibilities and high risks in innovation, development funding and production (Williams et al, 2002). Within the aerospace manufacturing industry, supplier relationship and customer satisfaction are fundamental (Chang et al, 2004). Because the fact that prime contractors play an essential role renders this supply chain to be different from the traditional supply chain. Moreover, as the aerospace industry is highly technology-intensive and quality demanding, manufacturers have to keep innovating to achieve product performance. The nature of this industry is fundamentally different traditional manufacturing industry, which raises the doubts of standability of the traditional theories within this industry.

Since major manufacturers have evolved from being vertically integrated to disintegration by outsourcing at least 70% of its production to suppliers (Fan et al, 2000; Williams et al, 2002). The evolved supplier-manufacturer relationship has also affected to the design of products. The simple way is to outsource a complete design and production to suppliers, but the risk increases as more responsibilities and bargaining powers have also been shifted to suppliers (Fan et al, 2000). Another way is to from a design team with both guest (from suppliers) and home (from manufacturers) engineers (Fan et al, 2000). This type of integration has been developed and implemented widely in various concurrent engineering and supplier initiatives; and reported as good practice in the industry (Fan et al, 2000). As a result of such integration, innovation performance is often improved (Fan et al, 2000).

The civil aerospace manufacturing industry has become one of the prime focuses of the China's development agenda, and the industry's recent performance has been phenomenal. The year of 2015 is one of the most important year of China's aerospace manufacturing industry: firstly, the first large aircraft of China has been released to production line; and also the first short-medium range turbofan regional aircraft, ARJ21 has started its service in the airline companies (Yearbook of Civil Aviation Industry of China, 2017). These two aircrafts have all been independently developed by China. The current industry in China involves close integration and coordination with suppliers to achieve innovation which is closely related to our research design. Therefore, this research is trying to find out how supply chain resources turn into innovation capabilities that ultimately result in innovation performance. Then, this research examines cases in China to establish the framework of Aerospace Supply Chain Innovation.

Corporate governance means the "system by which companies are controlled and directed and made accountable to shareholders and stakeholders" (Tylecote and Ramirez, 2006). Different types of corporate governance imply different characteristics of firms. The nature of the high-tech sector requires high novelty and high reconfiguration (Tylecote and Ramirez, 2006) because of its high need in R&D. High level of reconfiguration is inevitable in high-tech industries for firms to succeed in innovation, but it requires radical changes in an organisation that is costly and subject to resistance within an organisation (Tylecote and Ramirez, 2006). The performance in technological capability building is found to be more closely linked to the level of engagement of management team in strategy making, the expertise of managers and level of inclusion of stakeholders bundled with other benefits brought by the manufacturer's type of ownership (Liu and Tylecote, 2009). Therefore, in this research, not only factors of corporate governance but also special characteristics brought by type of ownership need to be considered when analysing the technical performance of manufacturers. Meanwhile, the country and sectoral characteristics of this research show a need in re-examining the existing theoretical relationships in supply chain innovation.

### *2.3.11 Supply Chain Innovation in other sectors*

SCI has also been examined in high-tech industries other than aerospace manufacturing, such as automotive, electronics, components, telecommunication, etc. Though different terminology has been used in these literatures, such as supply network-based innovation, suppler-enabled innovation, co-innovation, the investigation of supplier's contribution in OEMs' innovation process remains the primary research objective. Some of the main discussions of SCI in other sectors are similar to that of the aerospace manufacturing industry, as the discussion starts with scarcity of resources that no firm can has all the necessary resources (Pfeffer and Salancik, 2003). It then goes on to discuss that due to the scarcity of resources, knowledge is dispersed on the supply network (Kim et al, 2020). Recent researches have shown that OEMs are generally more able to manage potential risks of knowledge asymmetries when coordinating other organisations to gain access to the dispersed knowledge (Becker, 2001; Kim et al, 2020). The types of suppliers involved in OEMs' innovation processes have been discussed, that both direct and indirect component-level suppliers have been increasingly integrated in automotive manufacturers' innovation process (Kim et al, 2020). As a result, a positive relationship between coordinating direct suppliers and OEMs' innovation performance has been identified (Kim et al, 2020). When fewer direct suppliers are involved, the level of innovation performance generating from indirect suppliers is found higher (Kim et al, 2020). Moreover, OEMs' influence on the suppliers have also been proven to have negative impact on the relationship between direct suppliers and innovation performance (Kim et al, 2020).

Another research aspect in which relationship between strategic supplier relationship and supply chain innovation has also been carried out in the automotive industry (Modungwa et al, 2020). This research has pointed out that it is important for firms to invest in strategic relationship with suppliers as one sources of innovation (Lee and Schmidt, 2016; Modungwa et al, 2020). Traditionally, the roles of suppliers in the automotive industry rely on value adding components and engineering (Lockstrom et al, 2011; Modungwa et al, 2020), whereas main motivation for OEMs to integrate suppliers in different stages of innovation processes has shifted to the reliance on suppliers for new technology (Modungwa et al, 2020). From the strategic supplier relationship perspective, the level of supplier involvement increases from low to high during the

OEMs/ innovation processes from the pre-innovation stage to post-innovation stage (Modungwa et al, 2020).

Knowledge sharing on a collaborative supply chain/network has also been examined to explore the relationship between collaborative innovation and performance (Wang and Hu, 2020). OEMs in various industries have been obtaining knowledge from other participants in their supply networks to enhance their innovation performance. In the collaborative supply chain, collaboration has been proven to be the pre-existing condition for higher innovation performance (Singh et al, 2016) and knowledge sharing is the core process for OEMs to enhance innovation process (Wang and Hu, 2020). As a result, collaboration reduces time and cost required for information gathering and the increased level in communication and mutual support have a positive effect in OEMs' innovation performance (Soosay et al, 2008). Knowledge sharing in collaborative supply network means the share of R&D knowledge, experiences, skills, process, etc. which enable organisations in supply network to broaden and deepen knowledge pool (Lin, 2007; Wang and Hu, 2020). The creation of learning system between suppliers and OEMs has also been found to stimulate long-term trust and high innovation performance (Wang and Hu, 2020).

The fact that existing literatures of SCI in other industry sectors have shown similarities to that of the aerospace manufacturing industry is mainly because the foundation of which theories have been generated and developed from is the same. Meanwhile, where these researches of SCI were conducted, automotive and aerospace manufacturing industries have shown great similarities in characteristics of suppliers. For example, in both industries: technological advancement is still one of the most important criteria when selecting suppliers; suppliers' ability to integrate with OEMs' operations is regarded as a more important objective rather than cost reduction and suppliers' willingness to adapt existing operations to implement innovation is also a factor in OEMs' decision-making process (Modungwa et al, 2020). Moreover, the focus on the long-term relationship between supplier and customer in new product development, especially the automobile industry in Japan (Takeishi, 2001; Zirpoli and Caputo, 2002; Kotabe et al, 2003; Dyer and Hatch, 2006) shares similarities with the aerospace manufacturing industries as the innovation and production cycle of are relatively long.

However, the differences between aerospace manufacturing industry and other industries have made this research worth investigating. The aerospace industry in China is highly regulated and highly confidential, which makes knowledge sharing and creation of learning system between suppliers and OEMs in this industry more difficult than the others. For example, in other parts of the world, business share practices and IP to achieve operational excellence, even in the aerospace industry. However, such a high level of sharing is impossible in China for two reasons: the first reason is that the country started in this industry later than its highly reputable competitors around the world, it will be difficult for the country to join in sharing projects because it does not have enough knowledge to share. The second reason is that the industry is regarded as the leading contributor of the China's overall planning in innovation development; extremely highly regulated and controlled, which makes it even more difficult to facilitate open innovation with foreign countries. However, this does not mean the country has a closed innovation environment that only internal innovation is taking place. In fact, information sharing, knowledge and technology transfer take place in the aerospace manufacturing industry in China in a more cliqued manner. The high level of regulation and the late start of the aerospace manufacturing industry in China have made the industry distinctive from others and researches are needed to investigate whether existing literatures are still applicable within this special research context and how supply chain innovation operating within this specific industry.

## 2.4 Research Gap

This research has identified two main research gaps: the need for a unifying framework that fits in the aerospace manufacturing industry and the need for collecting data from the suppliers' side to provide a more comprehensive framework.

Firstly, this research extends the existing literatures by building an integrated that answers to the "HOW" question within the relationship between supply chain integration and innovation performance. The current literatures relating to SCI have been raised from different domains of theories of operations management, strategic management, relationship management, logistics, etc. Such different contexts take different aspects to serve the corresponding research objectives. As a result, the existing SCI literatures have mainly been explored in SCM theories and innovation theories, but some of them create fragmentations and sometimes contradicting answers to the relationship between supply chain integration and innovation performance. For example, from the resource dependency aspect, integrating suppliers in innovation processes have both positive and negative results in innovation performance (Smith and Transfield, 2005). However, from many other research aspects, such as involving supplier in NPD, supply chain accessibility, supplier relationship capability, etc., supply chain innovation has been proven to be positive. Theories from various aspects provide different results in relation to SCI, and such differences create confusion for manufacturers when making decisions on whether to implement SCI in their business strategies or not.

Secondly, the previous researches investigating the relationship between supply chain integration and innovation performance focusing on the buyer's side and collected case data from the buyers only (Petersen et al, 2005; Menguc et al, 2014; Jajja et al, 2017), whereas this research collects data from bother buyers and suppliers to provides a more comprehensive framework by investigating both angles and can provide practical implications to both buyers and suppliers in the aerospace manufacturing industry.

## 2.5 Summary

This chapter presents the theoretical backgrounds and foundations of this research. It starts with definitions and settings of the relevant theoretical constructs; it then reviews the theoretical developments of the foundations of this research. The chapter then goes on by addressing the theoretical gaps. The next chapter presents developments of theoretical frameworks of this research, research questions and objectives.

# Chapter 3 The Integrated Theoretical Framework

## 3.1 Previous development of the integrated Theoretical Framework

The development of the theoretical framework of this research has gone through three stages in general from the very beginning of this research to the stage developed prior to data collection. The third version of the theoretical framework is the final version that guides through the data collection stage and the entire research. However, the researcher feels necessary to present the overall development from the very beginning of this research to show how this research has been evolved.

### *3.1.1 Initial development*

The initial proposed theoretical framework at the beginning of this research programme was to investigate the relationship between supply chain management, strategic management and innovation performance. Because the buyer firms' traditional supply chain management objective does not place focus on improving innovation capabilities or facilitating innovation, whereas the linkage between supply chain management and innovation are inevitable and require more researches. Therefore, the researcher developed interests in exploring the relationship in greater depths. Therefore, the researcher has proposed a theoretical framework that addresses the research gaps based on the first round of literatures review (Figure 3.1).

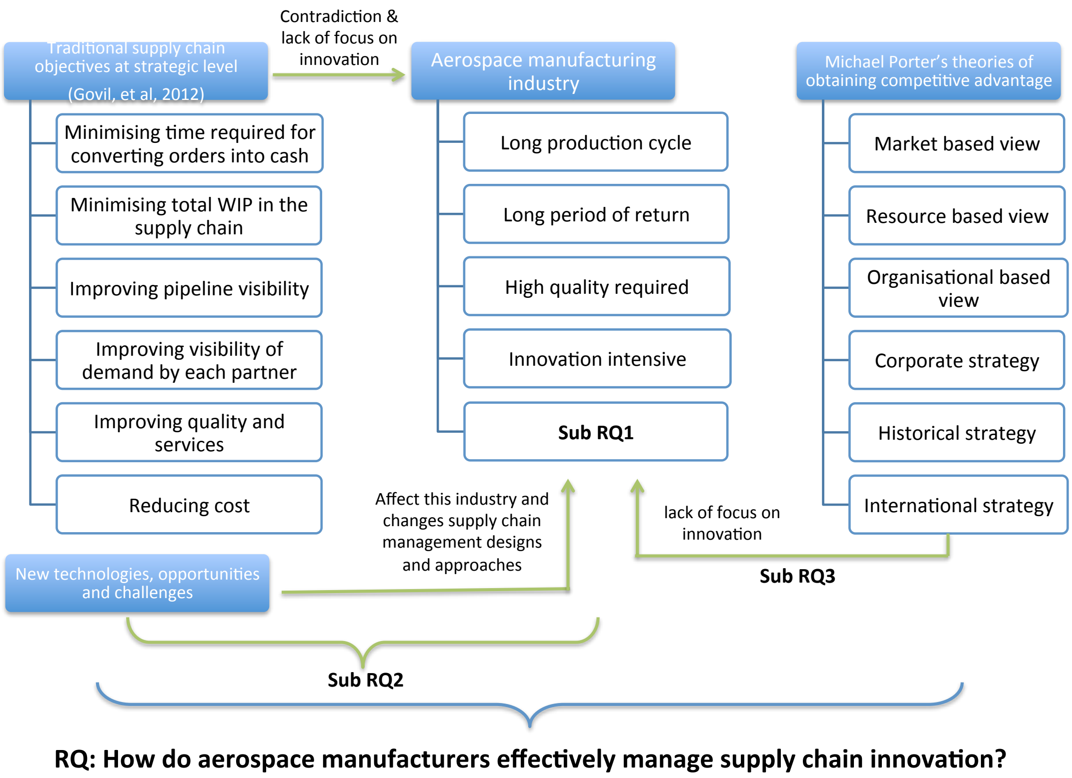



Figure 3.1: Initial proposal of Theoretical Framework

To sum up the research gaps presented in this framework: firstly, due to the uniqueness of aerospace manufacturing industry, the characteristics of aerospace manufacturing industry present contradictions to the traditional supply objectives at a strategic level. The traditional supply chain management principles need to be reviewed in order to find out the leading practices and principles in supply chain management in the aerospace manufacturing industry. Secondly, the traditional supply chain objectives do not focus on improving innovation capabilities or facilitating and coordinating innovation, but the importance of the linkage between supply chain management and innovation requires more research in this area. With the fact that the aerospace industry is high value-adding and technology-intensive, the role of innovation plays a crucially important role. Due to the characteristics of the aerospace manufacturing industry, the relationship between supply chain management and innovation needs to be re-examined. Thirdly, under the new trends and threats, i.e. from the introduction of new technology that would ultimately transform supply chain designing and management, more researches are needed to explore the changes and effects on the linkage between supply chain management and innovation. In order to identify the effects of innovation in the aerospace manufacturing industry, the principles of how to achieve competitive advantage through innovation, in addition to the traditional approach, need to be formalised.

### *3.1.2 Second stage of the development*

The researcher has realised the initially proposed topic was too broad and had too many indicators to measure, which seems impossible to complete as a PhD research. The research question and proposed framework have then been changed into Figure 3.2. Firstly, the research question and objectives have been rephrased. The research is still in the same area and my objectives are the same, but the researcher has opted out the things that are already present or the researcher has chosen not to focus on. The new theoretical model has turned into Figure 3.2.

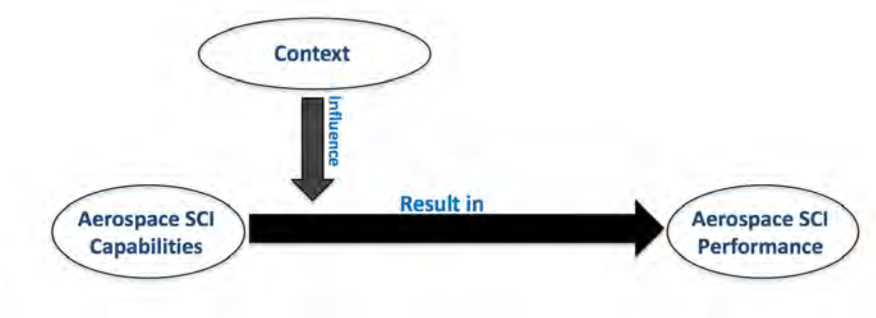



Figure 3.2 Second version of Theoretical framework

Supply Chain Management theories have suggested that SCM is not only about a set of generic purposes: such as cost, quality, price safety, etc., it also has implications on innovation (Bessant et al, 2003; Bruce et al, 1999; Lamming, 1993). With regard to the effects of SCM on innovation, there are two contradicting schools of opinions due to the resource deployments concerns (Liu et al, 2015; Revilla et al, 2015; von Haartman, 2015; McAdam et al, 2008; Irwin et al, 2007; Smith and Transfield, 2005 and Petersen et al, 2004). Therefore, there is a need for an updated and unified theory establishment of SCM and innovation. Based on the current literatures, context factors are also expected to be closely related to establishing the theoretical model. The existing literatures have suggested that the relationship between supply chain integration and innovation performance of the buyers' firms, but how this relationship is taking place and what should the firms do in order to facilitate such relationship have been vaguely discussed. Moreover, the relationship between supply chain integration and innovation performance is more of a causal mechanism relationship rather than causality. Therefore, the primary objective of this research has been evolved to establish the theoretical framework of SCI in aerospace manufacturing industry. The primary research question is: "*How do aerospace manufacturers enhance innovation performance through Supply Chain Management?*" To answer this question, we also need to identify the SCI capabilities, context factors and how the performance can be influenced and measured.

## 3.2 The Integrated Theoretical Framework

The second version of the theoretical framework has narrowed down the focus of this research to make it more plausible for a PhD research project, however, the research gaps have not been completely clarified in the framework and more details about the SCI relationship needs to be explored before starting the data collection stage. Therefore, the researcher has come up to the current theoretical framework (Figure 4.3) that has been guiding each step of this research. Data collection protocol has been designed and developed to collect information around the three important elements of SCI framework: SCI capabilities, SCI innovation performance and context factors. This theoretical framework is not completely different from the 2$^{nd}$ proposed version, but it is more reflective to the existing literatures and gaps between them.

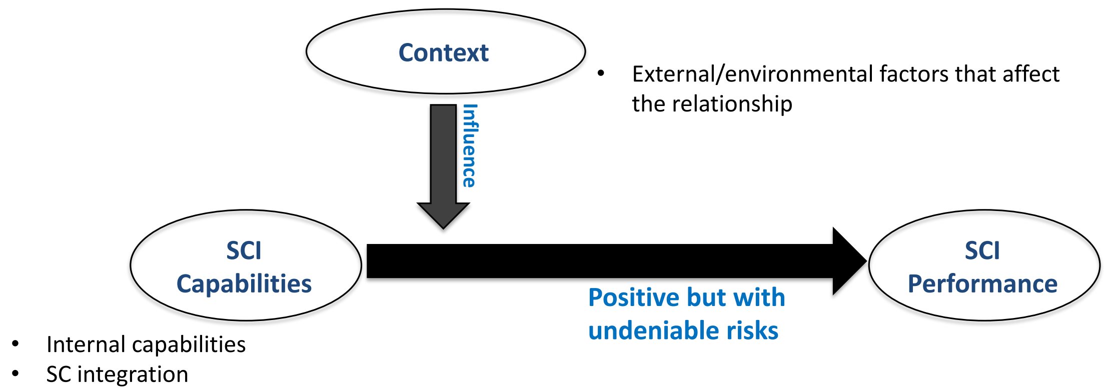



Figure 3.3 The Integrated Theoretical Framework of this research

By explaining elements of the theoretical framework that guides through this research, it is essential to understand the existing underlying literatures that have helped the researcher to come to the theoretical framework, as well as the current theoretical relationships between supply chain integration and innovation performance (Table 3.1, 3.2 and 3.3).

***SCI framework: Innovation Performance***

As the main unit of analysis in this research is innovation performance, the preliminary condition of the theoretical framework is the interpretation of innovation. This research implements the wide interpretation of innovation that includes technological change on both incremental (McDermott et al, 2002) and radical innovation (Chandy and Tellis, 2000); innovation that are new to the market (Chandy and Tellis, 2000) and new to the firm (Cooper, 1993; Johanssen et al, 2001), changes to product category (Johannessen et al, 2001) and process innovation (Jajja et al, 2017). Therefore, product innovation in this research can be measured by: incremental innovation in better product design as a result of supplier integration (Song et al, 2008; Monczka et al, 2010); radical innovation in new product (Ragatz et al, 2002), new capabilities developed (Wynstra and Weggemann, 2001) and superior products (Takeishi, 2001; Menguc et al, 2014).

The process innovation performance can be measured by increase in financial performance (Hudson et al, 2001), quality (Sink, 1985; Hudson et al, 2001), efficiency (Sink, 1985), effectiveness (Sink, 1985), productivity (Sink, 1985; De Toni and Tonchia, 2001; Saunilam 2016), customer satisfaction (Hudson et al, 2001), faster delivery to the market (Lau et al, 2010) and reduced error rates (Song et al, 2008). However, only two of the measurements (faster delivery to the market and reduced error rates) were discovered in existing literatures as a result of supply chain integration, whereas the others were not. Therefore, the relationship between supply chain integration and process innovation is unclear and unprecedented in the literatures.

Understanding the meaning and definition of innovation performance is important because it is about what constitutes innovation performance in this research. However, measuring the level or quantity of innovation is not the focus of this research. This is because that this research only considers innovation performance as an end result of determining whether the SCI integration in the innovation process has been successful or not. As long as there is innovation output in the examined cases (samples) due to the efforts of supply chain integration, the SCI framework can be established. The level/amount of innovation performance that supply chain integration has contributed to is not a unit of analysis. This research does not compare the selected samples (cases) horizontally based on the level of innovation performance or the level of supply chain integration.

***SCI framework: capabilities: Internal innovation capabilities***

The theoretical relationship between product development (Urban and Hauser, 1993) and internal innovation capabilities and innovation performance is well established (Francis and Bessant, 2005; Kallio et al, 2012; Saunila, 2016); thus, it is not the purpose of this research to explore in this relationship between them. However, internal innovation capability is still an important unit of analysis in this research because of its linkage to the underlying reasons that influences manufacturers' decision to integrate suppliers in innovation process (Pfeffer and Salancik, 2003; Liker and Choi, 2004;

Hoegl and Wagner, 2005; Soosay et al, 2008; Flynn et al, 2010; Yang et al, 2013; Un et al, 2016; Jajja et al, 2017).

With or without the existence and availability of manufacturers' internal capabilities, buyers still decide to integrate suppliers in the innovation processes. One of the reasons is the resource dependence view (Pfeffer and Salancik, 2003; Yeniyurt et al, 2014). Moreover, where there is lack of internal capabilities, it is more likely for manufacturers to seek for supplier's contribution to receive access to technology from suppliers (Chesbrough, 2013; Zang et al, 2014). Therefore, some theories have suggested the potential relationship between internal capability and level of integration and process of supply chain integration (Ragatz et al, 2002; Wynstra et al, 2003; Yeniyurt et al, 2014). But the relationship and how the relationship exists was not apparent in the literatures. Therefore, it is for this research to establish how the relationship between SC capabilities and manufacturers' innovation performance is affected by internal innovation capabilities.

***SCI framework: capabilities: external coordination***

Simply speaking, suppliers have not only provided the manufacturers with operational benefits, but also sources of innovation (Bellamy et al 2014). Therefore, including suppliers in the innovation process has become increasingly important to manufacturers, especially in the technology-intensive industries. However, the integration processes and reasons for SCI are more complex. Existing literatures have examined several capabilities of SCI as variables to test the relationship between supply chain integration and innovation performance (Table 3.1). As presented in the existing literatures, in general, it can be concluded that SC capabilities are positively associated with manufacturers' innovation performance through quantitative research. Firstly, suppliers' involvement in the new product development (NPD) process has been proven to have positive impacts on the buyers' innovation output (Wasti and Liker, 1997; Ragatz et al 2002; Wynstra et al 2003; Petersen et al 2005; Menguc et al 2014; Yeniyurt et al 2014). Secondly, supply chain accessibility (the ability for knowledge and information to move freely along the supply chain) is positively related to the buyers' innovation output (Yli-Renko et al 2001; Petersen et al 2005; Thomas, 2013; Bellamy et al 2014; Yeniyurt et al 2014; Jajja et al 2017). Thirdly, the supply chain interconnectedness (ease of knowledge exchange and collaboration along the supply chain) and supplier's innovation capability collaboratively positively associated with innovation output of manufacturers (Bellamy et al 2014). Fourthly, supplier relationship capability (Mitregea et al 2017) and the relationship between suppliers and buyers (Pfeffer and Salancik, 2003; Wagner and Hoegl, 2006; Wagner and Bode, 2013; Mitregea et al, 2017) are also established to be positively influencing innovation output of manufacturers respectively. Additionally, private research partnerships (PRP) and government research partnerships (GRP) are also proven to have positive impacts on innovation performance (Azadegan et al 2013). Last but not least, suppliers' willingness to contribute can be both positively and negatively influencing innovation performance depending on different circumstances (Monczka et al 2000; Paulraj et al 2008; Austry and Golicic, 2010; Corsten et al 2011; Yeniyurt et al 2014).

Table 3.1 Theoretical relationship between supply chain integration and Innovation Performance

| **Supply Chain factors** | **Relationship to Innovation Performance** | **Evidence** |
|---|---|---|
| Supplier in NPD | positive | Wasti and Liker, 1997; Ragatz et al 2002; Wynstra et al 2003; Petersen et al 2005; Megnuc et al 2014; Yeniyurt et al 2014 |
| Supply chain accessibility: knowledge exchange and information sharing | positive | Yli-Renko et al 2001; Petersen et al 2005; Thomas, 2013; Bellamy et al 2014; Yeniyurt et al 2014; Jajja et al 2017 |
| Supply chain interconnectedness: ease of knowledge exchange and collaboration * supplier's innovation capability | positive | Bellamy et al 2014 |
| Supplier relationship capability | positive | Mitregea et al 2017 |
| R&D partnership with private research partnerships (PRP) and government research partnerships (GRP) | positive | Azadegan et al 2013 |

| | | |
|---|---|---|
| Supplier relationship | positive | Pfeffer and Salancik, 2003;<br>Wagner and Hoegl, 2006;<br>Wagner and Bode, 2013;<br>Mitregea et al, 2017 |
| Supplier's willingness to contribute | positive and negative | Monczka et al 2000;<br>Paulraj et al 2008;<br>Austry and Golicic, 2010;<br>Corsten et al 2011;<br>Yeniyurt et al 2014 |

Therefore, to sum up the representative existing literatures (Table 3.1), a general positive relationship between supply chain integration and manufacturers' innovation performance can be established. However, the existing literatures have not answered the "How" and "Why" questions underneath the relationship. Therefore, the researcher intends to build theories to explain the relationship through two aspects: the purpose and processes of supply chain integration.

The purpose of supply chain integration has been discussed in the existing literatures (Ragatz et al, 2002; Menguc et al, 2014), and the processes of integration have been suggested to be understood: type/level of supplier (Ellis et al, 2012; Wagner and Bode, 2013; Un et al, 2016; Jajja et al, 2017); level of responsibility imposed on the supplier (Petersen et al, 2005); method of integration (Petersen et al, 2005); stage of R&D process (Ragatz, 2002; Petersen et al, 2005; Jajja et al, 2014); level and methods of information sharing (Griffin and Hauser, 1992; Petersen et al, 2005; McAdam et al, 2008; Yeniyurt et al, 2014). Therefore, the researcher has integrated findings from existing literatures to help to design the data collection instruments in order to understand the “How” and “Why” questions underneath the relationship between supply chain integration and innovation performance.

Additionally, as this research implements the broad definition of innovation that includes product innovation and process innovation that are incremental and new to the firm, process innovation is also one important unit of analysis in this research. But the relationship between SCI capabilities and process innovation is not present in the literatures. Therefore, one of the most important objectives for this research is also to establish and explain the relationships between SCI capabilities and process innovation.

***Context factors and SCI relationship***

Context factors includes the external factors fundamentally affect either directly or indirectly on both sides of the relationship between SCI capabilities and innovation performance. As presented in Table 3.2, depending on different circumstances, external/environmental factors have both positive and negative influences on the relationship between supply chain integration and innovation performance.

Table 3.2 Theoretical relationship between context factors and Innovation Performance

| **Context factors** | **Relationship to innovation Performance** | **Evidence** |
| --- | --- | --- |
| Location | Positive and negative | Roberts, 1995;<br>Lamming, 1996; |

| | | |
|---|---|---|
| | | Chesbrough, 2006b;<br>Azadegan et al 2013 |
| Strategic decision/organisational culture | Positive and negative | Roberts, 1995;<br>Bruce and Moger, 1999;<br>Collins et al 2017;<br>Sun et al 2017 |
| Corporate governance | Positive and negative | Tylecote and Ramirez, 2006;<br>Liu and Tylecote, 2009 |

Theories of Global Innovation Networks (GINs) have suggested that resources are scarce and thus firms are required to organise “a global network of interconnected and integrated functions and operations in engaging the development or diffusion of innovations” (Barnard and Chaminade, 2011; Chaminade and Plechero, 2015). Under the context of GINs, location matters because it is associated with access to knowledge and knowledge sharing that are affected by regional innovation systems (Chaminade and Plechero, 2015). As knowledge exchange and information sharing are essential sources of innovation, the accessibility affected by location is crucial to this research (Roberts, 1995; Lamming, 1996; Chesbrough, 2006b; Azadegan et al 2013). Additionally, with regard to the importance of location, the role of government is also relevant because its importance in regional innovation systems. The relationship has been established between location, role of government and innovation performance, but the linkage between location, role of government and supply chain integration is not obvious in the literatures. Moreover, the type of ownership of the manufacturers and suppliers are also potential important context factors as they are closely related to the strategic decisions they make (Roberts, 1995; Bruce and Moger, 1999; Collins et al

2017; Sun et al 2017), organisational culture they are in and type of corporate governance they are affected (Tylecote and Ramirez, 2006; Liu and Tylecote, 2009).

Although the existing literatures have already established the potential positive and negative impacts of the context factors on the SCI relationship, how these impacts are affecting such relationship and what general procedures the manufacturers can take to mitigate the negative impacts have been under-examined. Therefore, another important research objective is to explain the relationship between context factors and the SCI framework.

***SCI framework: potential risks***

Although the positive relationship between supply chain integration in manufacturers' innovation performance that has been suggested in most of the literatures, especially in cases of high-tech industries, concerns of risks and negative impacts on innovation performance have also been raised (Table 3.3). The main risks come from the reliance of supplier and interdependence that may result in inefficiency that hinders innovation performance (Takeishi, 2001; Petersen et al 2005; Yeniyurt et al 2014; Jajja et al 2017); replicability of manufacturers' success (Ketchen et al 2007; Salge et al 2013); inevitable knowledge spillovers (Roy and Sivakumar, 2011; Salge et al 2013) and undeveloped internal innovation capabilities due to supply chain integration (Menguc et al 2014). Theories have also suggested that these risks can also be mitigated. Therefore, this research also looks at measures taken by the manufacturers and suppliers in order to minimise the negative impacts of such risks.

Table 3.3 Potential risks between supply chain integration and Innovation Performance

| **Supply Chain factors** | **Influence on innovation Performance** | **Evidence** |
|---|---|---|
| Reliance of supplier and interdependence | risk | Takeishi, 2001; Petersen et al 2005; Yeniyurt et al 2014; Jajja et al 2017 |
| Ability to replicate the manufacturer's success | risk | Ketchen et al 2007; Salge et al 2013 |
| Knowledge spillovers | risk | Roy and Sivakumar, 2011; Salge et al 2013 |
| Undeveloped internal capability | risk | Menguc et al 2014 |

## 3.3 Research Gaps and Research Questions

The positive relationship between supply chain integration and innovation performance have already been proven in the existing literatures; however, the discussions around how this framework systematically works have been fragmentedly explored. Smith and Transfield (2005) studied the internal resources and capabilities of organisations. McAdam et al (2008) identified the need for both internal and external information sharing with suppliers to innovation (new product development), especially in high-tech industry. Moreover, engaging supplier coordination in early product development to leverage the supplier's expertise was found important (Petersen et al, 2005). Though discussions around the relationship between supply chain management and innovation performance have been mentioned all the time, there is no comprehensive answer that how supply chain management can benefit innovation nor a theoretical framework establishing how the activities along the supply chain can systematically result on firm's innovation performance; but the influences on supply chain management and innovation are inevitable.

This research focuses on exploring the contribution from the supply chain in innovation capabilities that can be converted/deployed by the manufacturers to obtain innovation performance. Existing literatures have addressed the importance of integrating suppliers into manufacturers' innovation (new product development) process to exploit suppliers' innovation capabilities and they have established a positive relationship between supplier integration in innovation through numerous quantitative researches. However, there is no definite answer in the previous literatures nor a comprehensive theoretical framework establishing how the activities along the supply chain can systematically result on firm's innovation performance. This research aims to build theories and answer the "how" question in explaining the relationship between supplier integration in innovation. Therefore, the main research question is: "**How do aerospace manufacturers enhance innovation performances through managing supply chain innovation capabilities?**" To answer this main research question, three sub research questions have been designed (Table 3.4).

Table 3.4 Research Question and sub research questions

| |
|---|
| **Main RQ: "How do aerospace manufacturers enhance innovation performances through SCI process?"** |
| Sub RQ1: How do firms decide whether and when to enter SCI collaborations?<br>Sub RQ2: How do firms assimilate innovation from suppliers?<br>Sub RQ3: How do firms' overall strategy influence innovation that takes place on the supply chain? |

This research aims to provide theoretical framework that answers to how the relationship between supply chain integration and innovation performance takes place systematically. After the integrated theoretical framework has been established in this research, the theory should be able to be applied to the manufacturers in the aerospace manufacturing industry in general although each company has different circumstances that details of the factors may be changed and adjusted. The objectives are: firstly, to explain the roles of manufacturers' internal capabilities and to determine how the relationship between supply chain integration and innovation performance is affected by internal innovation capability (Sub RQ1); secondly, to explain the roles of suppliers and how manufacturers deploy and assimilate innovation from suppliers (Sub RQ2); thirdly, how the sci is affected by manufacturers' overall strategy and other external factors (Sub RQ3); and last but not least, to provide practical implications of SCI framework for firms that are both suppliers and buyers (manufacturers).

## 3.4 Summary

The discussions around the relationships between supply chain management and innovation have been tested in existing literatures, but there is no unifying framework explaining how this relationship exists. This research provides the integrated theoretical framework that answers to how supply chain integration can enhance the manufacturers' innovation performance in the aerospace manufacturing industry. This chapter presents developments of the theoretical framework of this research. The next chapter describes and explains the rationale of the chosen research methods and provides justifications for research methodology.

# Chapter 4 Methodology

## 4.1 Research Philosophy

Before starting with different schools of research philosophy, this research began with thinking about ontology and epistemology. Ontology is about the researcher's assumptions of the nature of reality (Saunders et al, 2016). Objectivism and subjectivism are considered within the ontology context. Objectivism treats social entities indifferently from the physical entities and views the reality as independent and self-functioning entities regardless of the human interactions (Saunders et al, 2016). Subjectivism incorporates acts of humans and believes that reality is formed by perceptions and consequent actions of social actors (Saunders et al, 2016). This research takes an objectivist view that in believing that the reality and material world are independently existing regardless of human interactions. Epistemology is about the assumption of knowledge and what knowledge can be regarded as "acceptable" (Saunders et al, 2016). The schools of research philosophy differentiate from one and another in their beliefs in ontology and epistemology, and there are five common schools of research philosophy: "positivism, interpretivism, critical realism, postmodernism and pragmatism" (Saunders et al, 2016). Positivism means that the knowledge of the social world is obtained objectively (Thomas, 2013). Such kind of knowledge, in the positivists' views, is straight-forwardly perceived in the world by direct experience or observations (Robson, 2002). It is applicable to social science as well. The design is fixed, and it separates facts from values (Robson, 2002). Within this approach, the use of variables needs to be decided in advance to any fieldwork, and information collected tends to be more scientific (Robson, 2002). Interpretivism means “knowledge is not straightforwardly perceivable because it is constructed by each of us in a different way” (Thomas, 2013). It implies the reality that interpretations cannot be independent from human (Robson, 2002). This approach interests in people and the way they relate. The research design is often flexible for interpretivists, it requires interactions between the researchers and the participants and the key is “understanding” (Thomas, 2013). This approach tends to collect more qualitative data to explore emerging patterns (Robson, 2002). Critical realism believes that ontology determines epistemology (Laclau and Bhaskar, 1998) that the world and reality to be objective and independent, but it cannot be directly observed or accessed through knowledge (Saunders et al, 2016). Therefore, the reality can only be accessed through active constructive interactions (Laclau and Bhaskar, 1998). Postmodernism believes in collective description of a certain phenomenon or knowledge. It always seeks to question accepted ways of thinking and is open to the deconstruction of any forms of data (Saunders et al, 2016). Pragmatism is about searching for problems and working out practical solutions and believes in multiple realities and working with a combination of relevant methods to achieve the goal (Saunders et al, 2016).

## 4.2 Critical realism in this research

By reviewing the different notions of research philosophy, theoretically, this research is neither completely positivist nor interpretivist. This research is not completely interpretivist because it views the contemporary effects of this industry and no interventions has been made; it is not completely positivist or objective because it also engages with interviewees, and qualitative analytical methods that cannot be quantified in volumes. Moreover, as positivism and interpretivism can be combined rather than being treated as two opposing extremes (Amaratunga et al, 2001; Remenyi et al, 1998), this research can be viewed as more of a middle ground of a combination of these two. Therefore, it takes the ground of critical realism as explores the scientific reality with social constructions.

Critical realism is the middle ground between positivism and constructionism (interpretivism) (Easterby-Smith et al, 2015). It has been commonly used in the managerial and organisational researchers because it presents structured social and organismal problems (Easterby-Smith et al, 2015). Critical realists believe that the world and reality are independent from social actions (Bhaskar, 1978; Easterby-Smith et al, 2015). However, the reality cannot be directly accessed through knowledge (Saunders et al, 2016). In this research, the researcher has taken an objective view of reality and knowledge, but the access and observations of knowledge are socially constructed. This view falls in line with the theories of critical realism and therefore, this research takes the critical realists' view.

Under the perspective of operations management, critical realism takes an even broader application. As management practices are regarded as intellectual and social constructions, there lies a question of whether the social construct is a form of reality or not (Adamides et al, 2012). Sayer (2004) attempted to give an answer to the question that "there are practices or constructions, which exist independently of those which (the researchers) can influence". Therefore, the management practises that cannot be constituted or influenced by researchers can be regarded as reality (Fleetwood, 2005;

Adamides et al, 2012). Therefore, in the operations management perspective, management practise is “conceptualised ontologically” (Adamides et al, 2012).

Moreover, the school of research philosophy this research stands is also determined by the objective of this research. The objective of this research is to explore the potential causal mechanism of supply chain integration and innovation performance in the aerospace industry. The researcher does not assume or try to establish any type of causality, and it is the relationship between supply chain integration and innovation that matters. As the causal relationship is a potential in the view of critical realists (Easterby-Smith et al, 2015), the critical realists’ view is more suitable for this research.

As retroduction approach is mainly used to establish a causal mechanism in the core of critical realism, the main approach of data collection of this research is retroductive (Adamides et al, 2012; Saunders et al, 2016). The research started with establishing a theoretical framework that identifies a potential relationship between supply chain integration and innovation performance, but the researcher has been constantly questioning how the relationship exists and under what circumstances it can exist (Danermark et al, 1997; Meyer and Lunnay, 2012).

## 4.3 Research Design

Five components were suggested to be considered for the framework of research design: purpose, theory, research questions, methods and sampling strategy (Robson, 2002). There are two types of research designs: fixed design that pre-specifies all aspects before data collection; and flexible design, which sorts out the five framework components by the end of study (Robson, 2002). However, this does not mean flexible design ignores all the elements before data collection, it starts with a direction and goal, sets out the five components and keeps reviewing and adjusting elements in the framework (Robson, 2002).

Within the fixed design, non-experimental design provides descriptive studies whereas experimental is for explanatory studies; and the flexible strategy is more appropriate for exploratory work (Robson, 2002). Yin (1993, quoted in Robson, 2002), has mentioned that case study (which is a more flexible design) can also be explanatory, descriptive and exploratory. The most distinction between fixed design and flexible design is on the pre-specifications before the actual data collection (Robson, 2002). Therefore, this research follows a flexible design that includes a collection of both primary and secondary qualitative data to research in both exploratory and explanatory studies. The design elements have been set before the actual data collection, but they were then adjusted and evolved during the research, and the number of sufficient cases selected was determined upon the completion of theory formation.

The type of flexible designs this research follows is case study. Eisenhardt (1989) defines case study as “strategy which focuses on understanding the dynamics present within single settings”. There are two main reasons for choosing case study as the research design. Firstly, this research aims to provide insights that explain the relationship between supply chain integration and innovation performance and to establish the systematic framework of enhancing innovation performance through supply chain integration. The research is a theory-building process rather than the theory testing one. Therefore, case study is an appropriate method of theory building researches (Eisenhardt, 1989; Yin, 2014). The second reason is that this research aims to answer the "How" and "Why" questions by exploring the relationship between supply chain integration and innovation performance. It may be argued that other methods may also answer such type of questions (Yin, 2014), because of the complexity of research object, it requires more in-depth views of the industry and targeted interviews that give more depths to the research rather than breadths (Zhang et al, 2014). Therefore, this research implements a case study approach for data collection.

Adopting a case study research can involve single or multiple cases and a combination of data collection methods (Eisenhardt, 1989). As findings from the multiple-case study are likely to be more robust than a single case (Yin, 2014), this research adopts a multiple-case study approach to view the contemporary events in which relevant behaviours cannot be manipulated by the researcher (Yin, 2014).

Only a limited number of cases can be selected in case studies (Voss, et al, 2002; Eisenhardt, 1989), the main sample selection strategy this research takes is theoretical sampling. Due to the limit in quantity of cases available, it makes sense to select cased that are likely to "replicate or extend the emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types" (Eisenhardt, 1989). To build theories in this aerospace manufacturing industry, the researcher has targeted cases from different positions on the supply chain or based on the product category the case companies are in. The details of sampling strategies will be furtherly discussed in the data collection processes (Chapter 4.5).

## 4.4 Data Collection Instruments

This research implements a flexible design, but this approach does not exclude designing specific data collection instruments prior to data collection. Within the selected sampled cases, both primary and secondary data have been collected in this research (Table 4.1).

Table 4.1 Type of Data collected in this research

| | **Qualitative** |
|---|---|
| Primary | Semi-structured interviews, |
| Secondary | Government database, government reports, company websites, company documents |

For the primary data collected, semi-structured interview is the main data collection instrument in this research. The interviews give more qualitative insights from companies visited and the semi-structured format ensures the relevant questions to be answered and also allows the possibility for the researcher and interviewees to extend discussions on relevant and interesting questions (Thomas, 2013). The respondents approached were supply chain and procurement managers, director of technology/production department, chief executive officers, general managers, etc., who have sufficient knowledge of the process of the company and has roles in strategic decision making. Questions have been designed prior to the interviews, but the list of questions was not comprehensive and the researcher has been expanding the discussions with the respondents based on different situations in each conversation.

Secondary data have been summarised to supplement the findings in the interviews for the purpose of "filling the occasional gaps in developing case narratives based on interviews" (Yin, 2009; Zhang et al, 2016). The secondary data implemented in this research are: information from company websites, internal company documents, publicly available data archives, government regulations reports and government statistical reports. The secondary data contain firm-specific data, industrial and regional data. Examples of secondary data are (Appendix 1): annual statistics of national and regional production volume, revenue, profit, R&D investment, patent registration, growth rates, etc. in civil aircraft manufacturing industry in China. These data came from reports and publications from the National Bureau of Statistics of China, Ministry of Industry and Information Technology of China and the State Intellectual Property Office of China. The data provide an overview of the industry developments and current status of each case.

## 4.5 Data Collection process

The data collection processes of this research are mainly formed by two important sages: the preliminary stage (pilot study) and actual data collection stage. Figure 4.1 gives an overview of different steps in data collection within each stage.

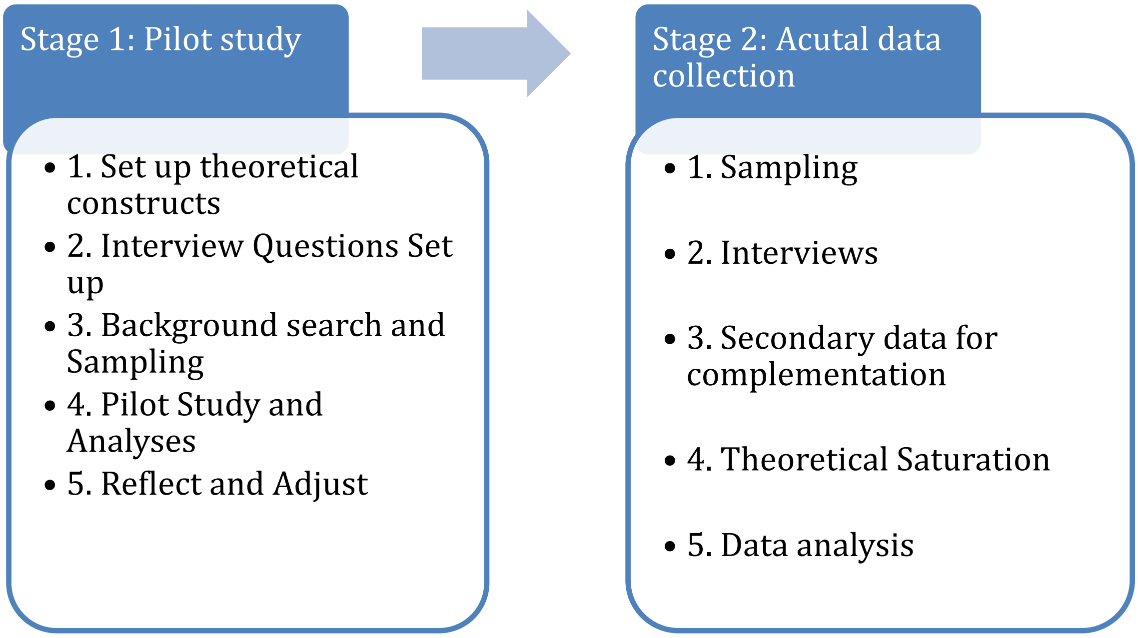



Figure 4.1 Data Collection process

### Industry sector background

The aerospace industry includes civil aircraft, military aircraft and aircraft maintenance (Chang et al, 2010). The civil aerospace manufacturing industry is high value-added and technology-intensive (Chang et al, 2010). Due to the fact that the investment is high and payback period is long in this industry, this industry still implements the "make-to-order" system (Chang et al, 2010). Therefore, under such make-to-order system, the level of work-in-progress and inventory is significantly reduced (Williams et al, 2002). The industry also has special characteristics that include: high value-adding, technology-intensive, innovation-intensive, high investment, highly regulated and vertical disintegrated (Chang et al, 2010). Tier 1 aerospace manufacturers, such as Boeing, Airbus, etc., have only kept the high value-adding and technology-intensive activities in-house while outsourcing low-value adding and labour-intensive activities to aerospace manufacturing suppliers (Tier 2 and Tier 3 manufacturers) (Chang, et al, 2010). Williams et al (2002) pointed out that within the aerospace supply chain, prime contractors are very important. They are the “platform assemblers and system integrators” who have traditionally played a dominant role in coordinating the value chain from top to down. 70% of the final value of an aircraft is outsourced and the prime contractor plays a leading role in such supply chain (Williams et al, 2002). However, the prime contractor also handles responsibilities and high risks in innovation, development funding and production (Williams et al, 2002). Within the aerospace manufacturing industry, supplier relationship and customer satisfaction are fundamental (Chang et al, 2004). Because the fact that prime contractors play an essential role renders this supply chain to be different from the traditional supply chain. Moreover, as the aerospace industry is highly technology-intensive and quality demanding, manufacturers have to keep innovating to achieve product performance. The nature of this industry is fundamentally different traditional manufacturing industry, which raises the doubts of standability of the traditional theories within this industry.

Since major manufacturers have evolved from being vertically integrated to disintegration by outsourcing at least 70% of its production to suppliers (Fan et al, 2000; Williams et al, 2002). The evolved supplier-manufacturer relationship has also affected to the design of products. The simple way is to outsource a complete design and production to suppliers, but the risk increases as more responsibilities and bargaining powers have also been shifted to suppliers (Fan et al, 2000). Another way is to from a design team with both guest (from suppliers) and home (from manufacturers) engineers (Fan et al, 2000). This type of integration has been developed and implemented widely in various concurrent engineering and supplier initiatives; and reported as good practice in the industry (Fan et al, 2000). As a result of such integration, innovation performance is often improved (Fan et al, 2000).

The civil aerospace manufacturing industry has become one of the prime focuses of the China’s development agenda, and the industry’s recent performance has been phenomenal. The year of 2015 is one of the most important year of China’s aerospace manufacturing industry: firstly, the first large aircraft of China has been released to production line; and also the first short-medium range turbofan regional aircraft, ARJ21 has started its service in the airline companies (Yearbook of Civil Aviation Industry of China, 2017). These two aircrafts have all been independently developed by China. The current industry in China involves close integration and coordination with suppliers to achieve innovation which is closely related to our research design. Therefore, this research is trying to find out how supply chain resources turn into innovation capabilities that ultimately result in innovation performance. Then, this research examines cases in China to establish the framework of Aerospace Supply Chain Innovation.

### *4.5.1 Pilot Study*

The first step before actual data collection is the development of theoretical frameworks (Eisenhardt, 1989). The nature of theory-building research suggests researchers to develop constructs at the initial stage of the research to allow the researchers to measure constructs more accurately (Eisenhardt, 1989). Moreover, identifying the research problem and constructs allow the researchers to target the design of data collection instruments in order to receive answers to the specific research questions (Eisenhardt, 1989; Yin, 2014). Therefore, constructs have been established for this research with linkage to the existing literatures prior to data collection within the Literature Review chapter.

Following the development of theoretical constructs, the researcher has set up interview schedules because semi-structured interview is the primary data collection method implemented in this research. The researcher has designed the interview questions around the theoretical constructs aiming to receive answers to the research question and sub-research questions. As the interview questions were designed in English and the actual interviews were supposed to be conducted in Chinese, translation and back-translation of the interview questions have been conducted to make sure information was not missed out or misinterpreted during translation. The English version of interview questions was translated into Chinese by the researcher and two other Chinese nationals who have received qualifications at reputable UK universities at postgraduate level. Without referring to the original English version of interview questions, the finalised Chinese version of interview questions was then back-translated into English by three other Chinese nationals having the similar education background. The translation and back-translation process did not compromise research ethics because only interview questions were revealed to the translators and no other information was made available to them. During this process, mismatches and misinterpretations in translations have been identified and after a meeting with all the translators, the interview questions have been finalised (Cha, et al., 2007). The finalised Chinese version of interview questions has been renumbered and re-categorised, but the questions remained unchanged with the English version.

After receiving approval of ethical review from the university, the researcher started with a pilot study. The pilot study set up in this research was a “small-scale version of the real data collection” as Robson (2002) suggested. It was used for try-out of the methods and data collection instruments.

Though the main sampling strategy for this research at phase two which is the actual data collection stage is theoretical sampling, after a thorough search of the history, background and current status of the aerospace manufacturing industry in China, the researcher has decided to start with a convenient sampling for the pilot study. The aerospace manufacturing industry is highly regulated in China, and the researcher has no prior experience or personal connections with the industry. Therefore, the researcher has to start the research with convenience sampling to gain access to this industry. The purpose of this pilot study is to test the accessibility of information and knowledge from this industry and to gain experience so that the researcher can learn from such experiences to complete a better research design. Even though convenience sampling often lacks creditability (Saunders et al, 2016), the sampling method in pilot study does not affect the creditability of the entire research, because convenient sampling will not be the sample selection criteria for the actual data collection stage.

The researcher started contacting the companies for pilot study through other universities that have joint research projects with our university, family, friends and any other channels the researcher could think of. The criteria set out for the type of company to be contacted for the pilot study is simply “any company that is involved in the supply chain of manufacturing any type of aerocraft”.

After receiving the full ethical approval from the university of this fieldwork, the researcher has started to arrange visits with the companies agreed to be part of this research. From starting to contact the companies to completing data collection for pilot study, the researcher has spent around three months for the pilot study.

At the data collection stage of this pilot study, three companies have agreed for the researcher to visit (Company A, B and C). The researcher has made visits to the companies as if it was the actual data collection for this research. Research data in the pilot study was collected through semi-structured interviews. The researcher has interviewed around 1-3 respondents from each of the three companies. These respondents came from the management level to ensure they have adequate knowledge of the company, and people from the equivalent position of the different companies were reached out. Within each interview, the researcher has explained the research background, aims and objectives to each interviewee. After receiving their consent to participate in this research, the researcher has started conducting semi-structured interviews with the interview schedule for the pilot study. Each interview lasted 30-45 minutes and was carried out face-to-face with each respondent respectively. The researcher has retained the interviewees’ contact details for follow-up email or telephone correspondences.

Following the guidelines of case study research by Yin (2014), the researcher started an inductive process of analysing data collected from the pilot study. The researcher has started with transcribing interview data and word-by-word coding in NVivo, then conducted cross-case analyses and kept records of any difficulties or problems that occurred in the data collection process or when analysing the raw data. After the preliminary data analysis process, the researcher has reflected on the pilot study, and the researcher has identified three main problems that occurred in the pilot study: data accessibility, interview skills, the content of the interviews.

The first problem is the issue of accessibility of this industry. As mentioned before, this industry is highly regulated and remained strictly confidential in China. It was extremely difficult for the researcher to get access to companies in this industry. Therefore, the researcher has decided not to look at the military sector or any company that works both for military and commercial sectors in the aerospace manufacturing industry in China. The researcher has also improved the research introduction leaflet of this research and has decided to give the leaflet to the potential interviewees at the earliest time when contacting them. Once they get to know more about the purpose and context of this research and identifies that this research is more about management practices, integration processes, experiences and reflections, rather than any confidential technical information, the potential interviewees will be more willing to participate in this research.

With regard to the accessibility problem, the researcher has also found out that due to cultural differences, it was extremely difficult to receive access to more than one interview in each company. While being asked to arrange more than one interviewee in each company, the interviewee who participated in the first interviewee would ask the researcher questions like: *"why are you asking for interviewing others?"; "If there is anything in our conversation that you do not understand, you are free to ask me and I can clarify it for you"; "Is it because you do not believe what I have told you just now?"*, and so on. The researcher could feel that the respondent who has already participated in the interview did not understand the researcher's purpose of asking to interview more people and immediately felt offended and being distrusted. To solve this question, the researcher identified the need for better communication when contacting the respondents and to explain more clearly of the purpose of meeting more than one interviewee in each company. Therefore, the researcher needs to clarify the number of participants needed for this research and communicate the underlying purposes to the potential interviewees prior to the visit.

The second main problem the researcher has identified during the pilot study is about the researcher's interview skills. In the first few interviews, the researcher has gone through the interview questions one-by-one with the interviewees rather than proactively engaging with the conversation and asking the questions following the natural flow of the conversation. The researcher has noticed the problem and worked on areas to improve interview skill: through reading recent news and publications in the industry and getting to know more about the background of the company before the interviews; and during the interviews, actively engaging with the respondent and ensuring smooth conversations and discussions as well as collecting answers to the interview questions. Another example happened in the interview with Company B. The first thing the interviewee said to the researcher was *"Sometimes we are only a tier 2/3 supplier on the aircraft manufacturing supply chain, our company does not innovate on the product itself, and we are not allowed to do so."* The researcher panicked when first heard this and did not know what to react because to the researcher's first reaction: the fact that Company B does not innovate at all means that this company does not comply with our research design and we should take this company completely out of consideration. Surprisingly, after further discussions with the interviewee of Company B, the researcher has found out some more interesting, useful and relevant facts of the company that actually are closely relevant to our research setting and indeed they have been innovating. After the interview, the researcher actually ended up with receiving useful information from Company B that looks at our research context from a supplier's point of view. To improve the interview skills, the researcher has kept records of the researcher's experiences and feelings in the interview, reflected on the records and searched for methods to tackle the problems through literatures and trainings. Moreover, the researcher has also learnt from this experience to ask questions using different terminologies and views from different positions on the supply chain to complete the research context.

The third problem occurred in the pilot study is related to the design of interview questions. Firstly, the research has found out that the pilot study only collected generic answers than specific ones; and secondly, some of the questions did not fit in the nature of the aerospace industry. the researcher has tackled these problems through adjusting the questions more specific to this research, adjusting the questions that involve measurements of relevant theoretical constructs and also improving interview skills from trainings, reflections and practices.

After the interview questions and data collection methods have been reviewed and adjusted for the actual data collection stage, similar to the pilot stage, the same translation and back-translation process of the new interview questions have been conducted, and the interview questions for actual data collection are presented in Appendix 5.1.

To sum up the impacts of the preliminary data collection stage (pilot study): firstly, the pilot study gives the researcher access to this industry; secondly, the pilot study gives the researcher more understandings of the industry status and helps the researcher to set sample selection criteria for the actual data collection stage; last but not least, the pilot study serves perfectly as a try-out of data collection methods and helps the researcher to improve research design (i.e. targeted number of interviews, specific interview questions, etc. have been changed after the pilot study) and research skills (i.e. tailoring different terminology in communicating with different interviewees, etc.).

### *4.5.2 Actual Data Collection*

To reflect on the problems occurred in pilot study and the data collection methods in actual data collection have been adjusted and improved accordingly. The nature of case study that only a small number of cases can be completed (Yin, 2012), it is impossible to conduct a probability sampling. Non-probability sampling strategy is used. The researcher has employed theoretical sampling method instead of a random one

(Eisenhardt, 1989; Creswell and Poth, 2017). The purpose of theoretical sampling is to "elaborate, refine a category, the relationships and interrelationships" (Glaser and Strauss, 1967; Strauss and Corbin, 1998; Yazid, 2015). Theoretical sampling is the method the researcher chose at the designing stage of the research and prior to the pilot study. However, as the researcher had no access to the industry at the time for pilot study, the researcher has to start convenience sampling for the pilot just to get access to the industry. As convenience sampling tends to be biased and less reliable and is only more suitable for pilot study (Saunders et al, 2016), theoretical sampling strategy is implemented for the actual data collection stage. The theoretical sampling method involves targeting participants who can contribute to the richness of data for the conceptualisation purpose or that may provide further view for the previous concepts that would lead to saturation (Glaser and Strauss, 1967; Glaser, 1978; Faris, 2017). The theoretical sampling process is also an ongoing process that continues till it reaches theoretical saturation (Goulding, 2002; Faris, 2017).

The theoretical sampling strategy started with an open search (Zhang, et al., 2016) of a full list of the aerospace manufacturers in China released from China's Network of Industrial Information website, which is governed by the Ministry of Industry and Information Technology of People's Republic of China. Due to the sensitivity of and the inaccessibility of military sectors, this research only considers civil and commercial aerospace manufacturing industry. Therefore, the researcher has narrowed down the list to civil and commercial aircraft manufacturers. The researcher conducted explorations of background information about histories, locations, types of ownership, main product categories, etc. of the potential case companies. As this research intends to identify the underlying relationship between supply chain integration in innovation performance which supply chain is an important factor, this research sets out the following selection criteria purposively to search for cases that will contribute to the conceptualisation of theories of this research: firstly, the case companies must be involved in manufacturing in the aerospace industry so that logistics providers, end users and service providers were excluded; secondly, the company must be involved in at least one type of innovation performance which indicates that the company is either innovating or contributing to innovation of the industry; thirdly, the researched companies must come from both the manufacturer and supplier side of the supply chain to provide a complete picture including different sides of this story; last but not least, the company must be at the higher tier of the complex aerospace manufacturing supply chain (at least tier 1-2) that its performance is vital and influential to the entire supply chain. Following these criteria and a careful selection, the list has been narrowed down to around 20 companies and the researcher started to contact these companies. The researcher has then received responses from 4 companies at first: Company A, B, C and D.

The fact that Company A, B and C were revisited in the actual data collection stage does not affect results or produce any biased views for the following reasons: firstly, all of the three companies satisfy all the sample selection criteria for the actual data collection stage and they would be selected anyway regardless of the fact that they have already been visited; secondly, the researcher has restarted the entire data collection process from the very beginning at the actual data collection stage and interviewed different respondents with the new interview schedule; last but not least, even after the pilot study, no prior judgement, assumptions or results have been carried into the actual data collection stage.

The researcher has visited the companies and replicated the same data collection procedure in each company (Yin, 2014). However, worrying about the ability to establish theory saturation with the current number of companies visited, the researcher has decided to implement a snowball sampling where the researcher gain access of more informants through the existing participants (Noy, 2008). The snowball sampling strategy was not carried out as a separate strategy apart from the theoretical sampling, instead, it was conducted for the purpose of establishing theoretical sampling. The criteria of theoretical sample selection still need to be met and the snowball sampling only gives the researcher more access to the industry. To avoid getting biased samples that align only on one particular tier of the aerospace supply chain, the snowball sampling was conducted both horizontally and vertically. Figure 4.2 presents the snowball referral process and the general positions of the case companies on the aerospace supply chain. In the end, four pairs of manufacturers-suppliers were visited and the researcher has collected data from 8 companies in total.

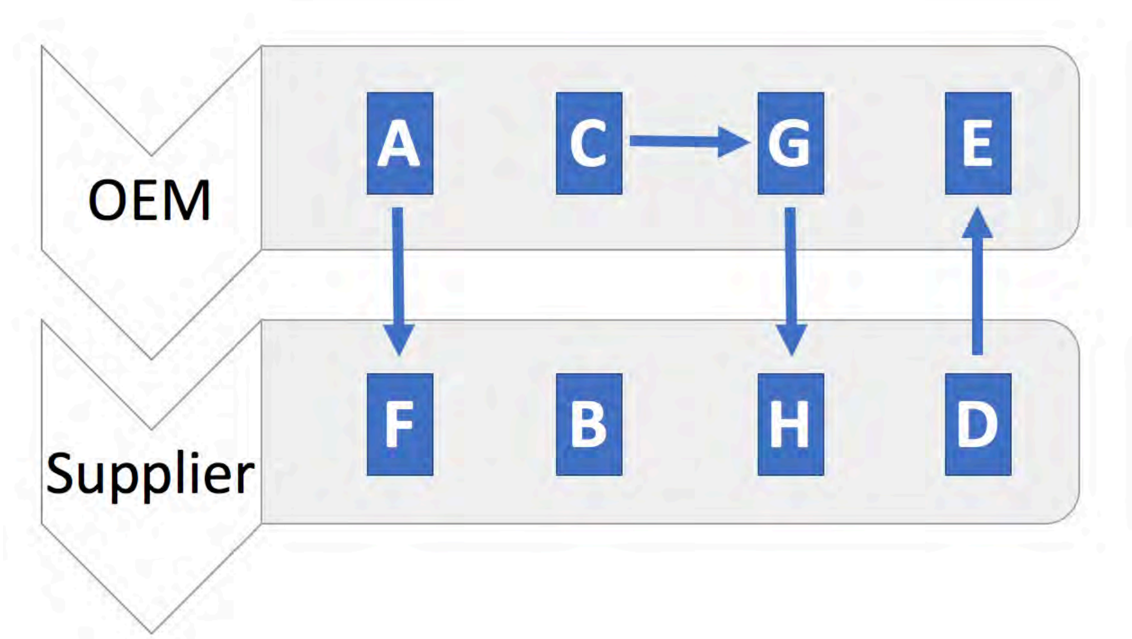



Figure 4.2 Snowball referral process and aerospace supply chain

As the purpose of snowball sampling strategy is to gain access to more companies; the main sample selection strategy is still theoretical sampling, and all the companies the researcher received through snowballing still need to meet all the criteria of theoretical sample selection. All the 8 case companies have met all the criteria for theoretical sample selection. Table 4.2 presents a summary of the status of each company visited on meeting the theoretical sampling selection criteria.

Table 4.2 Status of theoretical sampling criteria for each company

| | **Status of meeting theoretical sampling criteria** | | | |
|---|---|---|---|---|
| **Company or Organisation Number** | **Manufacturer** | **Innovation** | **Manufacturer/supplier** | **At least a tier 1-2 supplier** |
| **A** | YES | YES | Manufacturer | N/A |
| **B** | YES | YES | Supplier | Tier 1-2 |
| **C** | YES | YES | Manufacturer | N/A |
| **D** | YES | YES | Supplier | Tier 1 |
| **E** | YES | YES | Manufacturer | N/A |
| **F** | YES | YES | Supplier | Tier 1-2 |

| | | | | |
|---|---|---|---|---|
| **G** | YES | YES | Manufacturer | N/A |
| **H** | YES | YES | supplier | Tier 1 |

The data collection process has stopped after collecting data from the 8 companies/organisations because of theoretical saturation has been reached. Creswell (2014) and Yin (2014) have suggested 4 to 5 cases for a multiple-case study research, thus collecting data from 8 companies/organisations is appropriate to establish theoretical saturation. Moreover, after collecting data from 8 companies, the researcher has found that collecting new data does not bring new ideas (Charmaz, 2006) and no new findings have emerged, thus theoretical saturation is reached (Williams et al, 2007; Francis et al, 2010).

One case has been built for each company/organisation. The general description of each company is presented in Table 4.3. These eight companies/organisations come from different positions on the aerospace supply chain and they have different focuses in their business operations.

Table 4.3 Summary of General Information about Case Companies

| **Cases /Company Number** | **Supply Chain Position** | **Ownership & product category** |
|---|---|---|
| **A** | Manufacturer | • State-owned<br>• Producer of 2-4 seats helicopter and fixed-wing aircraft |
| **B** | Tier 1-2 supplier | • Private Company<br>• Long-term supplier of high-quality products to large civil aircraft manufacturers both domestically and internationally<br>• Supplier of Company C |
| **C** | Manufacturer & | • State-owned |

| | | |
|---|---|---|
| | Tier 1 Supplier | • Civil/commercial aircraft manufacturer<br>• Tier 1 supplier of foreign manufacturers |
| **D** | Tier 1 Supplier | • State-owned Joint Venture<br>• Engine producer<br>• Direct supplier of Company E |
| **E** | Manufacturer | • State-owned Joint Venture<br>• Producer of fixed-wing small aircrafts |
| **F** | Tier 1-2 Supplier | • Private Company<br>• Supplier of Company A & G<br>• Focus of innovation: product innovation, technology improvement, operational innovation |
| **G** | Manufacturer & Tier 1 Supplier | • State-owned<br>• Producer of large & fixed-wing aircraft<br>• Tier 1 supplier of foreign manufacturers |
| **H** | Design supplier | • State-owned institute of research<br>• Main product: design<br>• Supplier of Company G |

Figure 4.3 presents the overall structure of aircraft manufacturing supply chain in the simplest scenario. As this research only looks at the manufacturing part of aerospace supply chain, all companies visited come from the upper stream of the supply chain (from design to assemble sectors), and logistic providers and end users were excluded in this research at sample selection stage. Moreover, in reality, aerospace manufacturing supply chain is a tiered one (Chang et al, 2010), the researcher has adjusted the distribution of case companies/organisations on the tiered aerospace supply chain (Figure 4.4). As mentioned earlier in this chapter that the researcher followed a set of criteria of selecting case companies, that only companies on the higher tier were selected due to the level of influence, contribution and substitutability along the supply chain and within the industry in general.

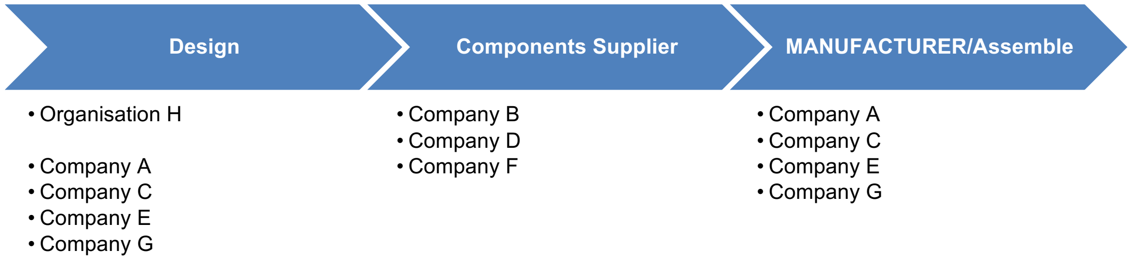



Figure 4.3 Aircraft Manufacturing Supply Chain

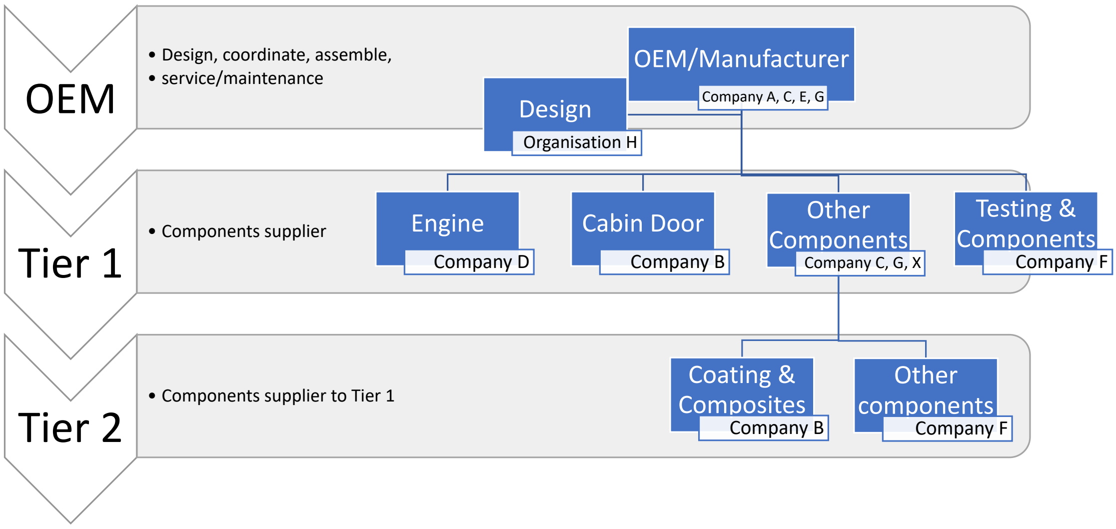



Figure 4.4 Adjusted Aircraft Manufacturing Supply Chain

There is no change from the pilot study to the actual data collection regarding the data collection instrument. This instrument has been carefully selected prior to pilot study to receive in-depth responses from the interviewees as well as allowing them to extend the conversations. Within the pilot study process, the researcher has gained more experiences in interviewing and reflected from the problems occurred. Therefore, the data collection methods in actual data collection stage have been improved to address problems in pilot study, but the main data collection instrument has remained the same.

The main data collection method for this case study research is semi-structured interview and the average length of each interview is around 30-45 minutes. Within each case, at least 3-5 informants were interviewed (Creswell, 2008) to collect enriched data and establish internal validity (Yin, 2014). The interviewees were approached through the process of theoretical sampling and snowball sampling. Once the company has agreed to participate in the research, the researcher sent out the interview schedule and participant requirements to the initial contact within each company and waited till the meeting appointments have been arranged. The participating interviewees came from management level of different departments of each company/organisation to ensure rich knowledge of the operations of the companies and enough information about supply chain integration and innovation performance for each case has been collected. The same data collection process and interview protocols have been replicated within each case (Yin, 2014), and the researcher completed the data collection process when this process reached theoretical saturation stage (Bowen, 2008; Francis et al, 2010), when either "incremental learning is minimal or incremental improvement becomes minimal" of adding more cases (Eisenhardt, 1989). The researcher has collected 37 useful interviews from 8 companies/organisations. Table 4.4 contains a full list of the 37 interviewees and their positions in each company/organisation.

Table 4.4 Respondents list

| **Case** | **Respondents Number** | **Position** |
|---|---|---|
| A | A1 | Director of Production and Technology Management |
| | A2 | Director of R&D |
| | A3 | CEO |
| | A4 | Director of Supply Chain and Procurement Management |

| | | |
|---|---|---|
| | A5 | Director of Supplier Management |
| B | B1 | Assistant General Manager |
| | B2 | Assistant General Manager |
| | B3 | Director of R&D |
| C | C1 | R&D and Technology consultant |
| | C2 | Director of International Supplier Management |
| | C3 | Director of Technology Management |
| | C4 | Former Director of Supply Chain Management |
| D | D1 | Assistant Manager at Technology Department |
| | D2 | Director of Supply Chain and Procurement Management |
| | D3 | Assistant Manager at Technology Department |
| | D4 | General Manager |
| | D5 | Director of Supplier Management |
| E | E1 | Director of Technology Department |
| | E2 | Assistant Manager at Procurement Department |
| | E3 | Director of Supplier Management |
| | E4 | General Manager |
| | E5 | Director of Supply Chain Management |
| F | F1 | Assistant Manager at Sales and Marketing Department |
| | F2 | Assistant Manager at Procurement Department |
| | F3 | Director of Technology Management |
| | F4 | Assistant Manager at Production Management |
| | F5 | Assistant Manager at Production Management |
| G | G1 | Director of Production Management |
| | G2 | Director of Technology Management |
| | G3 | Director of Supplier Management |
| | G4 | Director of Sales and Marketing |
| | G5 | Director of Supply Chain Management |
| H | H1 | Chief Engineer at Technology Department |
| | H2 | Chief Engineer at Technology Department |
| | H3 | Engineer at Technology Department |
| | H4 | Engineer at Technology Department |
| | H5 | Assistant Manager at Administrations Department |

Following the design of this research, the researcher has also summarised and compiled relevant secondary data (Appendix 1). These secondary data are: firm-level, regional and national data on sales information, imports and exports, GDP, investment in R&D, patent registrations, etc. These data came from the publicly available data reports from

National Bureau of Statistics of China, Ministry of Industry and Information Technology of China and State Intellectual Property Office of China, company websites and company report. The data provide an overview of the industry developments and current status of each case. The secondary data were not treated as a distinctive unit of analysis but rather as supplementary information to complete the case narratives and for the purpose of triangulation (Yin, 2009; Zhang et al, 2016).

## 4.6 Data analysis methods

Though the main research is conducted retroductively, the coding process is an inductive one (Eisenhardt, 1989; Bryman, 2012; Yin, 2014; Saunders et al, 2016). The data analysis processes of this research consist five stages: the pre-coding stage, the coding stage, within case analysis, cross case analysis and grouped case analysis.

### *4.6.1 Pre-coding stage*

With the primary data of 37 semi-structured interviews collected for this research, the researcher started the pre-coding stage of transcribing and translating (Temple and Young, 2004; Creswell, 2014). To ensure the neutral position of transcription, the research has conducted word-by-word transcription of the original speech of the interviewees. As all the interviews were conducted in Chinese, after a word-by-word transcription, the researcher has translated all 37 interview transcripts into English. When the researcher is objective, “it does not matter if the researcher carries out the translation or someone else does it” (Temple and Young, 2004). The fact that the researcher has translated all the interview transcripts does not compromise the credibility of this research. As the interviews were conducted orally, some of the answers do not have a full sentences or metaphors in Chinese have been used. The researcher has conducted a sentence-by-sentence translation of the original interview transcripts, without giving meanings to the proverbs, metaphors, subtexts in English nor completing the incomplete sentences with the researcher's assumptions. The researcher has then sent out the translated transcripts to the original interviewees respectively and allowing 1 three-month time period for them to inform the researcher with suggestions, changes or issues of the translations. No problems relating to translations have been reported.

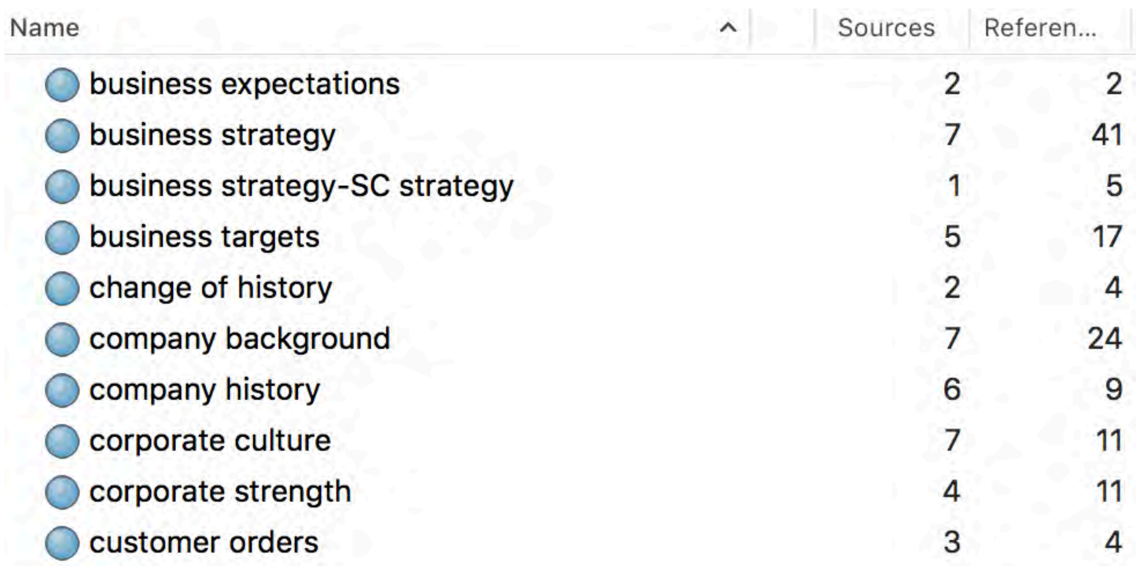
#### *4.6.2 Coding stage*

The coding stage is inductive and computer-assisted (Yin, 2014). The translated interview transcripts have all been compiled into NVivo for further analyses. However, NVivo, as an assisted tool for qualitative analysis, does not generate analysis automatically, it was only used as a tool that assisted the researcher to group, categorise, generate reports and better present the analyses (Yin, 2014). Rather than further interpretation, the coding process is more of a stage for denoting concepts to data (Creswell and Poth, 2017).

Coding stage started with open coding (Strauss and Corbin, 1998). The open coding phase started with line-by-line coding (Glaser, 1978). The researcher has reviewed the transcripts line-by-line (sentence-by-sentence) and given each line a name based on the exact content (Schwister and Fiedler, 2015). The line-by-line codes were then grouped and labelled with a conceptual code for each group (Schwister and Fiedler, 2015). The next step in open coding is the final categorisation of the emerged conceptual codes into different theoretical groups (Creswell and Poth, 2017). Table 4.4 gives an example of open codes generated for one quote from the interview transcript; whereas, Figure 4.5 gives a screenshot of a non-comprehensive list of examples of opening codes from recorded manually in NVivo ("Sources" indicate number of cases involved).

Table 4.4 Quotation from transcript and open coding

| **Quotation from transcript** | **Open codes** |
|---|---|
| *"Our company was established in 2011, and the current number of permanent employees is around 60 (in China). More than 1/3 of the permanent employees are related with technology department, and around 20% of the employees are in the supply chain department. With regard to number of R&D personnel, we have around 15 employees in China and 20 employees in the US specifically working on R&D projects only."* | • Year of establishment<br>• Number of employees<br>• Employee type<br>• Departments<br>• Tech staff<br>• Supply chain staff<br>• US subsidiary |



| Name | Sources | Referen... |
|---|---|---|
| business expectations | 2 | 2 |
| business strategy | 7 | 41 |
| business strategy-SC strategy | 1 | 5 |
| business targets | 5 | 17 |
| change of history | 2 | 4 |
| company background | 7 | 24 |
| company history | 6 | 9 |
| corporate culture | 7 | 11 |
| corporate strength | 4 | 11 |
| customer orders | 3 | 4 |

Figure 4.5 Examples of open coding

Axial coding follows the step of open coding (Strauss and Corbin, 1998). Axial coding is the process in which the researcher identifies open coding categories to focus on the "core phenomenon" and traces back the data to "create categories around the core phenomenon" (Creswell and Poth, 2017). This process involves identifying "causal conditions, strategies, contextual and intervening conditions and consequences" (Creswell and Poth, 2017). In this researcher, the axial codes are related to causal conditions, contextual and intervening conditions and consequences. Table 4.5 gives an example of how open codes are sorted into different categories based on the core phenomenon they represent.

Table 4.5 Example of axial coding and open coding of "company background"

| **Tier-1 open codes** | **Tier-2 axial codes** |
|---|---|
| business association | **company background** |
| business expectations | |
| change of history | |
| company background | |
| company history | |
| corporate culture | |
| corporate strength | |
| department responsibility-manufacturing | |
| department responsibility-operations | |
| department responsibility-others | |
| department responsibility-R&D | |
| department responsibility-sales & marketing | |
| department responsibility-service | |
| department responsibility-strategic planning | |
| employee type | |
| establishment capital | |
| group subsidiaries | |
| name history | |
| product category | |
| product category & background | |
| production time | |

| | |
|---|---|
| ownership type | |
| supply chain staff | |
| tech staff | |
| US subsidiary | |
| US subsidiary output | |
| year of establishment | |

The third step is selective coding, meaning selecting the model and developing propositions of the relationship and interrelationships between the axial categories (Creswell and Poth, 2017). The coding processes were consistent and same coding methods have been replicated in each interview (Yin, 2014), and the conceptual code and axial code names have been adjusted to remain consistency among all the interviewees in 8 cases. The selective codes will be analysed and discussed in more depths in Chapter 5.

### *4.6.3 Within case analysis*

Within-case analysis is the process that allows patterns to emerge from the case facts (Eisenhardt, 1989). During the within case analysis stage, the researcher has reviewed all the data collected for each case and completed "a detailed description of each case and themes within each case" (Creswell and Poth, 2017). Within this stage, the researcher has created an organised chart to display patterns emerged from each case. The emerged patterns in each case give the researcher depths of understanding of the case scenario and provide basis for cross-case analysis. These patterns were then used to analyse the evidences and explain the causal relations between supply chain integration and innovation from each case (Voss et al, 2002).

### *4.6.4 Cross case analysis*

After the within-case analysis process, cross-case analysis was conducted. The researcher started grouped codes of each case as the uniformed format to start the comparison and contrast (Creswell, 2014). The researcher deliberately searched for similarities and differences emerged from each case (Voss et al, 2002). The researcher has also categorised all the cases into two groups of four organisations, based on their positions on the aerospace manufacturing supply chain. Therefore, the eight companies/organisations were categorised into Category 1 (manufacturers): Company A, C, E and G; Category 2 (suppliers): Company B, F, D and Organisation H. The researcher went on to look for within-group similarities and intergroup differences to identify emergent theoretical relationships. The researcher has linked the patterns emerged from cases and compared with the theoretical framework of this research.

## 4.7 Trustworthiness of the research and research ethics

To establish the trustworthiness of this research, we need to first start with establishing transferability and generalisability of this research. Though individuals act differently in different case scenarios, it is still possible to establish transferability and generalisability of case study research if the case represents principles that are relevant to other domains (Gioia et al, 2012). In qualitative research, generalisation exists in a particular description and specific context (Creswell, 2014). Therefore, in this research, internal generalisation that is "generalisability of conclusions within the setting studied" (Robson, 2002) can be applied.

Validity is about the "degree to which the instrument measures it is supposed to be measuring" (Thomas, 2013). Robson (2002) has suggested that in order for the results to be accurate, correct and true, triangulation has been adopted to improve the validity. Triangulation methods includes adopting more than one single source and involving more than one participant for the researcher (Creswell, 2014). In this research, data triangulation and methodological triangulation have been adopted by implementing more than one method of data collection, replicating interviews with different respondents and collecting both primary and secondary. The main purpose for the secondary data is to complement the missing information from primary data collection, however, they can also serve the purpose of triangulation through obtaining data from different sources. Moreover, interviewing 3-5 interviews establishes validity of the research. As suggested by Voss et al (2002), internal validity can also be increased when cross-case analysis has been conducted. When the researcher has implemented a multiple-case study rather than a single case analysis, the internal validity has been increased. The multiple-case design involves deliberately searching for confirmation in different cases and the process leads to generating more reliable results (Voss, et al., 2002).

The reliability is about the extent to which the result is likely to be the same on different occasions with the same research instrument (Thomas, 2013). This means the measures need to be consistent (Gibbs, 2007; Bryman, 2012; Bryman and Bell, 2015). It is very difficult to maintain the consistency when the research involves interviews and human perception. However, the researcher has been keeping full record of the activities carrying out the study, so as neutralise inconsistency in different cases (Robson, 2011).

Moreover, the researcher has also reviewed the transcripts and made sure that they are free from obvious mistakes and data collection protocols, coding methods and analysis methods remain consistent for each case (Creswell, 2014).

***Research Ethics***

Robson (2011) considers research ethics as “what can be reported and how”. To ensure this research has been conducted by following the rules and regulations of research ethics, this research has taken the following methods: Firstly, this research was not carried out until receiving the formal ethical approval the university has been completed. Secondly, before visiting each participating companies of this research, the researcher has sent out formal statement of purpose of the visit, description of research and proposed interview questions, to ensure that the respondents can fully understand the research before making decision to volunteer to participate. Thirdly, during the visits, the researcher has confirmed respondents’ willingness to participate and strictly followed the interview protocols and research ethics during the interview. The respondents are allowed to withdraw their permission to take part in this research at any time before, during and after the interview by sending prior notice to the researcher before 1st June 2017. Fourthly, this research follows regulations and guidance of the University to ensure anonymity and unidentifiability of the participants in each case unless they have expressed the willing to disclose the interviewees’ names/companies’ names. Fifthly, the researcher has also assured that no sensitive business information will be collected. Moreover, the researcher also makes sure that the interviews will not be misinterpreted or translated by sending back the transcripts to the original interviewees for verification. Last but not least, the research data are stored and processed by strictly following the relevant university regulations.

## 4.8 Summary

This chapter sets out data collection instruments and records the processes of empirical data collection of this research. It starts with the grounds of research philosophy this research stands (Chapter 4.1 and 4.2), and then moves on to the details of data collection methods (Chapter 4.3-4.6), analysis methods (Chapter 4.7) and methods of evaluating the trustworthiness of this research (Chapter 4.8). The main data collection method this research implements is multiple-case study. There are two main reasons for the implantation of the multiple-case study design: firstly, the process of identifying the relationships between SCI capabilities, performance and context is a theory-building process (Eisenhardt, 1989). Secondly, case study "focuses on instances of a particular phenomenon with a view to providing an in-depth account of events, relationships, experiences or processes occurring in that particular instance" (Stuart et al. 2002; Denscombe, 1998; Meredith, 1998). As case study focuses on exploring in depth rather than breadth and it adopts multiple sources rather than one research method (Eisenhardt, 1989), case study satisfies this research's primary objective of exploring the theoretical relationship between the theoretical constructs. This research follows Eisenhardt's (1989) guidelines of multiple-case study design. The data collection process consists of two stages: the preliminary stage and the actual data collection stage. The main data collection method is through semi-structured interviews and the cases are also supplemented by secondary quantitative data. Within the preliminary stage, theoretical constructs have been set up and interview questions have been designed prior to data collection. A pilot study of three companies and totally 3 interviews have been performed as a pre-test for the actual data collection stage. Interview protocols were then adjusted based on the findings and to solve the emerged problems from pilot study. In the actual data collection stage, the researcher has followed the theoretical sample selection criteria, and replicated the data collection protocols till reached theoretical saturation. In total, 8 companies have been visited and 37 interviews have been conducted. The next chapter contains a detailed description of the inductive data analysis processes, and in-depth within case, cross-case and grouped case analyses.

# Chapter 5 Case Description and Analysis

## 5.1. Case Description

This chapter presents general information about the eight case companies/organisations. It provides a descriptive summary of case background, location, positions on the supply chain and business nature. The logic model presented in Appendix 6 gives a brief overview of general business operations of each case.

**Case A**

Company A is a limited corporation but its largest shareholders are state-owned companies. Company A was established in 2011, with the registered capital of 3 billion Yuan and 2000 acres. The company is located in south-east part of China. The company is located adjacent one of the major aerospace cluster in China. The company has established the “complete industrial chain” as its business scope covers manufacturing of private jets, helicopters and other related components; research and development of light aircrafts; aircraft service providing; pilot training; sales and marketing; repair and maintenance; and airport construction. In the year of 2012, Company A has full acquired its direct US competitor and set up its primary R&D centre in the US.

Company A’s manufacturing operations have two directions: firstly, it maintains continuous innovation process to keep up to the most recent and advanced aircraft models; secondly, it offers a straight-forward customisation of current aircrafts based on market demand. To achieve the second business operating direction, suppliers’ involvement in the innovation process is kept minimal.

Company A's primary business objective is to build a complete aerospace industry chain from manufacturing of products to services provider including: sales and marketing, private hiring service provider, pilot training, aircraft repair and maintenance, and airport construction. Therefore, at the early stages of Company A's establishment, innovation was not its primary focus and no financial or technological investment was made into innovation until 2012. Innovation performance of Company A has just started to take place recently and results in a relatively low performance within the industry, but it also has the potential to grow.

As China has not yet opened its low-altitude air zone to the public, no private customer can purchase or start using an aircraft for personal use. Market demand in China for Company A's product is extremely low, and it ultimately reflects on supply of products and motivation of R&D. However, Chongqing is also one of the first cities to open low-altitude air zone for a trial period, the market demand is expected to rise and thus the potential rise of supply and sale performance of Company A are also expected.

**Case B**

Company B is a private limited company; it is a subsidiary under a limited corporation group. It was established 2010 with registration capital of 20 million Yuan. Company B is located adjacent to the Shanghai aerospace cluster in China, thus it will also receive the location advantages. Company B is a long-term tier 1-2 supplier for both domestic and international customers. Company B's product category involves cargo door, APU cabin door, processing numeric control machines, coating and composites, and assembly of components, etc. In its international market, Company B’s customers are usually large aircraft manufacturers who have established leading position in the industry for decades in both market and technology performance. Examples of its customers are EADS, Airbus, GE, Latercoere, etc. Moreover, Company B also receives orders from tier 1 supplier of the global leading aircraft manufacturers, which makes Company B a tier 2 supplier (Figure 3.5) and further diminishes its bargaining power and motivation to innovate. As innovation capability is not the primary supplier selection criterion in the international market, Company B has absolutely no intention or right to innovate on the product itself. It can only compete in the market and maximise its profits through constantly improvements of operational process to reduce costs, delivery time and improve quality.

**Case C**

Company C was established in 2008 with the registered capital of 19 billion. Company C is the manufacturer of two major commercial aircrafts, one turbofan regional jet and one large aircraft, that have been domestically designed, tested, and assembled. The suppliers of Company C can be categorised into three categories, and the level of involvement level in Company C’s innovation process in each category is different. (Only a very brief case descritpiton is presented for Case C to avoid reptition in later chapters.)

**Case D**

Company D is a joint venture of a state-owned electronic technology group, a car and engine manufacturer that is one of the leading companies in sales, technology advancement, growth rates in China, and a European private aircraft manufacture. Company D was established in 2013 with the registered capital of 1.65 billion Yuan. Within the joint venture, Company D receives investment and capital transfer from its largest shareholder, the state-owned electronic technology group and technology transfer from the other two companies. Company D's current product and service category include: design, testing and manufacturing of aircraft engine that fits 2-8 seated fixed-wing aircrafts; sales and engine maintenance. Its current business agenda is to complete the construction and establishment of aerospace research and testing centre that is capable of conducting a series of essential aircraft/engine tests, for example: engine performance testing, high-altitude simulation tests, Electronic Fuel Injection, etc. Company D is the direct supplier for Company E and has established very strong relationship with Company E through coordination in production design and development.

Moreover, as a customer, Company D has not outsourced or coordinated its suppliers into any part of R&D process. The main source of technology for Company D is through infusion of technology-based stock from Joint Venture. Therefore, Company D is entirely internally capable of R&D and does not need any suppliers' involvement in the product design stage.

**Case E**

Company E was established in 2013 with registration capital of 800 million Yuan. It is located in the same aerospace cluster with Company D with shared facilities and plants. It is a state-owned joint venture with a European aircraft manufacturer (same company in Company D's joint venture. The enterprise is responsible for research, manufacturing, sales, repair and maintenance and service. The company receives technology transfer in this joint venture from the European manufacturer. It innovates on the current aircraft models to develop more energy-efficient models with higher level of passenger capacity.

Company E's business profile contains two main streams: sale and customisation of current aircraft models, R&D on new aircraft models. With regard to the current models, innovation means straight-forward customisation that does not need to involve any external R&D resources. The R&D of new aircraft models require of series of learning from the current Joint Venture of Company E, and domestically independent R&D. The innovation process of new product in Company E was initiated and lead by Company E, but it also requires intensive cooperation with Company D. The reasons for Company D's crucial role in Company E's innovation process are: firstly, Company D and E share part of the management team, which makes it easier to manage and keep core technology confidential; secondly, as engine is the heart of an aircraft, working closely with the engine provider---Company D will bring effectiveness and efficiency of the high-quality end products; Company D is in control of the most advanced technology within this area that Company E lacks. Due to the special business nature of ownership and management team of Company D and E, coordination and information sharing have become easier than all other cases. Innovation performance of Company E at this stage is measured with new technology, number of new product and number of product development.

**Case F**

Company F is a private limited company that was established in 2008 with registration capital of 4 million Yuan. By the year of 2012, the total value of its fixed assets was more than 31 million Yuan, and the company is still expanding its geographic location and business portfolio. Case F and Case B have a very similar case situation. Company F is a long-term tier 1/2 supplier for domestic customers and tier 2/3 supplier for international customers. In its international market, similar to Company B, Company F has very low bargaining power against its customers and has absolutely no intention or right to innovate on the product itself. It can only compete in the market and maximise its profits through constantly improving its operational process to reduce costs, delivery time and improves quality. Moreover, Company F is located in the same cluster with Company G and Organisation H. It is a private company, but it has a very close connection with Company G. It can benefit from location advantages and also connections and a great relationship with Company G.

Moreover, another type of products Company F provides is testing models, one of its direct customers for model building purposes is Company G. Company F is heavily involved in the model building and testing stage of its customer. With regard to the model building process, Company F keeps supplying the relevant test objects for its customers and proactively follows up with testing stage. After a series of explorations, tests, trials and errors, the perfect model is made. But when the product goes into production stage, Company F's involvement is low.

**Case G**

Company G was established in 1997 with the registration capital of 170 thousand Yuan. The company is a subsidiary of one of the main state-owned aerospace group that heavily involved in strategic plan, design, assembly, sale and maintenance of both military and commercial aircraft. As a subsidiary, Company G is mainly responsible for design, assembly, sale and maintenance of commercial aircraft. It is not only a manufacturer that works in strategic alliance with global leading aircraft manufacturers, but also a tier 1 supplier of components for both domestic and international customers.

Case G has very similar situation with Case C, that suppliers join the design and testing phases of Company G. The involvement of suppliers is often project based and the methods of involvement differ from projects to projects. The first method is through state allocation. The central government will allocate different parts of innovation of the end product of Company G to different companies based on the expertise and level of technology advancement of each company. For such kind of allocation project, the internal R&D department of Company G acts as a coordinator that oversees and ensures smooth cooperation between companies and makes sure the end product fulfils the quality and safety requirements. The second method through direct supplier coordination in product development. When the internal R&D department does not have the capability to perform certain innovation processes, Company G often coordinates with the suppliers who has the best expertise in the relevant area. Suppliers do not necessarily need to be components provider of Company G’s production process, but local institutions and universities.

Innovation performance of Company G is measured through number of new products (including patents registrations, new designs, etc.), number of developed products, sources of new technology, new applications of products and operational innovation.

**Case H**

The organisation in Case H is not necessarily a "company", it is an institute of aerospace research. Therefore, case H's respondents came from Organisation H, instead of "Company H". The institute of aerospace research in China is state-owned institutes focusing on researching, investigating and innovating in technology of the aerospace industry. Therefore, the most advanced technology in aerospace industry lies within the institutes, and each institute has certain specialised areas. The main business operations for institutes like Organisation H include being outsourced in design and providing technological assistance.

As a supplier, Organisation H contributes to its customers through direct personnel, knowledge and technology transfer. Coordination with customers is often project based through either state allocation or being outsourced. Institutions like Organisation H have very strong internal R&D capability, therefore, it may cooperate with universities or other institutes of aerospace research on a particular project, but it does not have any upstream supplier to work within its R&D process. After the direct transfer of the end product from Organisation H to its customers, any subsequent R&D process and testing phase are completed by the customers.

## 5.2 Case Findings and Analyses

The main data collection instrument of this case study is semi-structured interviews. As introduced in Chapter 4, 8 case companies and 37 interviews have been collected in total and secondary qualitative data has also be organised and added to fill in gaps in primary data collection. As explained in Chapter 4, the interview transcripts were organised by a three-tier coding process. The first-tier coding started with the sentence-by-sentence in the interview transcripts based on the meaning of each sentence. The first-tier codes were then grouped into a second-tier (axial coding) based on the context of the codes. Codes describing similar concepts were categorised into the same axial code. The axial codes were furtherly grouped into a third-tier codes via selective coding process by grouping codes with similar concepts. At this stage, presentation of case findings has been organised in accordance with the proposed theoretical constructs.

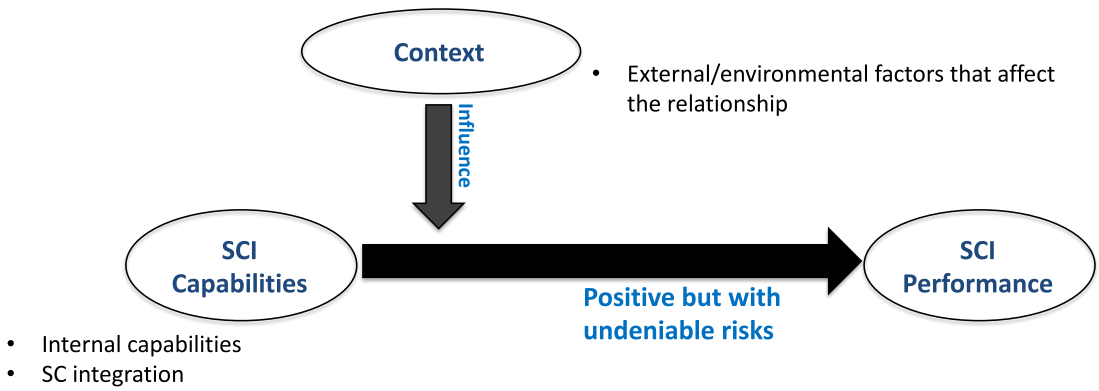



Figure 3.3 The Integrated Theoretical Framework of this research

The theoretical constructs are categorised and analysed in three main categories to present the data in the format of the propsed integrated theoretical framework (Figure 3.3). The three main categories are: SCI capabilitites, context and performance. **SCI capabilitites** include internal, external resources and SC integration. The direct linkage between internal resources and innovation performance will not be examined in this case as it has already been established in numerous literatures. The availability internal resources is still crucial for this research because it constitutes a main determinant for manufacturers' decision making of SCI. **SC integration** refer to activities of manufacturers to integrate suppliers in the manufacturers' innovation process. This research looks at how the manufacturers assimilate innovation from suppliers and diffuse innovation innovation process on the supply chain. **Context** refers to not only external but also internal contextual factors that can potentially affect the both ends of SCI relationship. Therefore, it can affect the way manufacturers coordinate reosources and integrate suppliers as well as innovation performance. **Innovation Performance** in this research refers to determining whether the company is innovating or not. This research only considers what type of innovation rather than level of innovation performance.

As introduced in Chapter 4, the interview transcripts were organised and presented in NVivo in the format of different tiers of codes. The analyses were organised to follow the operationalisation of SCI via practices that fall into the three main categories scattered in existing literatures, resources, integration and innovation performance. The analyses were also aided by Table 5.1 to present the importance of the constructs by the numbers of mentions and percentage of interview coverage. The frequency is the number of times mentioned by the interviewees during the interviews; and the percentage means the percentage of duration for discussing the relevant constructs during the interviews. As responses from the interviewees may overlap, the sum of total percentage may exceed 100%. In each theoretical construct, the analyses started with presenting key case results, explaining the practices of SCI and conduct a cross-case analysis to establish patterns for the SCI relationship.

Table 5.1 Summary of frequency of key constructs

| **Main Categories** | **Sub-Categories and Key Constructs** | **Frequency** | **Percentage** |
|---|---|---|---|
| **SCI Capabilities** (mentioned 564 times, with the total coverage of 47.68%) | Internal R&D | 90 | 11.17% |
| | • *R&D equipment & infrastructure* | 24 | 3.92% |
| | • *R&D investment* | 18 | 2.62% |
| | • *R&D personnel* | 48 | 4.63% |
| | SCI | 474 | 36.51% |
| | • *Resource deployment* | 36 | 3.32% |
| | • *Information sharing* | 54 | 4.78% |
| | • *Method of integration* | 146 | 9.08% |
| | • *Stage of R&D process* | 77 | 6.01% |
| | • *Supplier relationship* | 30 | 2.22% |
| | • *Level of suppliers* | 72 | 5.26% |
| | • *Level of responsibility* | 59 | 5.84% |
| **SCI Context** (mentioned 154 times, with the total coverage of 16.42%) | Ownership & corporate culture | 15 | 1.79% |
| | Strategic planning & positioning | 24 | 4.56% |
| | Government control & support | 115 | 10.07% |
| | • *International trade and relations* | 20 | 1.83% |
| | • *Regulations & limitations* | 25 | 1.75% |
| | • *Government Support* | 40 | 3.77% |
| | Location | 30 | 3.02% |
| **SCI Performance** (mentioned 195 | New application | 15 | 0.91% |
| | New product | 24 | 2.95% |
| | New service | 10 | 0.79% |

| | | | |
|---|---|---|---|
| times, with the total coverage of 15.52%) | New technology | 45 | 5.28% |
| | • *Acquire* | 10 | 1.11% |
| | • *Internal* | 35 | 4.17% |
| | Operational innovation | 101 | 5.59% |
| | • *Cost* | 35 | 1.47% |
| | • *Delivery time* | 30 | 1.55% |
| | • *Quality* | 36 | 2.57% |

### *5.2.1 Firm-level Capabilities*

The internal R&D has received 90 mentions and covers 11.17% of the interviews. It has been well established in previous literatures that product development (Urban and Hauser, 1993) and internal firm-level innovation capabilities will result in innovation performance (Francis and Bessant, 2005; Kallio et al, 2012; Saunila, 2016). Therefore, the theoretical or practical linkage between firm-level capabilities and innovation performance is not the primary focus of this research. However, firm-level capabilities still constitute an important unit of analysis in this research due to the impacts and potential connection to other theoretical constructs.

The key concepts in the category of Supply Chain Innovation Capabilities that have been most commonly mentioned involve the traditional concepts of a company's internal R&D and coordination with other participants along the supply chain. (Table 5.1). A company's internal R&D activities can be regarded as one type of SCI capabilities. They include: R&D equipment and infrastructure, R&D investment and R&D personnel. In this research, the three internal R&D elements have been mentioned 90 times in total but the length of the discussions of each element differs.

Table 5.2 Summary of availability of internal R&D capabilities

| **Case Number** | **R&D staff** | **R&D facilities** | **Investment** | **Testing facilities** |
|---|---|---|---|---|
| **A** | √ | √ | √ | |
| **B** | √ | √ | √ | |
| **C** | √ | √ | √ | √ |
| **D** | √ | √ | √ | √ |
| **E** | √ | √ | √ | √ |
| **F** | √ | √ | √ | |
| **G** | √ | √ | √ | √ |
| **H** | √ | √ | √ | √ |

Table 5.2 presents an overview of the availability of internal R&D capabilities of each company visited in this research. The main innovation capabilities of Company A come from three branches: the R&D centre in its headquarter, two joint laboratories in China and the R&D centre in its subsidiary company in the US. As this research only looks at manufacturers in China, and only obtained access to Company A's headquarter inside China, the operations from its operations in the US is not considered in this research. The data collected only represents Company A's operations in China, and all the textual information relating to its US subsidiary came from the interviews with respondents in China. Moreover, the joint laboratories are constituted by R&D personnel from both Company A's internal staff and experts from the two associated universities; the joint laboratories are regarded in this research as SCI capabilities rather than firm-level. Therefore, the firm-level innovation capabilities of Company A come merely from Company A's internal R&D department. Company A is not a large-scale manufacturer in the aerospace manufacturing industry; the annual production capability of Company A's headquarters reached 50 units of helicopters in 2015. The number R&D personnel

is only 30 in China. However, the group has been enhancing its internal innovation capability through intensive capital investment. The group reinvests at least 6% of its total revenue in R&D, by the year of 2015, the accumulated investment is more than 90 million Yuan (RMB) and all of the investment came internally. Company A has three R&D centres in China: one of them is its internal R&D department, and the other two R&D centres are state-level laboratories jointly developed with two major reputable Chinese universities. Before the year of 2015, there was no internal innovation capability within Company A, and all of the technology came from direct transfer from its US subsidiary. Since the establishment of the two joint labs in September 2015, Company A's internal R&D centre has become equally important as its US subsidiary in product innovation. It has even taken over the lead of innovation for its most recent helicopter model. As well as internal technology development, the internal R&D department of Company A is also capable of conducting strategic innovation management and business administrations through identifying the need of innovation, filtering and refining innovation that occurs in the supply chain, diffusing and coordinating different stages of innovation processes within its supply chain. Small-scale and lab-based experiments can be carried out inside Company A's internal R&D department and the two joint labs and all large-scale tests are outsourced to specialised suppliers.

The firm-level capabilities of Company B come from complete internal R&D, investment, accumulation of knowledge and learning and operational excellence. As Company B is a Tier1/2 supplier, its bargaining power is relatively low when negotiating with its foreign customers, it has absolutely no right to innovate on the product itself. Any change on the product is not acceptable by its customers. However the completion of orders brings Company B not only revenue but indirect impacts on technical level and operational excellence. As innovation capability is not required from Company B by its foreign customers, the company is not non-substitutable and it can only survive in the competitive market through reducing costs, improving product quality and reducing delivery time. Through processing orders from its foreign customers, Company B has to continuously improve its technical level to satisfy the requirements set out by its customers. Its customers also provide trainings o Company B on technology and operations management to help increase its internal capabilities. The technical team of Company B keeps improving the process its internal technical capacity to meet customers' requirements; and they also need to plan and adjust the structure and layout of the production plant to make operations more efficient. Therefore, the company is able to reduce costs of production, improve efficiency, improve product quality and shorten the production cycle. As a result of internal development and help from customers, the firm-level capabilities of Company B has been enhanced and it has obtained the expertise in the production of RAT door, aircraft elevator, rudder and landing gear door; it has also achieved top level of technical excellence in core components processing and taken over the lead in the competitive domestic market.

In Case C, the number of total employees in the R&D departments is around 2000, and around 700-800 of them are senior engineers. The total size of production and research facilities is 1200 acres. But this plant is shared by Company C and its subsidiary companies. All of the firm-level R&D capabilities have been developed internally.

From the view of its internal technical strength, Company C has gained experiences through R&D, producing and assembly of three series of aircrafts. The company has been granted (by the time of the interview, September 2016) about 600 domestic patents and more than 60 overseas patents. Within the total patents granted, 100 of them came from its independent R&D processes, and the remaining were completed through cooperation.

In Case D, the number of R&D personnel takes around 80-90% of the current number of employees. It is a newly established company and the current strategy for the company is the construction of plant and internal capability development. Company D has a total of 200 acres reserved land for the construction of R&D equipment and facilities, and the facilities are also to be shared with its direct customer---Company E. At present, Company D's research centre is not equipped with state-level labs, but it is on the process of applying for the accreditation of state-level labs to receive more government support and subsidies. The accumulated investment in R&D is around 300 million RMB in total, and the company has planned to invest 75%-80% of total investment into R&D. The current source of technology of Company D is from the direct transfer of technology-infusion from its parent company, and there are 23 patents transferred to Company D. Therefore, Company D is currently exploiting and learning from the direct transfer to improve its internal R&D capabilities.

In Case E, the total number of R&D personnel is currently 40-50, and similar to Case D, the main responsibility of R&D personnel in Company E is to learn and implement from the transferred technology from M&A and develop internal capabilities. The total investment in R&D is around 0.6 billion RMB and it all came from internal investment. Company E is currently in possession of the two aircraft models and relevant technical information. The current R&D objective for Company E is not remaking/customising the current aircraft models. Instead, the objective is to innovate a new aircraft model that has increased loading capacity and energy efficiency. To complete the production innovation, Company E has also been working very closely with its direct supplier---Company D.

In Case F, the internal capabilities are presented in the 50%-70% investment of R&D from total annual investment and a total number of 5 IP that have been developed independently. Company F does not need to integrate any of its suppliers in its innovation process as it does not require any innovation capability from its sub-suppliers. But manufacturers integrate Company F in their innovation process.

In Case G, there are around 100 employees inside the R&D departments. R&D investments are internal investments but some of the R&D facilities are to be shared within the holdings group. Company G has specialities in CNC processing, aircraft assembly, application of composites and other technical advantages in the industry.

In Case H, there are around 70-80 engineers inside the organisation and it has access to the R&D personnel within the holdings group it belongs to. There are totally 614 patents granted as a result of Organisation H’s internal R&D activities.

### *5.2.2 Reasons for buyers (manufacturers) to integrate*

Where there is lack of internal capabilities, it is more likely for manufacturers to seek for supplier's contribution to receive access to technology from suppliers (Chesbrough, 2013; Zang et al, 2014). SCI receives 474 mentions in total and covers 36.65% of the total interviews. It is suggested in the literatures that regardless of the internal capabilities, buyers still decide to integrate suppliers in the innovation processes because of the resource dependence view (Pfeffer and Salancik, 2003; Liker and Choi, 2004; Hoegl and Wagner, 2005; Soosay et al, 2008; Flynn et al, 2010; Yang et al, 2013; Un et al, 2016; Jajja et al, 2017), to build relationship with suppliers (Yeniyurt et al, 2014) and other reasons. Therefore, it is important to identify the reasons for buyers' decision to integrate suppliers in the innovation process as it is the fundamental condition that enables supply chain integration in innovation.

According to the findings in the interviews, the main reasons for integrating suppliers in product innovation can be summarised as: lack of internal capabilities of specific technology, lack of resources and as a result of strategic business decisions. Table 5.3 summarises the case findings of manufacturers' reasons to integrate from the 8 companies.

Table 5.3 Summary of Reasons to integrate

| **Case Number** | **Lak of internal capability** | **Resource dependence** |
|---|---|---|
| **A** | √ | |
| **B** | | √ |
| **C** | | √ |
| **D** | | |

| | | |
|---|---|---|
| **E** | √ | |
| **F** | | √ |
| **G** | √ | √ |
| **H** | √ | √ |

- Lack of internal capabilities

Where there is a lack of internal capabilities, Company A favours outsourcing the part of R&D process to its capable suppliers than developing its own internal capabilities as it is more cost and time efficient. Otherwise, as mentioned by the respondent, *"if we start from scratch and try to catch up, it may probably take us decades to achieve our competitors'/suppliers' current technology level. Then we will be stuck in the loop of always trying to catch up but always falling behind."*

Company B's suppliers have almost no contribution to its innovation capabilities, but it has been engaging actively with its domestic customers in improving their innovation capabilities. Therefore, this research also investigates from the supplier's side to find out how suppliers are integrated in its customers' innovation processes. One of the main reasons the customers integrate Company B into innovation process is because of its advanced technical level and leading position in the domestic industry sector. As mentioned early, Company B has leading expertise in specific parts of the aircraft where its customers lack. Therefore, due to its customers' lack of internal capabilities, Company B has been involved in its customers' R&D processes.

Mentioned by the respondent from Company C (C1): *"In fact, we are fully able to start from scratch and have 100% of the innovation developed from inside our company. We* *have this financial strength and technical ability."* From the size of the company, total number of R&D personnel and number of patents granted, Company C's internal innovation capabilities are strong. But as it is still a relatively new company that is experiencing learning and growing stage, there are areas in which Company C is not specialised or its suppliers have more experience or higher level of technical advancement. C1 has also pointed out that *"if we innovate in this way* (remarks by the researcher: meaning complete 100% innovation from internal capabilities)*, it takes a longer time for innovation. Moreover, for the skills that we do not have, starting from scratch cannot guarantee us to catch up with the world's advanced technical level in the short term. So, we have to learn practical experiences from the internationally renowned suppliers"*. Therefore, for R&D in such areas where Company C lacks internal capabilities, it seeks collaboration with its capable suppliers.

Respodnent from Company D has responded that, *"The current R&D relies on our internal resources. We receive existing technology from the JV… The technology we receive from the JV has not been fully exploited yet… Therefore, we can receive all the technology and relevant knowledge through the JV, and the rest of the technical learning and improvement are completed by our innovation personnel. There is no need to search for external resources."* Therefore, we can conduct that Company D has enough internal R&D capability that do not require external innovation capability from its suppliers.

The supplier's quality pre-determinates the quality of the final product, and the fact that Company D and E share facilities bring these two companies closer. The reason for

Company E to integrate D into innovation process is not only for quality and cost concerns but also due to lack of internal capability. The core technology from the engine of an aircraft is the key to fulfil Company E's innovation objective.

- Resource dependence view and strategic business decisions

Mentioned 36 times with the frequency of 3.32%, the resource deployment is closely related to the resource dependence view. As suggested in the resource dependence view, due to the scarcity of resources, a business entity cannot have "all the resources and abilities needed to achieve desired outcomes" (Pfeffer and Salancik, 2003). Collaborations are necessary and companies have to make strategic decisions on resource selection and utilisation. According to the interview responses, the decision to integrate suppliers in innovation of Company A is highly dependable on the R&D stage it is in, business strategy it focuses and the technology advancement level of its suppliers and the suppliers' willingness to participate.

The company in case C is financially and technically capable of completing every stage of R&D internally, even with the area it needs to start from scratch. However, the competitive market contains full of uncertainty and scarcity of resources does not allow a company to do so. Therefore, integrating a renowned supplier in the innovation process reduces time and cost needed for innovation and makes the innovated products more responsive and flexible to the changes in the market. Also found in Case C, another reason is due to the company's strategic business decision to compete on the operational level through SCI.

Since Company D receives technology through direct transfer from the JV taken place prior to the establishment of the company, it does not see the need for integrating its suppliers into the innovation process. The reasons for Company D not integrating any supplier in its innovation processes come from the concerns of confidentiality and knowledge spillovers. Moreover, it has enough internal and transferred technology to be infused and SCI in innovation may be considered in its strategic plan at later stages. The main reasons for the potential considerations are: the company aims to maximise localisation in production, it needs to work more closely with local suppliers and they are expecting trusted suppliers to collaborate; secondly, Company D is expecting to build closer relationship with its suppliers as they have no connection with these suppliers prior to the JV.

Similar situation takes place in Company G, where it is not necessarily due to lack of internal capabilities, SCI in innovation process also takes place as a result of scarcity in resources.

In Case H, there is no production operation in Organisation, nor it needs any sub-suppliers, therefore, it has no SCI in its internal innovation process. However, it has been integrated in its customers' innovation processes for the two common reasons as presented in other cases: customer's lack of internal capabilities and result of resource dependence. Moreover, it may also be a result of government planning.

### *5.2.3 SCI capabilities*

Existing literatures have already established a positive relationship between supply chain integration and product innovation (Petersen et al, 2005; Menguc et al, 2014). However, the "How" and "Why" questions underneath the relationship are not answered. The researcher has elaborated the theoretical framework to explain the relationship. The SCI capabilities can be analysed from two aspects: the purpose and processes of supply chain integration. Within the total 564 times of mentioning about SCI capabilities, discussions about SCI occupy a large proportion of the interviews. With regard to the contradicting debate brought up by Smith and Transfield (2005), in this case, all three companies felt that they have enough resources and energy for both SCM and innovation management, and they are not in conflict to each other. Method of integration is the most commonly cited concepts in the interviews (with 146 references and 9.08%).

#### 5.2.3.1 Purpose of integration

The purpose of supply chain integration in innovation process is different from the reasons for integration. The reasons for integration is about the fundamental reasons that enables supply chain integration; whereas the purpose of integration is about types of benefits manufacturers aim to receive through supply chain integration in innovation. The main purposes of supply chain integration in innovation are summarised as: access to technology, access to application information, enhancement of supplier relationship and reduction of uncertainty. Table 5.4 presents a summary of case findings with regards to the purpose of integration.

Table 5.4 Summary of purpose of integration

| **Case Number** | **Access to technology** | **Access to application information** | **Access to new market** | **Enhancement of supplier relationship** | **Reduction of uncertainty** |
|---|---|---|---|---|---|
| **A** | √ | √ | √ | √ | √ |
| **B** | √ | √ | | | √ |
| **C** | √ | √ | √ | √ | |
| **D** | √ | | | | |
| **E** | √ | | | | |
| **F** | | √ | | | |
| **G** | √ | √ | √ | √ | |
| **H** | √ | | | | |

- Access to technology

When there is a lack of internal capabilities or due to the concern of resource dependence, Mentioned by A2, Company A outsources parts of design to suppliers as *"these parts are often the part we are lacking in capabilities and talents. It is either due to our lack of capabilities or talents, or our suppliers have the most advanced technology level in the industry"*. Such suppliers are state-owned research institutes, companies that supply components and universities.

As the manufacturers in aerospace manufacturing industry in China are still young and growing, the more experienced and capable suppliers sometimes have more knowledge and specialties than the manufacturers. Therefore, Company B's customers integrate it in the innovation process to gain access to its cutting-edge technology. This situation only takes place when the supplier is more experienced than the manufacturer in the specialised area. From the supplier's side, one of the main purposes for Company B to get involved in its customers' innovation process is to gain technical improvement through collaborations. Learning and knowledge sharing brings mutual benefits to both parties in the SCI process, company B can also benefit from expertise in its customers to improve its technical strengths.

The primary purpose of Company C and Company G's SCI in innovation is to gain access to supplier's resources, such as: technology, equipment and machinery, knowledge on technical processes. For example, as pointed out by C3, the reason *"is related to our own technical competence level. After all, China's development of large aircraft project started later than the other countries and we started from scratch with a lot to catch up."* Therefore, they have realised the need for *"cooperation with suppliers with good experience and high technical levels, so that we can avoid the shortcoming of current aircraft models and thus enhancing our competitiveness"* (C3).

Working with Company D gives Company E access to technology that it does not have, and it also gives Company E access to D's resources and expertise. If Company E choose to work with market leaders in the industry, their requirements will be fully met, but all the core technology will be kept hidden from Company E. Therefore, the access to technology for Company E is the most important purpose for engaging supplier in innovation process. Similar findings have also been found in Case H, where the institute of research is in possession of the most advanced technology in the field, its customers integrate it in their innovation process to gain access to advanced technology.

- Access to application information

With regard to application information, Company A has to coordinate with suppliers to receive interface information of helicopter as the design needs to fit the installation of vendor's products. For example, before designing new product, Company A need to select its engine supplier and coordinate with the supplier in the design phase to receive product specifications of the engine and design the relevant interface to fit the installation of the new engine. This process only requires transfer of application information and Company A needs to complete supplier selection before completing design of the new product. Such type of cooperation does not only limit to technology-intensive products, it also applies to products that are much less technology-intensive, such as coating and interior design. In Case C, the manufacturer's regular partners in research are institutions that do not have practical experience, integrating component suppliers in innovation process gives the company access to application information. The main purpose for integrating Company F in the manufacturers' innovation process is to gain access to application information. As introduced by the interviewee from Company F (F3), "*when the customers are selecting the adequate materials/composites, they have access to the relevant specifications of the materials available in market. Such information is available in textbooks or other industry information databases. However, we have better knowledge than them in application of materials: i.e. whether the material is suitable or not; whether there is a better alternative or not, the specific parameters like hardness or flexibility of the material, etc. Because of our knowledge in application, we join the customers' design of the product and provide information to help them to find the most suitable materials*." Moreover, it is also pointed out by G5, "*for the purpose of receiving information from the suppliers that we have no access to,* *such as the required conditions of actual production stage, product specifications for us to select a more durable or lightweight materials, etc.”*, they need to integrate supplier in their innovation process.

- Access to a new market

According to the findings in the interviews, as the aerospace industry is highly regulated and security and safety are the priorities of this industry, entering a new market in a different country is difficult and all the products need to be in compliance with the local legislations and regulations. Therefore, integrating suppliers from the potential market in the R&D process helps the manufacturers to ensure compliance with requirements of the potential market at the very beginning. For example, respondents from Company A have addressed the importance of complying different regulations and legislations in both its domestic and foreign markets. They have also pointed out that information provided by its foreign suppliers has not only helped them to design the product to fit the installation of the components but also to comply with relevant laws and regulations the product will be sold in.

From the supplier’s side, one of the purposes for Company being actively participating in its domestic customers’ R&D process is to gain access to the domestic market. The integration stimulates potential demand of Company B’s products in the domestic market and it can also gain more bargaining power in the domestic market through SCI.

In Case C, as the manufacturer has targeted both domestic and international market, “*involving foreign companies in our R&D stage will reduce obstacles for us to gain* *airworthiness certificates in the home countries of the suppliers*" (C3). During the process of cooperation, Company C will able to set out quality standards, operation and management styles at the very beginning of R&D process in order to fulfil the requirements of obtaining airworthiness certicate and gain access to the potential markets.

- Enhancement of supplier relationship

Supplier relationship has only received 30 mentions with the frequency of 2.22%. Only a few of the interviews mentioned supplier relationship as part of the purpose of engaging in SCI. For example, due to the high level of quality requirement and low quantity in demand of this industry sector, the number of high-quality suppliers are limited thus the bargaining powers of such suppliers are extremely high. Company A has been seeking to build long-term relationship with its supplier through cooperation in product innovation not only to gain access to knowledge but also enhance relationship by closely working suppliers. Supplier relationship is also discussed in relation to methods of integration and as a result of SCI.

- Reduction of uncertainty

As learnt from the interviews, Company A also felt that coordinating with suppliers in production innovation potentially shares the burden with suppliers and reduce its own risk of uncertainty due to a closer connection with its suppliers. In Case B, through integrating Company B into the manufacturers' innovation process, the manufacturers are able to avoid drawbacks of existing aircraft models and produce a new aircraft model that is more efficient and comfortable.

5.2.3.2 Process of integration

The processes of integrating supplier in manufacturers' innovation process can be understood through analysing: type/level of supplier (Ellis et al, 2012; Wagner and Bode, 2013; Un et al, 2016; Jajja et al, 2017); level of responsibility imposed on the supplier (Petersen et al, 2005); method of integration (Petersen et al, 2005); stage of R&D process (Ragatz, 2002; Petersen et al, 2005; Jajja et al, 2014); level and methods of information sharing (Griffin and Hauser, 1992; Petersen et al, 2005; McAdam et al, 2008; Yeniyurt et al, 2014).

- Type of supplier

Table 5.5 Type of suppliers integrated in SCI

| **Case Number** | **Type of suppliers (Design/component/service)** |
|---|---|
| **A** | Manufacturer, Design, Component, testing service provider |
| **B** | Component |
| **C** | Manufacturer, Design, Component |
| **D** | Component |
| **E** | Manufacturer, Component |
| **F** | Component |
| **G** | Manufacturer, Design, Component |
| **H** | Design |

The type of supplier integrated in manufacturers' innovation process (Table 5.5) is critical to this research as it is heavily associated with the level of responsibility suppliers carry in innovation process, the method of integration and level of information sharing between suppliers and manufacturers. It has received 72 mentions with the coverage of 5.26% (Table 5.1). According to the case findings from eight companies in total, it can be concluded that that the suppliers that are generally integrated in the manufacturers' innovation process are: design supplier, Tier 1/2 component supplier and service provider for testing and experiments. Lower-tier suppliers from the general supply chain of aerospace manufacturing industry, such as suppliers for standard, universal or general components, are not considered because they are highly substitutable and their level of technology contribution into the final product is minimal. In Case A, all three types of suppliers have been involved in different stages of R&D processes, and the level of responsibilities imposed and method of integration differ among different types.

Company B is a Tier 1 supplier in the domestic market of ram air turbine (RAT) door of large aircraft, and it is also a Tier 2 supplier in coating and composites. In Case C, there are two types of suppliers involved in its SCI in innovation process: design suppliers and component supplier. The design suppliers are institutes of research and universities; and the component supplier are generally Tier 1 suppliers in the industry. In Case E, the type of supplier involved is its Tier 1 supplier---Company D. There are in general no other companies to work with yet. But the company is also planning on enhancing supplier relationship through closer cooperation. In Case F, as a Tier 1 component supplier, Company F has been integrated in its customer's innovation process. In Case G, the types of suppliers involved are design supplier and component supplier. In Case H, the type of supplier involved is design supplier.

- Stage of R&D

As explained earlier, innovation in this research only implies R&D in new product, new technology, product development and process innovation; straight-forward customisation of existing product is not considered. It has received 77 mentions during the interviews and covers 6.01% of the total interviews. In general, from the findings from the eight companies, there are three stages of R&D processes that requires collaboration with suppliers: design stage, building testing piece and implementation of innovation. Table 5.6 presents a summary of case findings for in which stage of R&D, SCI takes place. In Case A, supplier integration takes place in design of R&D and testing stages. In Case B, company B joins its customers' R&D processes in the design and testing stages. In Case C, SCI in innovation starts at early R&D stage, which is the design phase; but SCI in innovation takes place in various co-development projects throughout the entire R&D processes. In Case E, SCI takes place in early design stage, throughout the R&D process and at testing stage. Similarly, in Case G, SCI takes place from early design conceptualisation, design formation and design amendments stage (usually during and after testing).

Table 5.6 Summary of stage of R&D

| **Case Number** | **design** | **testing** | **implementation** |
|---|---|---|---|
| **A** | √ | √ | |
| **B** | √ | √ | |
| **C** | √ | √ | |
| **D** | √ | | |
| **E** | √ | | |
| **F** | √ | √ | |
| **G** | √ | | |

| | | | |
|---|---|---|---|
| **H** | √ | | |

- Method of integration

Summarising from the 37 interviews from 8 companies, the general methods of integrating supplier in innovation process are: direct transfer of technology, joint R&D and consultation (mentioned 146 times with the coverage of 9.08% of total interviews). One interesting fact about the method of integration is that, when describing supplier integration in innovation, one word has been used almost by all of the interviewees---"project-based". It can be then concluded that the general practice for supplier integration in innovation in the 8 companies the researcher has visited are project-/contract-based rather than perpetual. However, this does not mean the manufacturers and suppliers cease to collaborate after the project has been completed. In fact, there are always multiple/combined projects for the R&D of one product, the lengths of projects vary, and the completion of one project is always followed by the start of a new project. Therefore, the R&D personnel in manufacturers in these cases are also responsible for project management. As the integration process is project-based, the method of integration is of each project is dependable to the stage of R&D process, type of supplier involved and purpose of the integration. Table 5.7 lists out the summary of methods of integration from the case findings.

Table 5.7 Summary of methods of integration

| **Case Number** | **Direct transfer** | **Joint R&D** | **Consultation** |
|---|---|---|---|
| **A** | √ | √ | √ |
| **B** | | √ | √ |

| | | | |
|---|---|---|---|
| **C** | √ | √ | √ |
| **D** | √ | √ | √ |
| **E** | √ | √ | √ |
| **F** | | √ | √ |
| **G** | √ | √ | √ |
| **H** | √ | √ | √ |

In Case A, the types of methods of integrating suppliers in the innovation process are associated with four scenarios. The first scenario is when the purpose of SCI is to gain access to application information, access to new market and enhancement of supplier relationship, the suppliers involved are tier 1 suppliers of highly technology-intensive products and possessing high bargaining power. Examples of such suppliers are suppliers of critical components of the rotorcraft, such as engine and avionics. The SCI takes place at early R&D design stage, and the suppliers only need to provide specifications of the products they supply and the interface data. The methods of integration under this situation are direct transfer of documents and consultation.

The second scenario is when the purpose of SCI is to gain access to technology. The integration takes place at R&D design stage, and the method of integration is establishing joint laboratories. Under this scenario, the type of supplier involved is (tier 1) design supplier. Engineers from Company A and its supplier work closely together within the joint labs and they share human resources, facilities and capitals to complete the projects. The integration is still initiated and led by Company A, but both parties in the cooperative relationship play contribute significantly to the final product. Upon completion of the project, the engineers from suppliers continue providing necessary assistance to Company A on a consultation basis.

The third scenario of Case A is when the purpose of SCI is to gain access to technology and reduce risk of uncertainty. The SCI takes place at early R&D stage, which is usually the design phase. The type of supplier involved is tier 1 component and design supplier. For the areas that Company A lacks specialities or internal capabilities, it outsources parts of its design to the more capable supplier who has the most advanced technology in the relevant area. The method of SCI is direct transfer of knowledge and consultation. One example has been given by the interviewee that, they engage their coating and composite suppliers in their design stage to help them to select the best materials that are safe, light and energy efficient. Direct transfer of knowledge is involved in this type of integration and Company A also consults its suppliers for necessary technical assistance to make sure the application and implementation is accurate. This method of SCI not only allows Company A to gain access to the most advanced technology, but also enables Company A to reduce risk of uncertainty from starting to develop internal capabilities from the scratch. The relationship between Company A and its supplier is also inevitably influenced by this type of SCI as the relationship has grown from a mere contractual buyer-seller relationship into closer cooperation during innovation process.

The fourth scenario is when the SCI takes place in testing stage. The type of supplier involved is service provider that provides testing services and facilities. In this type of integration, integration only takes place through direct transfer of information and documents of tests.

As reported by the case findings of all 8 companies, SCI in R&D does not take place at manufacturers' production stage, as all adjustments and changes of the design and innovation must be taken place before production. Similar expressions have been emphasised repeatedly in a number of interviews that "the aerospace industry implement the safest technology rather than the most 'state-of-the-art' technology". Therefore, SCI in innovation during the production stage has been kept minimal and smooth and seamless transfer and implementation of new technology has been guaranteed before the product goes to the production stage.

The methods of integration in Case B are consultation and joint development. Integrating through consultation only requires mere change of knowledge and information and necessary consultation service; whereas in the joint development situation, engineers from Company B join its customers R&D processes at its customers' research centres and co-develop with its customers.

The methods of integration in Case C are: direct transfer of knowledge and technology, final product and application information; as well as joint development. The methods of integration are dependable to the type of suppliers and level of technology intensity of the products they supply. Take the SCI processes of Company C's new product---Model C, as a detailed example. There are in general 5 major groups of SCI activities taken place in the innovation processes of Model C. The five major approaches of SCI also overlap with one another and Company C also needs to coordinate between projects and combined projects to ensure quality of the result.

The first situation is where design suppliers are involved. These suppliers are the state institutes of research and universities that have the most cutting-edge technology of the industry. Company C has established joint development labs within its R&D centre. In this type of SCI, Company C and its partners exchange engineers, knowledge and technical information. Participants in this type of SCI actively engage in communication, and IP right of innovation results are shared between Company C and its design suppliers.

The other four methods of integration are related to SCI of both technology-intensive and non technology-intensive component suppliers. In the second method of SCI of innovating Model C, the supplier involved is the engine supplier. This supplier is a foreign supplier and the engine was specifically designed for the Model C and it is more energy efficient comparing to the similar models of its direct competitors. However, the level of SCI in innovation with supplier is low as the engine has been independently innovated and developed by the supplier. Supplier only provides application information of the engine for Company C to design Model C to fit the installation of the engine. Suppliers also participate in the SCI in innovation process of Model C through consultation. But the consultation was merely about evaluating the feasibility of design. The process for suppliers to evaluate the feasibility of design of its customer's products only takes place when the suppliers are more experienced or in possession of higher technical level in the relevant field. As explained by interviewee from Company C, due to the fact that Company C and its design partners lack practical experiences, component suppliers provide professional opinions on the feasibility of the design and raise concerns of potential technical difficulties through consultation basis. The non-feasibility of design may be the result of surreal design that implements technology no one in the industry can achieve, or the design exceeds the supplier's technical capacity. Company C will then work out solutions to the problems independently and sometimes with taking considerations of suppliers' suggestions.

The third type of SCI is through establishing joint development projects with component suppliers of avionics and balance systems. Prior to the new product---Model C, while innovating Company C's previous aircrafts models, the cooperation method with avionics and balance systems suppliers was the same method with the second scenario, in which suppliers have full control in innovation and core technology remain unrevealed to Company C. With the innovation of Model C, Company C has changed its method of cooperation with this type of suppliers. Company C has established joint development projects with both home and abroad suppliers of avionics and balance systems. During the combined projects of innovation, Company C has been actively involved in the joint development and information sharing has been kept at a technical level.

The fourth type of SCI approach is also through joint development. But unlike the previous method that engineers from Company C and suppliers work together, tasks and responsibilities have been merged. In the previous scenario, it is difficult to trace back the outcome back to the contributor as efforts have been merged. But the main difference in the fourth type of SCI approach is the clear description of responsibilities. This approach takes place while working with domestic materials and composites suppliers of aircraft's body---fuselage. The overall design of fuselage in Model C was completed by Company C, but the selection and setting out product requirements of materials and composites were completed together with trusted suppliers. As a result, Model C has passed all the strict quality requirement in the industry of being durable to cope with high pressure, large differences in changes of temperatures and high loading capacity as well as low fuel consumption; and the body weight of Model C has been reduced by 3% comparing to the product of its direct competitors.

The fifth type is about innovation in non-technology intensive parts where SCI has been kept at a minimal level. Examples of such suppliers involved in this situation are: suppliers of seats, interior designs, etc. The SCI starts at the design stage. Company C only provides list of requirements for the suppliers to fulfil, but the suppliers have full autonomy in terms of selecting the design and choice of materials of the parts they have been assigned with.

The methods of integration for case E are similar to the case situations in other companies. There are in general four types of integration: consultation, direct information sharing, direct personnel transfer and establishment of joint labs. The method of integration depends on the specific requirement of R&D at each stage and the intended results Company E wants to achieve.

In Case F, the methods of integration in general are: consultation and test piece production, and the situation is similar to Case B.

In Case G, SCI in innovation is usually short-term project-based due to cost concerns. There are generally 6 types of SCI reported in Case G. The first one is consultation basis. Whenever necessary, the company seeks for direct transfer of knowledge and technical assistance from capable suppliers on a consultation basis. *"In this case there will be some technical staff to participate in our follow-up project, to supervise us for a smooth implementation of the innovation. They will also give us professional advice on the implementation, matching, or installation of the R&D result"* (G2). The second type is through direct outsourcing and establishment of joint labs with its design suppliers, such as universities and research institutes. In this type, *"personnel communication is an exchange of experience and ability. R&D staff---engineers will directly participate in our R&D projects. They will be directly merged into our R&D team, and they will be treated indifferently from our internal staff"* (G2). The third type is through direct outsource of innovation to component suppliers. The fourth type is similar to Case C's situation with non-technology intensive products, Company G also shifts all of the responsibilities of design and innovation to the relevant suppliers. The method of SCI in testing stage is mainly divided into two categories: test product production and outsourcing entire testing stages to the capable suppliers. Last but not least, another type of integration is through direct investment from the suppliers into Company G's R&D. This method has faced strict requirements and regulations, and it rarely takes place.

In Case H, there are totally 4 methods of SCI in its customers' innovation processes: direct transfer of technology through consultation/being outsourced, joint development, technical assistance during the R&D process and amendments during the testing stage.

- Level of responsibilities

With 59 mentions and 5.84% coverage (Table 5.1), there are three types of SCI relationships in terms of the level of responsibilities imposed on suppliers: supplier driven, buyer (manufacturer) driven and grey box (Petersen et al, 2005). Table 5.8 presents the list of level of responsibility of SCI.

Table 5.8 Summary of level of responsibility

| **Case Number** | **Black box** | **Grey box** | **White box** |
|---|---|---|---|
| **A** | √ | √ | √ |
| **B** | | √ | √ |
| **C** | √ | √ | √ |
| **D** | √ | √ | √ |
| **E** | √ | √ | √ |
| **F** | | √ | √ |
| **G** | √ | √ | √ |
| **H** | √ | √ | √ |

As discussed earlier in this chapter, there are four scenarios of SCI in innovation in Case A. The first scenario is more supplier driven, since the manufacturers have minimal control of the part of product and only product specifications have been communicated to the manufacturers. The second scenario is more of a “grey box” situation since the suppliers and manufacturers play equally important roles through close cooperation. The third scenario is supplier driven. Though Company A (the buyer/manufacturer) play crucially important parts in this type of SCI, the projects are initiated and coordinated by Company A, the development of technology in question is still driven by its suppliers. In the fourth scenario, the R&D process is buyer (manufacturer) driven. Company A has outsourced the testing stage to its trusted suppliers, but all the tests are conducted under the instructions of Company and all the subsequent adaptations and changes on the design and product itself are driven by Company A.

Similarly, in Case B, integration through consultation is supplier driven. Though Company B under this circumstance plays a minimal role in the R&D process, the core technology and knowledge are still in the hands of Company B. The critical technical know-hows remain unrevealed to the manufacturers. The joint development between Company B and manufacturers is a "grey box" situation, where R&D projects are led by the manufacturers but the processes are neither supplier driven nor buyer driven. Contributions in R&D come from both parties and efforts are non-separable from one another.

In Case C, the level of responsibilities in terms of supplier's contribution in SCI in Company C's innovation processes depends on the methods of integration it implements. With regard to the first scenario, where design suppliers are involved, the process is both supplier-driven and buyer-driven (grey box situation). Secondly, engine supplier integration in the innovation process is completely supplier-driven. In regards to the third scenario, where suppliers of avionics and balance systems are involved, both supplier and manufacturer take joint responsibilities, and it is therefore a grey box situation. With regard to the design of aircrafts body, it is completely buyer-driven; whereas for non-technology intensive designs, the innovation process is completely supplier-driven, but Company C requires maximum level of knowledge and information sharing under this circumstance.

In Case E, where there is direct transfer of technology, personnel and information, innovation process is supplier driven but knowledge has been shared transparently between Company D and E. With regard to the joint labs, innovation process is both supplier-driven and buyer-driven.

In Case G, almost all the SCI processes are supplier driven except the establishment of joint labs and the method that integrates supplier in test piece production. With regard to the establishment of joint labs, both the supplier and Company G have been driving innovation processes; whereas SCI in test piece production, innovation is buyer-driven.

In Case H, innovation process is supplier driven in the first method of SCI, both supplier-driven and buyer-driven in the second method of SCI through joint development, buyer-driven in the third situation and supplier driven in the fourth method of SCI.

- IP and information management

As suggested in literatures, information sharing is critical for joint development of innovation (Petersen et al, 2005; Yeniyurt et al, 2014). Communication and information sharing enable both buyers and suppliers to better understand each other (Griffin and Hauser, 1992; Yeniyurt et al, 2014). Information sharing needs to be timely and honest and it is critical to any cooperative projects (Paulraj et al, 2008; Yeniyurt et al, 2014).

Since exchanging knowledge has positive outcome on innovation (Thomas, 2013; Jajja et al, 2017), information sharing is implemented in all Cases to ensure a smooth communication and cooperation. Originally, the researcher decided to implement a relative measurement on the level of information shared in the participating companies. However, the questions of how to determine the level of information sharing and what constitutes high level of information sharing have emerged. It is difficult to determine the level of information shared in the SCI process during innovation in the case companies when types of information shared are different. Therefore, this research will not impose the measurement on level of information sharing and it will look at types and methods of information sharing instead (54 mentions, 4.78% coverage). Table 5.9 presents a summary of information sharing methods summarised from case findings.

Table 5.9 Summary of methods of information sharing

| **Case Number** | **consultation** | **Regular level of communication** | **Direct transfer** | **platform** |
|---|---|---|---|---|
| **A** | √ | √ | √ | √ |
| **B** | √ | | √ | |
| **C** | √ | √ | √ | |
| **D** | | | √ | √ |
| **E** | | | √ | √ |
| **F** | √ | | √ | |
| **G** | √ | √ | √ | √ |
| **H** | √ | | √ | |

The types and methods of information sharing and how intellectual property is protected are dependable to the method of SCI the companies undertake and the type of suppliers they have been working with and the R&D stage which SCI takes place in. In Case A, only product specifications which are openly available in the industry are communicated from suppliers to manufacturer in SCI scenario 1, the direct contribution from supplier in the manufacturer's technology is very low and the suppliers retain the IP right of the products they supply and key technology of such products remained unrevealed to the manufacturers. In scenario 2, information and knowledge sharing are kept at a very dynamic level as engineers from the manufacturer and suppliers work closely together and they "share knowledge on the technology and expertise in the area". the manufacturer retain full IP right of the outcome of the R&D collaborations. Information sharing and IP right protection in scenario 3 and 4 are very similar that in both situations, Company A retains full IP right of the outcome of the collaborations, and information and knowledge sharing of core technology is more of a one-way flow from suppliers to Company A. When the product has come to later stages, information sharing with suppliers are kept at a regular basis of exchanging documents and email correspondents of usage updates, interface data, product life cycle etc. Communications between Company A and its suppliers are through keeping in touch and repeat orders.

In Case B, at the R&D stage of manufacturers, Company B shares knowledge with manufacturers and co-develop new products with manufacturers. Through the manufacturers retain full IP right on the final innovation outcome, Company B has also gained technical improvement and technical know-hows through collaborations. Information sharing and flow of knowledge has been kept free within the joint development projects to ensure smooth cooperation and seamless communication. The main type of information shared in this situation is knowledge on technology. However, information sharing is not so intensive in the consultation projects. In the projects where engineers from Company are only needed by the manufacturers as consultants, only experiences on application and evaluations on feasibility of a design are shared to the manufacturers.

In Case C, the type of information shared and the method of how it is shared between suppliers and Company C are also dependable to the method it implements for SCI in innovation. With regard to the first scenario, full knowledge and technology has been transferred to Company C and it retains IP right of the outcome. In the second scenario, the supplier retains IP right and keep core technology unrevealed to Company C and only the final product and relevant production information, user manual, product specifications, quality evaluation, test reports, etc. have been shared with Company C. In the third scenario where both domestic and foreign suppliers of avionics and balance systems are involved, flow of information has been kept free in the joint lab and both parties share the IP of the final outcome. With regard to the last type of cooperation with non-technology intensive suppliers, Company C requires full transfer of knowledge and information.

With regard to information management in Case D, only product manual, specifications, interface data, usage reports and error reports have been shared with its suppliers and as a supplier, Company D shares documents needed for supplier evaluation to its regular customers.

Information management in Case E depends on the supplier they have been working with. When working with Company D, there is intensive information sharing to ensure seamless communication and technology transfer. Company E has granted Company D with open access to its information platform that reflects highest level of trust. But with other suppliers, Company E only shares necessary information required by the daily business operations.

In Case F, there is no information sharing between F and its sub-suppliers other than necessary requirements from business transactions. However, it keeps close contact with its customer and to share expertise information to help them with testing piece production, amendments to designs, etc. It also sometimes helps its customer to set out supplier requirements.

Company G requires direct transfer of technology and full IP right of the outcome from its cooperation with design suppliers and non-technology intensive suppliers. But if the IP is a by-product from the innovation process, the suppliers are allowed to keep the IP right. However, with regard to the SCI of technology-intensive component supplier, information sharing has been kept at a minimal level for business transactions, and technology implementation; the core technology remains unrevealed to Company G.

- Supplier Relationship

Information sharing itself directly and indirectly affect supply chain integration in innovation process. Information sharing directly impacts on the facilitating and sustaining the cooperation, and it is indirectly influencing the SCI in NPD through supplier’s willingness to contribute (Paulraj et al, 2008). In order to sustain long-term collaborative buyer-supplier relationship, trust between the two parties needs to be established (Spekman et al, 2006; Yeniyurt et al, 2014). Trust is even more important for innovation related integration (Yeniyurt et al, 2014), and mutual trust is extremely in technology-intensive industries (Dyer and Singh, 1998). High level of trust enables high level of information exchange which will ultimately result in higher asset investment from the supplier into buyer (Corsten et al, 2011), and increase in supplier’s willingness to provide customers with access to technology (Ellis et al, 2012; Yeniyurt et al, 2014). Literatures have shown improved operational performance to be outcome of high level of trust in buyer-supplier relationships (Autry and Golicic, 2010; Yeniyurt et al, 2014).

Based on the findings from the cases, relationships between manufacturers and the suppliers have been tightened through SCI in innovation processes. Both the suppliers and manufacturers have enhanced their relationship within one another and they have built up information sharing platforms accordingly to ensure smooth cooperation and seamless communication. Suppliers have become more irreplaceable through working closely in collaborations. Moreover, in the situations where suppliers have been integrated in manufacturers’ innovation processes, the new product will be designed to fit the suppliers’ specifications. Therefore, it is more difficult to switch suppliers, and working with a familiar supplier reduces the uncertainty of switching to a new supplier. As addressed by Company C, “*If the suppliers are involved in the R&D process, it is almost impossible to change to another supplier. Because, from a technical point of view, such kind of switch cannot be completed as the development of products needs years of investment. We share mutual interests in the product, thus it is impossible to* *directly replace the supplier either from the technical point of view or the time we need to do so…We prefer to select a supplier whom we have already been working with during the R&D stage, unless the supplier we have chosen has a major security risk, quality problem, serious business management deficiency, etc.*"

The manufacturers have also developed both formal and informal methods to maintain supplier relationship. Examples of formal methods are: SCI in innovation process, repeat orders, sharing product-related information; and examples of informal methods are inviting suppliers to attend social networking events and ceremonies celebrating major achievements held by the manufacturers.

#### *5.2.4 Context*

Context (with 154 mentions, 16.42% of coverage) includes the external factors that fundamentally affect either directly or indirectly on both sides of the relationship between SCI capabilities and innovation performance. Such context factors potentially come from ownership as it impacts on the motivation and decision for the manufacturers to integrate suppliers into the innovation process (Roberts, 1995; Petersen et al, 2005; Saunila and Ukko, 2012); buyer-supplier relationship that includes supplier's attitude towards innovation (Lambert and Enz, 2017), supplier's expectation of long-term return (Yeniyurt et al, 2014), trust and relationship (Spekman et al, 2006; Corsten et al, 2011; Ellis et al, 2012; Yeniyurt et al, 2014). Theories of Global Innovation Networks (GINs) have suggested that resources are scarce and thus firms are required to organise "a global network of interconnected and integrated functions and operations in engaging the development or diffusion of innovations" (Barnard and

Chaminade, 2011; Chaminade and Plechero, 2015). Under the context of GINs, location matters because it is associated with access to knowledge and knowledge sharing that are affected by regional innovation systems (Chaminade and Plechero, 2015). Moreover, with regard to the importance of location, the role of government is also relevant because its importance in regional innovation systems. The relationship has been established between Location, role of government and innovation performance, but the linkage between location, role of government and supply chain integration is not obvious in the literatures. Therefore, part of the research objective is to explain the relationship between context factors and the SCI framework.

SCI context is a very important concept that it includes indirect impacts that can affect a company's Supply Chain innovation. As mentioned earlier, developing aerospace manufacturing industry is one of the priorities in China's strategic plan, all eight companies have felt been positively supported and subsidised by the government. Table 5.10 presents a summary of the context factors found in the case data.

Table 5.10 Summary of context factors

| **Case Number** | **ownership** | **Location** | **Government control** | **Government support** |
|---|---|---|---|---|
| **A** | SOE | Cluster 1 | √ | |
| **B** | private | Cluster 2 | | |
| **C** | SOE | Cluster 2 | | |
| **D** | Holding Group | Cluster 3 | | √ |
| **E** | Holding Group | Cluster 3 | √ | √ |
| **F** | private | Cluster 4 | | |

| | | | | |
|---|---|---|---|---|
| **G** | SOE | Cluster 4 | | |
| **H** | SOE | Cluster 4 | | |

- Location

All the eight case companies are located in either one of the major economic development cluster or adjacent to one; and the location gives the benefits to the companies through regional knowledge creation in clusters, and operational location advantages in terms of logistics concerns. For example, the owner of Company B values the geographic location of the company. He has selected the location for the convenient transportation network to both domestic and foreign markets, adjacency to one of the largest aerospace clusters and reputable high education institutions in aerospace and aeronautics in China and attractive government incentives. As presented in Table 5.10, the different numbers of clusters can help to specify locations of each company while remain the anonymity of this research. Company A is not located next to any of the other case companies, however it is located next to another major aerospace cluster in China.

- Ownership

Moreover, the ownership, corporate culture and the strategic planning and positioning of a company also emerge to be very important to the cases. For example, Company B and F are the only two private limited companies in this research. The type of ownership also determines the size of the company, level of capital capacity and level of support received from governments. However, the ownership also brings positive benefits to the companies as the management teams have autonomy in strategic planning and business decision making. For the other companies visited in this research, being owned by the state implies higher level of potential capital investment and higher level of government support; but autonomy of the companies has been compromised and the companies are more conservative and cautious in decision making and management teams tend to favour focusing on short-term performance.

Another situation where ownership can be very influential to the SCI in innovation in the industry is reflected in Case D, E, G and H. Company D and E have overlaps in top level management teams creates higher level of trust between them, and the fact that they have been established through M&A and technology infusion gives them high level of technology to start the business with. Therefore, they rely on its technology infusion from M&A and cooperate with each other to develop internal capabilities while ensuring confidentiality. The company/organisations visited in case G and H have a similar situation of being the subsidiary of the same holdings group. The holding group is one of the largest aerospace manufacturing holding groups in China. The ownership type gives these two case companies/organisations access to both human resources and physical resources within the same group. It widens both companies'/organisations' level of technology capacity and potential resources available to them. Therefore, the level and importance of SCI in innovation for these case companies are not as high as the other cases.

- Government support and control

However, there are also regulations and limitations that hinder their development. For example, for Company A, the most serious obstacle is about regulations. As Company A has an R&D centre at an overseas location and also targets the foreign market, international regulation is essential to its concern. The international trade agreements and Joint Airworthiness Regulations are decisive to its entry in the foreign market. It is also reported as a similar situation in findings from Case E. Another example in this research is represented in findings from Case D and E. The government has invested directly into the establishment of the company either through discounts on land purchase and taxation charges. The government support has given the companies benefits of cost reduction and left the companies with more to invest in innovation related activities. During the interviews, the researcher has also found out that other companies have also felt the support and control from government. But there is no enough evidences or examples within the case data that can be triangulated.

#### *5.2.5 Innovation Performance*

As the main unit of analysis in this research is innovation performance, the preliminary condition of the theoretical framework is the interpretation of innovation (Sub RQ1). The performance factor has received the second most common mentions (with 195 mentions). This research implements the wide interpretation of innovation that includes technological change on both incremental (McDermott et al, 2002) and radical innovation (Chandy and Tellis, 2000); innovation that are new to the market (Chandy and Tellis, 2000) and new to the firm (Cooper, 1993; Johanssen et al, 2001), changes to product category (Johannessen et al, 2001) and process innovation (Jajja et al, 2017). Therefore, product innovation in this research can be measured by: incremental innovation in better product design as a result of supplier integration (Song et al, 2008; Monczka et al, 2010); radical innovation in new product (Ragatz et al, 2002), new capabilities (Wynstra and Weggemann, 2001) and superior products (Takeishi, 2001; Menguc et al, 2014).

The process innovation performance can be measured by financial performance (Hudson et al, 2001), quality (Sink, 1985; Hudson et al, 2001), efficiency (Sink, 1985), effectiveness (Sink, 1985), productivity (Sink, 1985; De Toni and Tonchia, 2001; Saunilam 2016), customer satisfaction (Hudson et al, 2001), faster delivery to the market (Lau et al, 2010) and reduced error rates (Song et al, 2008). However, only two of the measurements (faster delivery to the market and reduced error rates) were discovered in existing literatures as a result of supply chain integration, whereas the others were not. Therefore, the relationship between supply chain integration and process innovation is unclear and unprecedented in the literatures.

As proposed in the theoretical framework, innovation performance is a critical unit of analysis of this research that determines the outcome of SCI in innovation process. However, the researcher has come across with difficulties in terms of separating the outcome of innovation through SCI from the result of internal capabilities. Some of the results of SCI in innovation are directly measureable through numeric measurements, i.e. number of new products, patents registration, etc. that come directly from the collaboration with suppliers. However, SCI in innovation combines efforts of suppliers and manufacturers' internal capabilities, it is extremely difficult to identify results of indirect contribution or combined projects. Moreover, financial performance and operational performance were also proposed in the research objectives to determine the success of outcomes of SCI in innovation. But the researcher has found difficulties in implementing this measure as determinants of success during the interviews with management team from the eight case companies. In general, the respondents from all eight companies felt that there should definitely be an increase in financial performance with integrating supplier in the innovation process. Here are some quotes from Company A on financial and operational performance.

*"There is definitely an impact on the financial performance, as we have reduced the time we need to spend on innovation and the amount invested in innovation. The overall financial performance is affected by the reduction in costs"* (A2).

*"The new product is not a mere customisation or slight adjustment on the current products; it is a new product that keeps up or even exceeds with the most advanced technology and the highest quality of the industry. However, we cannot do this without the contribution of our suppliers"* (A2).

*"When the suppliers are engaged in our innovation process, as their level of involvement increases, their enthusiasm and pro-activeness also increase. Moreover, it is not only us learning and benefiting from the suppliers, the suppliers also improve their technology level and operational efficiency from the relationship. Therefore, when the suppliers increase their operational performance, the delivery time is reduced and we can benefit from a shorter production cycle"* (A3).

Therefore, in the interviewees' points of view, financial performance and operational performance have been increased through: reduction in cost, reduction in the time needed for innovation, increased relationship with suppliers, increased in technology level and operational efficiency, reduction in production cycle. However, also as addressed by the interviewees, that “it is not easy to identify how much in saved or how much increase in overall performance due to allying with suppliers in the strategic decision we made at the very beginning as we do not have the alternative to compare with.” The decisions to collaborate with suppliers were made by each company’s top management team and the country’s overall planning objectives; we cannot compare the current performance with the alternative route to innovation through complete internal capabilities that has not taken place yet; nor we can take the interviewees’ experience or personal opinions as strict determinant to successful SCI in innovation. Therefore, this research only looks at the feasible outcomes of innovation activities from the projects/products in which suppliers have been involved in the R&D process. The feasible outcomes can be: new product, product development, broadened product category/portfolio, number of patent registrations. This research treat the the SCI process in innovation a successful one if the case presents any of these feasible outcomes of innovation; but it will not rank which company/case presents a more successful SCI process than the others because the outcomes are not comparable between one and another when the sizes and positions on the aerospace manufacturing supply chain of the companies are different.

Therefore, for Case A, the feasible outcome of innovation performance is its brand new rotorcraft model that possesses the most advanced technology with 7 patents and 3 TC certificates awarded. For Case B, the current number of patents granted are development internally within the company instead of being the result of SCI in innovation. However, the feasible outcome of innovation performance of Company B can be recognised in its participation in its customer’s products. Company B’s domestic customer has a new model of aircraft being rolled off to the production line. The rudder, aircraft elevator, landing gear door of the new aircraft are the results of joint development in the R&D process between Company B and the manufacturer. for Case C, the innovation performance is its new aircraft model---Model C, the one this chapter used to explain the methods of SCI in innovation. Model C has 170 patents and it cannot be completed without the close work with suppliers. Company E is expecting to complete its R&D in new product in 2017. By far, it has already obtained 23 new patents for the new product. In Case F, there are only indirect benefits on performance as a result of being integrated in its customer's innovation process: closer relationship with customers and increase of technical level as a result of mutual-learning in collaborations. The performance as a result of SCI is not obvious in Case H, as all the IP rights and technology have been transferred to its customers. But H's contribution to launch of new products are vital. The launch of new aircraft of Company G cannot be successful without the efforts in design and technical assistance from Organisation H.

## 5.3 Summary

This chapter presents general case description, results and analyses of the 8 cases collected in this research. The processes of analyses started from original data and three tiers of codes in NVivo (as introduced in Chapter 4). The analyses were formulated by following the framework summarised from literatures that SCI framework consists three parts: SCI capabilities, context and performance. The cases were then compared within horizontally within each theoretical construct, to create foundations for the research to identify patterns in the case data for discussions in Chapter 6.

# Chapter 6 SCI framework

## 6.1 Examples of case data presentation

When reviewing the results from the case data, the researcher has found that two main types of suppliers integrated in the SCI process are design and component suppliers. However, as all cases include either one or both of two types, the type of supplier does not show significant impact in establishing the relationship between SCI capabilities and SCI performance according to the case data. In the aerospace manufacturing industry in china, manufacturers are the main initiator of innovation projects, they spot and identify the need of innovation and coordinate their internal and external resources to fulfil the need of innovation. But the supply chain positioning of suppliers integrated into innovation process influence the subsequent decisions in the choice of SCI capabilities of each case company. It is worthy of investigating the influences of the proposed SCI relationship from different angles on the supply chain. Therefore, when analysing, the case companies have been divided into two groups: the manufacturer group (Group 1) and supplier group (Group 2). The case companies that are manufacturers in the industry are: Company A, C, E, and G; and the suppliers group consist: Company/Organisation B, D, F and H. The division of case companies into two groups is designed to serve the purpose of trustworthiness of research through viewing this situation from both sides of the supply chain.

By summarising all the case findings from the interviews and secondary data, the researcher has drawn figures that indicate the relationship between supply chain positioning in regarding to SCI capabilities and SCI performance. Appendix 7.1

includes figures of the supply chain positioning and the relationship between SCI capabilities and SCI performance for each case company.

The researcher has then combined the figures of each case company into different case groups to represent the relationships between SCI capabilities and performance in the proposed framework. With regards to the units of analysis in these charts, the researcher has taken selective codes from the case analysis process as the key category labels. For example, in Figure 6.1, the key categorical labels such as "strategic orientation", "sources of resources", "reasons to integrate", "purpose of integration", "SCI capabilities" and "SCI performance" are selective codes summarised in the data analysis process. The sub-categorical labels that represent the case characteristics when analysing the relationship, are derived from axial codes in the data analysis process. For example, in Figure 6.1, the labels like "internal R&D", "SCI", "resource dependence", "lack of internal", "access to technology", "access to application", etc. are all implemented from axial codes.

The researcher then went back to all case data to search for emerging relationships between the codes. The case findings for the relationships between SCI capabilities and SCI performance are presented as the arrows in the figures. Each arrow colour represents findings from one case company, and the colours of case companies remain consistent in all figures in Chapter 6.

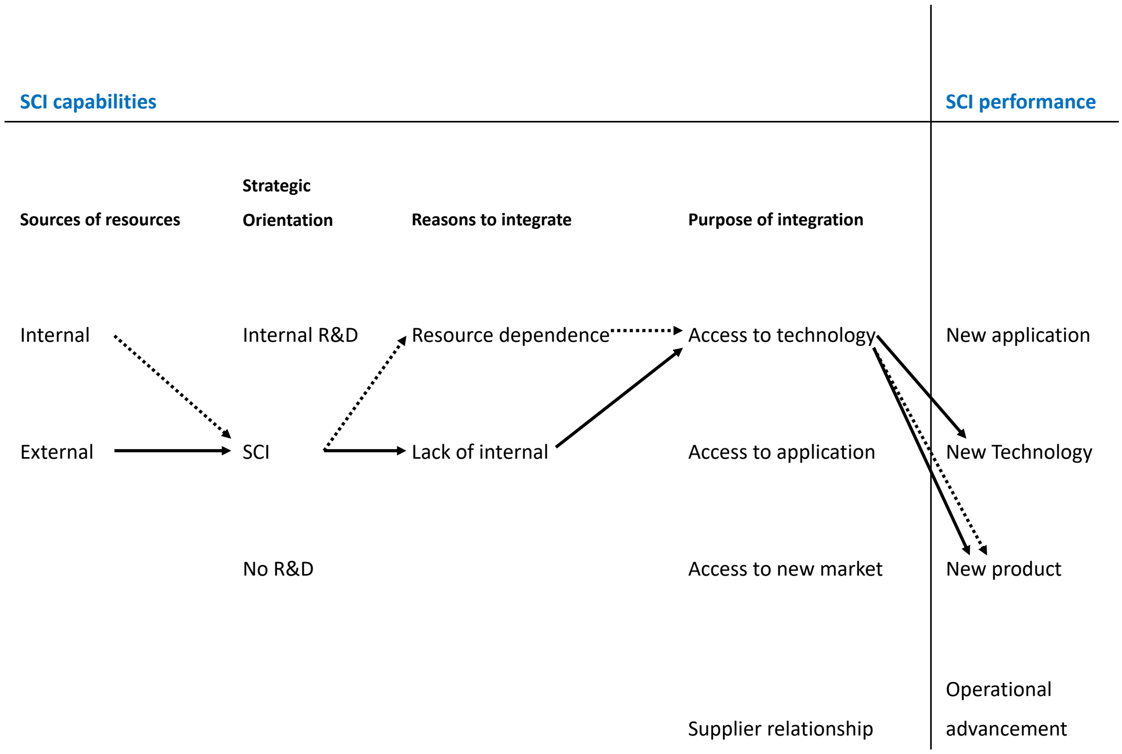



Figure 6.1 Demonstration of example for Resources and the relationship in SCI framework

Figure 6.1 demonstrates an example of the relationships between different elements in SCI capabilities and performance. The example is not related to any case company and it is only used to illustrate the meaning of different types of arrows. In this example, one type of arrow represents relationship of one scenario of a case company. Because an aircraft includes millions of components, we cannot specify the SCI relationship of all components, the arrows only represent core products, or groups of essential products that are technology-intensive and worthy of discussing in the respondents' points of view. The types of arrows differ in the line types of arrow (solid/dotted/dashed), and types of arrow heads and tails.

As presented in Figure 6.1, in case company X (fictional), the company has decided to implement SCI for two of its core products. For the first product (relationship presented in dotted arrow), Company X has enough internal resources and capabilities for internal R&D, due to resource dependence considerations, it still decides to integrate suppliers in its innovation process to gain access to suppliers' technology. As a result of R&D of the first product, company X has received a new product. For the second product (relationship presented in solid arrow), Company X has decided to involve suppliers in R&D due to lack of internal resources in order to gain access to suppliers' technology. As a result of SCI, the second product is a new product and Company X has learnt new technology as well. These are two simple demonstration examples of the meanings of the arrows in terms of SCI relationships, the relationships in actual cases are more complex. Moreover, these arrows do not imply a magic formula that a company can follow in order to obtain SCI performance, and it does not represent an equation that adding certain SCI capabilities equal to new technology/product. The arrows only represent case scenario and relationships emerged from the case data.

## 6.2 Resources and SCI framework

Three main categories of theoretical constructs of SCI capabilities have been found from literature review before data collection. These three categories are: resource, integration and information sharing. Therefore, the discussions will be presented in these categories.

Strategic orientation has emerged from the case findings as another critical factor that influences the SCI relationship. With regard to the effects of strategic orientations on SCI, at different stage of development of the company, the case companies report different results in innovation performance. For example, Company A, D and E have reported similar situation in terms of strategic orientation. At the time of interview, these three companies were at early stage of establishment, meaning that they have not yet been completely established, therefore, the need for innovation is also low. Learning has become the most important priority for their R&D department. However, this stage of strategic orientation does not only exist in company A, D and E. It was only brought by the interviewees due to the fact that these companies are relatively young comparing to other companies visited. Moreover, this research investigates the effects of strategic orientation on SCI relationship between the suppliers and manufacturers, but the fact that the companies decide not to place innovation as priorities also constitutes as an example of strategic decisions influencing SCI performance.

Emerged from all case companies, innovation capabilities of a firm require integration and coordination of both internal and external resources. The relationship between internal capabilities and innovation performance has been widely researched in existing literatures. As the relationship has been well established in current literatures (Francis and Bessant, 2005; Kallio et al. 2012; Saunila, 2016), it is not the focus of this research to loo, at internal capabilities and internal R&D. However, when discussing about innovation capabilities, it is essential to look at the application of resources (Stalk et al. 1992; Porter, 2000; Lin, 2013) and operational strength (Haynes and Wheelwright, 1984; Slack and Lewis, 2002; Voss, 2005; Zhang et al. 2016) that contributes to firm's competitive performance. Therefore, this research looks at how firms coordinate external resources and implement them in the R&D process. But internal resources are inevitable in this discussion of external resources as they are the pre-existing determinants for the reasons and purpose of supplier integration in SCI processes. Therefore, only the availability of internal resources and its connection to relevant decision making strategies are investigated in this research. Moreover, it is not the primary objective of this research to determine the measurement of level of innovation performance or numeric presentation of innovation performance. Therefore, this research only views the SCI performance in this research as an indicator of the result of SCI; thus, only types of innovation performance are viewed in this research to determine whether SCI has been successful or not.

***Case Group 1: Manufacturers (Company A, C, E and G)***

For a SCI relationship to take place, the first strategic decision for the company is to determine whether to deploy internal or external resources in R&D process. Figure 6.2 shows decisions on sources of resources, reasons to integrate and purpose of integration for each strategic decision a company makes.

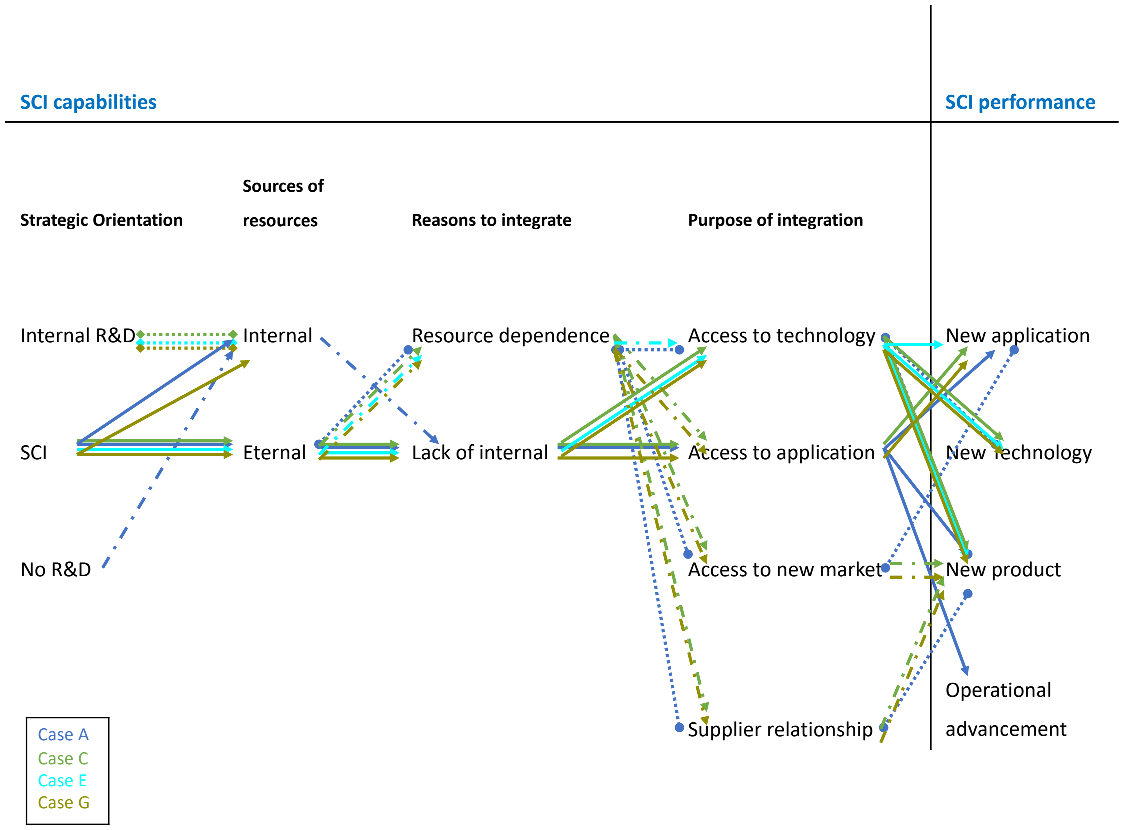



Figure 6.2 Resources and the relationship between SCI capabilities and SCI performance for case group 1

The first type of strategic decision takes place in whether to deploy internal R&D capabilities or implement SCI. Company C, E and G have both internal and external R&D capabilities, whereas Company A has focused more on SCI. With regard to the strategic decision of no R&D taking place, it is interesting to see that, in Case A, the strategic decision also involves no R&D taking place in its early development phase, because the company is relatively young and it was still in the process of building production plants, research centres and it was too early to start planning for innovation. But at later stages, when the infrastructures are completed, the company's strategic orientation shifts towards making the decision between internal R&D and SCI.

With regards to the sources of innovation, the main contribution of SCI to the manufacturers is through external sources of innovation. Summarised from the case data, Company A, C, E and G have received external resources of innovation like: R&D design, technology, knowledge and physical resources such as testing plants, etc. Moreover, even when companies implement SCI, not only external resources but also the internal ones are deployed. For example, Company A started with limited internal capabilities of R&D but it has developed its internal innovation capabilities through acquiring its direct competitor, who also used to be its supplier. Company A currently has several sources of internal innovation capabilities that come from its R&D centre in the headquarter, R&D centre in its US subsidiary and two joint laboratories with two reputable universities (who also used to be Company A's design suppliers) in the industry. In Case G, suppliers in SCI process invest not only technology but also infused fiscal investment into Company G. Company G has then converted such external resources as internal resources. However, even with the resources converted from suppliers' infusion, it is still not enough to fulfil the gaps in knowledge or technology. Therefore, all four companies in Case Group 1 still implement a large variety of SCI in its strategic decision in order to receive both internal and external resources.

The reasons for engaging suppliers in R&D processes are also discussed during the interviews. Where there is a lack of internal capability, the decision is made between developing internal capabilities and obtaining external resources and capabilities. In the situations where the manufacturers in Group 1 are not fully internally capable of mastering all the technology, specific product or application knowledge, they have chosen to receive innovation capabilities from their suppliers through SCI. Examples of such situations involve R&D of technology-intensive products like engine, avionics and balancing systems, etc.

However, for certain products/components where the companies in Case Group 1 have enough internal capabilities, they still implement SCI on the basis of resource dependence view, that due to scarcity of resources, no organisation can have all the resources they need. Therefore, regardless of the internal capabilities, manufacturers in Group 1 still decide to integrate suppliers in the innovation processes because of the resource dependence view (Pfeffer and Salancik, 2003; Liker and Choi, 2004; Hoegl and Wagner, 2005; Soosay et al, 2008; Flynn et al, 2010; Yang et al, 2013; Un et al, 2016; Jajja et al, 2017). There are also situations when the companies in Group 1 are internally capable to complete certain stages of R&D processes, they have made the strategic decision based on the concerns of scarcity of resources, access to new market and supplier relationship. These situations involve R&D of non-technology intensive products such as interior design, seats, etc. and a small number of technology-tensive products such as cabin doors, components and composites.

The general purposes of SCI are explored in the existing literatures and four of them are found particularly important in relation to this research: access to technology, access to application, access to new market and enhancement of supplier relationship. Combining the findings in Chapter 5 and linking with previous constructs, when the reason to integrate is a lack of internal resources, the purposes of integration are mainly to gain access to technology and application. Experienced suppliers gain technology through the accumulation of knowledge and practices, which makes them capable of providing technological insights to the manufacturers and enables them to help manufacturers to overcome technical difficulties. However, in situations where SCI involves suppliers who supply highly technology-intensive products and have strong bargaining powers, manufacturers can only obtain access to application information. For example, Company A, C and G have all found that when their suppliers are extremely specialised in technology-intensive goods, coordinating such suppliers at early stage of R&D process does not bring actual technology to the companies, but only application information instead. The companies only receive specifications and product usage statistics which help them designing specific interface on the manufacturer's new product to be compatible with their suppliers' products.

When the manufacturers integrate suppliers in SCI due to the scarcity of resources suggested by the resource dependence view, the companies are capable of internal R&D, all of the four purposes of integration are found relevant in Case Group 1. For Case A and E, access to technology is not exactly a purpose prior to SCI when the manufacturers are fully internally capable of R&D, it is more of a by-product that generates on the job because it turns out that the suppliers have higher level of technical advancement in their specialised aspects. For the non-technical intensive products/components of a certain product, Company C and G tend to outsource the relevant parts of R&D directly to their suppliers which make the suppliers fully responsible for the innovation as well as production of such products. In this situation, the R&D departments in Company C and G act more as a coordinator and supervisor of the research projects, they provide requirements and QA standards rather than closely involved in the R&D with suppliers.

There are also situations when the reason to integrate is resource dependence, but the main purpose of manufacturers implementing SCI is to gain access to new market or enhance supplier relationship. Especially with international markets, where the local authorities and regulations differ from the domestic ones, certain products must be custom-made to comply with local requirements. As found in case company A, C and G, whose target markets involves heavy focus on the international markets, they need to engage with international suppliers to get access to the suppliers' country. Similar SCI implementation methods take place when the manufacturers' purpose is to enhance supplier relationship. When suppliers contribute more towards the co-innovation process in manufacturers R&D stage, they tend to expect long-term return (Yeniyurt et al. 2014), thus trust and relationship between manufacturers and suppliers are enhanced (Spekman et al. 2006; Corsten et al. 2011; Ellis et al. 2012; Yeniyurt et al. 2014). Identified from the interviews, Case A, C and G expect to establish longer and stronger supplier relationship through SCI which makes suppliers more involved, but for the manufacturers, SCI also makes them more dependent on the suppliers.

As a result of SCI from the aspects of resources, when the purpose of integration is to gain access to technology, manufacturers receives new application of existing products, new technology and new product/product development (where significant technical change has taken place). When the aim is to receive access to application, the main innovation performance is new application has been identified. Moreover, the operational advancement in Case A is more of a by-product from SCI as integrating suppliers in the R&D process to gain their experienced knowledge provides the manufacturers with a shorter production cycle than starting from the scratch and all by themselves. One respondent from Company A has explicitly stated that "*It even surprises us how experienced our suppliers are. Sometimes, as soon as we sent out our enquiries and R&D requirements to our suppliers, depending on the complexity of the technical requirement of the product, the quickest respond from them, as far as I remember, was within the same day. It is because they have been outsourced with millions of similar tasks and they can spot our flaws and room for improvement the moment they see the design. Therefore, we have saved a lot of time comparing to starting with nothing and exploring what works and what does not all by ourselves.*" When the purpose of SCI is to gain access to new market, due to the level of complexity in the product nature and differences in suppliers involved, Case C and G receive new product in additional to the new market, whereas Case A receives only new application which is more of a straight-forward customisation and new usage of existing products. When the purpose of integration is to enhance supplier relationship, Case A, C and G have received new products as a result of SCI.

***Case Group 2: suppliers (Company B, D and F, and Organisation H)***

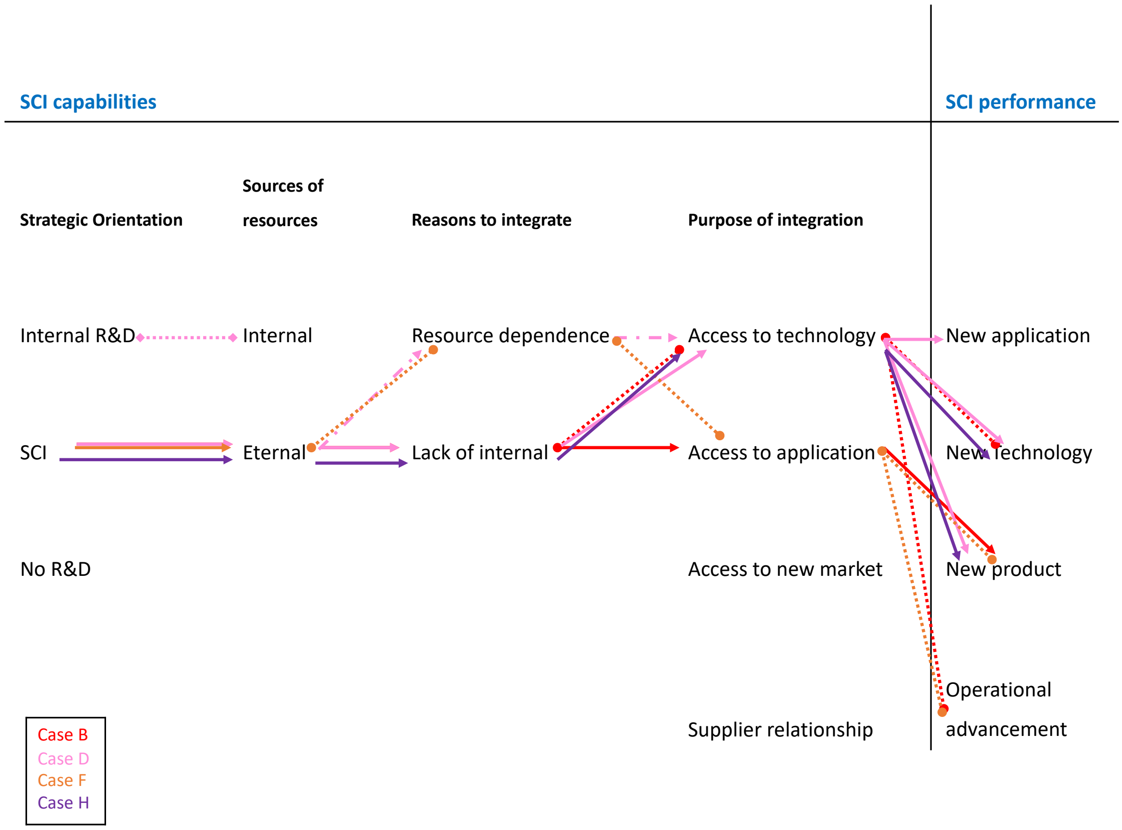



Figure 6.3 Resources and the relationship between SCI capabilities and SCI performance for case group 2

In general, findings from Case Group 2 have verified the overall findings from Case Group 1 from the aspects of suppliers. From the suppliers' view, engaging in manufacturers' SCI is also reflected by its strategic orientations. With regard to their foreign customers of the case companies (especially Company B and F) in Group 2, the suppliers' bargaining power is low and there is no contribution from the suppliers to their customers' R&D stage. The constant effort by the suppliers to deliver products with better quality, less costs and shorter production cycle is a result of continuous development instead of SCI relationship. However, when the power has shifted in the domestic market, the suppliers seize the opportunity to form a tighter customer relationship and improve its non-substitutability in the market. The main resources contributed to the domestic manufacturers' R&D stage are: technology, human resources and sometimes capital investment. As discussed in previous Chapters,

As a result, the SCI performance for the manufacturers are reflected through number of new products; and for suppliers is measured through the strengthened customer relationship, enhanced bargaining power, non-substitutability in the market and the improvement in technical level through joint development of innovation.

***Total Case Group***

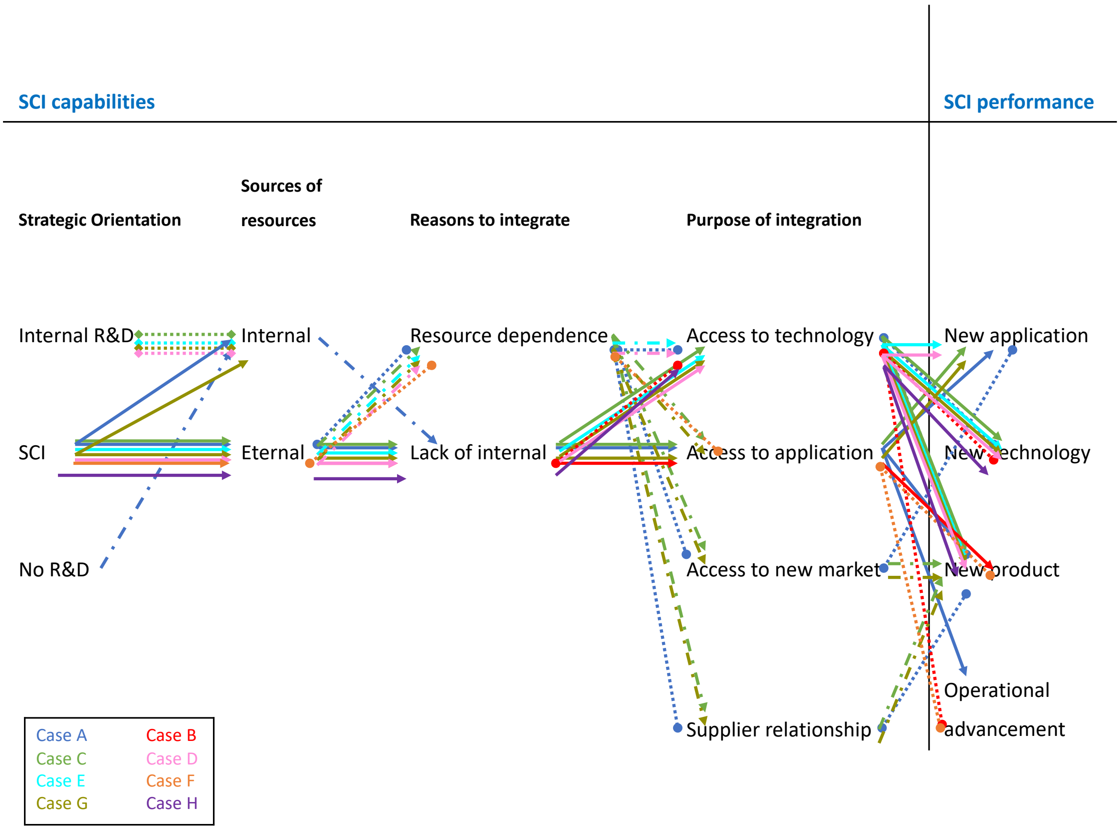



Figure 6.4 Resources and the relationship between SCI capabilities and SCI performance for all 8 cases

Based on the existing findings of SCI relationship in terms of resources, the general patterns can be found where the arrows in Figure 6.4 overlap. Therefore, Table 6.5 presents a clearer version of Figure 6.4 to show where all the overlaps take place.

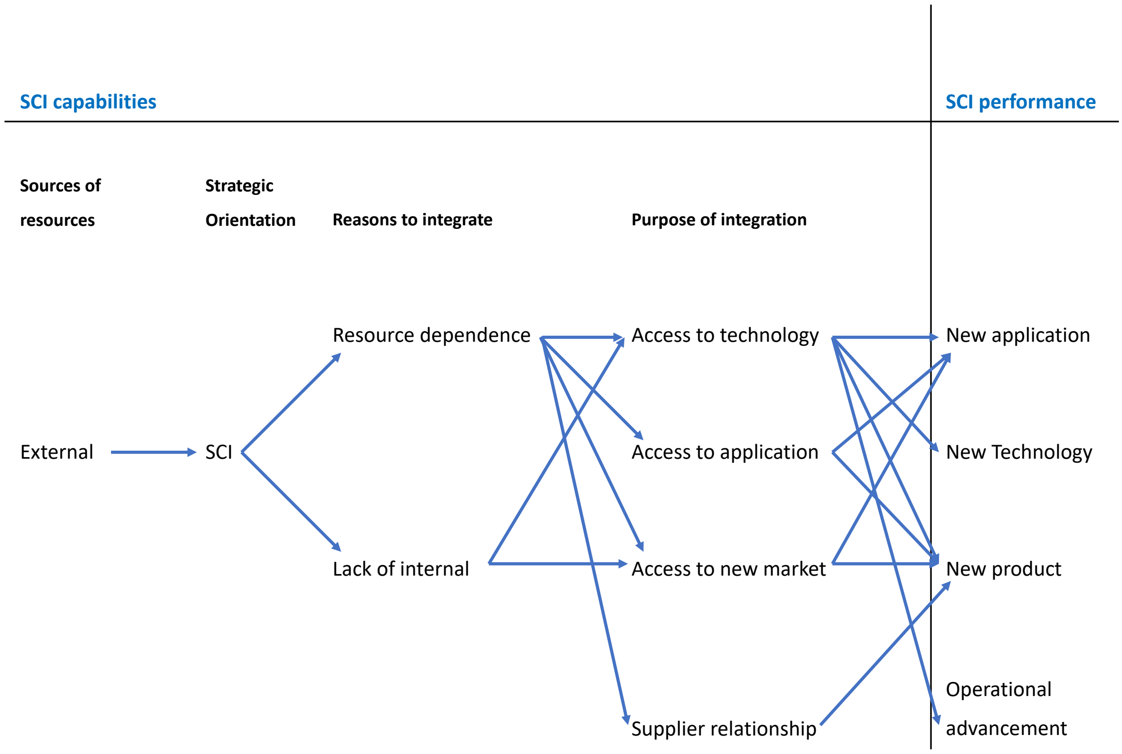



Figure 6.5 Patterns for Resources and the relationship between SCI capabilities and SCI performance

The strategic orientation of firms, the choice between developing internal resources and engaging in SCI gives answers to Sub RQ3 on how firms' overall strategy influence SCI and the reasons and purposes of entering SCI can give answers to the Sub RQ1 about how firms decide whether to enter SCI collaborations or not. The debates on whether to deploy internal or external resources and capabilities to enhance innovation have been discussed under various context. The resource dependence view has suggested that resources are limited and no firm can have all the resources they want

(Pfeffer and Salancik, 2003), thus collaborations are needed (Un et al. 2016), and the exchange of knowledge provides positive effects on innovation (Thomas, 2013; Jajja et al. 2017). Supply Chain integration establishes a positive relationship with innovation in various researches investigating different aspects of the Operations management context (Takeishi, 2001; Wynstra and Weggemma, 2001; Ragatz et al. 2002; Petersen et al. 2005; Song et al. 2008; Monczka et al. 2010; Menguc et al. 2014). On the other hand, it is also argued that supply chain integration also has negative impacts on innovation. One study examines the availability of internal resources and capabilities and deems that collaboration deviates a firm's internal resources and energy from focusing on innovation to facilitating the coordination processes (Bruce and Moger, 1999). Moreover, integration and collaboration create interdependence between suppliers and buyers (Takeishi, 2001; Yeniyurt et al. 2014) and the more integrated the both parties are, the more reliance it creates (Yeniyurt et al. 2014). The debates and contradictions of both schools of thoughts exist does because of the different research environment and different aspects of theories they examine. Therefore, to establish the SCI framework, this research starts with the aspect of resources and the relationship between SCI capabilities and SCI performance.

The availability of internal resources and capabilities have pre-determined the reasons to integrate. In general, there are two reasons for integrating suppliers in manufacturers' R&D process: lack of internal resources (Chesbrough, 2013; Zang et al. 2014) and consideration of resource dependence (Pfeffer and Salancik, 2003; Thomas, 2013; Un et al. 2016; Jajja et al. 2017). As found in this research, when there is lack of internal resources, SCI focuses on gaining access to suppliers' technology for core products and application information for non-technical/peripheral products. When the reason for SCI is due to the concerns of resource dependence, manufacturers gain access to technology in the areas where their suppliers are more specialised, to application information for non-technical products, to new market (especially international market) where the suppliers are located and to stronger supplier relationship (Ragatz et al. 2002; Menguc et al. 2014). As a result, with this type of integration, manufacturers gain access to suppliers' market, facilities and end products. it is not necessary for the suppliers to transfer full technology to the manufacturers (unless the primary focus of SCI is advanced technology) and mere exchange of product documentations, guidelines and requirements of quality standards are enough. The SCI performance for this situation is reflected in the new product (all 8 cases), and operational innovation of time and cost efficiency (Case B and F).

## 6.3 Integration and SCI framework

In the existing literatures, supplier coordination/integration in manufacturers' R&D stages have been discussed within a different context. A positive relationship between supply chain integration and product innovation has been reviewed and established (Petersen et al. 2008; Menguc et al. 2014) through identifying that integrating suppliers brings to the manufacturers: new product (Ragatz et al. 2002), new capabilities and new technology (Wynstra and Weggemma 2001) and superior products (Takeishi, 2001; Megnuc et al. 2014). However, the risk and uncertainty also exist because the more integrated and collaborated the manufacturers and suppliers are, and the more interdependency and more reliance exist between them (Takeishi 2001; Yeniyurt et al. 2014). Moreover, when the level of interdependence increases, the risk of suppliers being reluctant to contribute also increases (Monczka et al. 2000; Petersen et al. 2005; Yeniyurt et al. 2014). This research has identified that the cases companies have different strategies of integrating suppliers in its R&D process, the strategies vary in stage of innovation, method of integration and level of responsibilities that suppliers carry during the SCI process.

***Case Group 1: the manufacturers (Company A, C, E and G)***

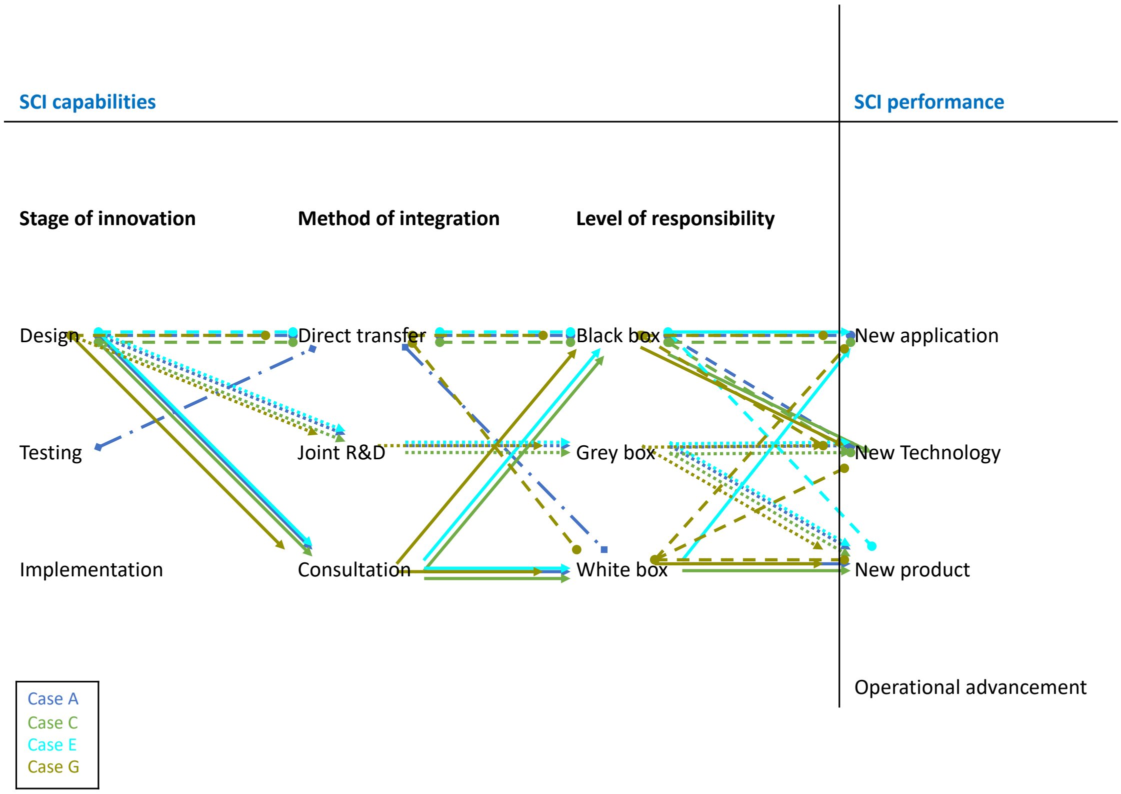



Figure 6.6 Integration and the relationship between SCI capabilities and SCI performance for case group 1

In general, there are briefly three stages of R&D process in the aerospace manufacturing industry: the design phase, building test piece and implementation of innovation. Products may repeat these three phases after testing stage as this industry values safety and quality the most, but the main stages of innovation process stay intact. Emerged from all four case companies in Group 1, the main innovation capabilities come from managing and coordinating both internal and external resources. On the manufacturer's side, the main internal resources of innovation capabilities come from internal R&D departments (including the research centre in its foreign subsidiary company in Case A) and joint laboratories established by the companies in Group 1 with reputable universities or research institutions in the industry. The types of internal resources are mainly: R&D personnel (engineers), R&D facilities and infrastructure and joint labs. With regard coordinating and managing internal resources to develop internal innovation capabilities, information sharing has been kept at the highest level within and across all R&D departments in each case company in Group 1. No secret information has been withheld and technical information has been moving freely within different organisations inside the case companies. As a result of internal R&D resources and capabilities, innovation performance is represented by the new customised product and new design of product. A straight-forward customisation of existing product to satisfy customers' requirements can also be regarded as innovation as this research takes a broader understanding of concepts of innovation. New design of product or early stage of R&D design phase can be completed with only internal R&D resources and capabilities in Group 1, but identified in the case findings, innovation of new product can only be completed by each case company in Group through integrating suppliers into its innovation processes.

Integrating suppliers into the manufacturers' innovation processes is viewed as integrating external resources. Under this circumstance, internal R&D departments in Group 1 take the coordinating position in innovation projects as they are the ones who design, spot and identify needs of innovation and search for suitable suppliers to integrate in innovation processes. The level of external resources infused into the manufacturers through SCI process depends on the level of technical intensity and type of suppliers integrated in SCI for the specific part of innovation process. Three types of suppliers are mostly involved in SCI in case Group 1: Design supplier, component supplier (of high technology-intensive products) and service supplier who provides testing equipment and infrastructures.

With regard to design suppliers, the suppliers involved in SCI in Group 1 are state institutes of research and highly reputable universities in China that contain cutting-edge technology of the industry. The external resources needed are product designs and technology. These SCI projects are often led and initiated by all companies with case Group 1, and level of information sharing is dependable to the different methods of integration of suppliers in manufacturers' innovation processes. When only design or direct transfer of technology is required, there is a one-way flow of knowledge and information from suppliers to manufacturers; whereas knowledge has been moved freely and information sharing has been kept at a high level between both parties when co-creation of innovation has been taking place between suppliers and manufacturers. as a result of innovation performance of such type of supplier integration in innovation process, manufacturer receives new design, technology, product and IP right of the innovated products. Through such type of SCI relationship, case companies in Group 1 have also broadened their internal R&D resources capabilities through knowledge transfer and learning.

With regard to integrating component suppliers into manufacturers' innovation processes, two type of integrations methods have emerged to be the most widely applicable methods in all case companies. First of all, suppliers of high technology-intensive products (such as engine suppliers) in the industry that have extremely strong bargaining power and they are only integrated in the innovation process through are only integrated on a consultancy and regular business transaction basis. The external resources manufacturers need from them are the actual product itself, product specifications, application information, user's manual, etc. and no technological resources have been transferred to the manufacturers. Information and knowledge sharing have been kept at a minimal level and only necessary documents have been transferred as required by business transactions. Suppliers also provide assistance on installation of product afterward. The innovation performance for this type of cooperation is the end product that has been customised to tailor manufacturers' needs and requirements, but this part of innovation has been completed only on the suppliers' side and no technology has been transferred to the manufacturers.

Secondly, with joint development in innovation through the contribution of both suppliers and manufacturers are also widely implemented in case Group 1, especially in Case C and G. In such joint development projects of SCI process, the manufacturers are the ones who spot and identify the needs of innovation and set out expectations and requirements of innovation; they have also initiated joint development projects and look for suitable suppliers to integrate. The joint development R&D centres are often located in the manufacturers' sites (presented in all cases in Group 1), and sometimes they even merged internal engineers and engineers from suppliers in the same team to ensure seamless communication and smooth cooperation. The external resources under such situation are human resources of R&D personnel transfer and knowledge brought by suppliers' engineers. Information sharing has been kept at a high level as knowledge and information move freely in this type of joint development. As a result, SCI performance of this type of cooperation is presented as generation of new product, new technology and new IP application.

With regard to testing suppliers, they are the ones providing testing facilities, equipment and testing services for the manufacturers in the aerospace manufacturing industry. The level of involvement in SCI projects is relatively low, but their efforts in manufacturers' innovation cannot be overlooked. The external resources provided by testing suppliers in all cases are knowledge from experienced suppliers, testing service and facilities. Under such type of cooperation, information sharing only involves mere transfer of documents, guidelines of testing and testing reports, etc. Supervision from manufacturers are not compulsory but can also be required when necessary. As a result, the manufacturers are able to receive feedbacks and suggestions from experienced testing service providers to find out the most energy-efficient materials with the highest product quality.

***Case Group 2: Suppliers (Company B, D, F and H)***

In general, case Group 2 has verified the types and methods of SCI cooperation projects through viewing from the suppliers' side. Similar situations are found in all four case companies in Group 2 that no contribution of their innovation capability come from their sub-suppliers. Therefore, this research only looks at the contribution of innovation capabilities from companies in Group 2 to their manufacturers---the aircraft manufacturers.

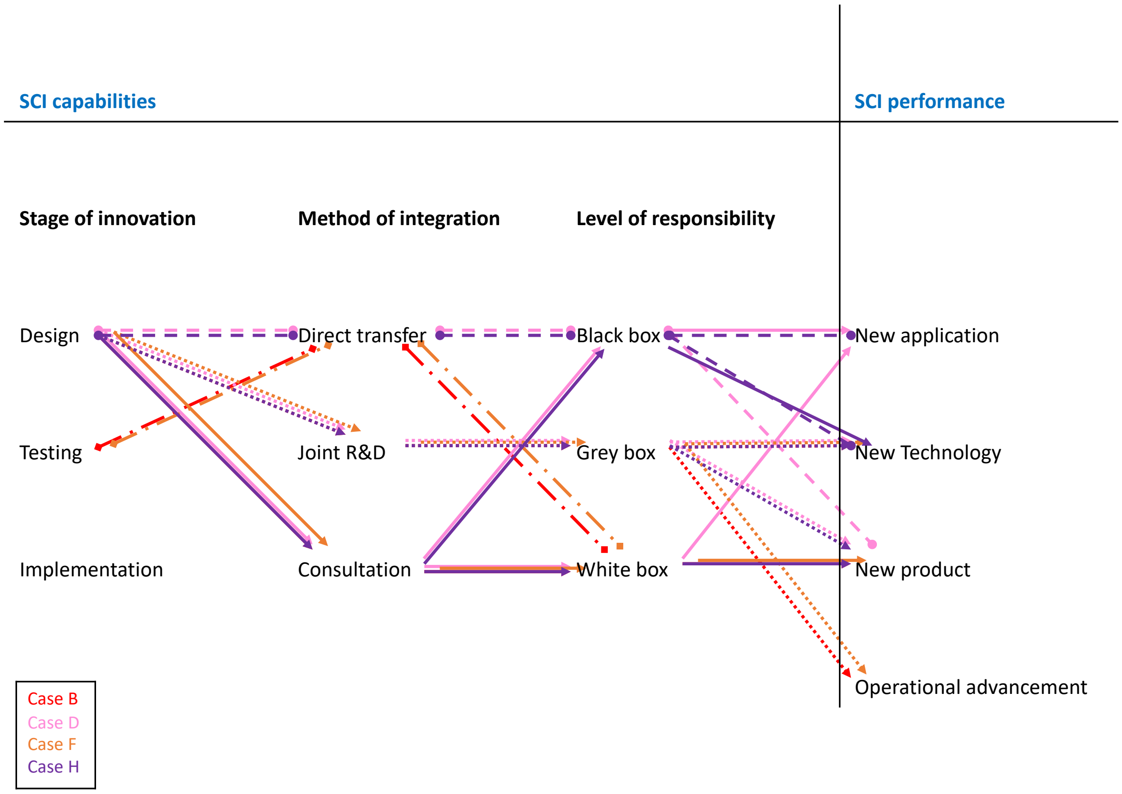



Figure 6.7 Integration and the relationship between SCI capabilities and SCI performance for case group 2

The internal innovation resources and capabilities of companies in case Group 2 are: R&D personnel, facilities and infrastructure and technology. As mentioned earlier, this industry values safety rather than novelty and creativity, innovation capabilities of suppliers are often neglected as they are not allowed to innovate on the product itself unless required. This situation is especially reflected in case B and F with their foreign customers. The powerful customers often have a lot of substitutes to choose from, therefore suppliers like company B and F can only compete through constantly improving quality, cost effectiveness and reducing delivery time. No SCI has been taken place under this situation and only production information has been communication between the suppliers and customers as necessarily required by basic business transactions. However, the case situation is different with domestic customers.

The domestic customers are often young entrants in the industry, and in specific product category, the suppliers have higher technical advancement than them. Therefore, the young domestic manufacturers need to integrate their suppliers in innovation projects to gain access to their expertise in knowledge and technology. The external resources and capabilities brought by suppliers into manufacturers are knowledge of technology in their specialised product category, knowledge of application and market knowledge. Communication and information sharing have been kept at an active level through the guidance and technical assistance these suppliers provide to their customers. But not all information moved freely within this SCI relationship. As the suppliers and manufacturers are separate business entities acting on their own best interests, they do not share all technology or knowledge with each other. As a result, the SCI performance of manufacturers are presented as new product and new technology (that does not necessarily need to be new to the world, as this research takes a wider implementation of concept of innovation); whereas, for suppliers, SCI performance is reflected in improved technical strength through collaboration.

***Total Case Group***

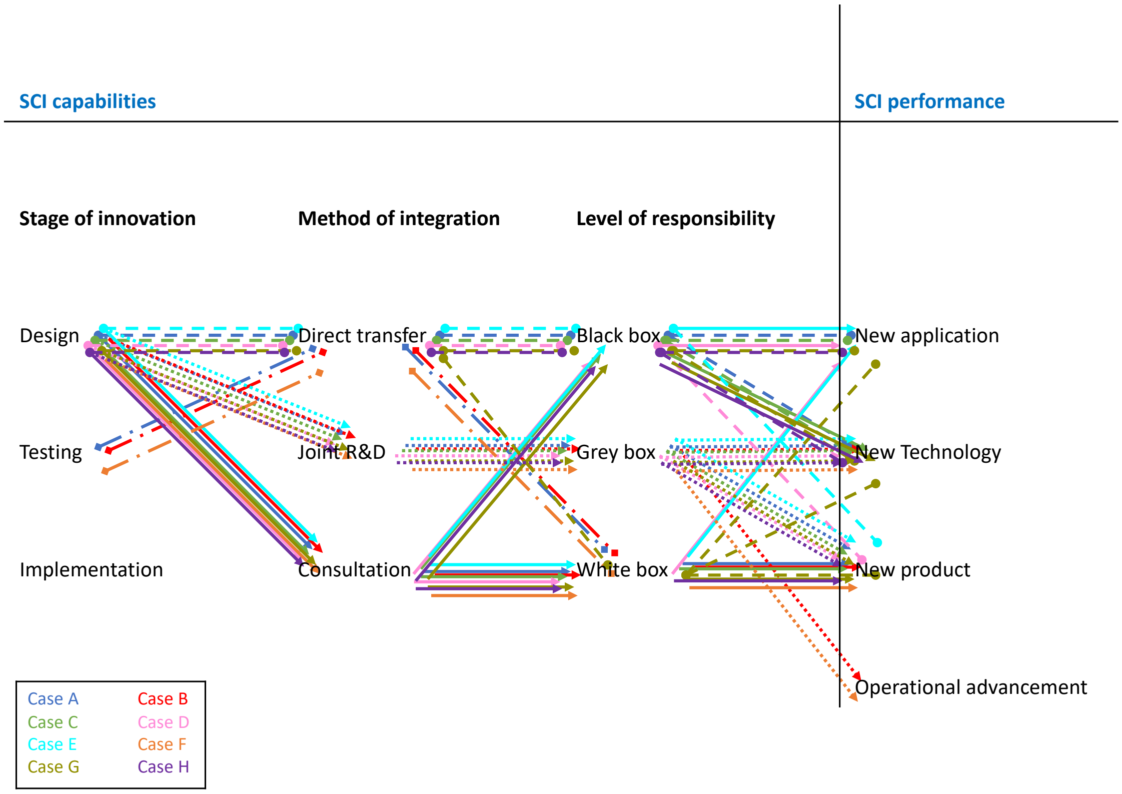



Figure 6.8 Integration and the relationship between SCI capabilities and SCI performance for all 8 case companies

Similarly, overlapping in case findings are presented in Figure 6.8 and the Figure 6.9 gives a clearer presentation of where the massive overlaps take place in the case findings.

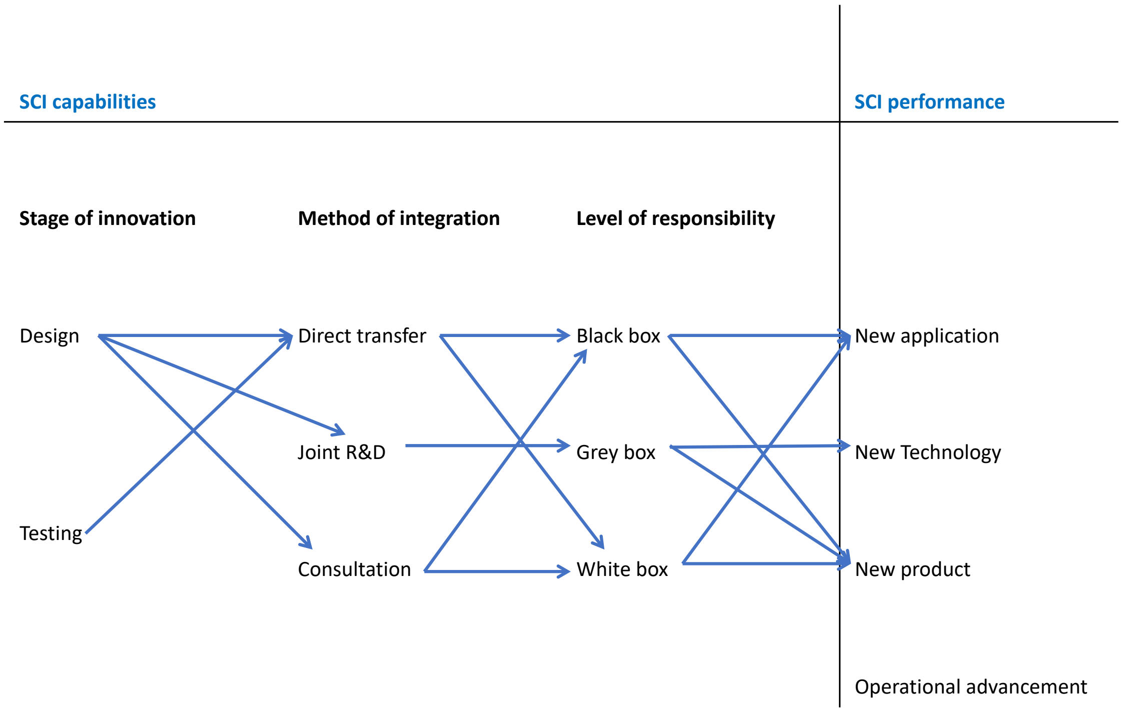



Figure 6.9 Integration and the relationship between SCI capabilities and SCI performance for all 8 case companies

The stage of innovation answers to the Sub RQ1 about when manufacturers enter SCI relationship. From the findings of all 8 companies, manufacturers generally decided to engage in SCI at design phase of R&D. With regard to SCI in the testing phase, only outsourcing contractual relationship and direct transfer takes place. Integrating suppliers into the manufacturers' innovation processes is viewed as integrating external resources. The level of external resources infused into the manufacturers through SCI process depends on the level of technical intensity and supply chain positioning of suppliers integrated in SCI for the specific part of innovation process. From the manufacturers' perspective (Case Group 1), the type of suppliers integrated in SCI processes are either or both design and component suppliers. The findings from all eight case companies are compatible with the literatures about tier and level of suppliers integrated in manufacturers' innovation process ((Ellis et al. 2012; Wagner and Bode, 2013; Un et al. 2016; Jajja et al. 2017) that only tier 1 suppliers in SCI process as lower-tier suppliers provide less technology intensive and peripheral products that are not considered as important to the serve the companies' purpose of enhancing innovation performance. Moreover, the case companies have also found in favour of the literatures that integrating suppliers in early stage of R&D brings benefits to new product development (Ragatz 2002; Petersen et al. 2005; Jajja et al. 2017). Within Case Group 1, SCI starts mainly in the design stage and the researcher has also found one case in Case Group 1 (Case A) and two case companies (B and F) from Case Group 2 show findings for integrating suppliers in the testing stage as well.

Though the importance of integrating suppliers have been identified in previous literatures in NPD (Ragatz 2002; Petersen et al. 2005; Jajja et al. 2017), the methods of integration have not been fully established in previous literatures, As shown in Figure 6.8, the methods implemented in these case companies are mainly: direct transfer, establishing joint R&D centres/projects and direct consultation. The analysis on integration factor also answers Sub RQ2 on the roles of suppliers (level of responsibility) and how manufacturers assimilate innovation from suppliers (methods of integration). Depending on the type of product involved in the direct transfer from suppliers to manufacturers, the level of suppliers' responsibility and results are different. Findings from all case companies show that when the manufacturers receiving design or product directly transferred from their suppliers, the level of suppliers' responsibility under such situation is extremely high. It is a black box situation when the suppliers take full responsibility of the technology (Petersen et al. 2005), as a result, SCI performances are new application (of existing products), new technology and product that rare new to the manufacturers. Moreover, with regard to Case G, there are also situations when suppliers are funding its R&D. In this case, the external resources received from suppliers can also be reviewed as internal resources as the manufacturer is taking full responsibility of the R&D.

Another commonly used SCI integration method is through establishing joint R&D centres with suppliers. In this situation, labs and R&D centres are established and engineers from both manufacturers and their suppliers coordinate and cooperate in R&D. Manufacturers are the ones who spot and identify the needs of innovation and set out expectations and requirements of innovation; they have also initiated joint development projects and look for suitable suppliers to integrate. The joint development R&D centres are often located in the manufacturers' sites (presented in Figure 6.7), and sometimes they even merged internal engineers and engineers from suppliers in the same team to ensure seamless communication and smooth cooperation. Though manufacturers act as coordinators of joint R&D projects, both the manufacturers and suppliers are taking equally responsibility towards the innovation process. Knowledge has been moved freely and information sharing has been kept at a high level between both parties when co-creation of innovation has been taking place between suppliers and manufacturers. As a result of innovation performance of such type of supplier integration in innovation process, manufacturer receives new design, technology, product and IP right of the innovated products.

With regard to consultation as a method of integrating suppliers in SCI processes, the level of suppliers' responsibility in SCI is also dependable. The SCI process is supplier driven (black box) if the suppliers have higher level of technical advancement in the relevant technology. Under this situation, manufacturers have minimum efforts in innovation and only new application of existing products is found to be the performance. On the other way around, when the manufacturers are taking full responsibility of the R&D processes, consultation with suppliers does not necessarily need to involve technology, nor technology-intensive products. The consultations are found to be more about product information, specifications and the manufacturers aim to learn from suppliers' experiences and technical know-hows instead of technology. In this case, innovation is still buyer-driven, but it is still SCI as suppliers are inevitably involved.

The last element of SCI performance indicator, operational advancement, includes innovation in process, reduction in cost, time, speed of product delivery and waste, etc. Only two cases show operational advancement as a result of SCI does not necessarily mean the other six companies do not have operational improvement. This is only because the other six companies target technological improvement, whereas operational improvement is not obvious to the respondents. Moreover, as explained earlier in Chapter 5, the most of the case companies have been implementing SCI since the start of their business and the lack of alternative approach makes it difficult to measure if implementing SCI gives a better operational performance than a mere application of internal R&D.

## 6.4 Information sharing and SCI framework

*Case Group 1: the manufacturers (Company A, C, E and G)*

Corporate Governance has implications that the type of companies' ownership determines its strategic orientations and style of business management. Therefore, corporate governance and corporate culture of a company also emerge to be very important to the cases. The type of ownership pre-determines the methods of information sharing between the manufacturers and suppliers. Therefore, the starting point of analysis on information sharing and SCI framework starts with ownership (Figure 6.10).

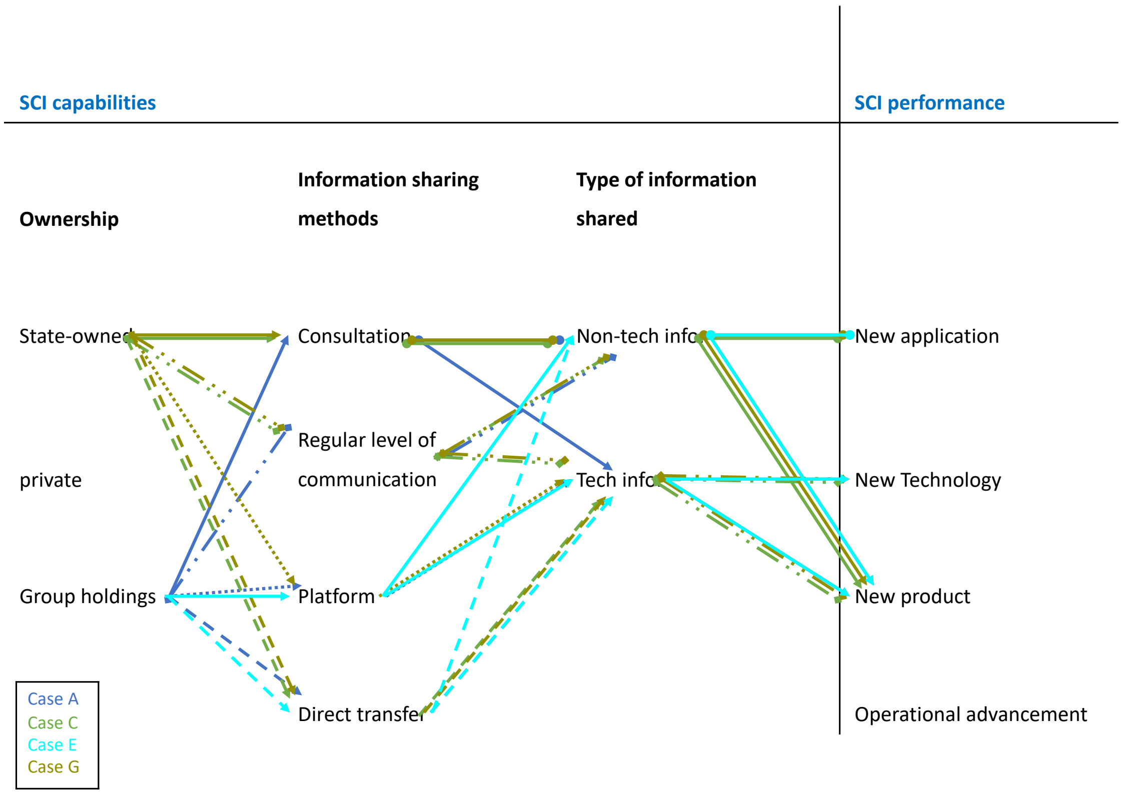



Figure 6.10 Information sharing and the relationship between SCI capabilities and SCI performance for Case Group 1

As presented in Figure 6.10, three of the four manufacturers visited are state-owned enterprises, it does not make any difference in terms of information sharing method choices based on the ownership within these three enterprises. As the R&D processes in aerospace manufacturing industry are project based, all of these three state-owned enterprises (A, C and G) have implemented all kinds of information sharing methods in SCI. But Company E, as a subsidiary of a Holding Group company, it only implements one method of information sharing in SCI, which is through building a sharing platform which allows the supplier to gain full access. The maximum level of information sharing comes from the nature of ownership of the company and that of the supplier involved in SCI of Company E.

The internal R&D departments in Group 1 act more as a coordinator of R&D projects in this circumstance. The external SCI resources and capabilities the OMEs receive from their suppliers are: direct transfer of technology and knowledge, engineers and expertise infused into co-creation projects and direct transfer of end products. To facilitate and coordinate the first two type of resources received from suppliers, the manufacturers in Group 1 have built up information and knowledge sharing systems/platforms for communication and technology to be transferred smoothly. As a result, SCI performance are represented by the number of IP transfer, number of new product and technology generated and enhancement of manufacturers' technical advancement through learning. However, with regard to the next type that only involves direct transfer of product and product documentations, the SCI performance can still be represented by the number of new product generated. But the manufacturers gain access to the technology without learning and no internal technical enhancement can be generated.

***Case Group 2: Suppliers (Company B, D, F and H)***

Case Group 2 look from the suppliers' angle and generates a slightly different relationship map from Case Group 1. The organisation interviewed in Case H is a state-owned research institute. As its main targets is R&D, Organisation H has very strong technological capability in the aerospace industry. The methods of information sharing when Organisation H is involved in its customers' SCI are consultation and direct transfer. Only technical information is shared during the processes and the manufacturers receive new technology and new product as a result. Company B and F are private companies with similar scales, the main methods of information sharing they are involved in are consultation and direct transfer. When only consultation is necessary, non-technical information is shared with manufacturers and the performance only results in new application and new product (with minimal technical developments). Moreover, in Case B, direct transfer of information also gives it operational development due to reduction in waste and improvement of cost and time efficiency.

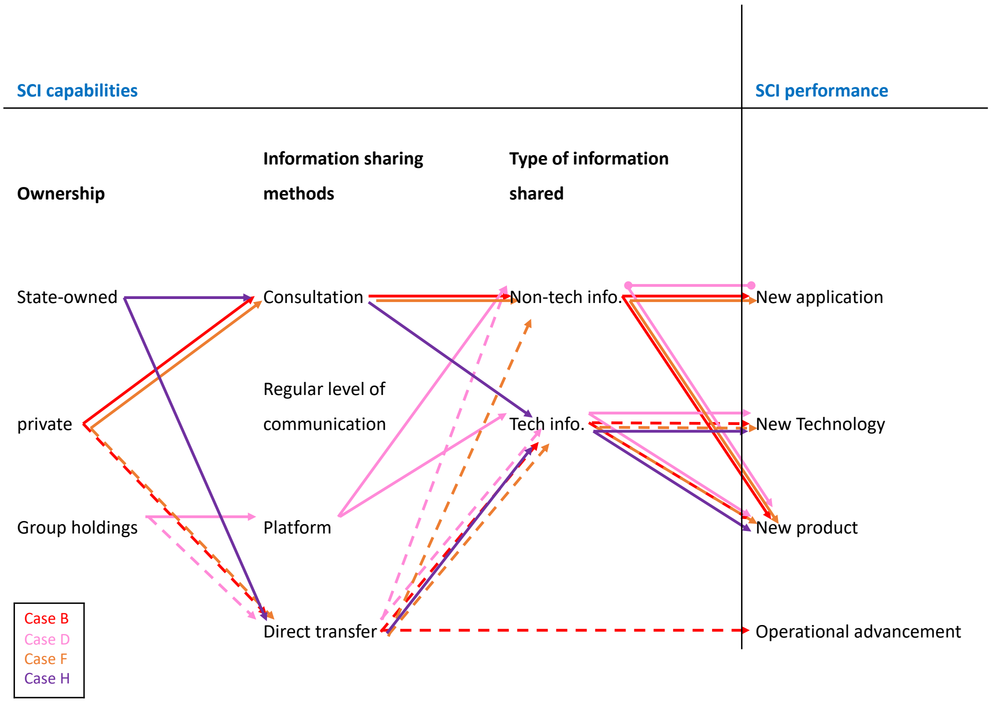



Figure 6.11 Information sharing and the relationship between SCI capabilities and SCI performance for Case Group 2

***Total Case Group***

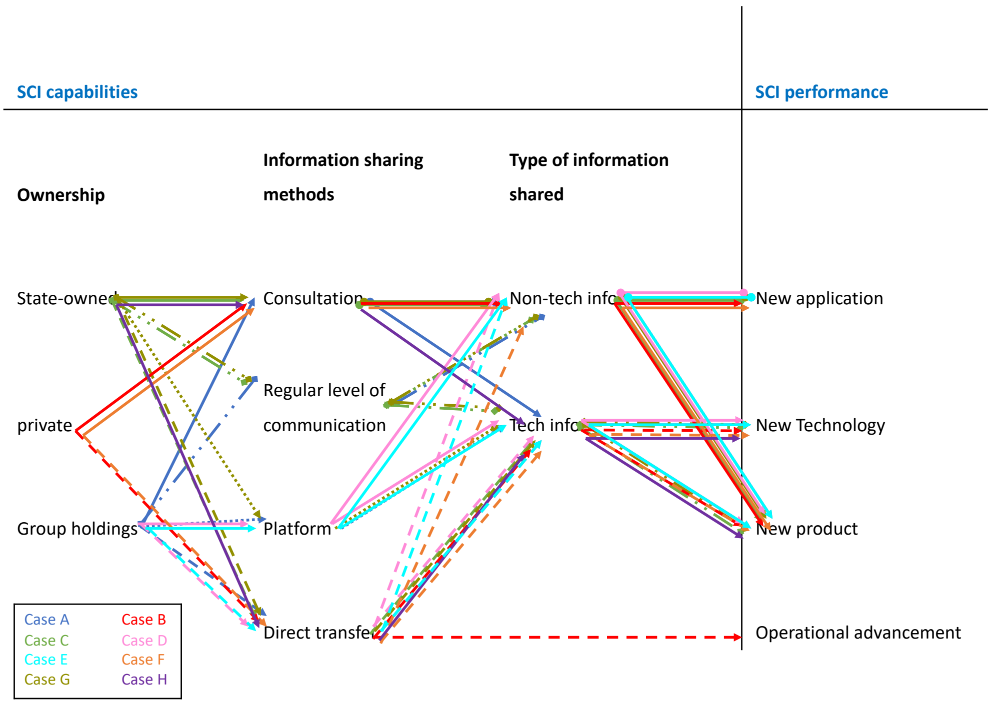


Figure 6.12 Information sharing and the relationship between SCI capabilities and SCI performance for all 8 case companies

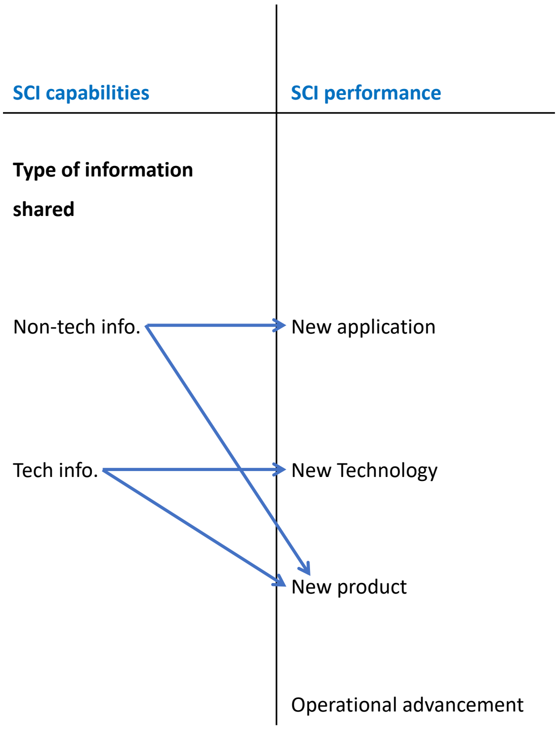



Figure 6.13 Patterns between type of information and innovation performance

As presented in Figure 6.12, it is extremely difficult to find out the patterns of SCI in terms of information sharing because the overlaps are not apparent, only the patterns of relationship between types of information shared and innovation performance are present. Knowledge sharing and level of information sharing are critical to obtaining innovation performance through SCI. With regards to Company A, D and E, which are state-owned holdings enterprises, the internal innovation resources and capabilities of three companies reported to be similar as R&D investment, R&D personnel and infrastructure. Because of the special type of ownership, these three companies share the benefits of state-owned company that has high level of current resources and access to external resources that are potentially available to them. This ownership type also implies autonomy in strategic planning and business decision making as these companies are not managed by the central government, but board of directors instead. Therefore, they are separate business entities from the government but they have access to the benefits of government support as the state-owned companies do. For example, all three companies have received benefits on land acquiring for building offices and factories, tax reduction and incentives for exports from the government. Therefore, the companies are allowed to manage business freely and choose who to work with and what type of information to share with their partners at stage of innovation. The ownership type does not hinder the companies from engaging suppliers (or being engaged) into the aerospace manufacturers' innovation processes.

Moreover, due to the fact both Company D and E were formed as a result of mergers and acquisitions, they consist of rich level of internal technical resources that have not been fully infused or deployed. Therefore, linking to the influences of strategic orientation on SCI, Company D (as a manufacturer in the engine industry) and E do not integrate other suppliers in their innovation process as a result of lack of internal capabilities. The external resources received by Company D and E in SCI are more about access to market and application information. Moreover, as mentioned before, Company D and E have high level of overlaps in shareholders, that makes the two companies much closer than others. Therefore, information sharing between the two companies has been kept at a maximum level between these two companies. When working with each other, there is intensive information sharing to ensure seamless communication and technology transfer. Company E has granted Company D with open access to its information platform that reflects highest level of trust. But with other suppliers, Company D and E only share necessary information required by the daily business operations. The seamless information avoids misunderstandings in communications and eliminates the waste in complications in knowledge sharing. The SCI performance of companies in Group I are new product that is not a mere customisation of existing products but contains cutting-edge technology and new technology transferred and infused into the companies from suppliers.

With regards to all the other state-owned enterprises, Company C, G and Organisation H, the nature of ownership in this group implies the level of resources available to them and the level of openness in terms of information and knowledge sharing. But this nature of ownership also compromises autonomy in business decision making and the companies are more conservative and cautious in decision making and management teams tend to favour focusing on short-term performance. The type of internal resources available to these three organisations are R&D personnel and facilities and high level of capital investment. When engaging suppliers in innovation process, these state-owned enterprises/organisations are more restricted and cautious in terms of knowledge and information sharing and type of resources received from suppliers. For the manufacturers (Company C and G), they are large aerospace manufacturers that have strong bargaining power, the domestic suppliers have to comply with their requirements. Although some of the domestic suppliers have more advanced technical level in specific area, they still need to comply with requirements set out by Company C and G. The compliance is not as a result of Company C and G’s ownership type, but due to the fact that Company C and G have the largest and the most important innovation projects in aerospace manufacturing industry in the country. Participating in these SCI projects are beneficial to all the engaged suppliers. Therefore, information sharing in this situation is more of a one-way flow of technology and knowledge from suppliers to manufacturers in this case group. But information sharing within the group is high. For example, Company G and Organisation H are two separate and independent business entities but they belong to the same holdings group in China. The holding group is one of the largest aerospace manufacturing holding groups in China. The ownership type gives these two case companies/organisations access to both human resources and physical resources within the same group. It widens both companies'/organisations' level of technology capacity and potential resources available to them. Therefore, the level and importance of SCI in innovation for these case companies are not as high as the other cases, but the free movement of knowledge and technical information only takes place within the clique. In terms of SCI performance of Company C and G, new aircrafts that has the most cutting-edge technology have been innovated and they exceed the level of loading capacity and energy efficiency of their strong competitors in the market.

The level of available internal resources of private companies are limited by its ownership type. The type of ownership also determines the size of the company, level of capital capacity and level of support received from governments. However, the ownership also brings positive benefits to the companies as the management teams have autonomy in strategic planning and business decision making. The two private companies (Company B and F) have reported the maximum level of freedom in strategic decision and choice of information sharing in all three case groups. These private companies have been actively engaging in learning and sharing in SCI process with their manufacturers; and they have also improved their technical level through knowledge co-creation with manufacturers. But this industry requires high level of investment, whereas the payback period is long, the internal resources capability and level of external resources available are vital in the aerospace manufacturing industry. Both internal and external resources of private limited companies are restricted by the nature of ownership. However, this drawback of corporate governance does not affect its level of contribution in its suppliers' innovation processes. Through active information sharing from the suppliers to manufacturers and learning through knowledge co-creation, these two companies form a tighter bond with their customers (manufacturers in the industry), that enhance relationship with customers and improve their irreplaceability as suppliers. The SCI performance for the manufacturers are reflected through number of new products; and for suppliers is measured through the strengthened customer relationship, enhanced bargaining power, non-substitutability in the market and the improvement in technical level through joint development of innovation.

## 6.5 SCI framework

### *6.5.1 SCI framework*

As discussed in details in Chapter 6, this research identifies the relationship between SCI capabilities and performance in the SCI framework. Figure 6.14 presents an updated framework of SCI. Summarised from analyses and discussions in Chapter 5 and 6, SCI performance can be enhanced through managing SCI capabilities via coordinating resource, integration and information sharing along the supply chain.

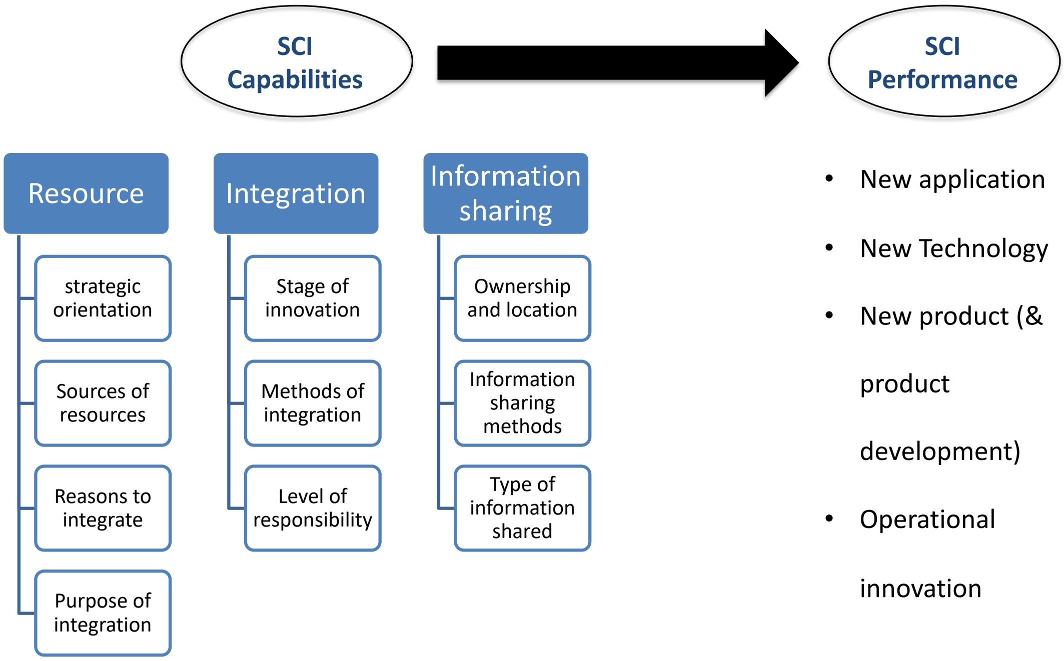



Figure 6.14 integrated framework of SCI

As presented in this framework (Figure 6.14), The process of SCI starts with managing SCI capabilities. Firstly, it is for manufacturer's the strategic and managerial management team to make the choice between internal R&D and SCI. The sources of resources, reasons to integrate and purposes of integration are the main determinants of selecting SCI. Secondly, with regards the integration processes of SCI, this research found mainly in favour for integrating SCI in NPD (Ragatz, 2002; Petersen et al. 2005; Jajja et al. 2017), but also at testing stage especially for products/components that require to be tested in large plant.

In order to identify the methods of integration, we need to first find out which tier/level of suppliers are suitable for SCI. This research has found that tier 1 suppliers in the industry are mainly involved in SCI (Ellis et al. 2012; Wagner and Bode, 2013), whereas suppliers in lower tiers are only responsible for peripheral products and are not closely involved in SCI. Depending on the nature of suppliers' products, the level of technology intensity of the relevant products and bargaining powers the suppliers have, different integration methods have been implemented through direct transfer, joint R&D and consultation (Ragatz 2002; Petersen et al. 2005; Jajja et al. 2017). Manufacturers assimilate innovation from suppliers through consultation of non-technology intensive products and the products that only requires application information, direct transfer of designs, resources and products that can be assimilate inside manufacturers and stabling joint R&D research centres with highly trustable suppliers or the suppliers who have most advanced technology level. When considering the methods of integration, information sharing method is also an important capability of this framework. Depending on the supplier relationship, level of technology intensity of the relevant products/components and the methods of integration, SCI information is shared through consultation, direct transfer and establishment of sharing platforms which grant the suppliers with full access.

The manufacturers diffuse responsibility of innovation on the supply chain based on the level of technology intensity of the relevant products/components. The level of responsibility that suppliers carry in SCI is dependent upon the integration methods. The manufacturers integrate suppliers of core products/highly technology-intensive products closely in SCI when the bargaining power of suppliers are relatively low; whereas with the suppliers who have more advanced technology than the manufacturers and strong bargaining powers, manufacturers can only receive interface data even with engaging them in SCI.

Therefore, to answer the main research question, manufacturers enhance innovation performance through coordinating resources, integration and information sharing along the supply chain.

### *6.5.2 SCI framework and case example*

Combining the research findings and analyses in Chapter 5.2 and the discussions from Chapter 6.2-6.4, Case findings from Company C has been re-summarised and re-organised to present how SCI framework takes place in a real-life case.

Case Company C has a new aircraft---Model C: the innovation process of Model C has been complete; the complete aircraft has been released to assembly line and it has taken its first journey in air in the year of 2017. It will be a good case to explain the discussions of SCI framework. Following the sequence of the discussions in Chapter 6, case scenario in Company C for the innovation processes of Model C has been reviewed and re-organised in relation to the corresponding variables (Figure 6.15).

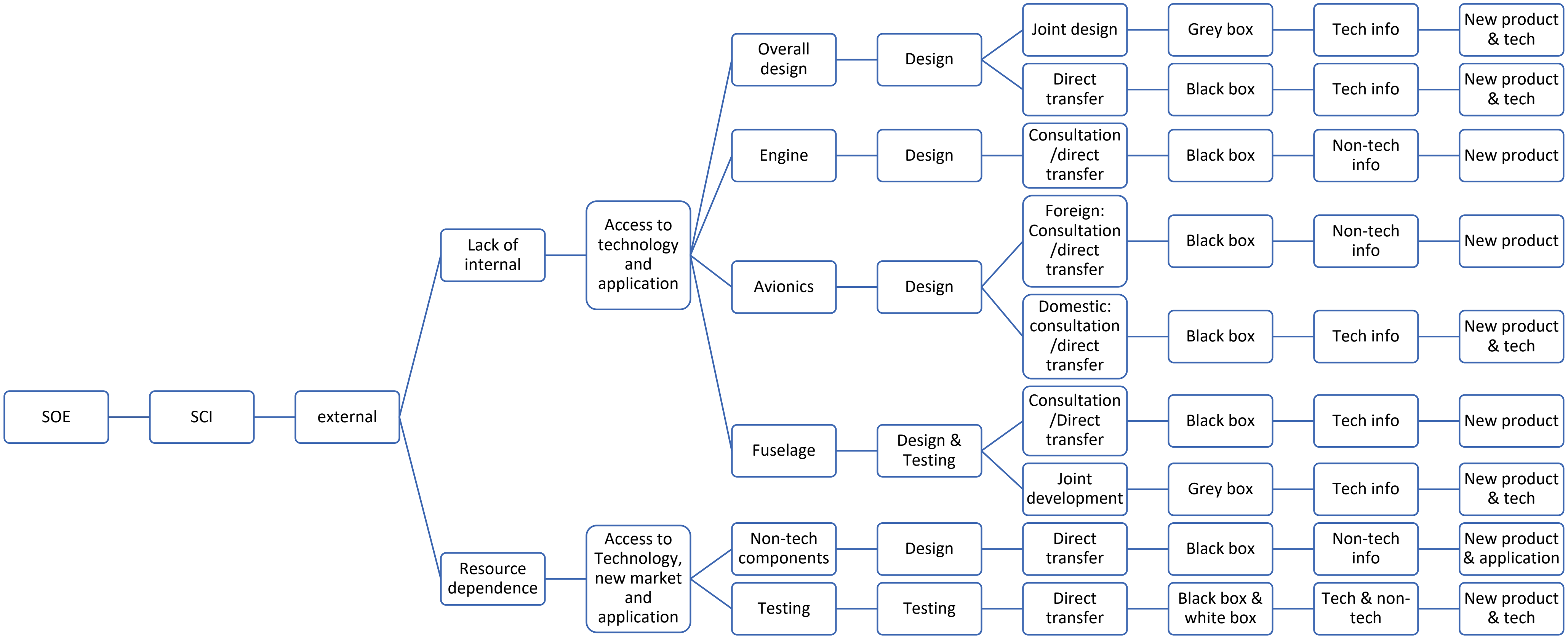



Figure 6.15 SCI case example: Company C: Aircraft Model C

As the main focus of research is not internal R&D capabilities, this research only looks at SCI of Company C. When innovating Model C, engaging in Supply chain innovation mainly brings external resources. The external resources received from suppliers are: direct product, technology, equipment and machinery, knowledge and testing facilities. As presented in Figure 6.15, there are two reasons for receiving external resources from engaging in SCI: lack of internal resources and capabilities and as a result of resource dependence view.

When there is a lack of internal resources and capabilities, the main purpose of Company C engaging in SCI is to gain access to technology and application information, and the SCI processes of Model C of different parts of the aircraft vary depending on different types of suppliers involved. The first type of supplier involves design suppliers. The overall airframe design of Model C was conducted internally, but detailed design was completed both internally and through SCI. To be more specific, the overall design of airframe with detailed plans including specifications requirements of engine, avionics, wing, aeronautics, and other high-tech components which are crucially important and the design of aerodynamics were conducted within Company C's internal R&D capability. The design of fuselage, materials used and coating specifications were set out via collaborating with domestic suppliers. Such suppliers come from local universities, research institutes and tier 1 component suppliers in the aerospace manufacturing industry who have either the most advanced level of technology in the relevant field or the most experiences in production and application. Collaborating with design suppliers takes place in the design phase of R&D and both joint research labs and direct transfer of knowledge are involved. With regard to the joint research labs, both Company C and the design suppliers take joint responsibility in R&D (grey box), they share engineers, technical information, experiences and knowledge, and as a result, new technology and new designs have been innovated. With regard to the method of direct transfer, the innovation project is supplier-driven (black-box). It involves direct transfer of product design or technical knowledge to Company C. Within these SCI with suppliers in overall aircraft designing, Company C retains full IP right of the outcomes and the performance is presented in the form of new technology and new product.

The second type of suppliers involved in SCI of Model C are the suppliers of products that are highly technology-intensive. For example, the supplier of the most important part for an aircraft---engine, is involved in SCI. The engine supplier of Model C is a foreign supplier and the engine was exclusively designed to fit all the requirements set out by the manufacturer. SCI with the engine supplier takes place at the design stage. However, as the engine supplier is a well-renowned supplier in the industry, it has very high level of bargaining power in the market, it conducts all the innovation of the engine independently, and the level of involvement of the engine supplier in SCI is relatively low. The main role of the Company C in the SCI collaboration with the engine supplier is to set out product requirements and specifications of the product whereas the engine supplier takes full responsibility in innovation (black box). The engine supplier also takes part in Company C's early product design phase in a consultation format to help Company C to evaluate the feasibility of the design and provide suggestions on product requirements. This type of SCI relationship mainly involves direct transfer of product and only non-technical information such as user manual, product specifications, quality evaluation reports, test reports, etc., has been transferred to Company C. The supplier retains full IP right and the core technology of the product has been kept unrevealed to Company C. As a result, the new product---new engine is delivered to Company C and experiences in designs are obtained.

The third type of suppliers involved are also related to technology-intensive products but both foreign and domestic suppliers are involved in SCI. An example of this type of suppliers involved in SCI of Model C are the suppliers of avionics and balancing systems. Within this situation, SCI takes place at the design phase of R&D and the level of suppliers' involvement are different between foreign suppliers and domestic suppliers. When collaborating with foreign suppliers, Company C has relatively low control of product innovation and methods of innovation, level of responsibility in innovation and method of information sharing are similar to the scenario of the second type of supplier---engine supplier. As discussed earlier in Chapter 5, SCI projects of avionic systems for early aircrafts prior to Model C only involve foreign supplier, thus the collaboration method was almost the same as that of the second type. With regard to the SCI projects with foreign suppliers of avionics systems, the suppliers retain full ownership of the patent and technical knowledge has been remained unrevealed to Company C. However, as technical level of Model C has evolved and allows multiple suppliers for the avionics systems, Company C has gained more control over the SCI projects when experienced domestic suppliers are involved. With regards to collaboration with domestic suppliers in the avionics and balancing systems, SCI still takes place at the design phase and innovation of the products are conducted independently by the suppliers. However, both consultation at design phase and direct transfer of products and technical knowledge are involved; as a result, Company C and suppliers share IP of the final outcome and both new product and new technology have been innovated.

The forth type of SCI is through joint development. One example of the joint R&D projects is the collaboration with domestic materials and composites suppliers for fuselage. SCI takes place in the design and testing phases. In this scenario, Company C takes control in designing and sets out product requirements and specifications but the selection of suppliers and product testing have been completed through collaborating with trusted domestic suppliers. Company C and its relevant suppliers have established joint research projects in designing and testing to find out the perfect materials and composites for the fuselage. During these joint research projects, innovation is both supplier-driven and manufacturer-driven. Company C and the relevant suppliers involved in SCI share engineers, experiences, materials and other resources and capabilities, information sharing of technical knowledge has reached a maximum level inside the joint research labs and design of fuselage has been refined after series of complex testing experiments. The IP right of the outcome is shared between Company C and suppliers integrated in this SCI project. As a result of SCI in fuselage, Company C has obtained new product and new technology.

As discussed earlier in Chapter 5, Company C is a well-established aircraft manufacturer who has been in the industry for decades, it has strong innovative and financial capabilities for internal R&D. However, it has also outsourced parts of innovation processes, which they are fully capable of internal development, to its suppliers due to resource dependence reasons. The main purpose of outsourcing innovation to suppliers is to gain access to technology, new market and application. Take Model C as an example, the first part of innovation processes outsourced to suppliers are innovation for peripheral products that are non-technology-intensive. Such products include interior design, seat design, standard components and composites, etc. SCI starts at design phase where Company C sets out requirement of innovation and product specifications. The suppliers conduct independent R&D and the innovation process is completely supplier-driven. Invention and new IP may not be the case for SCI of peripheral products, non-technical information has been transferred to Company C. As a result, Company C receives the new product and new application.

Last but not least, during the innovation process of Model C, Company C has also outsourced most of its testing stage to suppliers. Both domestic and foreign suppliers are involved in this process. Direct transfer of both technical and non-technical information has taken place between Company C and its suppliers. This SCI process with testing suppliers is both supplier-driven and manufacturer-driven. The design phase of products and testing requirements are manufacturers-driven, whereas the testing phase is mainly supplier-driven. As a result, SCI performance is presented as new technology and new product.

To sum up the case findings, discussions of Case Company C in relations to the SCI framework, SCI has mainly taken place at the Design and testing stage of R&D. The reasons, processes and methods of integration depends on the type of suppliers involved and the manufacturer’s level of internal capability and control in the SCI processes. Figure 6.15 has only listed out some of the representative examples of different types of

SCI processes, together with thousands of other SCI projects which share similarities in processes and methods and Company C's internal R&D resources and capabilities, Company C's has completed innovating its new product, Model C. The aircraft has been released to assembly line in the year of 2015, and it has taken its first journey in the year of 2017.

# Chapter 7 Conclusion, Limitation and future work

## 7.1 Summary of the Research Process

This research has been conducted within the background of the view of resource dependence that due to scarcity of resources, firms cannot have all the resources and capabilities they need (Pfeffer and Salancik, 2003), and to achieve their innovation objectives, collaborations are necessary and exchange of knowledge will provide positive effects on their innovation initiatives (Jajja et al, 2017). Managers and academics have increasingly realised the importance of involving suppliers into a focal company's innovation process (Bellamy et al., 2014).

After a series of literature reviews in the relevant topic, the researcher has found two main research gaps of SCI. Firstly, the supply chain integration in the focal company's innovation process has been researched in different domains of operations management and innovation management contexts. It is difficult to generalise the theory outside the pre-determined context settings, and contradictions in existing theories occur due to the different aspects the previous researches examined. Some of the important arguments include engaging suppliers in buyers' R&D processes, especially in the early stage of new product development (Petersen et al., 2005; Menguc et al, 2014). It has been believed such engagement can help leverage suppliers' expertise (Arlbjørn and Paulraj, 2013) but may also lead to inevitable risks (Petersen et al, 2005; Menguc et al, 2014; Jajja et al, 2017). There is no unifying framework explaining how diverse supply chain activities can impact on the focal company's innovation performance in a systematic way. The second research gap exists where the existing literatures take a predominant view from the buyers' side (Petersen et al., 2005; Yeniyurt et al, 2014; Jajja et al, 2017).

To address these major knowledge gaps, this research extends the established theories of supply chain management by developing a framework of supply chain innovation (SCI) which highlights the situations and circumstances that supply chain integration can enhance the innovation performance of aerospace manufacturers. Therefore, the main research question is: ***How do aerospace manufacturers enhance innovation performance through SCI process?*** The main objectives of this research are: firstly, to explain roles of manufacturers' internal capability and to determine how SCI is affected by internal capabilities; secondly, to explain the roles of suppliers and how manufacturers deploy and assimilate innovation from suppliers; thirdly, to find out how the SCI is affected by the firms' overall strategy and external factors; last but not least, the provide managerial implications of SCI framework for both supplies and buyers (manufacturers).

In order to answer the research questions, this research has implemented a multiple case study approach which is a flexible research design. Both qualitative primary and secondary data have been collected. During the data collection stage, 37 semi-structured interviews were conducted in 8 companies in the aerospace manufacturing industry in China. The data were then analysed by following Yin's (2018) guidelines of case study research and thematic analysis (Braun and Clarke, 2006).

## 7.2 Research Findings

This research aims to provide the integrating theoretical framework of SCI to fill in the relevant research gaps. To address this research aim, this research has explained how firms decide whether and when to enter SCI collaborations (Sub RQ1), how firms assimilate innovation from suppliers (Sub RQ2) and how firms' overall strategy influence innovation that takes place on the supply chain (Sub RQ3). The findings and connections to existing literatures have been summarised as bellows and the answers to the research questions are presented.

### *7.2.1 Resources: Strategic orientation*

As discussed in Chapter 2.3.9, company ownership types affect decision making through: investment decisions for R&D (Roberts, 1995; Collins et al, 2017), organisational culture and management style (Roberts, 1995), resource deployment (Bruce and Moger, 1999), incentives to innovation (Ferreira, 2014) and decision on investing human capital in innovation (Sun et al, 2017). The case findings are supportive to all of the views above and found out that firms' strategic decision affect firms' ability to turn external resources into internal innovation capability. For examples, Case A's decisions on entering M&A with its direct competitor/supplier; not having any innovation prior to the year of 2015 and establishing joint research labs have all made critical impacts on Company A's innovation performance. This also gives answers to the Sub RQ3 on how firms overall strategy influence innovation performance.

### *7.2.2 Resources: Sources of resources*

Chapter 3.2 has discussed that there are two sources of innovation resources: internal and external. The internal resources are not the primary research object of this research. However, previous research has shown its importance in relation to the level of integration and process of SCI (Ragatz et al, 2002; Wynstra et al, 2003; Yeniyurt et al, 2014). This research found in favour of the argument that the level of internal resources is associated to the reasons to integrate and methods of integration in SCI, and details will be explained in later part of this chapter.

With regard to the external resources, it the major resource of SCI. External resources include human resource, knowledge and technology, financial resources, equipment, machinery and facilities, etc. Suppliers' involvement in the new product development has been proven to have positive impacts on the manufacturers' innovation output (Wasti and Liker, 1997; Ragatz et al, 2003; Wynstra et al, 2003; Petersen et al, 2005; Menguc et al, 2014; Yeniyurt et al, 2014). In this research, all 8 case companies have verified the argument and showed the importance of external resources in SCI.

### *7.2.3 Resources: Reasons to integrate*

There are two reasons to integrate in SCI: lack of internal resources and resource dependence. As discussed earlier that SCI gives manufacturers positive innovation outcomes (Wasti and Liker, 1997; Ragatz et al, 2003; Wynstra et al, 2003; Petersen et al, 2005; Menguc et al, 2014; Yeniyurt et al, 2014). Presented in all 8 cases, there is no doubt that companies will seek for external resource when there is lack of internal capabilities.

The relevant literatures of resource dependence have been discussed in Chapter 2.3.4. Because "organisations lack all the resources and abilities needed to achieve desired outcomes" (Pfeffer and Salancik, 2003), collaborations with universities, suppliers, customers as well as competitors help manufacturer to gain access to knowledge that supports innovation (Un et al, 2016). The case findings have verified the literatures that one reason of SCI is resource dependence. The findings also gives answer to the first part of Sub RQ1 on how firms decide whether to enter SCI or not.

The literatures have also raised the concerns of increasing interdependence between suppliers and manufacturers that increases switching cost, reduces supplier's willingness to be integrated and increases level of uncertainty between the supplier-manufacturer relationship (Takeishi, 2001; Petersen et al, 2005; Yeniyurt et al, 2014). However, the concerns of negative influences of increasing interdependence and level of uncertainty cannot be supported in the case findings. This is mainly because of the manufacturers' increasing level of control in SCI within the specific industry. For example, as found in Case C, when designing the new aircraft model, the overall design of airframe with detailed plans including specifications requirements of engine, avionics, wing, aeronautics, and the design of aerodynamics were conducted within Company C's internal R&D capability. This means Company C has the control in SCI to sets out requirements and select the suppliers who are eligible to be integrated in SCI. Even with the engine supplier in the case who is experienced and has high bargaining power in the market, and only transfers the product and non-technical information to Company C, the manufacturer is still able to switch suppliers if the current suppliers fail to meet the requirements. In the case of switching suppliers, switching cost definitely exists and change of the entire design is required, but there is no evidence showed in the cases that increasing interdependence between the manufacturers and suppliers creates negative influences on innovation.

Additionally, with regards to the joint development projects where joint research labs have been established and creates a closer linkage between manufacturers and suppliers and implies an even higher switching cost, negative influences from increasing interdependence still does not take place in the case findings. Due to the nature of the aerospace manufacturing industry, manufacturers only integrate highly trusted suppliers in SCI and such suppliers include reputable universities, state-owned research institutes, component suppliers that are either state-owned or the best supplier with most advanced technical levels and experiences. Moreover, in the SCI between case company D and E, sharing of critical technical information only takes place between them because they are the subsidiaries of the same group holdings company. Therefore, the risk of negative influences and uncertainties on innovation due to increasing level of interdependency between suppliers and manufacturers were not supported by the case findings in this research.

### *7.2.4 Resources: Purposes of integration*

As discussed in Chapter 2.3.4, purposes of integration have been summarised from various literatures and case findings. In the case, five purposes have been proposed: firstly, access to technology, because suppliers possess technological know-hows, spillovers, knowledge gained through practices and experiences (Bellamy et al, 2014); access to application information, as SCI cannot only benefit from suppliers' manufacturing capabilities but also their key learnings (Bellamy et al, 2014); access to new market (Schwald, 2008); supplier relationship (Lamming, 1996; Pfeffer and Salancik, 2003; Smith and Transfield, 2005; Wagner and Bode, 2013; Jajja et al, 2017); and reduce uncertainty (Petersen et al, 2005; Jajja et al, 2017). The case evidences found in favour of the literatures on access to technology, application and new market, whereas there is no enough information from the case data to support the purpose of increasing supplier relationship and reducing uncertainty. The main reason is that the purpose of integrating suppliers in SCI always involves a complex answer with mixed purposes, supplier relationship and reduction of uncertainty may be the purpose of SCI for some SCI projects of the case company, the evidence from case data was not clear enough to verify the literatures. Only two out of 37 respondents have mentioned about the purpose of increasing supplier relationship and reducing uncertainty, the answers are not enough to establish internal validity with this research. The purpose of integration also helps to answer Sub RQ1 on how firms decide whether to enter SCI or not.

### *7.2.5 Integration: stage of innovation*

The literatures show that at early stage of innovation (i.e. NPD) is beneficial for the manufacturers in SCI (Ragatz, 2002; Petersen et al, 2005; Jajja et al, 2014). Therefore, the main stage of innovation when suppliers is the Design phase. All 8 cases have found in favour of this argument and this research also extends the literatures with empirical findings of SCI in the testing stage. The findings also give answer to the Sub RQ1 on when to integrate suppliers in SCI.

### *7.2.6 Method of integration*

The methods of integration have been identified as: direct transfer, consultation and joint development (Petersen et al, 2005). The method of integration helps to answer Sub RQ2 on how the manufacturers assimilate innovation from suppliers. In this research, all eight cases companies have verified the theory on methods of SCI integration and the type of methods used depends on the type of suppliers involved.

### *7.2.7 Level of responsibility*

The level of responsibility of suppliers in SCI have been discussed and in general there are three levels: black box, where the innovation is supplier-driven; white box, where the innovation is manufacturer-driven and grey box, where the innovation is a joint effort between the supplier and manufacturer. Data from all 8 cases have supported this argument on level of responsibility and it helps to answer Sub RQ2 on how the innovation from suppliers is assimilated.

### *7.2.8 Information sharing: ownership and location*

The type of ownership impacts on the motivation and decision for the manufacturer to integrate suppliers into the innovation process (Roberts, 1995; Petersen et al, 2005; Saunila and Ukko, 2012). The case findings have found in favour of the argument that ownership type affects decisions made and therefore affects innovation performance. There are three types of ownerships found in the case findings to have impacts on manufacturer's decision on SCI: SOE, SME and subsidiaries from a Holding Group Company. As found in the cases, SOEs have the characters of high level of autonomy in decision making, high level of investment, high level of variety in the pool of resources and capabilities available for innovation and high level of trust between other SOEs which makes it easier for the SOEs in the highly-regulated aerospace industry to collaborate with universities and state-owned research institutes. SMEs in the cases are usually tier 1-2 suppliers in the industry and it is difficult for them to gain access to technical information and to be integrated in SCI. The Holding Group has similar situations with SOEs as some of the companies investigated are SOEs and subsidiaries of the same Holding Group Company (Company D and E). In situation like this, an extremely high level of trust is established and technical knowledge has been moving freely and it is easier to create an environment for open innovation between the subsidiaries under the same holding group company. However, this situation only takes place between case company D and E and the findings cannot be generalised at this stage.

Location is associated with regional systems of innovation (Chaminade and Plechero, 2015). As the cases companies have located in different aerospace clusters, when selecting the cases, companies from the same clusters have been visited in order to explore the location factor in SCI. However, the cases do not show supports of the regional innovation systems theories. Access to knowledge and knowledge sharing are more as the result of type of ownership (i.e. Company D and E) rather than the result of location.

The role of government in SCI has also been reviewed in this research (Jagtap et al, 2010; Azadegan et al, 2013). As found in the research, the role of government has been reflected in information sharing. As discussed before, the aerospace manufacturing industry in China is highly regulated, and new entrants of the industry found extremely difficult to survive. However, the highly regulated industry creates a safe environment for information sharing in SCI as technical-intensive knowledge is only shared between trusted partners. All 8 case companies have felt comfortable in sharing information with their trusted partners in the industry without the fears of negative knowledge spillovers. Additionally, government support can also be found in the cases with SOEs, especially in Case C and G, but the findings of linkages between government support and SCI performance in the cases are very straight-forward. The examples found in the cases are: the government has been invested directly in Company E's innovation capabilities; helping Company C to coordinate supplier selection and gain access to desired suppliers. Such examples show direct impacts on SCI, but in-depths explorations and explanations are needed as to the impacts on SCI.

#### *7.2.9 Information Sharing: Methods*

Chapter 2.3.8 and 5.2.3 has discussed the positive outcomes of information sharing and innovation outcome. As suggested in the literatures, information sharing is critical for joint development of innovation (Petersen et al, 2005; Yeniyurt et al, 2014), communication and information sharing enable both buyers and suppliers to better understand each other (Griffin and Hauser, 1992; Yeniyurt et al, 2014) and information sharing needs to be timely and honest for integrated projects (Paulraj et al, 2008; Yeniyurt et al, 2014). Information sharing is implemented in all the cases to ensure smooth communication, cooperation and to receive positive outcome of innovation (Thomas, 2013; Jajja et al, 2017). The level of accessibility to knowledge is important for SCI (Bellamy et al, 2014) and the methods of sharing has been summarised as consultation, regular level of business communications, direct transfer and joint development platform (according to their accessibility to knowledge).

However, the literatures have also identified two major risks of information sharing: ability to replicate success (Ketchen et al, 2007; Salge et al, 2013) and knowledge spillovers (Roy and Sivakumar, 2011). Theoretically, an underlying risk of information sharing is the ability for other market players to replicate one's success. However, though one respondent out of 37 has expressed the concerns of the replicability of success, the overall findings from the case data are found against this theory. Unlike consumable products which have a harmonious environment for new market entrants, new entrants in the aerospace manufacturing industry is extremely difficult. Within this specific industry, only managerial processes are non-confidential information and can be replicable. In addition, the innovation and product cycle in the aerospace manufacturing industry are relatively longer than the other products; and as presented in the case example in 6.5.1, IP right and core technology remained confidential, success cannot be obtained through replication. Moreover, with regards to the knowledge spillover, as discussed earlier above (Chapter 7.2.8) the threat of knowledge spillover is not the case as this risk has already been neutralised by the nature of the industry and manufacturers' controlling position in SCI.

#### *7.2.10 Information sharing: Type of information shared*

The level of information shared has a close link to the level of accessibility to knowledge and learning (Bellamy et al, 2014). As this research is a qualitative research where main data collected are textual rather than numeric, instead of developing numeric measurement of the "level" of information shared, this research investigates level of accessibility to knowledge through type of information shared. The share of technical information and non-technical information presents a relative "level" of accessibility. Both types of information sharing have been found in all cases and the linkage between different types of information sharing and other theoretical constructs have been established.

### *7.2.11 SCI Performance*

This research implements the wide interpretation of innovation that includes technological change on both incremental (McDermott et al, 2002) and radical innovation (Chandy and Tellis, 2000); innovation that are new to the market (Chandy and Tellis, 2000) and new to the firm (Cooper, 1993; Johanssen et al, 2001), changes to product category (Johannessen et al, 2001) and process innovation (Jajja et al, 2017). Therefore, product innovation in this research can be measured by: incremental innovation in better product design as a result of supplier integration (Song et al, 2008; Monczka et al, 2010); radical innovation in new product (Ragatz et al, 2002), new capabilities developed (Wynstra and Weggemann, 2001) and superior products (Takeishi, 2001; Menguc et al, 2014).

The process innovation performance can be measured by increase in financial performance (Hudson et al, 2001), quality (Sink, 1985; Hudson et al, 2001), efficiency (Sink, 1985), effectiveness (Sink, 1985), productivity (Sink, 1985; De Toni and Tonchia, 2001; Saunilam 2016), customer satisfaction (Hudson et al, 2001), faster delivery to the market (Lau et al, 2010) and reduced error rates (Song et al, 2008).

Understanding the meaning and definition of innovation performance is important because it is about what constitutes innovation performance in this research. However, measuring the level or quantity of innovation is not the focus of this research. The level/amount of innovation performance that supply chain integration has contributed to is not a unit of analysis. This is because that this research only considers innovation performance as an end result of determining whether the SCI integration in the innovation process has been successful or not. As long as there is innovation output in the examined cases (samples) due to the efforts of supply chain integration, the SCI framework can be established. his research does not compare the selected samples (cases) horizontally based on the level of innovation performance or the level of supply chain integration. Therefore, as found the cases, SCI performance is not used to evaluate the outcome or numeric measurement, as long as there is any type of innovation taken place, regardless of the size and amounts of work in the final products, this research views it as a successful SCI process. However, the current case examples did not show significant findings in SCI performance in process innovation.

### *7.2.12 Summary of Research findings*

This research identifies the relationship between SCI capabilities and performance in updated integrated framework (Figure 6.15). Manufacturers in the aerospace manufacturing industry can enhance innovation performance through coordinating SCI capabilities: resource, integration and information sharing along the supply chain. Within the SCI capability of **resource**, strategic orientation sets a preliminary foundation for SCI to take place and the strategic decisions determine whether to engage in SCI or not. According to the empirical findings, the main contributor of SCI capability is external resource and only a few internal resource (from joint research labs) was found in the cases. From the case findings, the reasons to integrate is found to be either lack of internal resources or resource dependence. The **integration** was found in the empirical data the most of the companies initiate SCI from the Design stage, and only a few cases have reported findings in testing stage. The methods of integration were found to be mainly consultation and direct transfer of personnel or knowledge from suppliers to the manufacturers. Co-development is found in the empirical data as well, but the case is special when the suppliers and manufacturers are under the subsidiaries of the same holding group. The level of responsibility depends on the type of integration. From the findings of the 8 case companies, SCI was mainly either buyer-driven or supplier-driven. **Information sharing** includes both technological and non-technological information. Methods of information sharing varies from case to case, but it was evident in the cases that ownership and business strategy affects the method of information sharing. As a result, different types of **SCI performance** are reported in the cases. The causal relationship between SCI capabilities and performance is established and the SCI framework is established and updated from this empirical research. Manufacturers in the aerospace industry are able to enhance their innovation performance through coordinating resources, integration and information sharing along their supply chain.

## 7.3 Theoretical Contributions

The primary contribution of this research is to establish the integrating SCI theoretical framework to fulfil the first research gap. As pointed out in the early chapters, the primary research gap is in the fragmentation and contradictions in existing literatures. The current literatures relating to SCI have been raised from different domains of theories of operations management, strategic management, relationship management, logistics, etc. Such different contexts take different aspects to serve the corresponding research objectives. The existing SCI literatures have mainly been explored in SCM theories and innovation theories, but some of them create fragmentations and sometimes contradicting answers to the relationship between supply chain integration and innovation performance. Theories from various aspects provide different results in relation to SCI, and such differences create confusion for manufacturers when making decisions on whether to implement SCI in their business strategies or not.

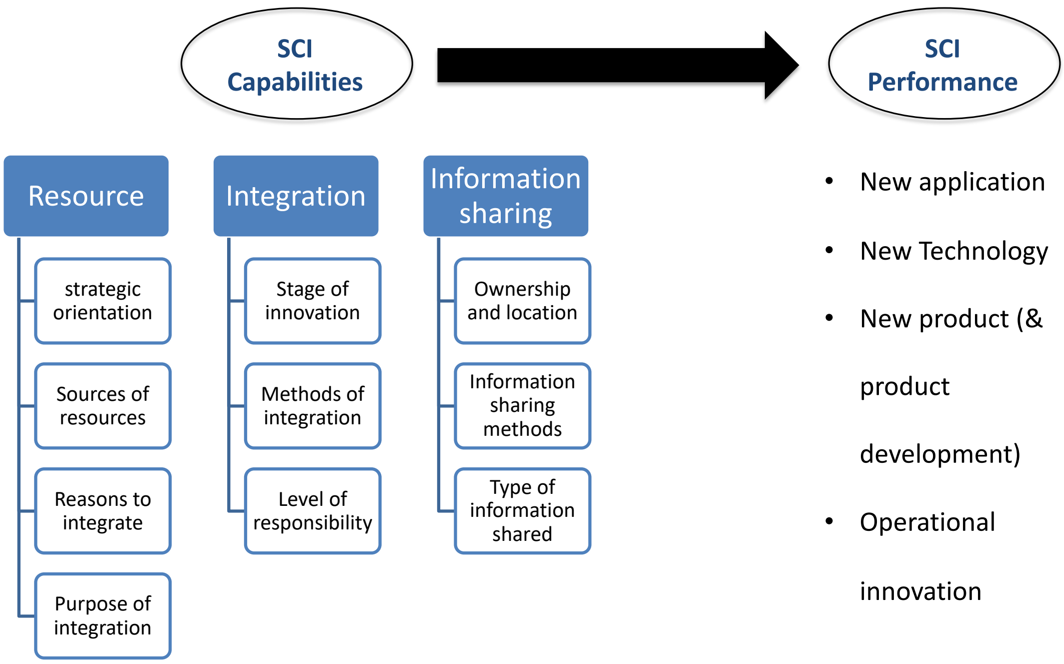



Figure 6.14 integrated framework of SCI

Through reviewing, summarising and integrating different domains of theories on Supply Chain Innovation, a SCI framework was proposed prior to the data collection stage. After collecting, analysing and reviewing empirical data and the linkages between empirical data and existing literatures, this research has established an integrating SCI framework (Figure 6.14). This SCI framework provides a unifying and systematic approach to innovation with traditional aerospace supply chain objectives and complemented by supply chain objectives of enhancing innovation performance.

The second theoretical contribution is that the second research gap has been filled this research. As presented in Chapter 2.4, the second research gap is that the existing literatures take a predominant view from the manufacturers' side but very little on the suppliers' side; this research has fulfilled the gap by collecting data from 4 manufacturers and 4 suppliers in the industry to provides empirical data to enrich the suppliers' side of stories. The research findings from the suppliers' side show no contradictions to the findings from the manufacturers' side and internal validity can be established through collecting data from both sides.

Additionally, as also discussed in Chapter 2.4 of the Research Gap that existing literatures need to be reviewed as to whether they are still applicable, and the contradicting theories need to be answered in the specific industry context. The third theoretical contribution is established through building supporting arguments of existing literatures. Within the SCI framework, the research findings have found supporting evidences to some of the existing literatures. As detailed linkage between research findings and existing literatures have explained in Chapter 7.2, to avoid repetition, this chapter will only give a brief summary of theoretical contribution. This research has supported the theories that strategic orientation have direct influences on firm's innovation strategies (Ferreira, 2014; Sun et al, 2017); the external resources constitute to major sources of SCI (Wasti and Liker, 1997; Ragatz et al, 2002); the main reasons to integrate suppliers in SCI are lack of internal resources and resource dependence (Pfeffer and Salancik, 2003; Bellamy et al, 2014); the main purposes of SCI is to gain access to technology, application (Bellamy et al, 2014) and new market (Schwald, 2008); the main stage of innovation to start SCI is the design stage (Petersen et al, 2005). This research has also found evidences to verify the methods of integration (Petersen et al, 2005), level of supplier's responsibility in SCI, benefit of information sharing (Griffin and Hauser, 1992; Paulraj et al, 2008; Yeniyurt et al, 2014), impacts of ownership on decision making (Petersen et al, 2005), information sharing methods (Petersen et al, 2005).

The forth theoretical contribution of this research derived from findings of this research that extend existing literatures. With regards to the stage of integration, literatures have suggested that integrating suppliers in manufacturers' innovation process has mainly taken place at the design phase of R&D (Ragatz, 2002; Petersen et al, 2005; Jajja et al, 2014). This research has added supporting evidences to the case data that SCI in testing phase is also very common in the industry. Integrating suppliers in the testing phase does not only provide testing services but also knowledge that helps the manufacturers to review and refine initial design (i.e. Case C).

The fifth theoretical contribution of this research is through providing counter arguments of existing literatures that verify the need of reviewing applicability of existing literatures. Literatures have indicated the risk that information sharing increases the ability of replicate manufacturers' success (Ketchen et al, 2007; Salge et al, 2013), but the case data show evidence against this risk that within the aerospace manufacturing industry, chances of replicability are low and due to long innovation and product cycle, replication cannot lead to success (Chapter 7.2.9).

Last but not least, this research has also contributed to the theories by providing answers to the contradictory debates with the supporting findings from the aerospace manufacturing industry. As the research gap has pointed out contradictions in existing literatures, while analysing and discussing the research findings, two contradictory debates can be answered. Firstly, on the one hand, a large number of literatures have suggested that supply chain innovation can provide benefit in innovation (Wasti and Liker, 1997; Ragatz et al 2002; Wynstra et al 2003; Petersen et al 2005; Menguc et al 2014; Yeniyurt et al 2014); on the other hand, literatures have also suggested that integrating suppliers in manufacturers' innovation process increases the level of interdependence (Takeishi, 2001; Yeniyurt et al, 2014) and there are underlying risks of uncertainty (Petersen et al, 2005; Jajja et al, 2017) and the reduction in suppliers' willingness to contribute (Takeishi, 2001; Yeniyurt et al, 2014). This research has found evidences that show low risk of interdependence in the aerospace manufacturing industry (Chapter 7.2.3). Additionally, this research has also provided answer to the asymmetries between benefits of information sharing (Petersen et al, 2005; Yeniyurt et al, 2014) and risk of knowledge spillovers (Roy and Sivakumar, 2011; Salge et al, 2013). Within this research, the risk of knowledge spillovers has been neutralised due to the special characteristics of the aerospace manufacturing industry in China as the highly regulated industry creates a safe environment for information sharing in SCI as technical-intensive knowledge is only shared between trusted partners (Chapter 7.2.8).

## 7.4 Contribution to Managerial Implications

***From the manufacturers' side***

This research raises the awareness of enhancing innovation performance through coordinating capabilities from the supply chain rather than mere in-house R&D. SCI does not work in contradiction with the internal development, instead it complements and broaden the pool of innovation capabilities of the manufacturers. This research gives the industry inspiration to search for alternative innovation capabilities especially when the manufacturers meet bottleneck of innovation or when resources are scarce and the companies need to search for external resources for innovation.

To be more specific, it is for the manufacturer's management team to make the decision on whether to integrate suppliers into its innovation process or not. As illustrated in the SCI framework, decision to engage in SCI or not includes considerations of level of internal resources and capabilities, reasons of integration, purposes of integration and the decisions are also affected by the type of ownership of the manufacture. Once the decision has been made on implementing SCI, the stage of integration, methods of integration and processes of integration and the theoretical innovation outcome have all been detailed in the SCI framework, and the choice of integration methods is dependable to the type of suppliers and suppliers' level of innovation capabilities. However, the SCI framework does not provide a step-by-step guide on the best pathway to supply chain innovation, it is only used as a reference when manufacturers are making decisions on SCI.

Moreover, the research findings have also pointed out that, at the design phase, it is important for the manufacturers to take control of the SCI process even when integrating powerful suppliers such as the engine supplier in Case C. Taking the control of SCI helps manufacturers to neutralise the risk of interdependence. Additionally, during the SCI process, it is also important for the manufacturers to retain patent ownership and IP right of the product/technology in SCI in order to neutralise the risk of replicability and avoid knowledge spillovers.

***From the suppliers' side***

From the suppliers' side, especially for tier 1 supplier in the aerospace manufacturing industry with advanced technology, this research also provides them with the potentials to strengthen relationships with buyers, increase technology capability, enhance operational improvement for the suppliers' benefits to be actively involved through engaging in their manufacturers' SCI process. Keeping these benefits of SCI in mind, if a supplier has decided to be actively engaged in SCI, the SCI framework also works from the suppliers' side. That the supplier can find out the possible methods they can participate into the manufacturers' innovation process, contributions they can make and potential benefits they will receive based on its position on the supply chain and level of technology it possesses.

## 7.5 Limitations and future research

There are three major limitations of this research, the reasons why they exist and possible future research opportunities are presented as below:

The first limitation of this research exists in the situations where the contributions of internal R&D and SCI into innovation performance have merged. The examples discussed in this research only came from scenarios where innovation performance is only a result of SCI projects. Innovating a brand-new aircraft model is not as simple as single project of innovation discussed, in reality, aerospace manufacturers have thousands of SCI projects running in parallel to one another, as well as internal R&D. The measurement of innovation performance of this research can hardly distinguish the contribution of internal R&D and SCI to innovation performance when internal R&D and SCI are combined. In order to deal with the complex situation where more than one innovation projects are considered and different sources of innovation have been employed, there is need to explore a more detailed measurement that can distinguish the innovation performance contribute by SCI and internal R&D. In the future research, a longitudinal research can be used to trace back the level of contribution of each project into the final innovation performance. Conducting a longitudinal study to identify the level of contribution of SCI will enrich this framework, the manufacturers can have a clearer understanding of the level of contribution by each project and design and they will be able to choose the best option to innovation.

The second limitation is about the industry this research is conducted. This research is conducted in the aerospace manufacturing industry in China, which has a lot of industry-specific characteristics that predetermines the research settings. Some of the research findings from this industry are contradictory to the findings of other industries due to the special characteristics of the industry. Even with the establishment of the framework, the conditions for this SCI framework to work and methods of integration are dependable to the nature of products that suppliers provide, level of technology intensity of the relevant products/components, bargaining power of the suppliers, level of availability of manufacturers' internal resource and capabilities and ownership and strategic orientations of the manufacturers. Therefore, the overall framework can be applicable to other high-tech industries that produce complex products and requires integrating suppliers in innovation process, but it needs more research on the applications in other industries within different country specifics. Because the general practices and theories of SCI can be applicable to different industries/countries that share similar characteristics, but where the findings are industry-specific or country-specific, they cannot be generalised to other industries/countries. Therefore, the next step of this research is suggested to explore the generalisability of research findings in this industry to other industry sectors/countries.

The third limitation exists due to the nature of qualitative research. This research establishes an SCI framework that combines different theories from different aspects through case studies from China. However, this only provides a starting point that helps firms in decision making to consider SCI and proposed processes of what to do in decision making on SCI. It provides relationships and patterns between SCI capabilities and performances emerged from the 8 case studies. The SCI framework can be used as a reference in decision making. For situations where two or more options are available, it does not provide the measurement of most effective and efficient step-by-step guide for firms to enhance innovation capabilities through SCI. Due to the nature of qualitative research, the research findings can only be generalised in industries that have similar aspects and context with the aerospace manufacturing industry in China. As qualitative research only establishes causal relationship rather than causality, there is no magic formula that specifies the equation of adding several SCI capabilities to obtain innovation performance. This research has also provided foundations for potential for further quantitative research. The quantitative research is needed to test on the proposed relationship and find out causality within the relationship, thus a best approach to implement SCI will be established.

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# Appendices

## Appendix 1 Secondary Data

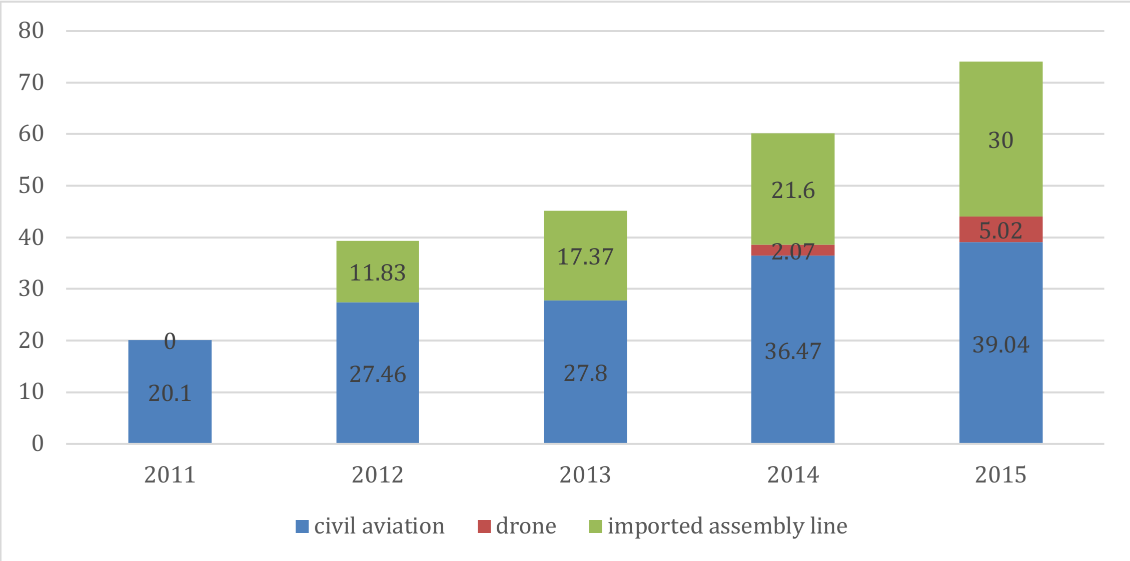


Figure 10.1 Total production volume (monetary value) in civil aviation in China from 2011-2015 (unit: RMB billion)
(Source: Yearbook of Civil Aviation Industry of China, 2017 p3)

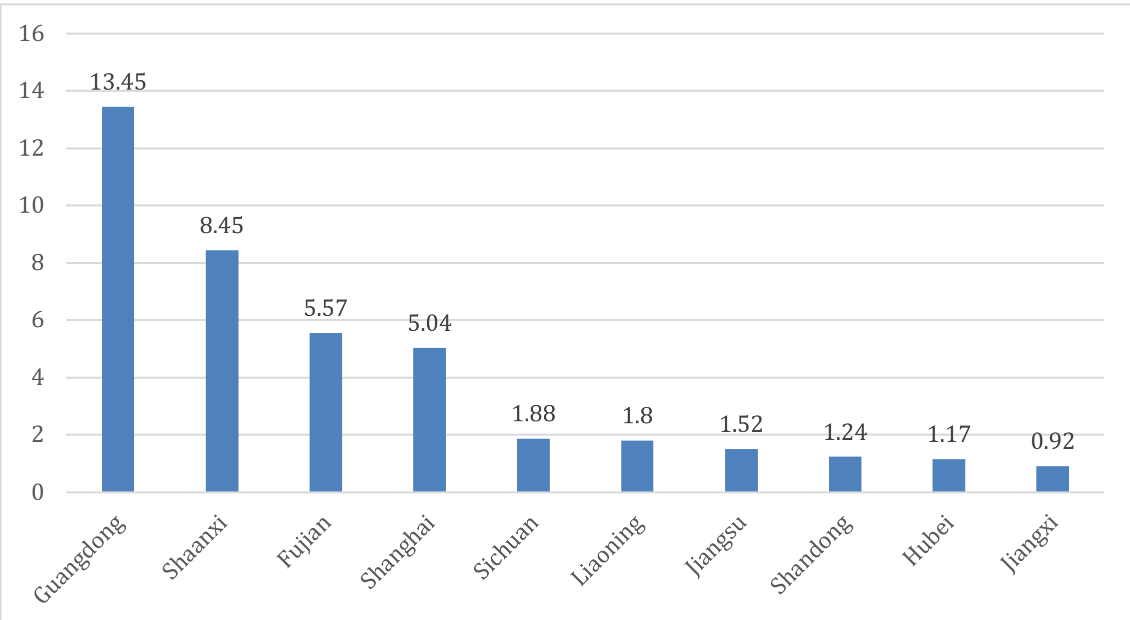


Figure 10.2 Total production volume in Civil Aviation in Regional clusters in China (unit: RMB billion)
(Source: Yearbook of Civil Aviation Industry of China, 2017 p4)

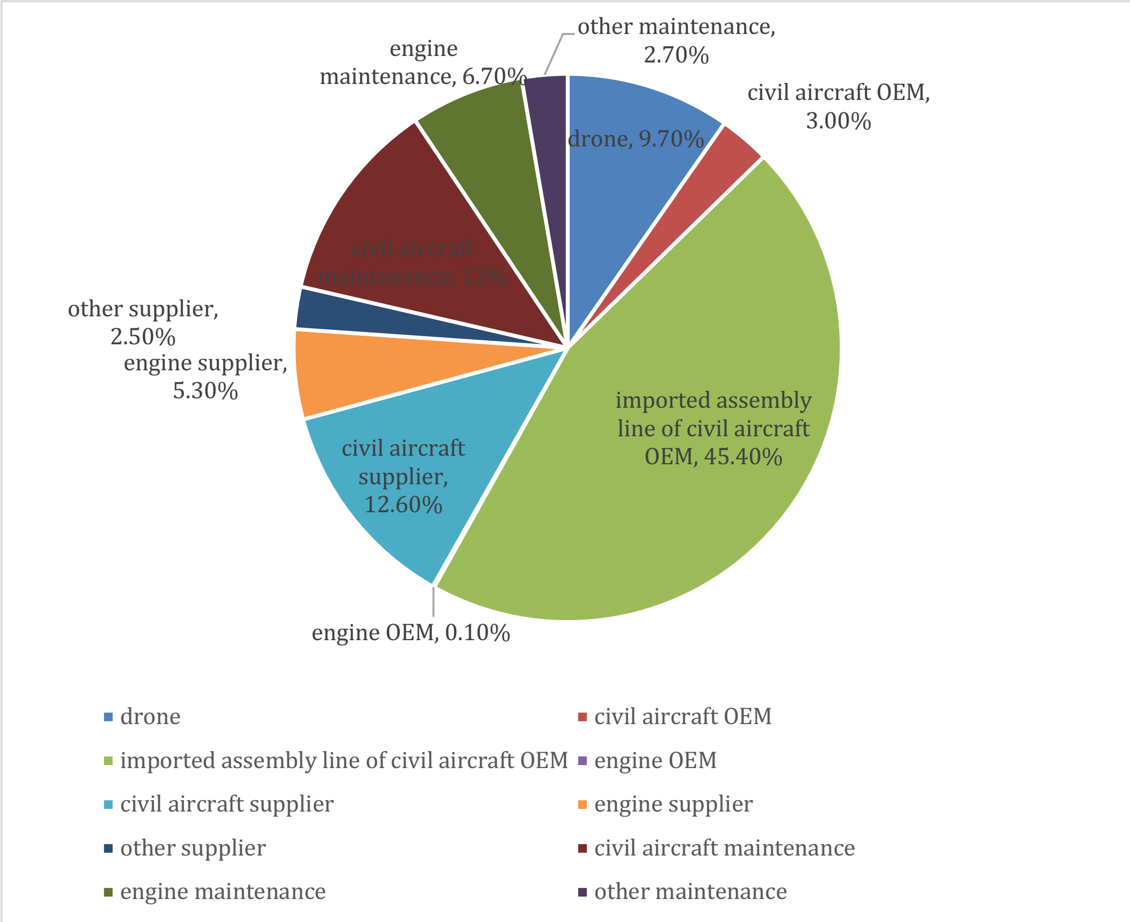


Figure 10.3 Proportion of Value contribution from different divisions of Civil Aviation Manufacturing
(Source: Yearbook of Civil Aviation Industry of China, 2017 p5)

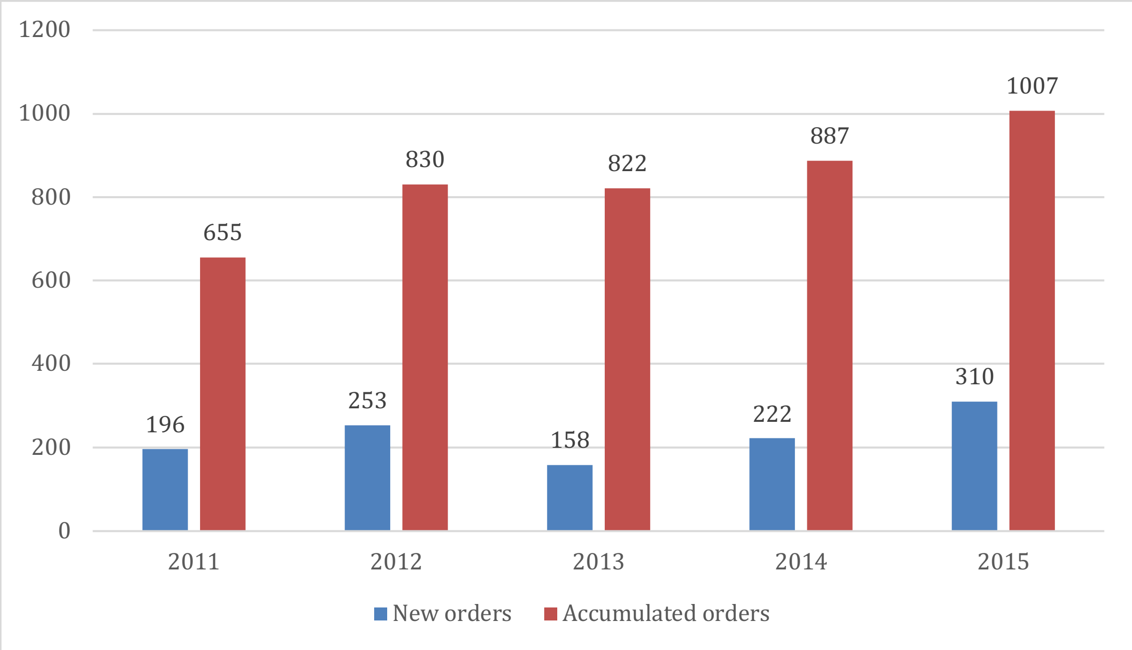


Figure 10.4 Total Orders of civil aircrafts in China from 2011-2015
(Source: Yearbook of Civil Aviation Industry of China, 2017 p6)

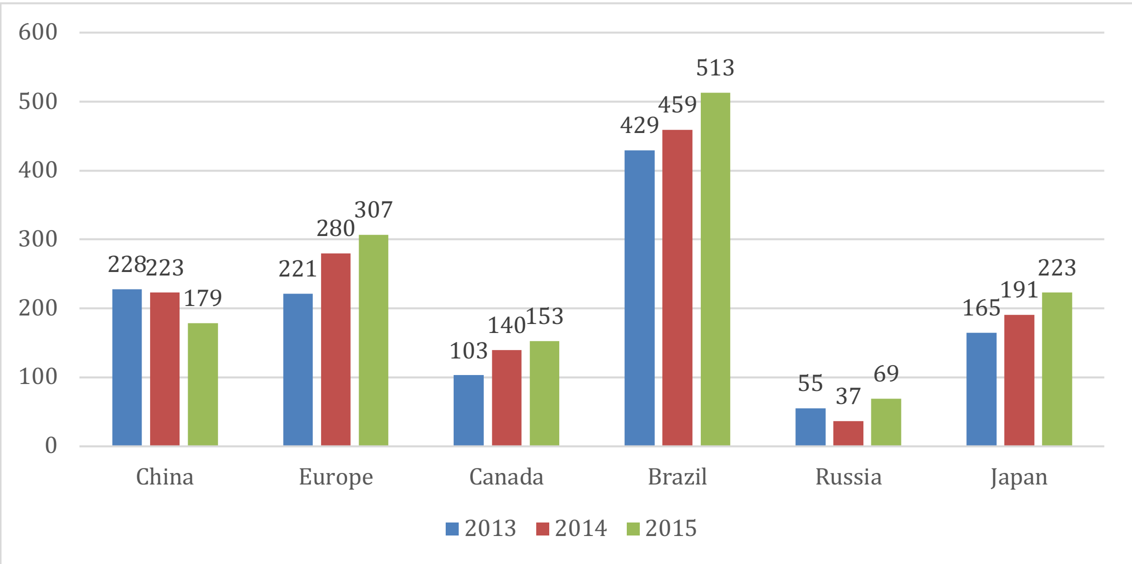


Figure 10.5 Total Confirmed Accumulated orders of regional aircrafts from 2013 to 2015
(Source: Yearbook of Civil Aviation Industry of China, 2017 p6)

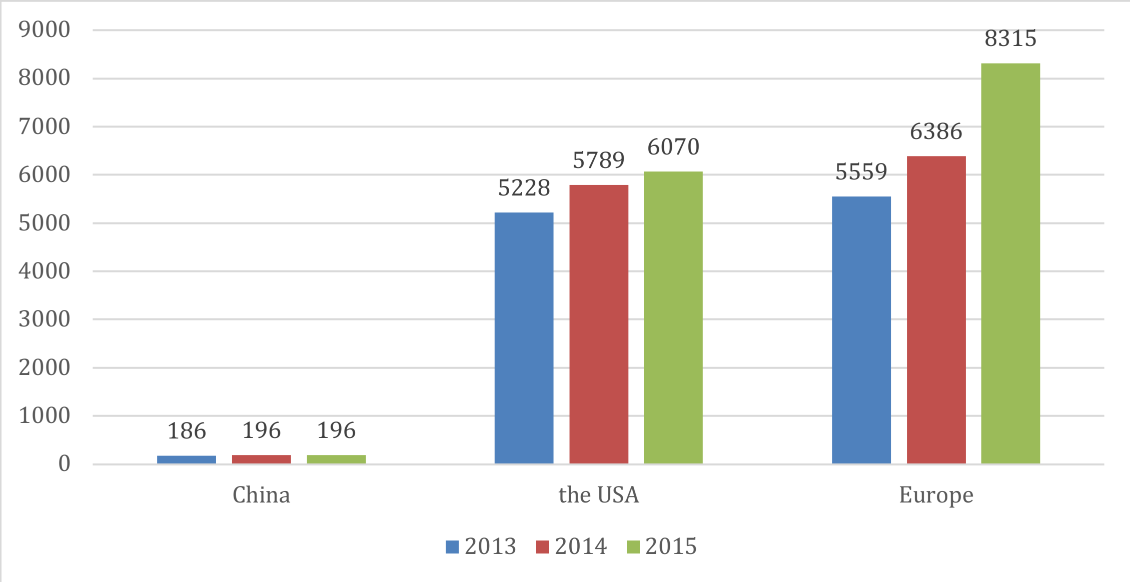


Figure 10.6 Total Confirmed Accumulated orders of mainline aircrafts from 2013 to 2015
(Source: Yearbook of Civil Aviation Industry of China, 2017 p6)

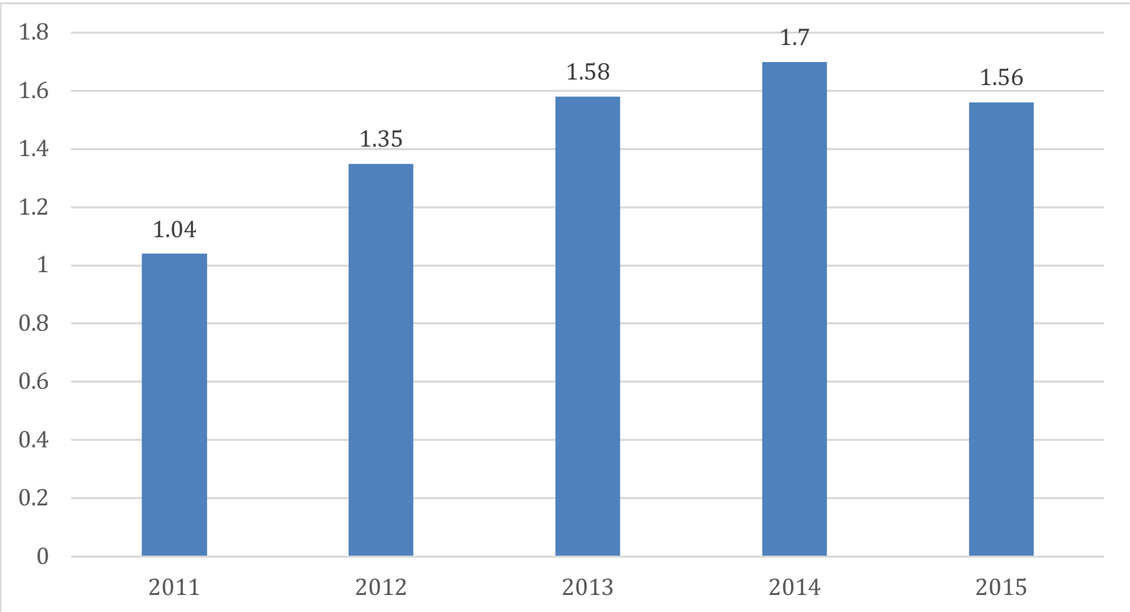


Figure 10.7 Total subcontract production volume (monetary value) in civial aviation in China from 2011-2015 (unit: USD billion)
(Source: Yearbook of Civil Aviation Industry of China, 2017 p7)

Table 10.1 National Civil aviation industry performance in 2015

| | Number of companies | Total employees | Total production volume | Total Revenue | Total Profit |
|---|---|---|---|---|---|
| | | | 000 Yuan | 000 Yuan | 000 Yuan |
| type of ownership | | | | | |
| State-owned | 25 | 45,190 | 1,178,420 | 2,634,300 | 1,742,080 |
| Limited company | 71 | 243,878 | 20,102,300 | 16,427,680 | 5,809,160 |
| Co., Ltd. | 10 | 21,368 | 2,220,960 | 2,482,500 | 357,450 |
| Private enterprise | 24 | 3,565 | 999,880 | 1,331,190 | 123,770 |
| Capital from Special Regions | 7 | 1,180 | 13,811,730 | 7,152,580 | 1,011,780 |
| Foreign capital enterprise | 8 | 2,569 | 35,744,560 | 31,310,060 | 4,003,140 |
| Regions/Location | | | | | |
| East China | 87 | 100,238 | 60,497,530 | 48,761,670 | 7,695,530 |
| Mid China | 24 | 80,344 | 2,936,900 | 3,441,680 | 2,344,160 |
| West China | 34 | 147,788 | 10,623,400 | 9,134,950 | 3,007,700 |

(Source: Yearbook of Civil Aviation Industry of China, 2017 p136)

Table 10.2 Total quantities delivered in civil aircrafts from 2011-2015

| | 2015 | 2014 | 2013 | 2012 | 2011 | Growth rate in 2015 |
|---|---|---|---|---|---|---|
| Mainline aircrafts | 49 | 47 | 44 | 36 | 0 | 4.3% |
| Regional aircraft | 7 | 14 | 6 | 13 | 9 | -50% |
| General Aviation | 74 | 101 | 73 | 57 | 66 | -26.5% |
| Helicopter | 10 | 17 | 26 | 8 | 2 | -41.2% |
| Drome | 612,250 | 312,150 | 96 | 6 | 7 | 96.1% |

(Source: Yearbook of Civil Aviation Industry of China, 2017 p143)

Table 10.3 National Civil aviation industry distribution in 2015 (type of ownership)

| Regions | Total | State-owned | Ltd. | Co., Ltd. | Private | Capital From Special Regions | Foreign capital enterprise |
|---|---|---|---|---|---|---|---|
| Nationwide | 145 | 25 | 71 | 10 | 23 | 7 | 9 |
| Beijing | 12 | 3 | 7 | 0 | 2 | 0 | 0 |
| Tianjin | 10 | 1 | 4 | 1 | 1 | 1 | 2 |
| Hebei | 2 | 0 | 2 | 0 | 0 | 0 | 0 |
| Shanxi | 3 | 1 | 2 | 0 | 0 | 0 | 0 |
| Liaoning | 3 | 0 | 3 | 0 | 0 | 0 | 0 |
| Jilin | 2 | 0 | 2 | 0 | 0 | 0 | 0 |
| Heilongjiang | 2 | 0 | 2 | 0 | 0 | 0 | 0 |
| Shanghai | 8 | 4 | 4 | 0 | 0 | 0 | 0 |
| Jiangsu | 15 | 3 | 4 | 2 | 2 | 0 | 4 |
| Zhejiang | 17 | 0 | 5 | 0 | 11 | 1 | 0 |
| Anhui | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Fujian | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Jiangxi | 3 | 0 | 2 | 1 | 0 | 0 | 0 |
| Shandong | 8 | 2 | 1 | 1 | 2 | 1 | 1 |
| Henan | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Hubei | 8 | 3 | 1 | 1 | 3 | 0 | 0 |
| Hunan | 4 | 1 | 3 | 0 | 0 | 0 | 0 |
| Guangdong | 11 | 1 | 2 | 2 | 1 | 3 | 2 |
| Sichuan | 7 | 1 | 5 | 1 | 0 | 0 | 0 |
| Guizhou | 7 | 1 | 5 | 1 | 0 | 0 | 0 |
| Yunan | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Shaanxi | 18 | 4 | 13 | 0 | 1 | 0 | 0 |
| Gansu | 1 | 0 | 1 | 0 | 0 | 0 | 0 |

(Source: Yearbook of Civil Aviation Industry of China, 2017 p138)

Table 10.4 National Civil aviation industry distribution in 2015 (total number of employees)

| Number of companies | With no. of employees Below 300 | With no. of employees 300-1000 | With no. of employees 1000-2000 | With no. of employees above 2000 |
|---|---|---|---|---|
| Nationwide | 40 | 30 | 23 | 52 |
| Beijing | 6 | 2 | 1 | 3 |
| Tianjin | 5 | 3 | 1 | 1 |
| Hebei | 0 | 0 | 1 | 1 |
| Shanxi | 1 | 0 | 1 | 1 |
| Liaoning | 0 | 0 | 0 | 3 |
| Jilin | 1 | 0 | 0 | 1 |
| Heilongjiang | 0 | 0 | 0 | 2 |
| Shanghai | 0 | 2 | 1 | 5 |
| Jiangsu | 3 | 7 | 2 | 3 |
| Zhejiang | 14 | 2 | 0 | 1 |
| Anhui | 0 | 0 | 0 | 1 |
| Fujian | 0 | 0 | 0 | 1 |
| Jiangxi | 0 | 1 | 0 | 2 |
| Shandong | 5 | 1 | 2 | 0 |
| Henan | 0 | 0 | 0 | 1 |
| Hubei | 2 | 2 | 0 | 4 |
| Hunan | 0 | 1 | 1 | 2 |
| Guangdong | 2 | 4 | 3 | 2 |
| Sichuan | 0 | 3 | 2 | 2 |
| Guizhou | 0 | 0 | 3 | 4 |
| Yunan | 0 | 0 | 1 | 0 |
| Shaanxi | 1 | 2 | 3 | 12 |
| Gansu | 0 | 0 | 1 | 0 |

(Sources: Yearbook of Civil Aviation Industry of China, 2017 p139)

Table 10.5 Regional products delivered status in Civil Aviation industry in China from 2011-2015 (unit: 000 Yuan)

| Regions | 2015 | 2014 | 2013 | 2012 | 2011 | growth rate in 2015 |
|---|---|---|---|---|---|---|
| Nationwide | 66,045,590 | 56,728,440 | 41,664,710 | 233,517,600 | 17,641,240 | 16.4% |
| Beijing | 334,860 | 708,320 | 278,990 | 439,710 | 197,270 | -52.7% |
| Tianjin | 30,213,240 | 21,819,730 | 17,383,960 | 11,901,840 | 40,600 | 38.5% |
| Hebei | 602,170 | 419,220 | 234,410 | 140,050 | 76,390 | 43.6% |
| Shanxi | 6,400 | 46,820 | 39,680 | 23,120 | 670 | -86.3% |
| Liaoning | 1,761,960 | 1,658,940 | 1,549,370 | 2,089,600 | 1,641,580 | 6.2% |
| Jilin | 6,410 | 1,110 | 3,460 | 6,850 | 10,830 | 477.5% |
| Heilongjiang | 732,410 | 1,120,110 | 1,268,220 | 565,850 | 519,200 | -34.6% |
| Sanghai | 531,120 | 514,090 | 453,950 | 436,520 | 437,750 | 3.3% |
| Jiangsu | 715,660 | 1,367,050 | 1,009,540 | 1,013,930 | 355,090 | -47.6% |
| Zhejiang | 407,560 | 107,820 | 38,790 | 28,200 | | 278% |
| Anhui | 4,850 | 11,610 | 233,190 | | | -58.2% |
| Fujian | 5,571,460 | 5,092,610 | 1,487,770 | 1,357,550 | 1,305,340 | 9.4% |
| Jiangxi | 374,690 | 635,260 | 432,180 | 159,670 | 483,760 | -41% |
| Shandong | 502,590 | 1,123,570 | 1,013,570 | 1,089,340 | 904,790 | -55.3% |
| Henan | 36,110 | 53,720 | 5,230 | 2,580 | | -32.8% |
| Hubei | 1,066,590 | 1,033,170 | 1,035,690 | 57,910 | 127,700 | 3.2% |
| Hunan | 428,460 | 293,370 | 202,380 | 210,420 | 195,410 | 49.5% |
| Guangdong | 2,032,350 | 2,301,260 | 1,574,440 | 2,104,320 | 886,320 | 35.8% |
| Sichuan | 574,180 | 599,930 | 572,360 | 482,020 | 500,500 | -11.7% |
| Guizhou | 910 | 1,310 | 900 | 1,590 | | -4.3% |
| Yunan | 6,113,340 | 7,492,840 | 6,558,210 | 6,061,540 | 5,090,320 | -30.6% |
| Shaanxi | 6,113,340 | 7,492,840 | 6,558,210 | 6,061,540 | 5,090,320 | -18.4% |
| Gansu | 2,420 | 2,240 | 7,700 | 2,800 | 2,430 | 8% |

(Sources: Yearbook of Civil Aviation Industry of China, 2017 p144)

Table 10.6 Total revenue in Civil Aviation industry in China in 2015 (unit: 000 Yuan)

| Regions | Total revenue in products sales | Total operating revenue | Product sales revenue/ Operating revenue |
|---|---|---|---|
| Nationwide | 60,338,290 | 213,682,205 | 28.24% |
| Beijing | 806,120 | 7,463,299 | 10.8% |
| Tianjin | 30,373,270 | 35,061,506.2 | 86.63% |
| Hebei | 598,050 | 1,201,630 | 49.77% |
| Shanxi | 4,980 | 546,730 | 0.91% |
| Liaoning | 1,439,870 | 1,548,200 | 93% |
| Jilin | 7,050 | 489,120 | 1.44% |
| Heilongjiang | 1,360,090 | 12,163,450 | 11.18% |
| Sanghai | 4,308,380 | 7,970,227 | 54.05% |
| Jiangsu | 1,291,780 | 7,754,509.2 | 16.66% |
| Zhejiang | 346,410 | 115,051.1 | 301% |
| Anhui | 5,020 | 1,027,597.8 | 0.49% |
| Fujian | 1,400,940 | 1,400,941.6 | 99.9% |
| Jiangxi | 686,780 | 21,894,870 | 3.14% |
| Shandong | 364,020 | 1,772,749 | 20.5% |
| Henan | 36,110 | 4,721,370 | 0.76% |
| Hubei | 966,090 | 8,593,453.9 | 11.24% |
| Hunan | 375,560 | 6,442,240 | 5.83% |
| Guangdong | 6,832,820 | 14,924,400 | 45.78% |
| Sichuan | 1,704,310 | 20,821,260 | 8.19% |
| Guizhou | 466,700 | 10,330,120 | 4.52% |
| Yunan | 900 | 137,090 | 0.66% |
| Shaanxi | 6,960,620 | 46,871,560 | 14.85% |
| Gansu | 2,420 | 430,830 | 0.56% |

(Sources: Yearbook of Civil Aviation Industry of China, 2017 p162)

Table 10.7 Total investment in R&D and fixed assets in 2015 (unit: 000 Yuan)

| Regions | R&D investment | Growth Rate | Fixed assets investment | Growth Rate |
|---|---|---|---|---|
| Nationwide | 9,285,480 | 38.1% | 4,468,110 | -24.9% |
| Beijing | 843,470 | 283.9% | 162,030 | 30.1% |
| Tianjin | 44,760 | 174.9% | 22,960 | |
| Hebei | 42,370 | 43.9% | 241,040 | -42.9% |
| Shanxi | | -100% | | |
| Liaoning | 37,440 | -26.3% | 174,400 | 37.6% |
| Jilin | 280 | | | |
| Heilongjiang | 375,620 | 48.5% | 7,260 | |
| Sanghai | 5,473,090 | 53% | 2,523,490 | -21% |
| Jiangsu | 98,430 | 129.3% | 38,460 | -87.6% |
| Zhejiang | 27,140 | 21.2% | 24,040 | -58.6% |
| Anhui | 680 | 41.7% | | |
| Fujian | | | | |
| Jiangxi | 130,210 | -66.5% | | |
| Shandong | 80,210 | 6.9% | 17,100 | 1477.5% |
| Henan | 23,040 | 2.6% | | |
| Hubei | 24,280 | -69.5% | 128,450 | -3.4% |
| Hunan | 77,080 | 30.4% | 29,810 | 136.2% |
| Guangdong | 241,930 | -39.4% | 279,200 | -67.8% |
| Sichuan | 287,460 | 4.9% | 398,640 | 27.1% |
| Guizhou | 11,350 | | 1,070 | -66.6% |
| Yunan | | | 0 | |
| Shaanxi | 1,466,640 | | 420,160 | -25% |

(Sources: Yearbook of Civil Aviation Industry of China, 2017 p166)

# Appendix 2.1 Research Introduction

## Birmingham Business School
## University of Birmingham

### Aerospace Supply Chain Innovation

***Outcomes***

- An overview of leading practices for aerospace supply chain innovation in China
- A theoretical framework for managing aerospace supply chain innovation
- Practical guidance for improving innovation capabilities through effective supply chain management

***Further information***

Researcher: Sijia He

**Aims**

This research aims to provide theoretical and practical guidance for aerospace manufacturers to enhance innovation capabilities through effective supply chain management.

- To explore key challenges and major trends relevant to supply chain innovation in the aerospace manufacturing industry
- To identify leading practices for effective supply chain management in the aerospace industry through extensive study in China
- To develop theoretical insights and practical guide for manufacturers to enhance their industrial performance in the current business environment.

**Background**

In order to survive in market competition, innovation has become crucially important as well efficient and effective business operations management. Therefore, companies can benefit from both innovation activities and supply chain management through supply chain innovation, enhancing innovation capabilities through effective supply chain management.

The evolution of manufacturing has gone through important stages and paradigms, and businesses re-structuring and re-engineering themselves to adapt to the challenges and demands in the market. During the recent decades, major changes of manufacturing industry,

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like the shifting focuses to service industry and re-emphasising the importance of manufacturing, and the introduction of new technologies have significantly affected the industry. The global aerospace manufacturing industry is highly regulated and it has distinctive characteristics that involve high value adding activities, technology intensive process, high investment, complex supply chain, long production and payback term. This industry requires intensive integration in production and servicing across firms and nations. Due to the uniqueness and importance of this industry, it is important to develop theoretical insights and practical guide for supply chain innovation in the aerospace manufacturing industry China China.

**Key issues to investigate**

- Leading practices of supply chain management in the aerospace manufacturing industry
- Effects/influences of new trends/threats in technology on supply chain management
- Methods that supply chain management can contribute to managing internal and external sources of innovation
- Mechanisms of obtaining competitiveness through supply chain innovation

**Benefit to Companies**

- This research will help companies with industrial positioning: understanding how good you are in supply chain innovation in specific and engineering operations in general
- It will provide a systematic theoretical framework for managers to identify the methods of improving innovation capabilities through effective supply chain management
- It will also suggest practical working tools for companies to gain sustainable competitiveness for the future

# Appendix 2.2 Research Introduction---Chinese

# 英国 伯明翰大学商学院

**面向航空航天制造业创新管理的供应链管理理论及方法**

**---中国航空航天制造业深入研究**

***拟研究成果***

- 深入分析中国航空航天制造业供应链创新管理模式
- 支持航空航天制造业创新管理的供应链理论模型
- 通过供应链管理提升航空航天制造业创新能力的具体实践方法

**研究目标**

- 分析当前航空航天制造业的发展趋势及挑战
- 研究支持航空航天制造业创新能力提升的先进供应链管理模式
- 为提高航空航天企业创新力及竞争力提供全方位理论及实践支持

**研究背景**

在发展过程中，制造业企业往往需要通过重组企业结构、更新设计生产流程、调整市场定位等方式来适应不断变化的市场环境以及逐渐加剧的竞争趋势。近年来，服务业蓬勃发展的趋势有所减退，国家政策的调整以及新兴技术的诞生为制造业带了新的发展机遇与挑战，行业政策以及新兴技术已成为影响制造业发展的关键因素。作为典型的政策管控和知识密集型产业的航空制造业，具有产品附加值高、高科技集中、

投入成本高、供应链复杂等特征。同时，航空航天产品生产周期长、收益回收慢的特点决定了航空航天制造业具有较高的利润风险。为此，如何有效提高航空航天制造业企业创新能力与效益已成为相关领域的研究热点。

本研究从供应链管理出发，深入研究中国航空航天制造业的供应链管理模式，研究通过供应链管理提升企业创新能力的方法，为提高企业可持续竞争力提供理论及实践支持。

**关键问题**

- 深入研究中国航空制造业的先进供应链管理模式
- 分析新兴技术为航空航天制造业供应链带来的机遇与挑战
- 研究通过供应链管理提高企业创新能力的理论方法
- 研究创新对提升航空航天制造业可持续竞争力的作用

**应用价值**

- 帮助航空航天相关企业发现自身优势，评估企业现有供应链管理模式
- 为企业提供支持创新能力提升的供应链管理理论框架及实践方法
- 为企业提供通过创新管理提高可持续竞争力的相关方法

***参研人员及联系方式***


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# Appendix 3.1 Consent Form

**Research topic:**

Aerospace Supply Chain Innovation

This research aims to provide theoretical and practical guidance for aerospace manufacturers to enhance innovation capabilities through effective supply chain management. It intends to explore key challenges and major trends relevant to supply chain innovation in the aerospace manufacturing industry; identify leading practices for effective supply chain management in the aerospace industry through extensive study in China and develop theoretical insights and practical guide for manufacturers to enhance their industrial performance in the current business environment.

The information you provide will be kept anonymous. The information will only be analysed and processed for the purpose of the researcher's PhD research and any potential non-commercial uses, such as: publishing journal article, conference paper and book. The information will not be archived in public database. The full information you provide will not be published; only anonymised summaries of data results will be published.

This information is collected as part of a research project concerned with aerospace supply chain innovation by the Department of Management in the University of Birmingham. The information that you supply is part of the research project that will be entered into a filing system or database and will only be accessed by authorised personnel involved in the project. The information will be retained by the University of Birmingham and will only be used for the purpose of research, statistical and audit purposes. By supplying this information you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

By signing this consent form:

- I confirm that I have read and understand the participant information leaflet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. If I withdraw, my data will be removed from the study and destroyed.
(Please note that the revocation of consent can only be made before 1st June 2017; otherwise implied waiver of revocation right will be assumed)
- I understand that I have the right to refuse to answer any question if I feel the answers may involve confidentiality of myself or my company.
- I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.
- Based upon the above, I agree to take part in this study.

Name of participant...................................................... Date...............

Do you consent with the researcher to digitally record the conversation or not?
(Please tick the relevant)
Yes ☐ No ☐

Signature....................

To be completed by the researcher:
Name of researcher/
individual obtaining consent......................................... Date...............

Signature....................

# Appendix 3.2 Consent Form---Chinese

**参与研究项目同意书**
**Consent Form**

**研究课题**

**面向航空航天制造业创新管理的供应链管理理论及方法**
**–––中国航空航天制造业深入研究**

**Research topic:**
Aerospace Supply Chain Innovation

本研究从供应链管理出发，深入研究中国航空航天制造业的供应链管理模式，研究通过供应链管理提升企业创新能力的方法，为提高企业可持续竞争力提供理论及实践支持。本研究拟研究成果为：中国航空航天制造业供应链创新管理模式深入分析；支持航空航天制造业创新管理的供应链理论模型；通过供应链管理提升航空航天制造业创新能力的具体实践方法。其应用价值为：帮助航空航天相关企业发现自身优势，评估企业现有供应链管理模式；为企业提供支持创新能力提升的供应链管理理论框架及实践方法；以及为企业提供通过创新管理提高可持续竞争力的相关方法。

This research aims to provide theoretical and practical guidance for aerospace manufacturers to enhance innovation capabilities through effective supply chain management. It intends to explore key challenges and major trends relevant to supply chain innovation in the aerospace manufacturing industry; identify leading practices for effective supply chain management in the aerospace industry through extensive study in China and develop theoretical insights and practical guide for manufacturers to enhance their industrial performance in the current business environment.

贵司提供的任何信息将会被匿名保存，所有信息和资料的原文不会以任何形式被保存在公共信息库。相关信息将会被分析、整理和总结之后发布于且仅用于研究者博士毕业论文以及相关学术论文、期刊、教材，不用于其它任何商业目的。

The information you provide will be kept anonymous. The information will only be analysed and processed for the purpose of the researcher's PhD research and any potential non-commercial uses, such as: publishing journal article, conference paper and book. The information will not be archived in public database. The full information you provide will not be published; only anonymised summaries of data results will be published.

该航空航天供应链与创新管理研究隶属于英国伯明翰大学商学院，作为研究的一部分，并且出于统计以及审核的目的，贵司提供的信息也许会收录入伯明翰大学资料库，且仅会被研究者以及伯明翰大学相关授权教职工查阅。签署该文件表明贵司同意伯明翰大学保存贵司所提供的资料且仅用于以上目的。所有资料将会匿名存储并且不会发布任何可识别贵司名称及个人身份的信息。在存储处理过程及使用中，伯明翰大学将会遵守《信息保护法 1998》。

This information is collected as part of a research project concerned with aerospace supply chain innovation by the Department of Management in the University of Birmingham. The information that you supply is part of the research project that will be entered into a filing system or database and will only be accessed by authorised personnel involved in the project. The information will be retained by the University of Birmingham and will only be used for the purpose of research, statistical and audit purposes. By supplying this information you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

签署此同意书表明：
By signing this consent form:

- 我确认我已阅读并明白该研究的研究目标与研究范围；我有权利对研究者提出问题并得到满意的答案。
- I confirm that I have read and understand the participant information leaflet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.

- 我自愿参与本研究，并且明白我有权在 2017 年 6 月 1 日前任意时刻要求退出本研究（逾期将自动视为愿意继续参与研究）。一旦我退出研究，研究者不得保留/发表任何与我公司相关的调研资料。
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. If I withdraw, my data will be removed from the study and destroyed. (Please note that the revocation of consent can only be made before 1st June 2017; otherwise implied waiver of revocation right will be assumed)

- 我明白如果我觉得答案涉及企业机密，我有权拒绝回答研究者提出的问题。

- I understand that I have the right to refuse to answer any question if I feel the answers may involve confidentiality of myself or my company.

- 我明白我的个人及公司信息会被且仅被使用于该学术研究，并且受到数据保密协议相关法律保护。
- I understand that I have the right to refuse to answer any question if I feel the answers may involve confidentiality of myself or my company.- I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.

- 根据以上信息，我同意参与此次调研。
- Based upon the above, I agree to take part in this study.

您是否同意您的对话被录音？（请勾选相关选项）
Do you consent with the researcher to digitally record the conversation or not?

是 YES ☐ 否 NO ☐

参与者：...................................................... 日期：...............

参与者签名：....................

以下信息均由研究者填写：
To be completed by the researcher:

研究者：...................................................... 日期：...............

研究者签名：....................

# Appendix 4.1 Interview Schedule for Pilot Study

**Moderating context**

1. Company's corporate governance, culture and leadership style
    1) What is the type of ownership of your company (maybe search for this information before the interview)?
    2) What is the type of leadership style you think your company adopts (maybe search for this information before the interview)?
2. Location, Cluster
    1) Is there any specific reason for this location choice of your company?
3. Experiences in difficulties and challenges for current industry
    1) What do you think of your company's overall performance so far?
    2) Do you think your company is facing any kind of challenges? i.e. new technology, competition, etc.

**Aerospace supply chain innovation capabilities 1/2**

4. R&D investment
    1) What is your annual investment in R&D
    2) What is the industry average(maybe search for this information before the interview)?
5. R&D personnel
    1) What is the number of R&D personnel you have in your company? (i.e. PhD, scientists, etc.)
    2) What is the industry average (maybe search for this information before the interview)?
6. R&D equipment and infrastructure
    1) What is the number of R&D equipment and infrastructure in your company? (i.e. research centre, experiments test grounds, etc.)
    2) What is the industry average (maybe search for this information before the interview)?

**Aerospace supply chain innovation capabilities performance**

7. Patent registration
    1) What is the number of your company's annual patent registration?
    2) What is the industry average (maybe search for this information before the interview)?
8. New product and product improvement
    1) What percentage of sales does new product/improved product contribute into your company's annual sales?
    2) What is the industry average (maybe search for this information before the interview)?
9. Financial performance
    1) What kind of benefits or disadvantages do you think your new product/innovation have brought to your company financially?
10. Design performance
    1) What kind of benefits or disadvantages do you think your new product/innovation have brought to your company in terms of operational performance?

**Aerospace supply chain innovation capabilities 2/2**

11. Involvement of supplier in R&D
    1) Do you engage your supplier at the process of R&D?
    2) At what stage do you start to let your supplier to involve in R&D? (i.e. early product design, product R&D, experiments testing, etc.)
12. Supplier selection criteria
    1) Do you choose your supplier based on innovation capability or cost, or any other criteria?
    2) Which one do you think is the most important criteria when you select a supplier?
13. Information sharing system with suppliers
    1) How do you share your information with your supplier?
    2) What kind of information do you share with your supplier?
14. Activities maintaining supplier relations

1) How does your company maintain supplier relations?
2) Does your company also have social-networking events with your suppliers? How often?

15. Processes of supply chain: current status and challenges

1) Do you find your current supply chain efficient and effective enough?
2) What kind of challenges you think you are facing with your supply chain?

# Appendix 4.2 Interview Schedule for Pilot Study---Chinese

**调研问题**

**一、企业背景与现状**

1. 公司背景资料与所有制
2. 公司地理位置：在公司选址的时候是否有特别的考量因素？
3. 公司现有业绩与成果
    a. 您怎样评价贵公司现有的业绩与成果？
    b. 您认为贵公司目前面临那些挑战？

**二、企业创新战略管理**

4. 创新再企业战略决策中的地位
5. 每年对于产品研发的投资大致是多少？占销售收入百分比？
6. 产品研发的人员数量多少？
7. 研发中心的数量以及研发基础配套设施（例如：试验场地）大致是多少(面积)？研发中心之间的关系（平行进行，相互辅助，一方主导其他方支持）？
8. 每年专利注册数，申请成功的专利数是多少？
9. 新产品（含现有产品的改进产品）的销售额占总销售额的百分比？
10. 您认为新产品（含现有产品的改进产品）对公司财政业绩是否有提高？或者带来了新的挑战？
11. 您认为新产品（含现有产品的改进产品）对公司流程优化是否有提高？或者带来了新的挑战？

**三、生产与销售**

12. 客户的主要来源：国内外比例
13. 供应商来源：国内外比例（各个国家的比例）

14. 新产品研发到投入市场所需时间
15. 现有产品生产所需时间
16. 现有机型的生产，组装或整机生产或零部件供应？

**四、供应商关系**

17. 在研发过程中是否有供应商的参与？如果有，供应商在哪一阶段开始参与研发（研发设计，研发过程，成果测试）？
18. 如供应商参与研发，供应商在研发中的作用和贡献？
19. 供应商选择
    a. 贵司选择供应商的标准有哪些？
    b. 您认为其中哪一条是贵公司最看重的标准？
20. 供应商信息共享平台
    a. 贵公司是否会与供应商信息共享？
    b. 贵公司会与供应商共享哪种类型的资料？
    c. 贵公司通过什么渠道与供应商实现信息共享？
21. 贵公司通过哪些渠道维系与供应商的关系？（例如：年会，保持信息资源共享，重复订单，等）
22. 您觉得贵公司现有供应链管理是否有效？是否面临挑战，如果有，请举例说明？

# Appendix 5.1 Interview Schedule for actual data collection

**Interviewee's background**

1. Name, Position at the company, years of employment

**Moderating context & overall information**

2. Company Background information
    1) Years of establishment, total number of employees, total number of employees in Supply Chain department, number of departments and subsidiaries
    2) Company's corporate governance, culture and leadership style
    3) Location: Is there any specific reason for this location choice of your company?
3. What is the importance of supply chain strategies in the overall company's strategic decisions? (What is the estimated percentage of Supply chain strategies of the overall company's strategic decisions?)
4. Do you have overseas supplier/customers? Do you think political support/regulations will affect your overall performance, access to resource, access to suppliers and access to market or not? And How are they affecting?
5. Supply chain: current status and challenges
    1) What kind of challenges you think you are facing with your supply chain?

2) What kind of opportunities you think you are expecting with your supply chain?

6. Experiences in difficulties and challenges for current industry

    1) What kind of challenges you think you are facing with your company's overall performance?

    2) What kind of opportunities you think you are expecting with your company's overall performance?

**Aerospace supply chain innovation capabilities**

7. Innovation investment (exact amount/%)

    1) What is your current resources capital for innovation?

    2) What is your annual investment in innovation?

    3) How much of the investment is your company's internal investment?

    4) How much is from the co-development projects with your supplier?

    5) How much is directly from the supplier?

8. Innovation personnel

    1) What is the number of R&D personnel you have in your company? (i.e. number of engineers, number of PhD students, number of researchers, etc.)

    2) How many of the people are your company's internal personnel?

    3) How many are from the co-development projects with your supplier?

    4) How many are directly from the supplier?

9. innovation equipment and infrastructure

    1) What is the number of R&D equipment and infrastructure in your company? (i.e. research centre, experiments test grounds, etc. & background of research

centres: state founded, university oriented, or company owned) (industry average, and how they would benefit the firm’s performance)

2) How many of the facilitates are from your company’s internal investment?

3) How many are the co-development projects with your supplier?

4) How many are directly from the supplier?

10. New knowledge and technology

1) How much of the new knowledge is your company’s internal development?

2) How much is from the co-development projects with your supplier?

3) How much is directly from the supplier?

11. Innovation related Supplier selection criteria

1) What are the supplier selection criteria? (cost, innovation capability, technology capability, commercial capability, understanding and meeting your goals, etc.)

2) How would you value the importance of each criterion when you select a supplier?

12. Innovation related Supplier coordination

1) How do you share your information with your supplier?

2) What kind of information do you share with your supplier?

3) What kind of activities/measures do you take in order to maintain your relationship with your suppliers?

**13. Involvement of supplier in innovation**

1) At what stage do you start to let your supplier to involve in innovation? (i.e. early product design, R&D process, experiments testing, production, etc.)

2) What kind of resources are you receiving from the suppliers? (access to resources, capabilities, etc.)
3) How the suppliers are involved in your innovation process?
4) Will supplier’s history/background affect your access to the capability? (the accessibility to information, technology, and skills; supplier’s ability to provide such capabilities; the willingness to establish the relationship, etc.)
5) What are the reasons of involving supplier at the process of innovation? (i.e. supplier’s capability: to see if one product is out of the reach of supplier’s capability; interviewee’s firm’s capability: to get access to supplier’s specific knowledge, technology and skills, etc.)
6) Why do you choose to extract supplier’s innovation resources instead of developing internal resources?
7) What are the internal investment/development you make in order to facilitate the innovation resources from co-development projects with supplier/directly from supplier?
8) Benefits/disadvantages
    i. What are the benefits of involving suppliers in innovation?
    ii. Do you think there is any risks associated with involving suppliers in innovation? (i.e. path dependency, resource dependency, etc.)
9) Do you think any of the supplier selection criteria may affect/compromise the deployment of supplier’s capabilities? (i.e. try to cut cost may hinder the access to supplier’s ideas and innovation, etc.)

**Aerospace supply chain innovation capabilities performance**

14. Patent registration

1) What is the number of your company's annual patent registration?
2) How much is developed internally?
3) How much is developed with suppliers?
4) How much is directly transferred from suppliers?

15. New product and product improvement

1) What percentage of sales does new product/improved product contribute into your company's annual sales?
2) How much is developed internally?
3) How much is developed with suppliers?
4) How much is directly transferred from suppliers?

16. Financial performance

1) What is the increase (decrease) in sales/profitability since the involvement of supplier in innovation process?

17. Operational performance

1) What is the improvement in operational performance since the involvement of supplier in innovation process? (cost, quality, delivery time, efficiency, etc.)

# Appendix 5.2 Interview Schedule for actual data collection---Chinese

2016 年伯明翰大学航空行业供应链创新调研提要

**一、基本资料**

1. 姓名，职位，加入企业时间

**二、企业基本信息（相关数据无需精确数据，可以是大概数据，或者百分比）**

2. 企业背景资料
    1) 成立时间，员工数量，与供应部相关的员工数量，部门总数与分公司总数
    2) 企业所有制及管理模式
    3) 企业地理位置：在企业选址的时候是否有特别的考量因素？
3. 您认为供应链的决策在企业战略决策中的重要性（百分比）？
4. 贵企业是否有来自海外的供应商/客户？您认为相关政策与法律法规是否会影响贵企业的绩效？以及如何是如何影响的？
5. 供应链管理的现状、机遇与挑战
    1) 您认为贵企业的供应链管理目前面临哪些挑战？
    2) 您认为贵企业的供应链管理将会迎来怎样的机遇？

6. 行业的现状、机遇与挑战

   1) 您认为贵企业在该行业目前面临哪些挑战？

   2) 您认为贵在该行业将会迎来怎样的机遇？

**三、航空行业供应链创新能力**

7. 研发投入（具体数据/百分比）

   1) 每年研发的投入是多少?

   2) 往年累计投入总和是多少？

   3) 研发投入中，企业自主投资占多少？

   4) 研发投入中，与供应商合作项目投资占多少？

   5) 研发投入中，供应商直接投资占多少？

8. 研发人员

   1) 产品研发的人员数量多少？（例：工程师数量，博士生数量）

   2) 研发人员中，企业自身研发人员占多少？

   3) 研发人员中，与供应商合作研发项目人员占多少？

   4) 研发人员中，供应商人员直接参与占多少？

9. 研发中心以及研发基础设施

   1) 研发中心的数量以及研发基础配套设施（例如：试验场地）大致是多少(面积)？（在行业的先进性以及技术水平）

   2) 其中，企业自有设施占多少？

3) 其中，与供应商合作研发项目设施占多少？

4) 其中，供应商直接投入设施占多少？

10. 新技术产生

1) 企业自主研发新技术有多少？（多少来源于自主研发？多少来源于并购与技术转移？）

2) 与供应商合作研发项目产生的新技术数量为多少？

3) 供应商直接投入新技术占多少？

11. 创新相关供应商选择标准

1) 贵司选择供应商的标准有哪些？

2) 您认为每条标准所占比重是多少？哪一条是贵企业最看重的标准？

12. 创新相关供应商合作

1) 贵企业怎样会与供应商信息共享？

2) 贵企业会与供应商共享哪种类型的资料？

3) 贵企业通过哪些渠道维系与供应商的关系？

13. 供应商对创新能力的影响

1) 在研发过程中是否有供应商的参与？如果有，供应商在哪一阶段开始参与研发（前期研发设想，研发过程，成果测试）？

2) 如供应商参与研发，供应商在研发中的作用和贡献？贵企业能从中获得什么资源？

3) 供应商是怎样参与到研发当中？

4) 您是否觉得供应商的背景与历史对他们投入的创新能力有一定的影响？

5) 选择供应商参与到研发中的原因？

6) 为何选择不完全自主研发内部资源？

7) 为了更有效地协调与供应商的合作研发项目（或供应商直接投入的技术），贵企业是怎样投入/改进现有设备/资源的？

8) 优势与风险

   i. 您认为供应商参与研发为企业带来什么优势？

   ii. 您认为供应商参与研发为企业带来什么风险？

9) 您认为，贵企业现有的供应商选择标准会影响供应商在合作研发项目中的资源投入吗？

**四、航空行业供应链创新绩效**

14. 专利注册：每年专利注册数，申请成功的专利数是多少？（细分：企业内部研发的数量，企业与供应商合作研发数量，供应商直接投入的数量）

15. 新产品：新产品（含现有产品的技术改造与升级）的销售额占总销售额的百分比？（细分：企业内部研发的数量，企业与供应商合作研发数量，供应商直接投入的数量）

16. 经济效益：积极投入供应商合作项目是否对企业的销售额/利润带来提高（具体数据是多少）？

17. 企业运营管理绩效：积极投入供应商合作项目是否对企业的运营绩效带来提高？

# Appendix 6 Logic Model of each case company

Logic model can 'stipulate and operationalise complex chain of occurrences or events over an extend period of time' (Yin, 2014). Therefore, logic models are used in this research when summarising and analysing case findings. These models can provide an overview to the researcher as well as the readers brief information of each company. The logic models of each company include company background information, secondary data the researcher has searched from company websites, data archives, annual public reports of the civil aviation industry in China, documentaries, news clips and also information received during interviews with the respondents of this case study research.

Appendix 6.1 Logic Model: Case A

Scenario 1: new & product development

**Design**

- US subsidiary company design the general aircraft;
- core R&D: outsource to state-owned research centres; co-work with stated-owned research centres/universities; engineers and research personnel from suppliers for technical assistance;
- core product: key technology is in suppliers: i.e. avionics, engine, etc. Suppliers retain the core-technology, but release product information & specifications for company A to design the aircraft to fit the installation of the products

Internal R&D department of Company:
1. follow the complete design of the aircraft, supervise the design from suppliers;
2. for several co-work projects, co-work with suppliers, universities, research centre personnel to develop internal capability;
3. oversees, coordinate the design process;
4. learn and gain technology through direct transfer, and retain full IP right for designs from suppliers;
5. also receive R&D personnel from suppliers for technology assistance to improve internal capability for later stage

**Model Building**

- different products came from the suppliers;
- company A assembles the product

actively engaging with suppliers to fulfil the design

**Supplier requirement:**
1. more experienced suppliers;
2. look for suppliers' ability to innovate within themselves to keep up with the technology advancement;
3. quality, cost, etc. (all other requirement)

**Testing**

- outsources testing stage to suppliers that have testing/experiment facilities;
- company A oversees the process-record & report the process.

[actively engage with suppliers who were involved I the design process to share information & receive assistance]

**Production**
information sharing with suppliers is minimum

Improve A's overall innovation capability through developing from supply Chain

Can also reach the outcome, but it is full of uncertainty

**Competing Model**
In-house R&D
Difficulties:
1. lack of talent & experience;
2. lack of capability/no capability in certain area;
3. everything will be starting from scratch: i.e. engine design---not being able to keep up with the technology advancement (may take more than 10 years to reach other firms' current technological performance;
4. full of uncertainty;
5. cost inefficiency

**Outcomes**

**Immediate outcome:**
new technology to company A, customised product (scenario 2)

**Intermediate outcome:**
New product/product development

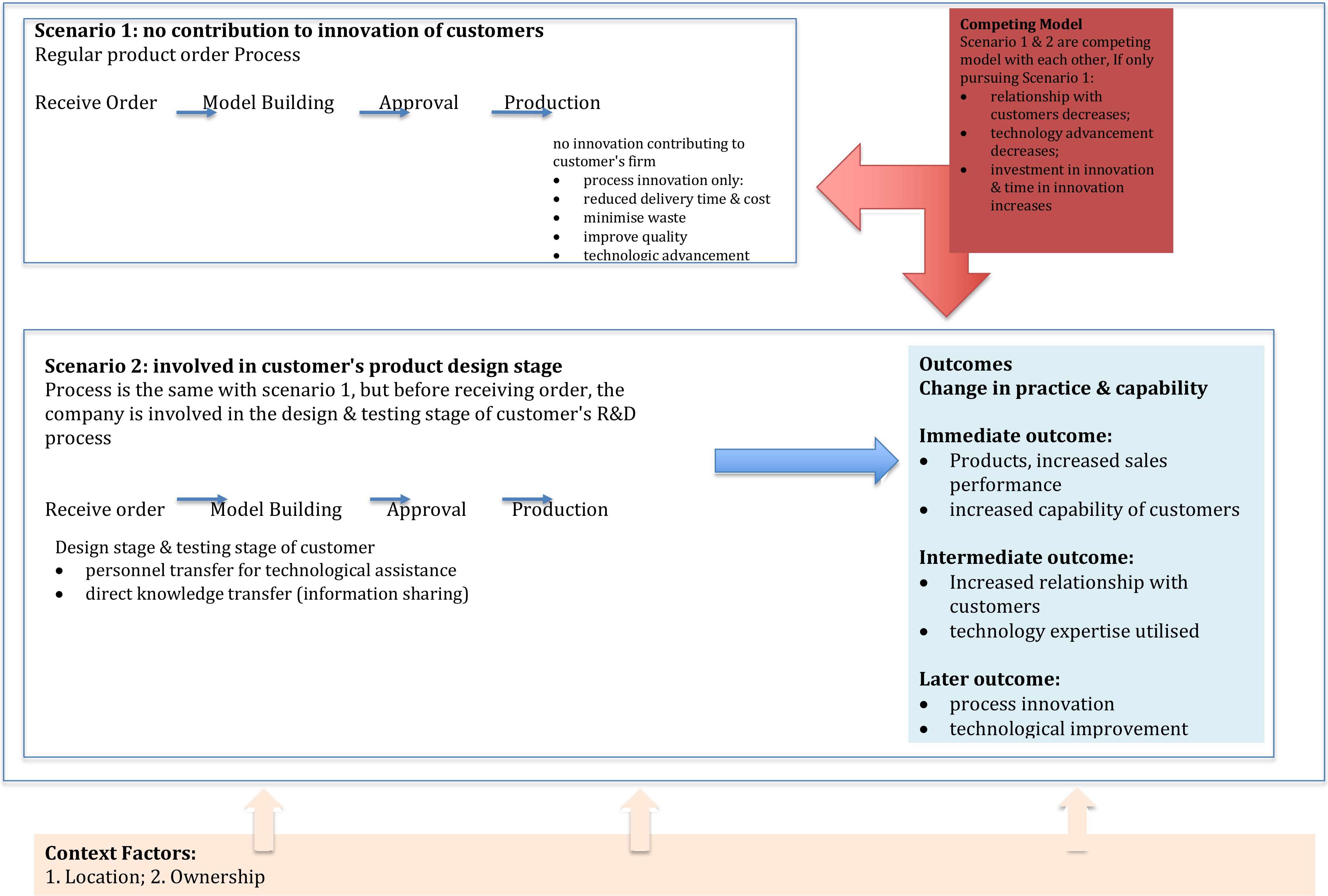
**Later outcomes:**
Operational innovation: reduction in investment in R&D; reduced time of R&D (opposing to the competing model)

Scenario 2:
Internal R&D: straight forward customisation of current products
very little engagement with suppliers in R&D

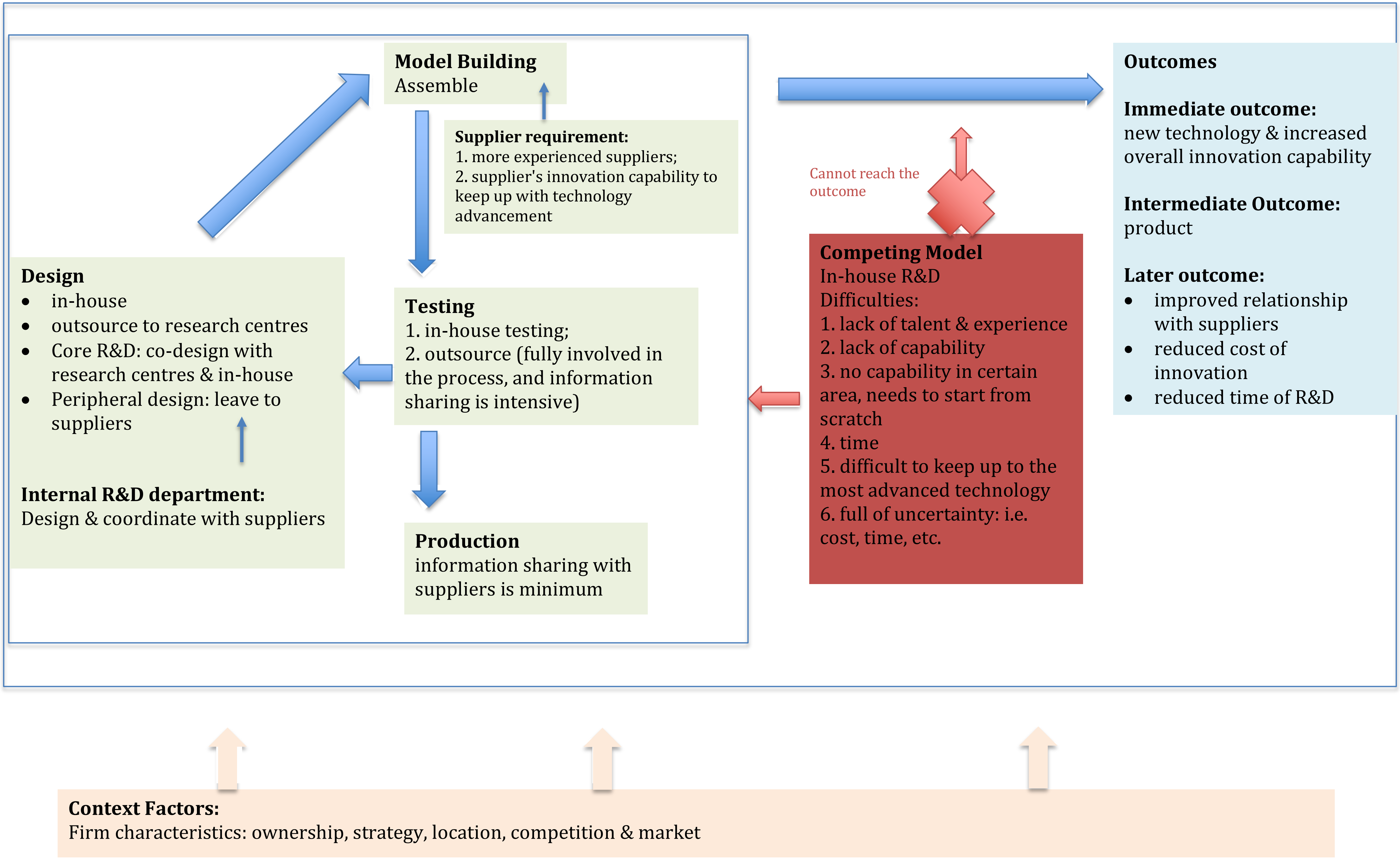
**Production**

**Context Factors:**
1. company strategy
2. Location
3. government support & limitations
4. international market:

Appendix 6.2 Logic Model: Case B



Appendix 6.3 Logic Model: Case C



Appendix 6.4 Logic Model: Case D

As a customer

- in-house R&D only (in-house R&D and outsource testing stage)
- technology transferred through JV

**immediate outcome:** new product

**intermediate outcome:** improved technology advancement

**Competing model**
outsource/supplier coordination in innovation

- can be good/beneficial
- However, waste the JV and everything beneficial from JV
- already capable of innovation, can wait till internal innovation capabilities are fully exploited

As a supplier (direct supplier to company E)

- very strong relationship with Company E
- in product design & development:
  - personnel transfer for technologic assistance
  - direct knowledge transfer (information sharing)

Change in practice & capability

**Immediate Outcome:**

- products, increased sales performance
- increased customer's capability

**Intermediate outcome:**

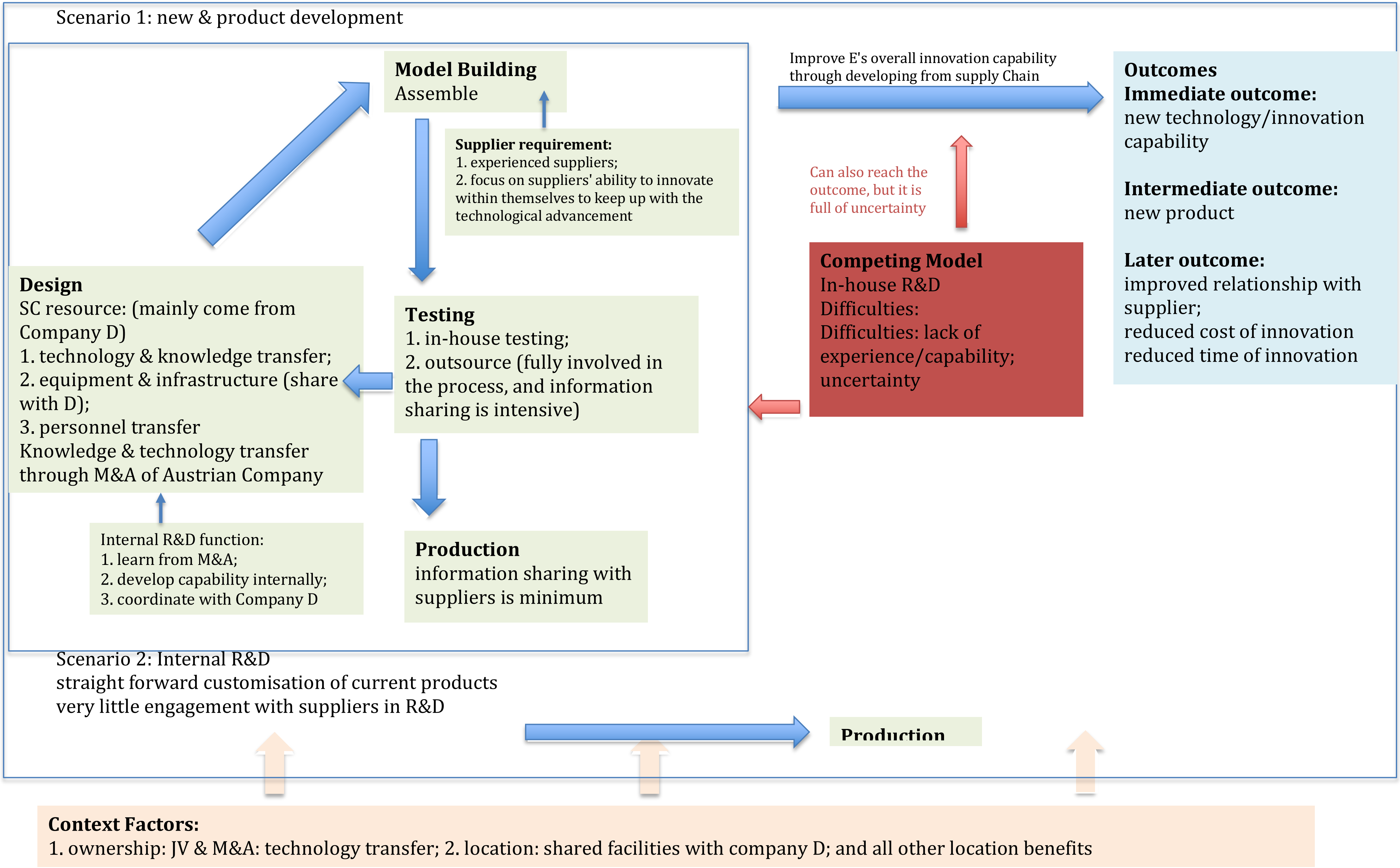
- increased relationship with customer
- technological expertise utilised

**Later Outcome:**

- process innovation
- technological improvement

**Context Factors:**
Firm characteristics: ownership (JV), location

Appendix 6.5 Logic Model: Case E



Appendix 6.6 Logic Model: Case F

**Scenario 1: no contribution to innovation of customers**

Regular product order Process

Receive Order → Model Building → Approval → Production

no innovation contributing to customer's firm

- process innovation only:
- reduced delivery time & cost
- minimise waste
- improve quality
- technologic advancement

**Competing Model**

Scenario 1 & 2 are competing model with each other, If only pursuing Scenario 1:

- relationship with customer decreases;
- technological advancement decreases

**Scenario 2: involved in customer's product design stage**

Order Process is the same with scenario 1, but before receiving order, the company is involved in the design & model building and testing stage of customer's R&D process

The following chart is the process of Company F's customer and F's engagement within the process

Design → Model Building → Testing → Production

Design:

- project based
- personnel transfer for technological consultancy

Model Building:

- main part of F's business is supplying in model building for testing
- cooperate with customers to explore & test
- trial & error, till the perfect model is built

Testing: follow up on testing, actively involved

Production: not necessarily important for F to involve in customer's production stage

**Change in practice & capacity**

**Immediate outcome:**

- products, increased sales performance
- increased customer's capacity

**Intermediate outcome:**

- Increased relationship with customers
- increased technological advancement in the model building & experimenting process
- technological expertise utilised

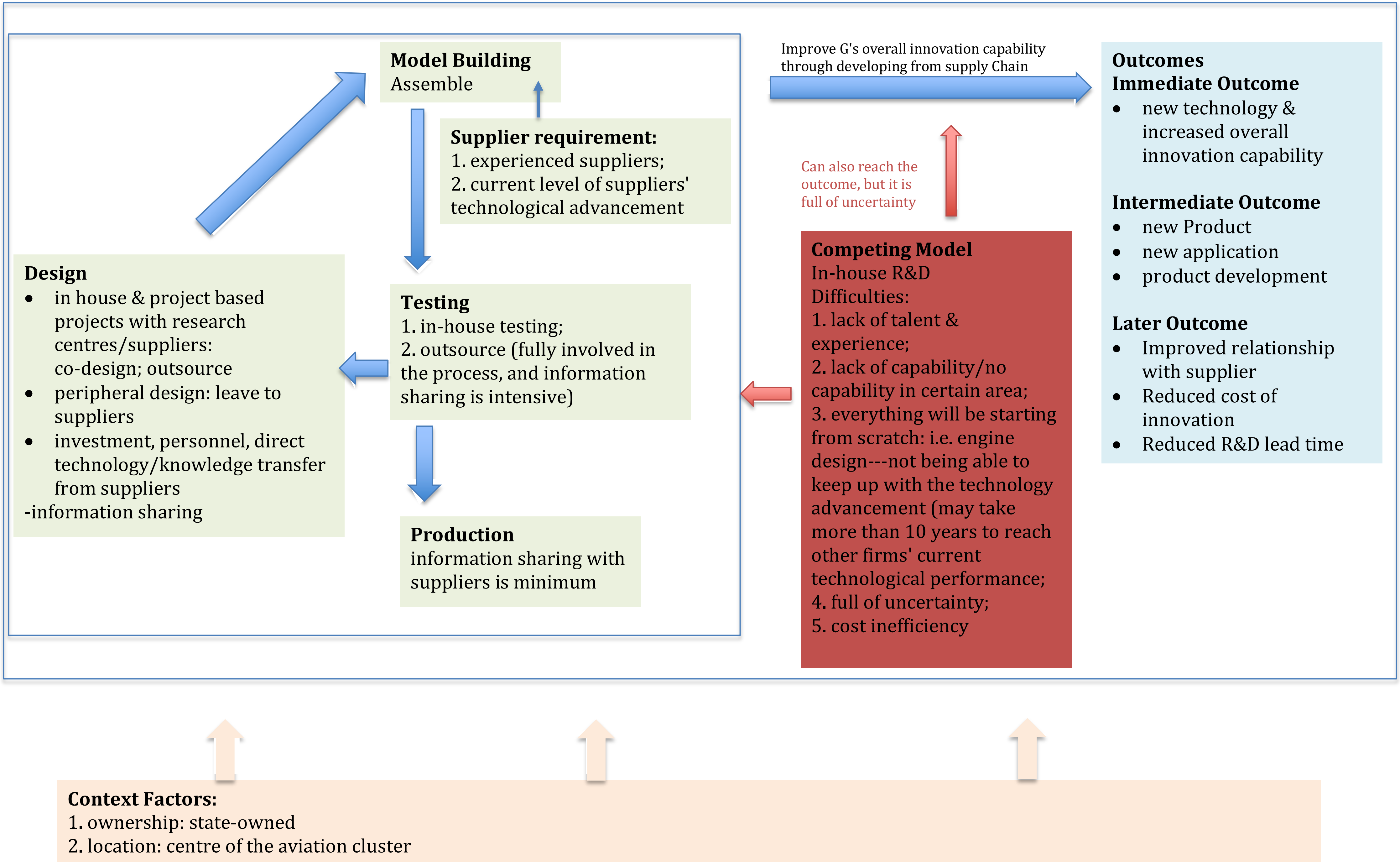
**Later outcome:**

- increased bargaining power
- process innovation
- technological improvement

**Context Factors:**

Firm characteristics: ownership, strategy, location

Appendix 6.7 Logic Model: Case G



Appendix 6.8 Logic Model: Case H

As a supplier, contribute in:

- SC resources:
    - personnel
    - technology & knowledge
- information sharing: through coordination

No relevant competing model

**Immediate outcome:**
new technology/innovation
new product design

**Intermediate outcome:**
level of technological advancement

**Later outcome:**
improved relationship with suppliers

**Context Factors:**
1. ownership: state-owned & business nature
2. location: centre of the aviation cluster
3. regulation & control

# Appendix 7 Extra Figures in Chapters 6

## 7.1 Resources and the relationship between SCI capabilities and SCI performance

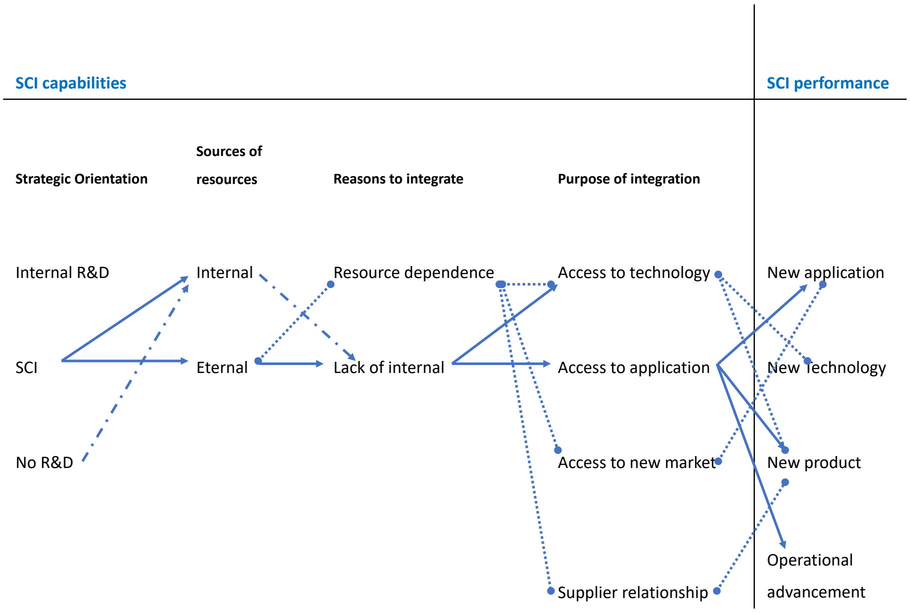



Figure 1 Resources and the relationship between SCI capabilities and SCI performance of Case A

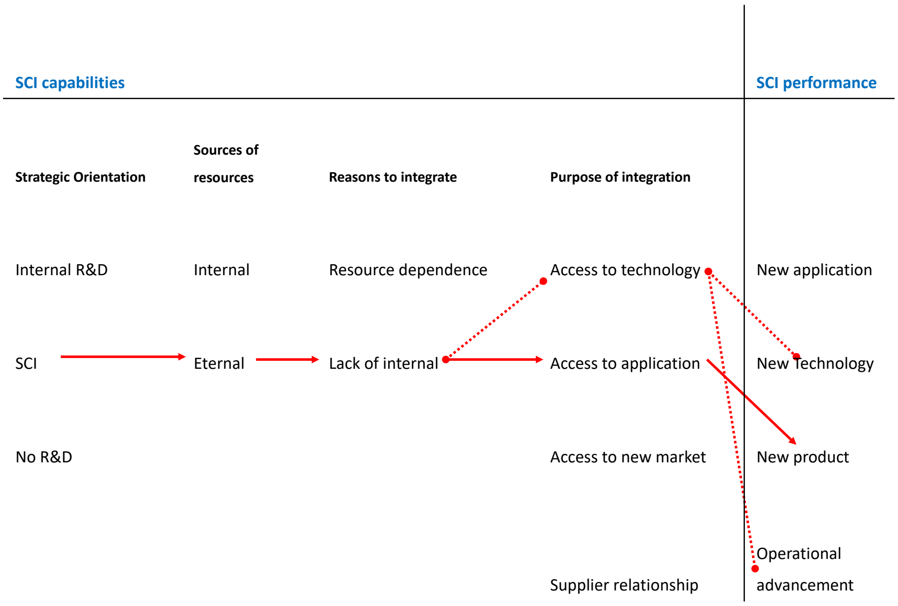



Figure 2 Resources and the relationship between SCI capabilities and SCI performance of Case B

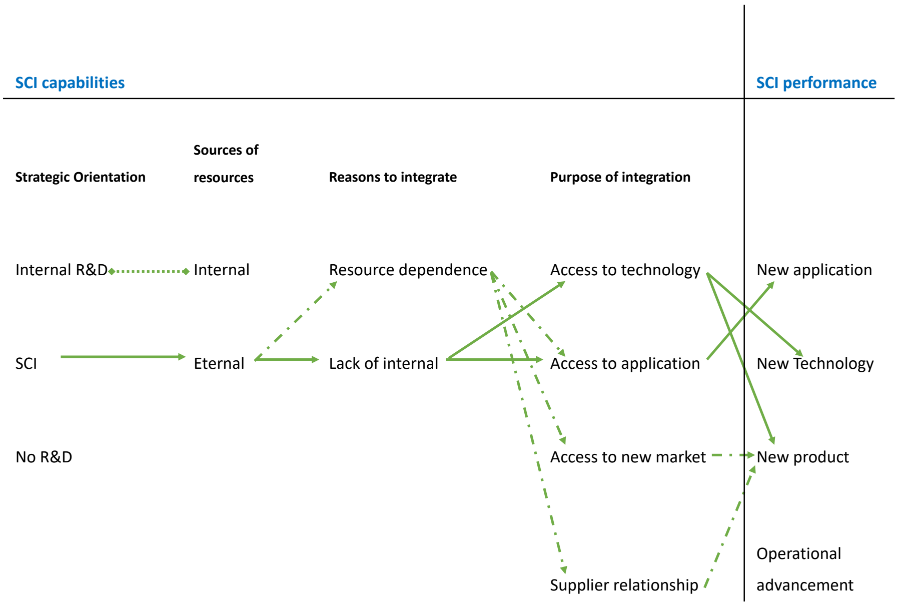



Figure 3 Resources and the relationship between SCI capabilities and SCI performance of Case C

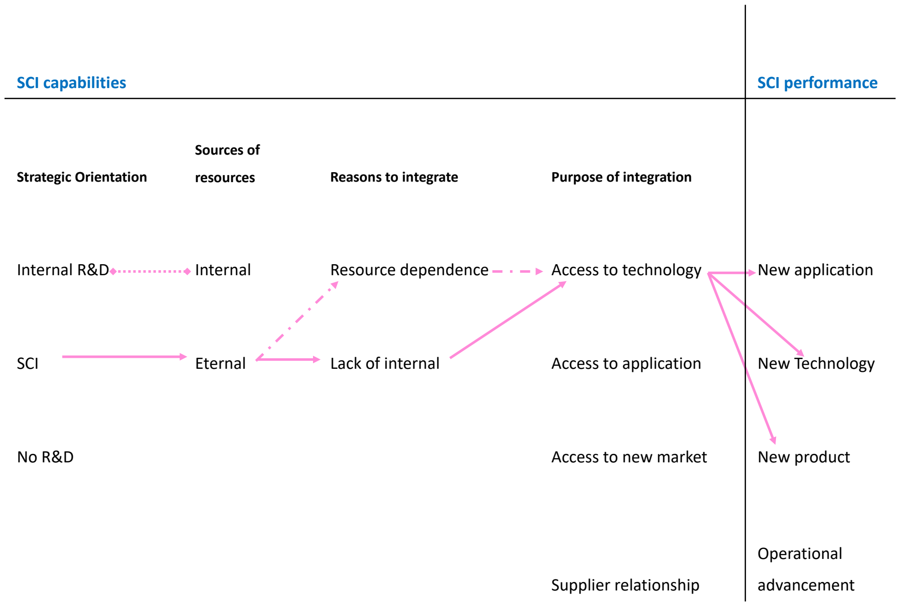



Figure 4 Resources and the relationship between SCI capabilities and SCI performance of Case D

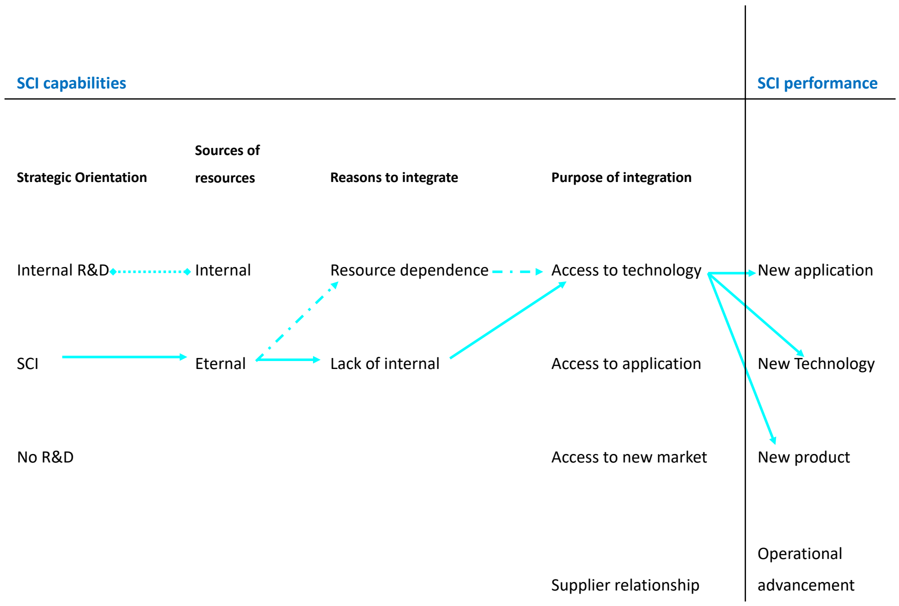



Figure 5 Resources and the relationship between SCI capabilities and SCI performance of Case E

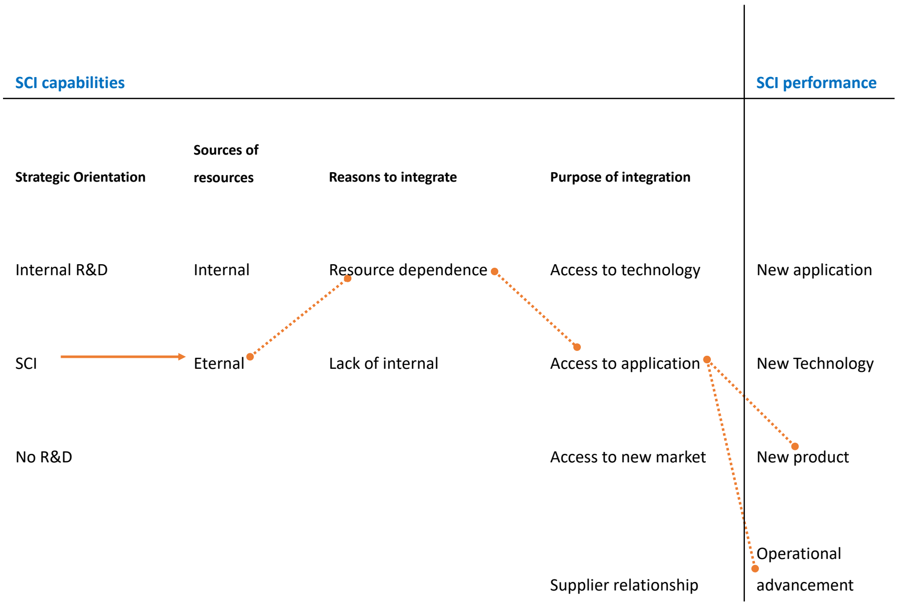



Figure 6 Resources and the relationship between SCI capabilities and SCI performance of Case F

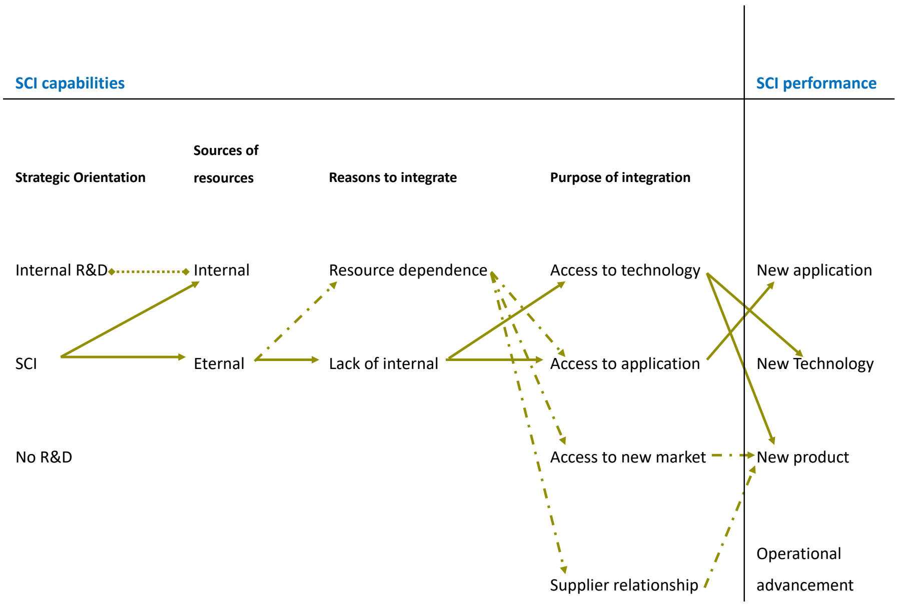



Figure 7 Resources and the relationship between SCI capabilities and SCI performance of Case G

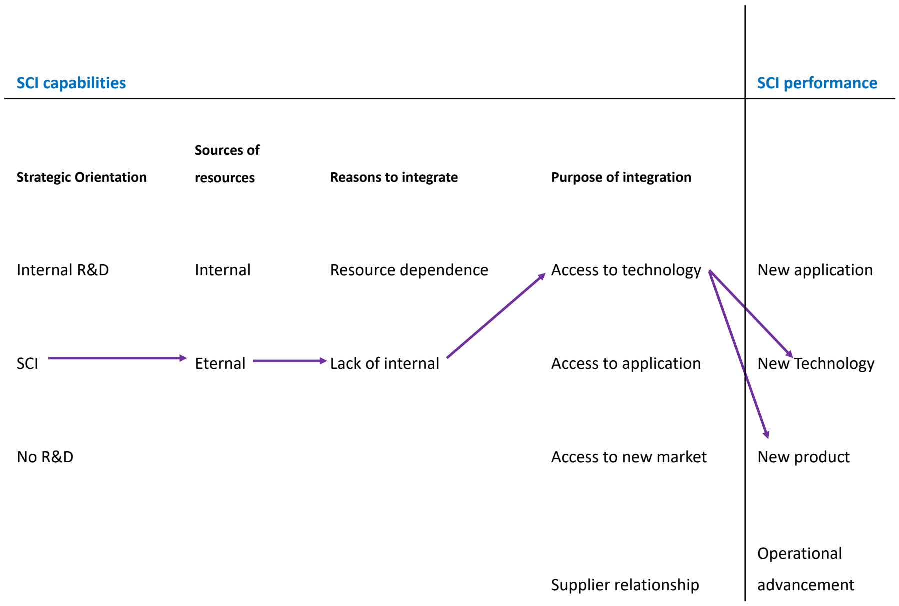



Figure 8 Resources and the relationship between SCI capabilities and SCI performance of Case H

## 7.2 Integration and the relationship between SCI capabilities and SCI performance

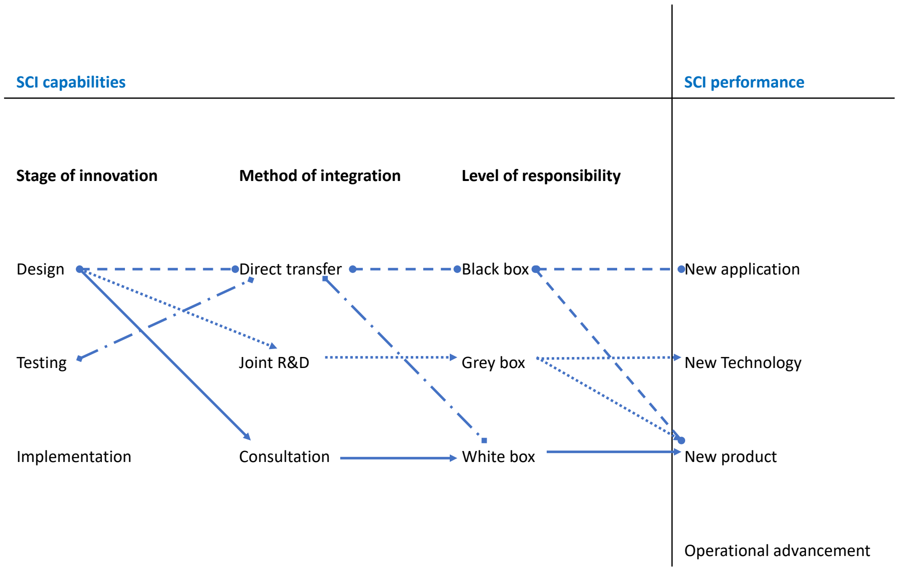



Figure 1 Integration and the relationship between SCI capabilities and SCI performance of Case A

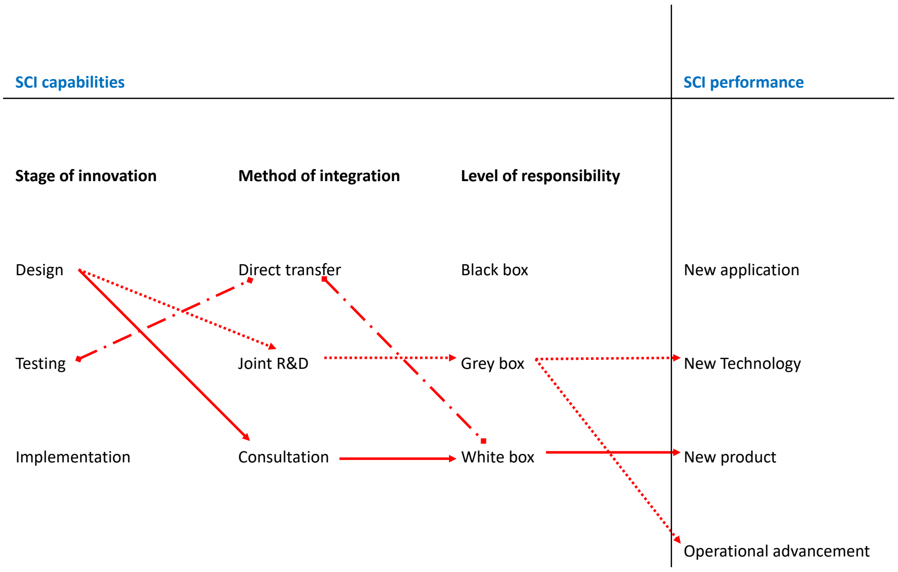



Figure 2 Integration and the relationship between SCI capabilities and SCI performance of Case B

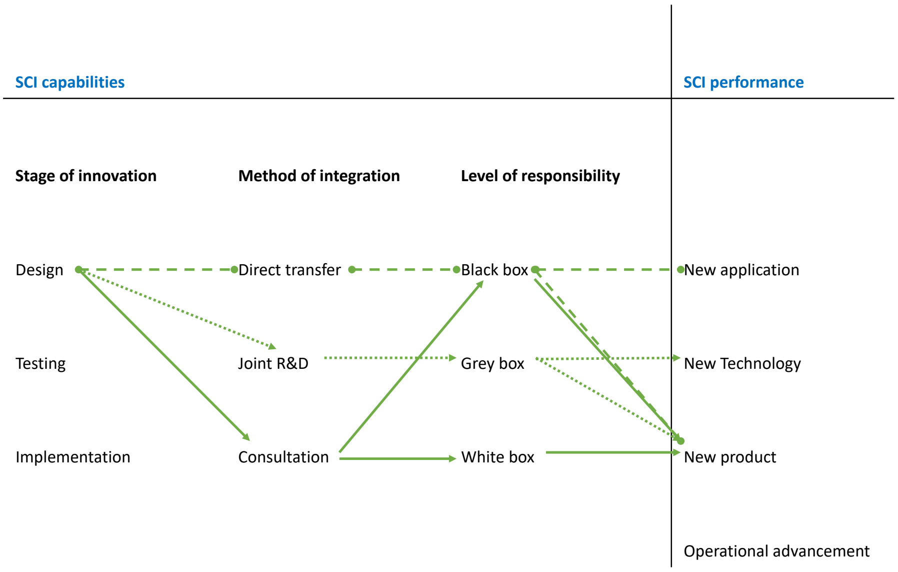



Figure 3 Integration and the relationship between SCI capabilities and SCI performance of Case C

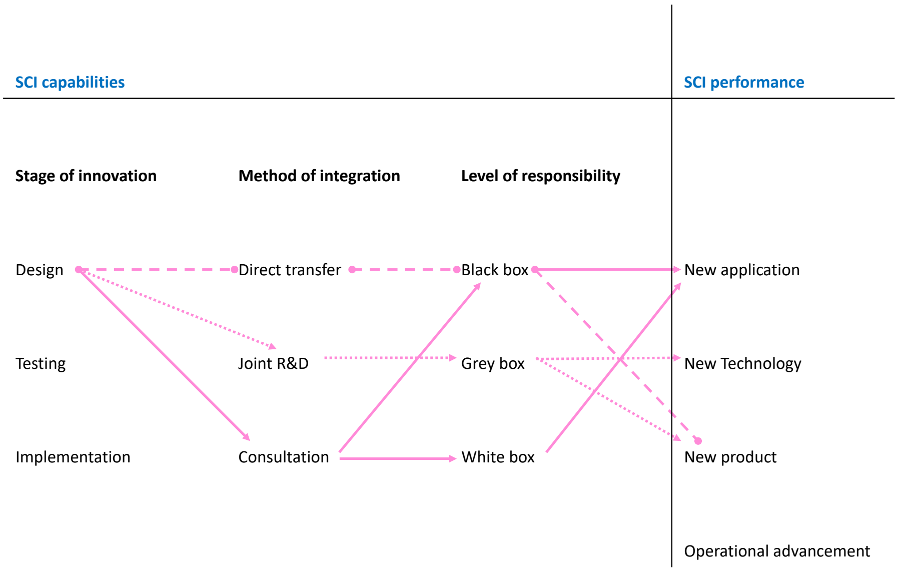



Figure 4 Integration and the relationship between SCI capabilities and SCI performance of Case D

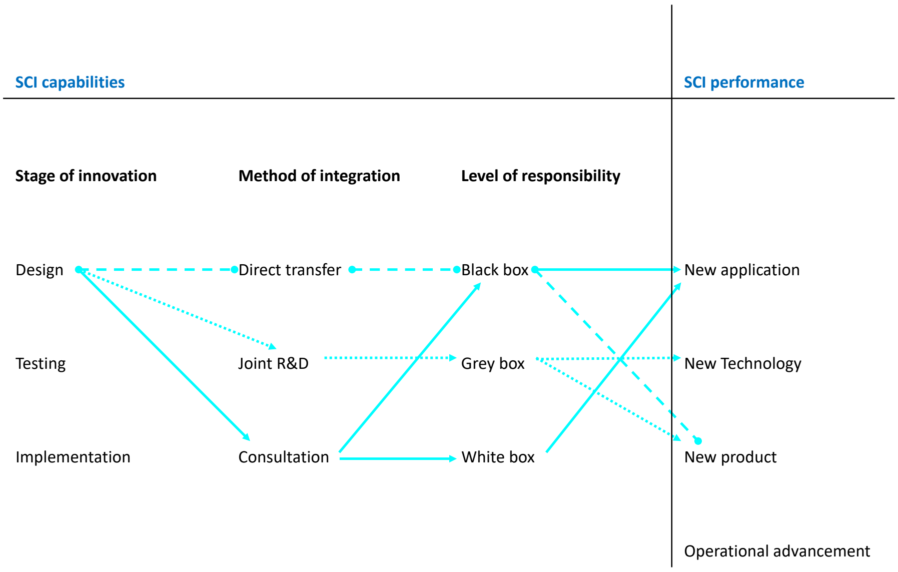



Figure 5 Integration and the relationship between SCI capabilities and SCI performance of Case E

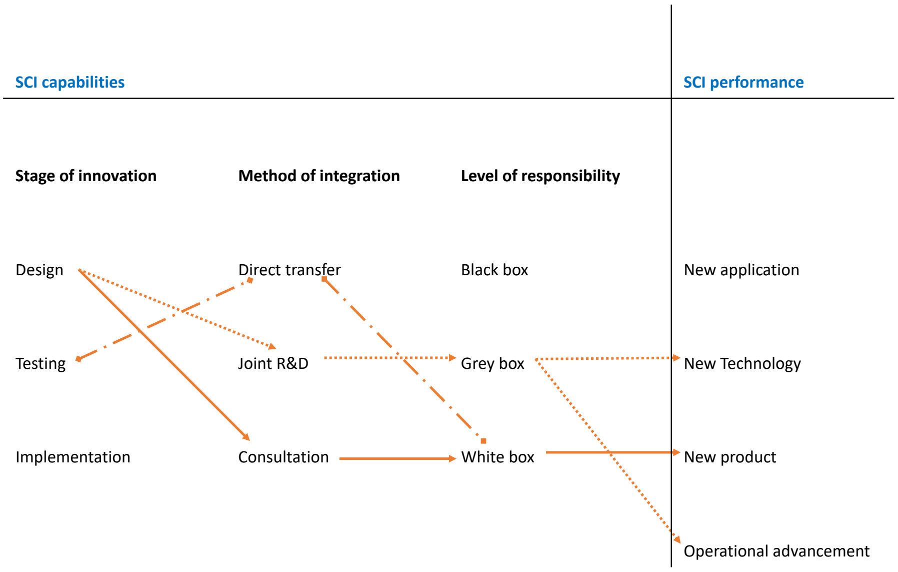



Figure 6 Integration and the relationship between SCI capabilities and SCI performance of Case F

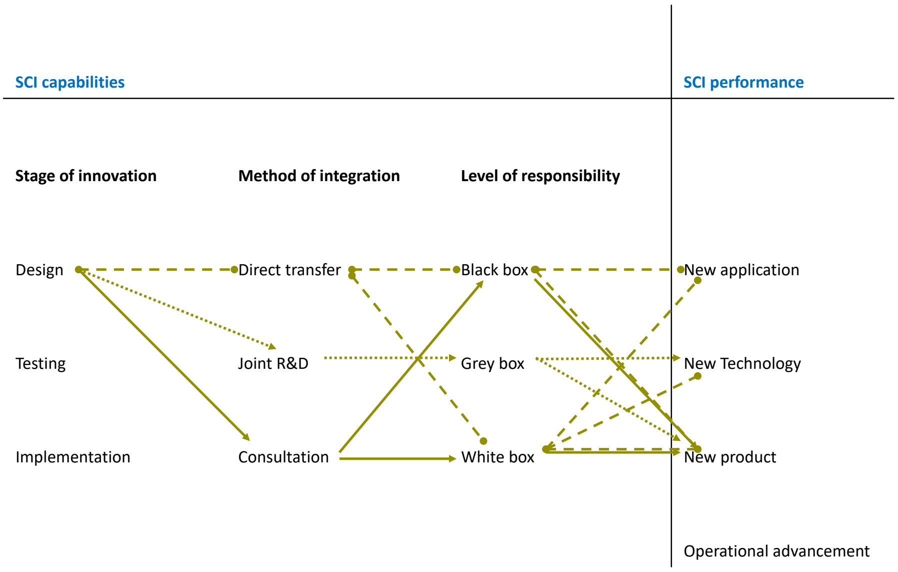



Figure 7 Integration and the relationship between SCI capabilities and SCI performance of Case G

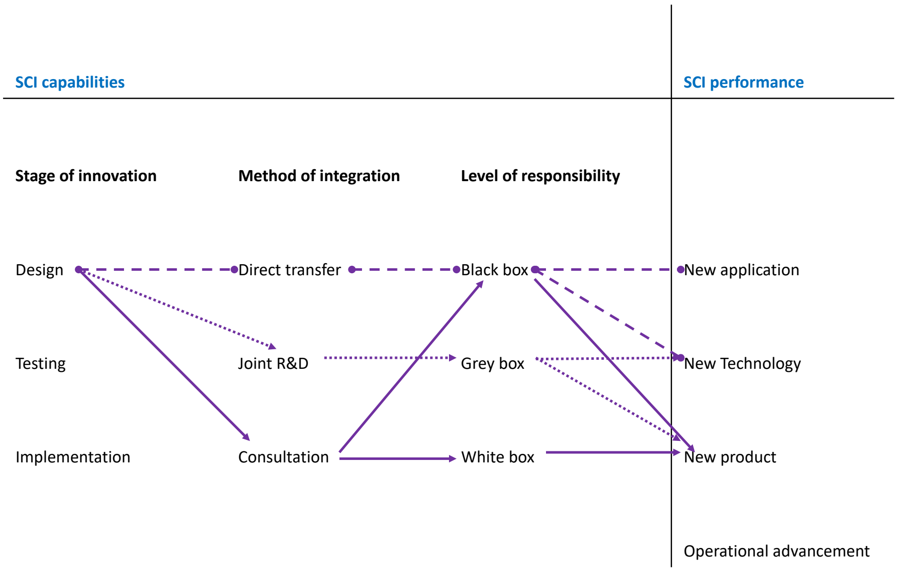



Figure 8 Integration and the relationship between SCI capabilities and SCI performance of Case H

## 7.3 Information sharing and the relationship between SCI capabilities and SCI performance

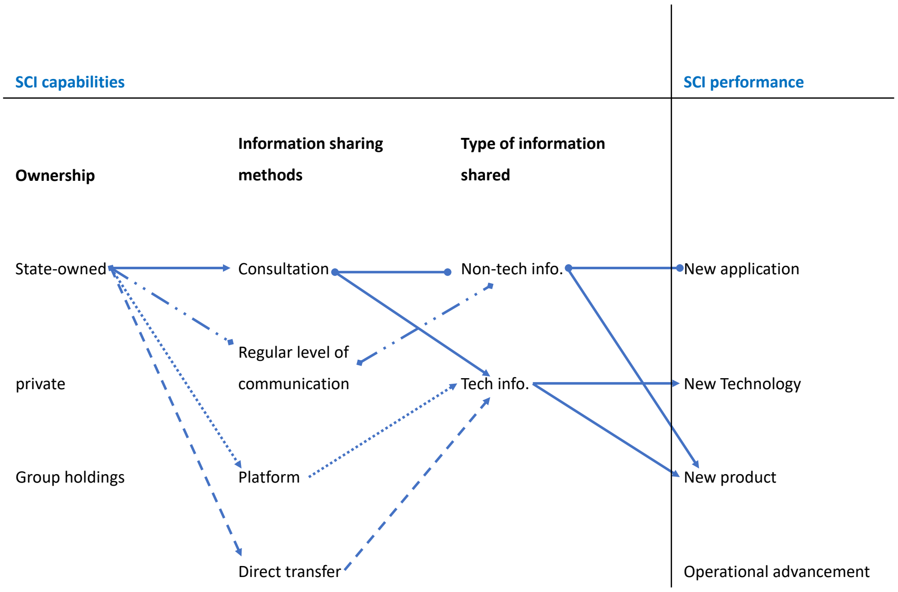



Figure 1 Information sharing and the relationship between SCI capabilities and SCI performance of Case A

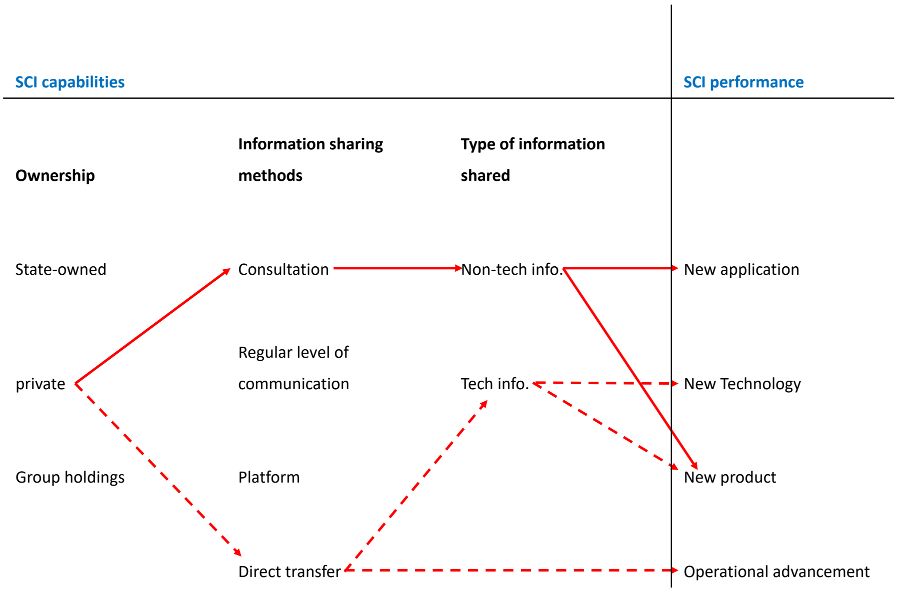



Figure 2 Information sharing and the relationship between SCI capabilities and SCI performance of Case B

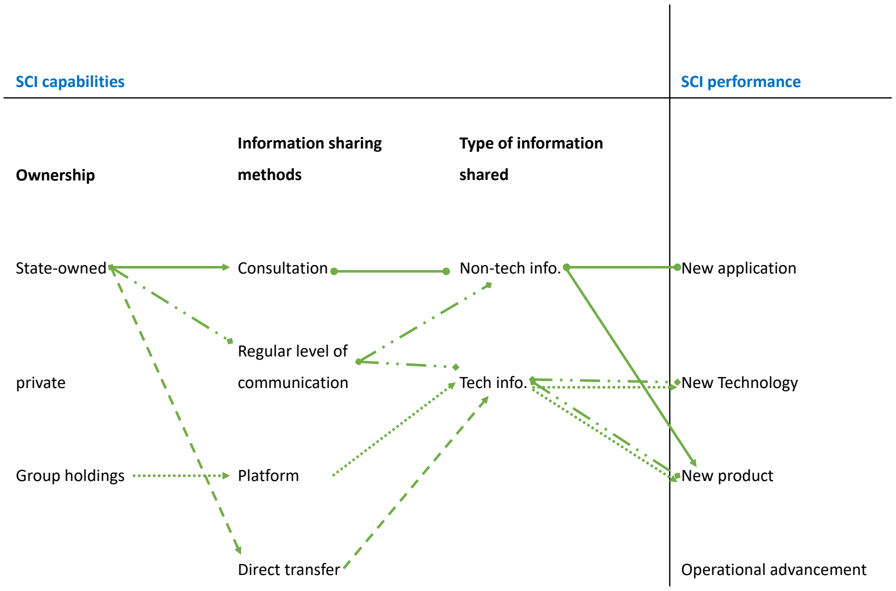



Figure 3 Information sharing and the relationship between SCI capabilities and SCI performance of Case C

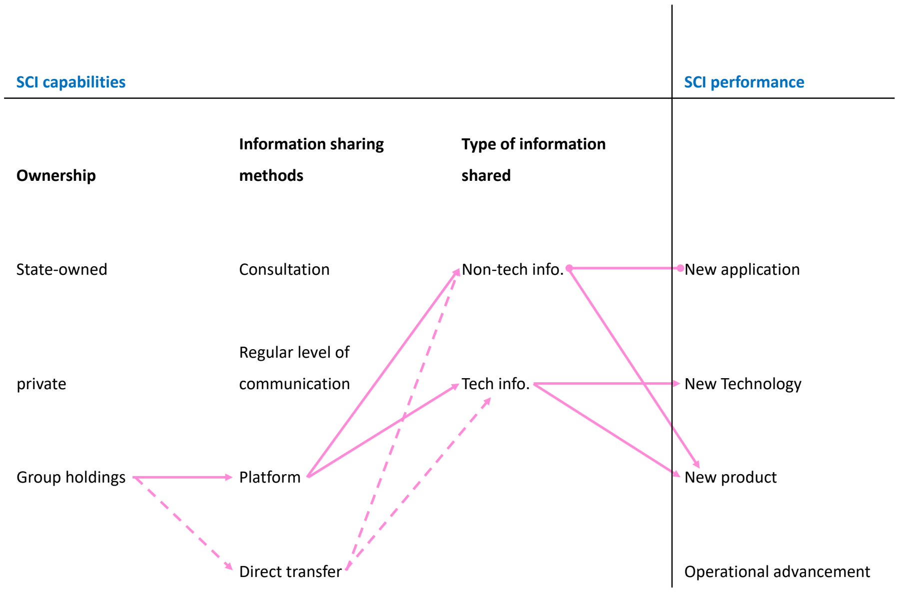



Figure 4 Information sharing and the relationship between SCI capabilities and SCI performance of Case D

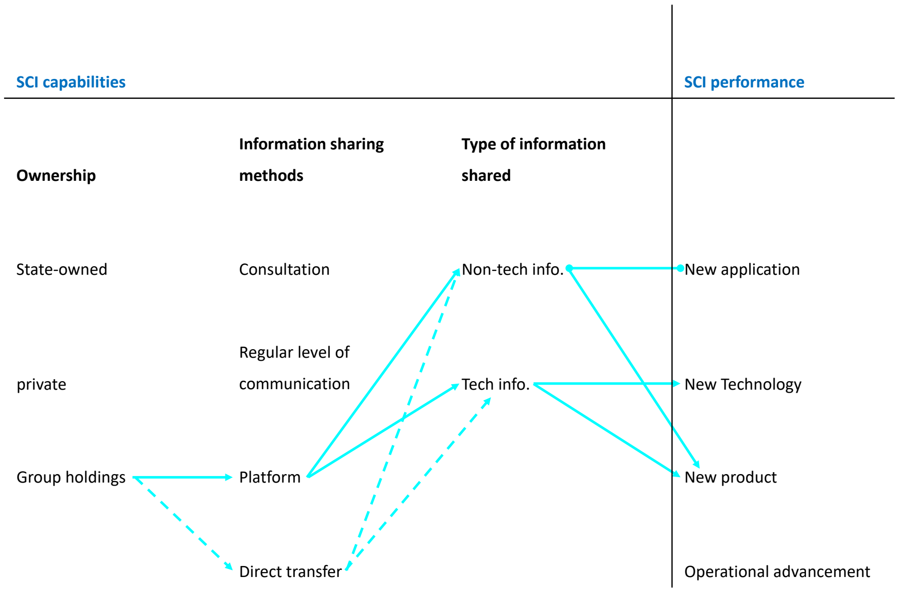



Figure 5 Information sharing and the relationship between SCI capabilities and SCI performance of Case E

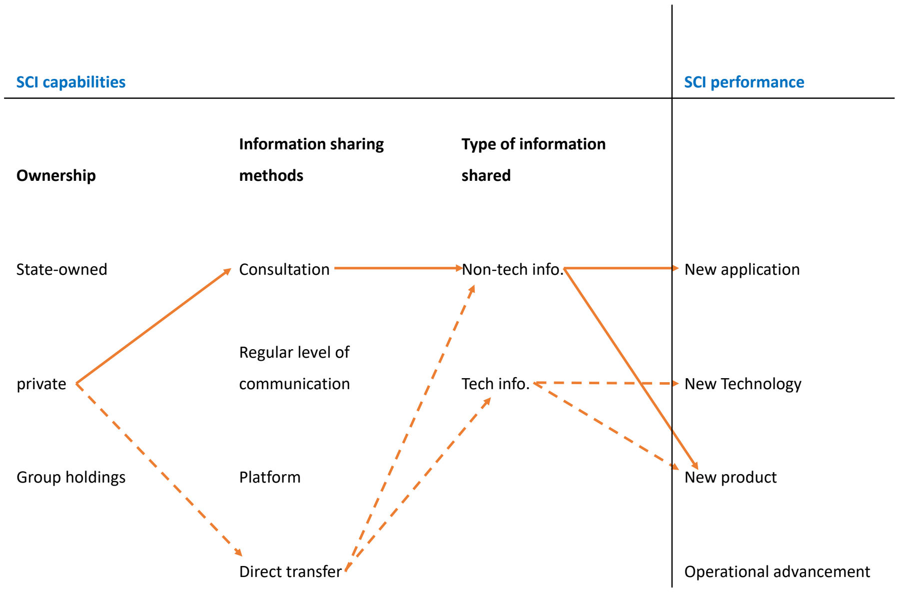



Figure 6 Information sharing and the relationship between SCI capabilities and SCI performance of Case F

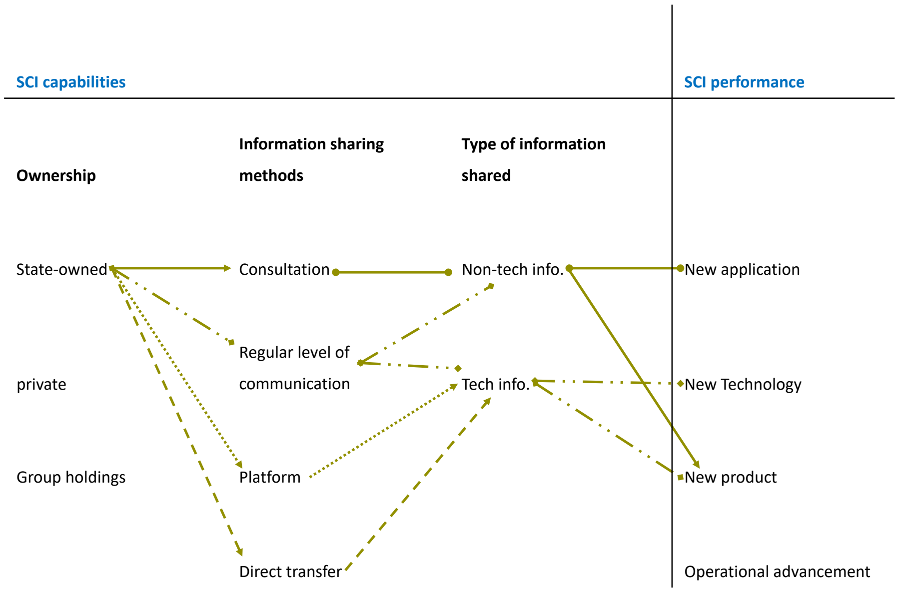



Figure 7 I Information sharing and the relationship between SCI capabilities and SCI performance of Case G

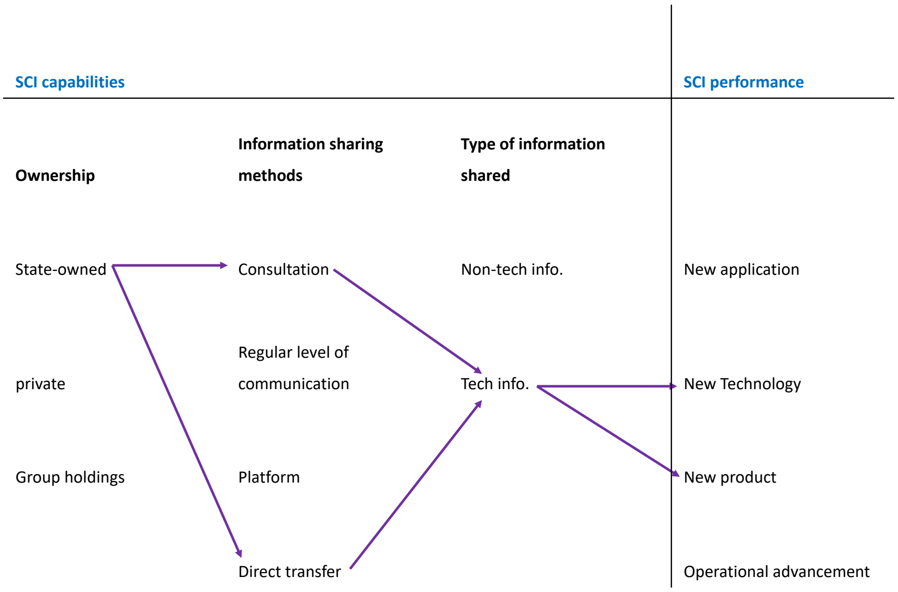



Figure 8 Information sharing and the relationship between SCI capabilities and SCI performance of Case H