A Comparative Analysis of Supply Chain Management Practices by Boeing and Airbus: Long-term Strategic Implications

By Tzu-Ching Horng

B.S. in Civil Engineering
National Taiwan University, 2004

SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN TRANSPORTATION

AT THE

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Abstract

The goal of this research is to develop an improved understanding of supply chain management strategies and practices being pursued by Boeing and Airbus in the 787 Dreamliner and the A380 Navigator programs, respectively, and to identify their long-term strategic implications for supply chain management in the future. The research takes as its point of departure a review and synthesis of supply chain management principles and practices, with particular emphasis on lean supply chain management concepts. Guided by this review, the research focuses on the common set of suppliers supporting both programs and employs a questionnaire survey, followed by telephone interviews with representatives of selected suppliers. The research also makes extensive use of the open source information on both companies, on both programs and on the common suppliers. A major finding is that Boeing's new supply chain model in the 787 program represents a significant break with past practices in the aerospace industry, allowing major partnering suppliers an unprecedented role in terms of design, development, production and after-market support, where they are integrated early in the concept development stage and are incentivized to collaborate with Boeing, as well as among themselves, as risk-sharing partners with deep responsibility for system integration, involving detailed interface control at the system and subsystem levels. Airbus, as well, is found to rely heavily on its major suppliers in connection with the A380 program, but acting as the primary system integrator in the more traditional mode and exercising much greater control of all design interfaces. Also, both Boeing and Airbus have been outsourcing more and more activities to suppliers located in non-traditional regions, such as Eastern Europe and the Asia-Pacific region. Finally, aerospace manufacturers, in general, are aggressively adopting information technologies (e.g., EDI, PLM, 3-D Digital Model, RFID) to facilitate greater data sharing and communications with their partners and lower-tier suppliers dispersed in many geographical regions, as part of a broader trend involving more collaborative supplier relationships reaching down to the subtier level.

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Chapter 1 Introduction: Research Goals and Strategy

1.1 Motivation

As much as 65%-80% of the final cost of aerospace products and systems consist of materials, parts, components and services provided by suppliers. The capabilities and performance of a firm's supplier network becomes, therefore, an important differentiator of its overall competitiveness. In recent years, aerospace manufacturers have been aggressively changing, evolving or in some cases revolutionizing their business models and supply chain management strategies in response to the growing competition in a global market environment.

The research reported in this thesis concentrates on comparative analysis of supply chain management strategies by Boeing and Airbus for the 787 and the A380 programs. Boeing and Airbus, engaged in an increasingly fierce competition on a global scale, are currently two largest players in the commercial aircraft industry. The rivalry between them has been a significant factor shaping their business models and their respective supply chain management strategies, as well as that of their suppliers. By conducting a comparative analysis of their supply chain management strategies and practices focusing on these two large current development programs, this research expects to provide an improved understanding of the current supply chain strategies and practices in this very important segment of the aerospace industry and, thereby, help explore their longer-term implications in terms of the evolution of aerospace supply chain management strategies in the future.

1.2 Research goal and research questions

In particular, this research aims to achieve the following specific goals:

1. Develop an improved understanding of how Boeing and Airbus manage their supplier networks;
2. Define the emerging supply chain principles, strategies and practices adopted by Boeing and Airbus for the 787 and A380 programs, respectively; and,
3. Identify the key features of emerging supply chain management strategies in the commercial aircraft industry observed from these two programs and explore their longer-term implications for supply chain management in the aerospace industry in general.

In order to attain these larger goals, the research strives to address the following more specific questions:

1. What are the key characteristics of the supply chain management strategies and practices adopted by Boeing and Airbus in connection with the 787 and A380 programs?
2. What are the main similarities and differences between the Boeing and Airbus supply chain management strategies, as revealed by these two large programs?
   - How do Boeing and Airbus design their supplier network structures?
   - How do Boeing and Airbus manage their relationship with their suppliers?

- To what extent are Boeing and Airbus suppliers involved in the product design and development stage?

- How do Boeing and Airbus streamline the interfaces across their supplier networks? In particular, how do the business data and technical/engineering data flow across their supplier networks?

3. What are the long-term implications of the observed corporate, as well as supply chain management, strategies in connection with these two programs in terms of the general direction and outlines of supply chain management design and management strategies in the aerospace industry in the future?

1.3 Research design and methodology

A defining characteristic of this research is that it directly focuses on the common set of suppliers supporting both the Boeing 787 and Airbus A380 programs. Since each supplier covered in this set supplies the same or similar components or systems to both programs and also because these two programs are still in the development stage, this research design thus controls for various types of variability. For example, one is company-related variability, in the form of an aggregation bias, when the companies that are compared have in place multiple programs at different stages of development or production and where the respective programs exhibit different supply chain design and management practices. That is, the companies that are covered may not necessarily be pursuing a uniform and consistent supply chain management approach across the various product platforms. Another is temporal variability, when the comparisons made refer to programs at different stages in their evolution, such that supply chain management practices may well be altered as the programs evolve from design and development into production.

Further, this research strives to capture the bottom-up "supplier's voice", which differs from the general top-down approach focusing on supply chain management as seen from the perspective of the system-integrator (prime). An implicit assumption in such a research strategy is that it would most likely provide a sharper, "unvarnished", and "closer-to-the-truth" understanding of supply chain management practices, thus avoiding any filtered or plausibly embellished views that may emerge from a top-down approach relying on the prime's inputs. Ideally, of course, both top-down and bottom-up views should be encouraged. However, both time constraints and the difficulty of access to the primes have favored the approach adopted in this research. This may potentially limit the generalizability of the research results. Thus, an attempt has been made to make use of the open literature on these two major programs -- including web-based information, press reports, trade publications and other data sources – in order to ensure the external validity of the major findings.

The research reported in this thesis has been accomplished by following a number of steps outlined below:

1. Literature review:

The first step was to identify, review and synthesize the extensive existing literature on supply chain design and management principles, strategies and practices across many industries. The specific topics covered have included supply chain design, supplier engagement in design and development, supplier integration to achieve synchronized flow supporting just-in-time manufacturing, supplier development, knowledge and information sharing across supplier networks, and the deployment of information technologies and systems infrastructures. A main emphasis here has been to identify and highlight key features of lean supply chain management practices.

2. Questionnaire survey and telephone interviews

For this research, we have developed an on-line questionnaire survey instrument (please see Appendix A), which is targeted at the common suppliers supporting both the Boeing 787 and Airbus A380 programs. The common set of suppliers supporting these two major programs were identified from the website-based information provided by both Boeing and Airbus, press announcements identifying individual suppliers selected by the two programs, and program-specific listings of suppliers provided in open sources (e.g., World Aviation Directory & Aerospace Database, published by The McGraw-Hill Companies). The questionnaire survey encompassed questions related to basic company information (e.g., the products the supplier company provided to both Boeing and Airbus in connection with the two programs, the company's annual sales, total number of employees, how and when they were selected as suppliers, how they perceived the supplier relationship management practices of their two large customers, the more general supply chain management practices of their customers as they perceive such practices (e.g., continuous improvement programs), supplier certification and what benefits if any accrue to them from becoming certified suppliers, supplier development activities of their customers affecting their own performance, and issues revolving around the development of information technology infrastructures and technical information exchanges. The responses from the participating supplier companies offered a general understanding of their background and how they work with Boeing and Airbus as suppliers.

For the purposes of conducting the on-line questionnaire survey and the follow-on telephone interviews, a target list of about 15-20 supplier companies was developed. The suppliers included in this list covered the key industry segments, such as electronic systems, major systems (e.g., landing gears, power systems), aerostructures, and propulsion. The suppliers identified within each segment covered leading companies in their fields. Care was taken to include suppliers with unique technological capabilities, in view of the dominant technology content of the components and systems embodied in both commercial aircraft platforms (e.g., composite structures). Also, an effort was made to include both large and small suppliers. When possible, a further effort was made to link up a major common supplier with one or more of its lower-tier suppliers, to probe in more detail into two-way major supplier-lower-tier interactions. The companies on the list were then approached to elicit their participation in the study. In the end, both on-line questionnaire surveys and follow-on telephone interviews were conducted with a subset of these companies.

After each participating supplier company filled out the on-line questionnaire survey, we conducted at least one follow-on telephone interview with representatives of that company. The questions asked during telephone interviews were narrowed down to certain areas based on the information contained in that company's response to the questionnaire survey and previous telephone interviews with the other participants. The aim of the telephone interviews was to examine more closely specific topics pertaining to how Boeing and Airbus respectively approached particular supply chain management issues in connection with the 787 and A380 programs. For example, we would ask the participant to offer a detailed description of the supplier selection process under both programs, the type of contract employed, scope of responsibilities (e.g., design and development, "build-to-print", etc.), technical interactions with other peer suppliers as well as with lower-tier suppliers, and other specific topics.

3. Comparative analysis:

By pursuing the first two steps, we gained a sufficiently detailed picture of the key characteristics the supply chain management strategies adopted by Boeing and Airbus in connection with the Boeing 787 and Airbus A380 programs, as seen from the perspective of the selected common suppliers. Focusing on these characteristics, we explored the existing open source information from academic journals, theses, industrial reports from consulting or financial companies, web-based information available from both Airbus and Boeing as well as from individual suppliers, press reports, and trade publications and newspapers. All the information collected from questionnaire survey, telephone interviews and open resources were synthesized and integrated into a detailed comparative analysis of supply chain management strategies and practices by Boeing and Airbus. The longer-term implications of the major findings were then explored to identify emerging strategies and practices that would most likely govern supply chain management in the aerospace industry in the future.

The research strategy just outlined is consistent with the principles and methods of the "grounded theory" approach, enabling the use of multiple data sources and progressively probing more deeply into the observed phenomena to evolve integrated insights (Turner, 1983; Eisenhardt, 1989; Corbin, J. and Strauss, A.,1990; Pandit, 1996).

1.4 Chapter overview

Following this introductory chapter, Chapter 2 provides a general overview of the commercial aircraft industry to set the overall context for this research. The discussion in this chapter highlights the distinguishing features of the commercial aircraft industry and outlines the driving forces shaping the industry's evolution in recent decades. The basic motivation in this chapter is to gain a high-level understanding of how key developments affecting the industry have shaped the strategic behavior of the incumbent firms, such as Airbus and Boeing. It is thought that supply chain management strategies are quite reflective of the higher-level corporate strategies and, in fact, the two need to be integrated going-forward. Chapter 3 gives a review of the existing literature on best supply chain management principles and practices across many industries. The discussion in this chapter strives to present a synthesis of the existing academic literature, with primary emphasis on lean supply chain management concepts. Finally, Chapter 4 first gives an introductory description of the Airbus A380 and the Boeing 787 programs, which are at center stage in this research, and subsequently provides a detailed comparative analysis of supply chain management strategies and practices employed by Boeing and Airbus in connection with the two programs. This discussion is based on a synthesis of the results from our questionnaire survey, the follow-on telephone interviews, and a review of open source information. Finally, in Chapter 4, we present an exploration of the longer-term implications of the major findings for supply chain management strategies and practices in the aerospace industry in the future.

Chapter 2 Overview of Commercial Aircraft Industry

The commercial aircraft industry has been one of the most consistently productive and sustainable industries in both the U.S and Europe. It encompasses extensive and diverse sectors and affects a full range of services, from air travel to baggage handling. The U.S. aerospace industry, which has been leading the global aerospace industry for decades, created $170 billion in sales during 2005 and the civil aircraft sales contributed to $39 billion of it[1]. The European aerospace industry comes a strong second. In 2004, the European aerospace and defense industry generated revenues 103.9 billion euro in total, of which the aeronautics sector contributed $72.3 billion Euro, with the civil aeronautics sector accounting 64.4% of it[2].

In general, as defined by the U.S. Bureau of the Census, the aerospace industry comprises two large sectors: aircraft and parts (which includes aircraft production, engines and parts, and equipment and parts) *and* guided missiles, space vehicles and parts (which includes guided missiles and space vehicle manufacturing, guided missile and space vehicle propulsion units and parts manufacturing, and other guided missile space vehicle parts and auxiliary equipment manufacturing).. Aircraft products can be further divided into the following segments: large civil aircraft, helicopter (civil and military), regional aircraft, business jets, and military aircraft. Large civil aircraft segment, which is the focus of this thesis, accounts for approximately 25 percent of total aerospace industry output[3]. The market for large civil aircraft typically contains two product categories: narrow-body and wide-body aircraft. Narrow-body aircraft refers to single aisle, short-range aircraft (up to 6,000 km) that usually can carry 100 to 200 passengers. The Boeing 737, the Boeing 757 and the Airbus A320 belong to this category. Wide-body aircraft

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1 '2005 Year-End Review and 2006 Forecast', AIA, 2005
2 'Facts & Figures', AECMA, 2004
3 'Aerospace in Year One and Year One Hundred', William Corley (http://www.ita.doc.gov/exportamerica/NewOpportunities/no_aero1_1002.html)

refers to double-aisle, medium to long-range aircraft (up to 14,000 km) that can carry between 200 to 450 passengers. The Airbus A300, the Boeing 777, and the Boeing 747 are the leading models in the wide-body aircraft categories.

2.1 Major players in the commercial aircraft industry

2.1.1. Boeing

The Boeing Company, headquartered in Chicago, Illinois, is the largest aerospace & defense company in the world. After its merger with McDonnell Douglas in 1997, Boeing became the sole domestic large commercial aircraft manufacturer in United States. Boeing offers products and services to customers in more than 140 countries, purchases from suppliers located in more than 100 counters and hires approximately 153,800 employees in the United States the 67 other countries over the world[4]. Boeing consists of three major business units: Integrated Defense Systems (IDS), Commercial Airplanes, and Boeing Capital Corporation. Integrated Defense Systems and Commercial Airplanes, are the two largest revenue-generating units, contributing 56% ($30.8 billion) and 41% ($22.6 billion) of total sales and operation revenues ($54.8 billion) in 2005[5], respectively.

Boeing's Commercial Airplanes Division is the most relevant unit for the research reported in this thesis. It is headquartered in Renton, Washington and encompasses the 787 program and other major airplane programs, commercial aviation services (flight services, spares, technical services), and other business activities, such as airplane trading services[6].

[4] http://www.boeing.com/
[5] Boeing Annual Report 2005
[6] http://www.boeing.com/commercial/overview/overview2.html

- **787 Program**: This business unit is focused on the new airplane development program **787 Dreamliner**. The 787 program was launched in April 2004 and is expected to enter service in 2008. The 787 program is the research focus in this thesis and will be discussed with more details later.

- **Airplane Programs**: Airplane Programs unit offers a series of Boeing airplane families to its customers to serve the passenger market from 100 seats to more than 500 seats and cargo freighters. Currently, the product lines offered include the 717 (whose production was concluded in 2007), 737, 767, 777 and 747, in order of passenger capacity.

- **Commercial Aviation Services**: This unit provides an array of aviation support services and products to its customers by deploying its capabilities in five key areas – customer support, material management, maintenance and engineering, fleet enhancements and modifications, flight operations support. The services and products offered include field service representatives and technical expertise to support airline operations and resolve technical difficulties; comprehensive spare-parts sales and distribution network and one-day shipment service on routine orders; customized digital; modify aircraft configurations.

Boeing reached its first real success in the commercial aircraft market in the 1950s with the development the 707, which was the world's first successful commercial jetliner. After the introduction of its twin-aisle, long-range, and 400-500-seat 747 family, Boeing solidified its dominance in the commercial aircraft market in 1970. It introduced various models of the next-generation Boeing 737, by far the most popular in Boeing's product portfolio and then rolled out its two-engine 777 family in June 1995. Since its introduction, 777 family of jetliners have been the leader in medium-to-long rage market. Currently, 76% of the airplanes flying in the air are manufactured by Boeing. In 2003 alone, Boeing Commercial Airplanes purchased almost $11.2 billion in goods and services from an estimated 11,000 partners and suppliers and $9 billion in the U.S alone. With the recovery of the airline industry and the following increased demands for new aircraft, Boeing's performance in new orders has improved significantly in recent years. In 2005 alone, Boeing Commercial Airplanes received 1028 orders, compared with new orders in each of the two previous years.

2.1.2. Airbus S.A.S.

Headquartered in Blagnac (Toulouse), France and with its main aircraft assembly operations in Toulouse, France, Airbus S.A.S. (generally known over the years as Airbus Industrie) is the largest commercial aircraft producer in Europe. It also has the distinction of a major aircraft maker with a relatively short history. Airbus was formally established in 1970 as a consortium of French, German, and later Spanish and U.K companies. In 2001, Airbus officially became a single integrated company. Its major stakeholders include European Aeronautic Defense and Space (EADS) Company with 80 percent shares of stock and BAE system with 20 percent shares of stock. Its total revenue was about 20 billion euros in 2004 and 22.3 billion euros in 2005[7]. In 2001, Airbus has spent 14.1 billion euros in procurement all over the world and sourced from more than 1,500 suppliers in more than 30 countries. The current number of employees in Airbus is 55000. In addition to Airbus, the other major business units of EADS include aeronautics

[7] http://www.airbus.com/en/

(Munich, Germany and Toulouse, France), defense and security systems (Munich, Germany), space (Paris, France), and military aircraft (Madrid, Spain).

Around the world Airbus has five spare parts centers, 120 field sites and three fully-fledged training centers -- in Toulouse, Miami and Beijing[8]. After initiating a major organizational reengineering, Airbus established a series of Centres of Excellence (CoE) located in different countries all over the world. The establishment of Centres of Excellence aims not only to streamline and unify the design and production processes but also to reinforce cross-national or cross-regional relationships. Each CoE has a different set of responsibilities and decision-making processes; the major areas in which the CoEs are engaged fall into three major categories: operations, programs and core functions[9].

- Operations: Six CoEs are responsible for manufacturing major aircraft components: wings in UK; forward, vertical tails and aft fuselage in Germany; nose, center fuselage, pylon and nacelle in France; horizontal tail and A380 sections in Spain. Final assembly is conducted in Toulouse, France and Hamburg, Germany.
- Programs: CoEs are also responsible for driving all design and production activities across the company and work closely with the final assembly line in Toulouse and with customers to offer satisfactory customized products.
- Core functions: Core functions include procurement, human resources, engineering, quality and customer services.

In 1970, Airbus launched its first model A300, the world's first twin-engine wide-body passenger jet. Following Boeing's lead in offering aircraft families sharing common features,

[8] http://www.airbus.com/en/corporate/people/company_structure/
[9] http://www.airbus.com/en/corporate/people/centres_of_excellence/

Airbus launched A310 in early 1980s, a stretched version of the A300. With the A300/A310 family, Airbus gradually established its reputation for innovation and leadership in extending usage of composites to secondary and, later, to primary structures[10]. In the mid 1980s, Airbus launched the A320, a single-aisle aircraft with 150-seat capacity. The A320 was a huge commercial success for Airbus and with more than 2500 deliveries till today, the A320 family still brings in more than half of Airbus' total sales revenues. One of the most important features contributing to the A320's success is the introduction of "fly-by-wire" technology. This innovation enabled the pilot to maneuver the aircraft using a side-stick control, reduced the weight of the aircraft, and increased fuel-efficiency. Most importantly, this innovation allowed Airbus to introduce the concept of "commonality" – different aircraft platforms sharing the same features, such as using the same cockpit design within the same family or across different families. The A320 family, the A330/A340 family, the A350 family and the A380 family all share this commonality.

The "commonality" philosophy can not only speed up the product development cycle but also significantly reduce the time and expense associated with pilot training. In 2000, Airbus launched the "double-decker" A380, the world's biggest and most advanced passenger aircraft, directly competing against Boeing's 777. The aircraft entered production in January 2002. First flight (with the Rolls-Royce engines) took place from Blagnac Airport, Toulouse, in April 2005. Airbus also launched the new wide-body medium-size plane A350 in 2005, which is a longer-range twin-engine aircraft representing Airbus' answer to Boeing's 787 in the 250-300 seat market. The A350, which started as a modified A330 and more recently has come under some criticism by customers, is being re-designed and, having fallen behind by about three years,

[10] 'Airbus Way', Airbus

is now expected to be introduced 2012.[11]

Since 2003, Airbus has received more new orders and delivered more aircraft than Boeing (Please see Table 2.1.1) and attained the first-place market position in terms of deliveries and orders for three years in a row.

	2002		2003		2004		2005	
	Boeing	Airbus	Boeing	Airbus	Boeing	Airbus	Boeing	Airbus
orders	251	300	249	284	277	370	1028	1111
deliveries	381	305	281	305	285	320	290	378

Table 2.1. 1 The comparison of orders and deliveries of Boeing and Airbus from 2002 to 2005

2.2 Supply chain structure

2.2.1 Customer

Compared with other industries, the customer base of the aerospace industry is quite small. The main customer base in the commercial aircraft sector, consisting of three main groups: airline companies, aircraft leasing companies, and air freight companies. Currently, there are approximately 500 airlines around the world operating large commercial aircraft. However, a few large airlines are responsible for the majority of the new orders. For example, 50 largest airlines in the world operate 35% of the world's fleet[12]. Leasing companies are those companies that purchase aircraft directly from manufacturers or from the second-hand market and then lease them to the airline companies. Since leasing companies handle most of the asset holding costs for the airline companies, their role as the source of new aircraft orders becomes even more important during business turndowns in the airline industry. Meanwhile, the size of the global

[11] J. Lynn Lunsford and Daniel Michaels, "Bet on Huge Plane Trips Airbus", Wall Street Journal, June 15, 2006, p.A1.
[12] 'EADS The A380 Debate', Morgan Stanley Research, September 5th, 2005

fleet of jet freighters has reached more than 1,700 units and this is expected to more than double over the next 20 years.[13]

Since airlines represent the largest customer group for commercial aircraft, airline profitability becomes the most significant factor driving aircraft sales. Airlines also play an important role in spurring innovation in aircraft production, by pushing for greater fuel efficiency, speed and safety. Airlines do not act as buyers working in isolation; their demand for new aircraft is heavily influenced by a whole array of factors, such as the state of the global economy shaping both passenger travel and air freight traffic, the social and political environment, and, of course, energy prices. Hence, airlines' requirements tend to be quite similar in terms of the functionalities of the aircraft and the timing of delivery in relation to when they need new aircraft to be available for service. For instance, it is because most airlines favored lower operating costs rather than a marginal increase in speed that Boeing was forced to cancel the Sonic Cruiser project in 2001 and turned its attention to developing the 787 Dreamliner instead, which is perhaps slower but more fuel-efficient[14]. However, during 2005, the commercial aircraft industry started to experience the growth in new orders, reflecting the fact that the airline industry has been recovering due to the growing air travel demands.

Traditionally, the customers, especially the large airlines, have strong bargaining power over the aerospace manufacturers. For aircraft manufacturers, each sale is considered as a "must win" not only because of the immediate revenue generated by the sale and the increase in market share but also because of the expected long-term revenues from after-market service over the service life of the aircraft[15]. Furthermore, losing a particular sale from a potential customer usually

[13] "Cargo Jets Flourishing," Robert V. Dahl, Aviation Week & Space Technology, Aerospace SourceBook 2006, A publication of the McGraw-Hill Companies, January 16, 2006, Vol. 164, No. 3, p.61.
[14] http://www.aerospaceweb.org/aircraft/jetliner/sonic_cruiser/
[15] 'Redirecting R&D in the Commercial Aircraft Supply Chain', RAND Issue Papers by RAND's Science and

implies the prospect of facing a lower probability of wining any the future contracts from that same customer. This is because the airline companies can exploit economies of scales by operating a fleet sharing the same or similar engine types or many other common features. The fierce rivalry between Boeing and Airbus and the current over-capacity in the airline industry gives airlines even greater power when demanding lower prices (Lam, 2005).

2.2.2 Supplier base[16]

Aircraft manufacturing is supported by an extensive, deep and multi-tired supplier base. The major first-tier suppliers can be segmented into three groups: aerostructures (including fuselages, wings, landing gear, interior cabin systems and components), engines and avionics.

In general, the aerospace industry has very high entry barriers compared with other industries, owing to the large capital investment and high requirements of technological maturity and capabilities (Perrons, 1999). Therefore, the number of qualified suppliers, especially the first-tier suppliers, is limited; it's very common that different aerospace manufacturers purchase corresponding parts or components from the same suppliers.

2.2.3 Product manufacturing

Aerospace products are complex systems that often involve an enormous number of materials, design features, technical specialties, manufacturing processes, and assembly methods. Aircraft manufacturers usually offer customized aircraft to their different customers, providing these customers a high-level of flexibility in an effort to accommodate their particular operating

Technology Policy Institute, 2002

[16] For extensive discussion of the aerospace supplier base in the context of the overall dynamics of the aerospace industry, see Kirkor Bozdogan, "The Aerospace Industry: An Industry of Industries," Working Paper, Lean Aerospace Initiative, Massachusetts Institute of Technology, November 14, 2000.

models. As a result of the complex manufacturing processes and customization, the aircraft production usually requires long lead time.

The commercial aircraft manufacturing industry sector can be best described as exhibiting low profit margins, high nonrecurring costs and high risk. Despite the fact that each aircraft sale can generate significant revenues, the profit margins can be, and usually are, as low as under five percent (Newhouse, 1988; Lynn, 1998).

Another distinguishing feature of aircraft manufacturing is the low-volume production rates. For example, there were only less than 700 commercial airplanes delivered by Boeing Commercial Airplanes and Airbus, taken together, in 2005. Compared with millions of units manufactured by the automobile industry or the telecommunication industry in a given year (for example, there were 10.29 million vehicles produced in Japan alone during 2003[17]), the annual production volumes in aerospace industry are much smaller.

2.2.4 Policy and regulatory environment

Since the failure of aerospace products typically results in immeasurably high social and economic impact, the commercial aircraft industry is tightly regulated and controlled by governmental and international regulatory organizations. In United States, the Federal Aviation Administration (FAA) is responsible for certifying the airworthiness of commercial aircraft. The counterpart of FAA in Western Europe is the Joint Aviation Authorities (JAA), which has had its own standards and practices since 1970. In addition, the industry is subject to numerous laws, treaty or regulations on export controls, antitrust, environmental impacts and security controls.

[17] http://en.j-cast.com/2004/11/01000150.html

2.3 Industry dynamics

The socio-political environment has been a significant factor in shaping the evolution of aerospace industry. Since airline deregulation in the late 1970s and particularly since the end of the Cold War, the industry has drastically shifted its emphasis in product development from an emphasis on performance to an emphasis on affordability. During the post-September 11, 2001 period, this emphasis is being modified to introduce greater safety features into new aircraft as well to increase the safety of existing fleets in order to thwart various terrorist threats. Meanwhile, since the fall of the Berlin Wall, due to massive consolidations in the defense aerospace industry in the wake of a precipitous decline in defense spending, the number of players in the industry as a whole has become significantly smaller

In addition to the political environment, another important driving factor has been the rivalry between the two giants in aerospace industry, Boeing and Airbus. The rise of Airbus has changed the long-term dominance Boeing had enjoyed over many decades. The competition between the two competitors stimulates innovation not only in terms of their new product development activities but also in terms of their business strategies and supply chain management practices. The changing terms of competition between these two large companies would be expected to have far reaching ramifications for the landscape of the aerospace industry at the global scale.

Airline deregulation and Post-cold war

The U.S. airline deregulation in 1978 brought fundamental changes in the cost structure of the airline industry -- the most important customer group for commercial aircraft -- and had an important impact on product development practices and innovation in the commercial aircraft manufacturing industry. Before deregulation, the airline industry was dominated by a handful of major airline companies. They maintained their closed and mutually-beneficial relationships with aircraft producers and were able to influence the launching of new programs or were able to exert their bargaining power by playing the aircraft producers against one another. The deregulation lowered the entry barriers to the airline industry and exposed it to free competition. More new entrants came into the airline industry and intensified the competition, which largely cut down the fares and decreased the profit margins of major carriers. Deregulation forced the airline companies to become more cost conscious and made it more difficult for airline companies to become launch customers and finance new programs. In response to the increased cost consciousness of airline companies, the most important commercial aircraft customers, the civil aerospace producers started to pay attention to the "affordability" and "cost efficiency" of aircraft.

The end of Cold War not only accelerated this trend in the commercial aircraft sector but also hastened the pace of the military sector to adopt commercial practices. During the Cold War period, domestic aircraft producers had enjoyed abundant contracts funding the development of military aircraft that could be used for commercial purposes. The commercial spillover effects of military spending, as well as the military orders themselves, allowed aircraft producers to avoid ruinous price wars by stabilizing their revenues over the business cycles with the mix of commercial and military orders and also by benefiting from the military-to-commercial spillover effects.

However, sharp cutbacks in defense outlays and fewer acquisition programs after the end of the Cold War forced both military and commercial aerospace companies to change their attention from performance-enhancing "technological innovation" and "greater functionality" to the cost structure (i.e., affordability) of the aircraft itself. In order to meet the growing demand for "affordability" on both commercial and military aircraft, aerospace launched new initiatives to foster collaboration among suppliers and manufacturers in product development and production. The industry also introduced lean manufacturing principles and quality control methods to drive down costs while maintaining high product quality.

Rise in Mergers/Consolidation and Collaboration

Firms have been pursuing mergers, acquisitions, partnerships and strategic alliances since the early days of the Industrial Revolution to strengthen their market position and enhance their competitiveness (Powers *et al.*, 2001). Recent years have been no exception to this broader trend in industry. The most significant benefit consolidation can bring is increased scale economies, as well as economies of scope, by allowing firms to pool their resources and capabilities. The global competition is intensified as trade barriers are brought down certainly contribute to the already established trend of wide scale industry consolidations. Automobile, telecommunications and other industries have already been trend setters, pointing the way forward for the aerospace industry.

In the aerospace industry, the changing nature of the commercial aircraft industry during the postwar years resulted in mergers and consolidations in both the United States and Europe. In United States, the rapid consolidation in the mid-1990s was encouraged by the Department of Defense in response to the declining defense budgets and a significant reduction in the number of new acquisition programs. The number of players in the aerospace industry was reduced to a handful, resulting in the creation of today's five giants: Boeing, Northrop Grumman, Lockheed Martin, Raytheon and General Dynamics[18]. In terms of aircraft manufacturers, by the 1970s, there were only 3 U.S. companies left; in 1981 Lockheed was forced to withdraw from

[18] "Restructuring the Global Aerospace Industry: The Shifting Roles of Suppliers", AT Kearney, 2003

commercial aircraft production; later in 1997, Boeing became the sole U.S. aircraft producer after its merger with McDonnell Douglas.

Due to the nationalism and trade barriers within the European countries, European aerospace industry had been fragmented and the players were confined in their own domestic markets and failed to build up an effective market presence to counteract U.S. aerospace firms. Facing strong competition from the consolidated U.S. aircraft manufacturers, Europeans recognized that the weak and divided European aerospace industry would be eliminated if cooperative actions were not taken to pool resources and compete effectively against U.S. dominance. After much political wrangling, Airbus Industrie was borne in 1970 as a consortium of French, German and, later, Spanish and U.K. companies. Airbus Industrie was formed as a Groupement d'Intérêt Economique (GIE) under French Law. This "economic interest group" made possible the cooperation of the various participating companies across Europe in such areas as research, buying and selling, and production[19]. The consortium members, including France's Aerospatiale S.A., Germany's Daimler-Benz Aerospace, British Aerospace PLC, and Construcciones Aeronauticas S.A. of Spain, cooperated in manufacturing commercial aircraft while still competing against each other in other markets, such as in military applications and production of small civilian aircraft. In July 2000, the European Aeronautic Defence and Space Company N.V. (EADS) was formed resulting form the merger of Aerospatiale Matra SA of France, Daimler Chrysler Aerospace AG of Germany and Construcciones Aeronauticas SA of Spain. In 2001, thirty years after its creation, Airbus formally became a single integrated company owned by EADS (with 80% share of stocks) and BAE Systems (with 20% share of stocks). Despite a series of consolidations in Europe, the lower-tier aerospace supplier market in

[19] http://events.airbus.com/about/history.asp

Europe remains highly fragmented[20].

Post September 11

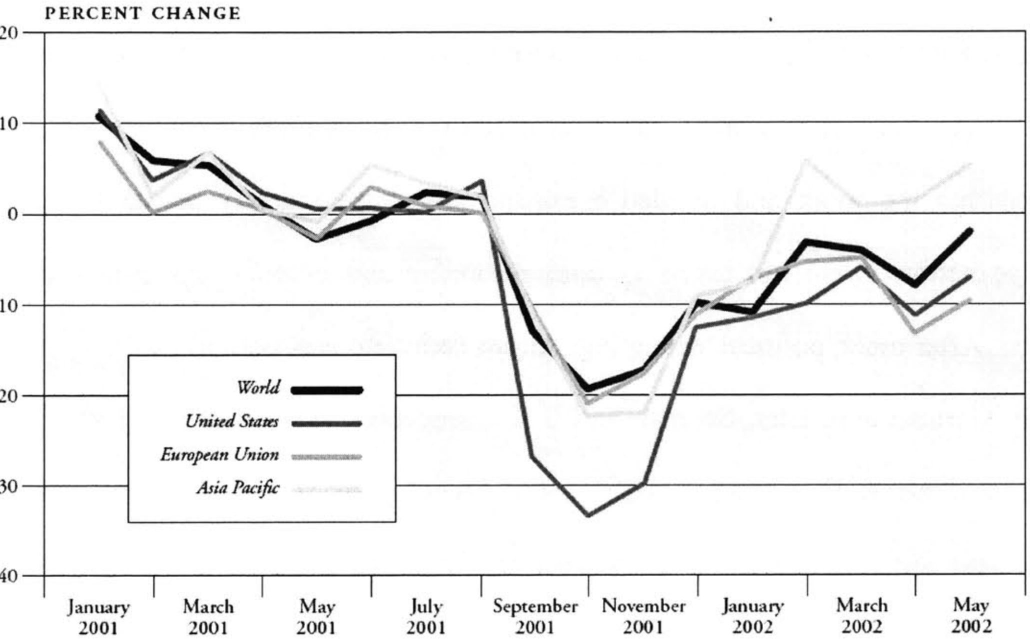

Figure 2.3 1 The trend in declining revenue-passenger-mile before September 11, 2001

The terrorist attacks on September 11th in 2001 brought about a serious impact on the civil aviation industry. Prior to September 11, the civil aviation industry had already been in a downturn as a result of the global economic recession. For instance, airfreight traffic had already decreased by about 10 percent well before September 11; the airfreight sector was worst year in two decades. Some airlines were already in financial trouble and considering further consolidation[21]. The September 11 tragedy worsened and accelerated the already existing downward trend (please see Figure 2.3.1).

[20] "Restructuring the Global Aerospace Industry: The Shifting Roles of Suppliers", AT Kearney, 2003
[21] 'Aerospace in Year One and Year One Hundred', William Corley (http://www.ita.doc.gov/exportamerica/NewOpportunities/no_aero1_1002.html)

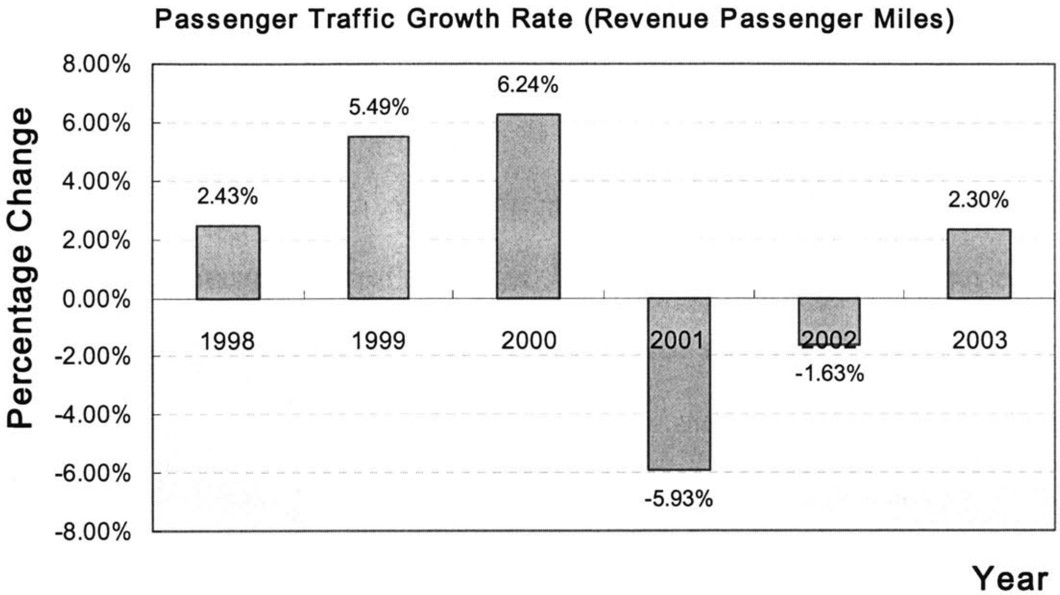

Figure 2.3 2. Passenger traffic growth rate before and after September (Data Source: ATA)

After September 11, the rising security concerns kept the public away from air travel and the other aftereffects continued to hurt the industry. As shown in Figure 2.3.2 the annual revenue passenger miles[22] for the U.S airlines declined by 5.9 percent to 652 billion in 2001, which is the largest drop in U.S. history,[23] and this downward trend continued until 2003. According to ICAO's preliminary estimates, the world's scheduled airlines suffered losses worth $11.9 billion in 2001 alone and more than half of it – $7.4 billion- was shed by 10 major U.S. airlines (Lam, 2005). As shown in Figure 2.3.3, the U.S. airlines faced an accumulated profit loss; the net profit losses of U.S airlines from 2001 to 2003 exceeded the net profits generated from 1995 to 2000. Suffering from financial distress, some major airlines filed for bankruptcy, including Swissair, Sabena, U.S. Airways and United Airlines. In order to survive, the airlines initiated massive cost-reduction measures. Some airlines began shedding their employees or approached labor cost reduction through labor union negotiations. To match the sharp demand drop, airlines largely cut

[22] Revenue Passenger Mile – One fare-paying passenger transported one mile, which is the most common measure of air travel demand

[23] '2003 Annual Report', ATA, 2003

down their flights and grounded aircraft, especially those less fuel-efficient and more maintenance-intensive. In addition to grounding their aircraft, airlines also postponed deliveries of new aircraft to decrease their fleet sizes. For deliveries that were planned to take effect in 2002 and 2003, only 202 and 137 firm orders stayed in place, respectively, compared with 283 and 186 orders reported as of December 2000[24]. Suffering from the massive financial losses, airlines have also been reducing their new aircraft purchases (please see Figure 2.3.4[25]). Many airlines began to look into other options, including leasing, power-by-the-hour (pay for service), modification of existing aircraft and conversion from freighters to passenger planes (Lam, 2005).

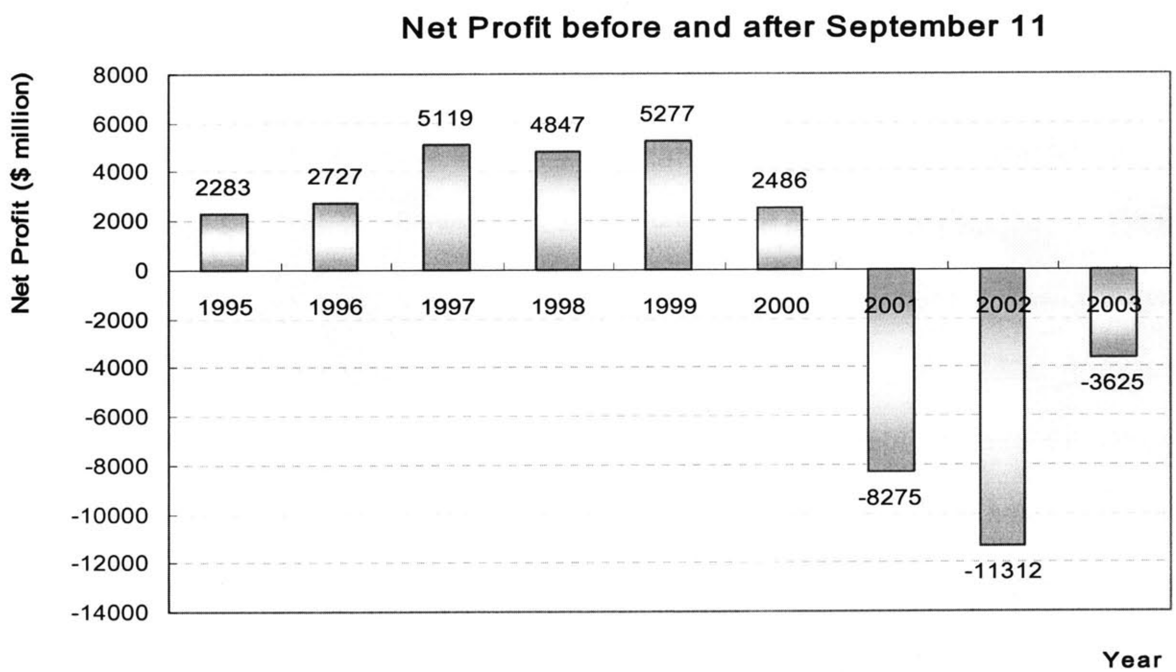

Figure 2.3 3. Net profit of U.S airlines before and after September 11 (Data Source: ATA)

[24] '2002 Annual Report', ATA, 2002
[25] '2003 Annual Report', ATA, 2003

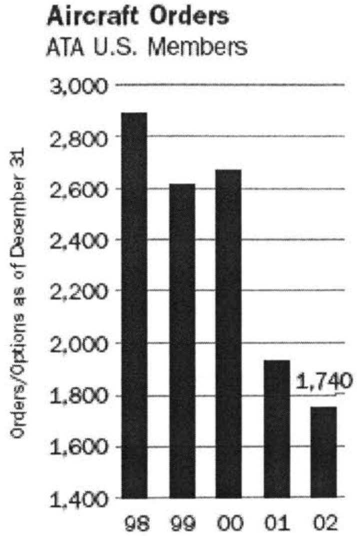

Figure 2.3 4. Aircraft orders before and after September 11th, 2001 (ATA U.S. members only)

In response to the elevated security concerns after the September 11 tragedy, government and airline companies approached the issues by rigorously improving the airport security procedures and aircraft safety. However, the measures, such as increased identification checks and searches, increase the overhead of the airport operations. The resulting congestion and longer waiting time at the airports, especially the major ones, have tended to discourage people from air travel. Improving aircraft safety, such as by transforming the cockpit doors into miniature bank vaults, also added more cost pressures on the airline companies. The heightened insurance premiums after the September 11 worsened the problem even more. The insurance premiums rose fifteen-fold for war risk and eight-fold for passenger liability. So far the airlines can only reduce the high insurance costs by increasing the flight ticket prices or passing them on to the government[26].

While the major airlines were suffering tremendous financial distress, the low-cost carriers,

[26] 'The Emerging Airline Industry', A.T. Kearney, 2003

as demonstrated by EasyJet in the U.K and Southwest or Jet Blue in the U.S., were still enjoying significant growth in the post-September 11 market. These low-cost carriers adopted cheaper point-to-point operation model, avoiding crowded and expensive major hub airports and flying their passengers directly to specific destinations. In order to cut down costs, they do not provide full flight services, either. The cost savings are reflected in lower fares, which successfully attract new customers and creates new demand. With increasing congestion in major airports as a result of stringent airport security measures, their strategies of avoiding major hub airports have become even more attractive to passengers.

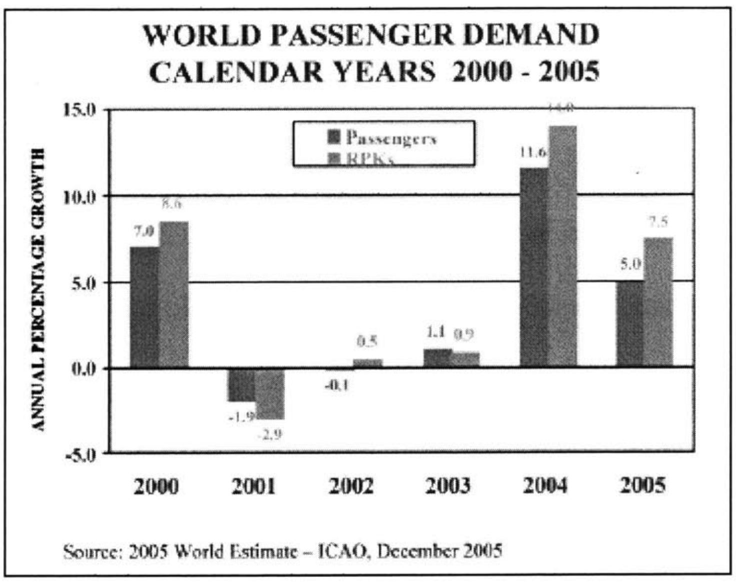

Figure 2.3 5. World passenger demand from 2000 to 2005

Despite the recovery of the airline industry (please see Figure 2.3.5[27]), the high fuel prices, increased insurance premiums, and the price pressure from low-fare carriers still largely shrink the profit margins of the major carriers. "Minimizing operation costs" undoubtedly becomes the most significant criterion when the major carriers choose what types of aircraft to purchase. The

[27] "FAA Aerospace Forecasts: Fiscal Years 2006-2017", FAA, 2005

even higher cost consciousness of airline customers in the post-September 11 market forced aircraft manufacturers to continue stressing even more cost savings and, of course, prices. In an attempt to reduce their financial burden, the manufacturers continue to increase their outsourcing activities and aggressively seek partnerships and collaboration with their suppliers to spread risks and share costs. Furthermore, pursuing even more cost-efficiencies is receiving greater attention from commercial aircraft producers when developing new aircraft so that they can respond more effectively to the needs of their airline customers seeking greater operating efficiency as well as lower lifecycle costs.

Duopoly in the Aerospace industry- Boeing versus Airbus

After decades of consolidation and competition in the twentieth century, the market for commercial aircraft with greater than 100-passenger capacity has evolved from U.S dominance into an effective duopoly; no other aircraft manufacturers can compete with Boeing and Airbus models in terms of efficiency, reliability, comfort or operating costs.

U.S. aerospace manufacturers have dominated worldwide aerospace industry over many decades. There are several factors contributing to the rapid growth of U.S. aerospace industry in 1950s and 1960s. During Cold War period, the role of the United States as the military and economic leader of the free world necessitated and justified huge expenditures in military aircraft research and development. The spillovers of the government funding on military procurement benefited the development and production of commercial aircraft sharing a high degree of commonality with military aircraft. Furthermore, the highly regulated domestic airline industry and the demand for airline travel during the Cold War decades provided a stable and growing market that stimulated the production of larger and more efficient commercial aircraft. Protected in the secure environment of the Cold War, U.S. aerospace industry was shielded from foreign competition and still maintained its conventional mass production system. The entire industry gradually became one characterized by large economies of scale in order to fulfill growing demand, overall high costs (especially expenditures in research and development), adversarial buyer-supplier relationships, and a high level of dependence on technology[28] (Olienyk and Carbaugh, 1999).

The U.S. dominance in the aerospace industry started to face increasingly stronger challenges since the rise of Airbus Industrie. Airbus first began production of aircraft in the early 1970s with substantial direct government subsidies such as debt forgiveness. Throughout 1970s and 1980s, U.S. government and aircraft manufacturers continued to protest that these subsidies allowed Airbus to offer prices at least 10-percent below the prevailing prices offered by the other competitors and gave Airbus an unfair advantage to compete in the market. Although during the 1970s and 1980s the argument against direct subsidies to Airbus had continuously been raised by the U.S. government, it had difficulties gaining full support from U.S. domestic aerospace companies since such support conflicted with their growing business interests in Europe. The other countries were also reluctant to support the U.S. on this issue since U.S. dominance in the market made it hard to convince others that it needed any protection. Furthermore, the fact that U.S. domestic aerospace manufacturers also benefited from the spillover effects of military aircraft development, also helped weaken the U.S. position. The failure of the U.S. government and the U.S. aerospace industry to take firm and effective action on the subsidy issue gave Airbus enough time to gradually stabilize its foothold in the market. By 1992, when both U.S. and EU finally reached official agreement on bi-directional reduction of direct government subsidies, Airbus had already reached its self-defined "surviving threshold" – 30 percent of the

[28] Kirkor Bozdogan, "The Aerospace Industry: An Industry of Industries," Working Paper, Lean Aerospace Initiative, Massachusetts Institute of Technology, November 14, 2000.

global market share.

In the 1990s, Boeing continued to suffer from its own production problems. Boeing started its lean initiative and production process reengineering in the mid-1990s, aimed at reducing its production costs and new product development cycle time. However, with the attempt to gain a greater share of the market, Boeing dramatically raised its production rate regardless of the fact that its assembly lines and manufacturing processes were still under transformation and the company's production systems were not prepared and well-equipped to handle much higher production volumes. The merger with McDonnel Douglas in 1997 did not seem to help, either. Before the expected cost savings from the merger were materialized, Boeing started to encounter difficulties consolidating the resources and management systems of the two companies. The power struggles at the top management levels distracted the company's management from solving production problems and further exacerbated the issue. In 1997, Boeing was forced to shut down two assembly lines, which cost the company \$2.5 billion[29] (Olienyk and Carbaugh, 1999).

While Boeing was struggling with its production problems, Airbus continued to increase its market share. After it successfully entered the aircraft marketplace with the A300 in the 1970s, a wide-body short-haul aircraft, Airbus followed this achievement with the introduction of its most popular A320 series aircraft in the narrow-body short-haul market, and then the A330/A340 aircraft in the wide-body, long-haul markets. Though largely sponsored by European governments, Airbus's success fundamentally resulted from the utilization of advanced technology (e.g., fly-by-wire and composite material) supported by a vibrant R&D system (Lynn,1998; Heppenheimer, 1995). Under the Airbus's consortium structure, various

[29] 'Boeing Straightens up and Flies Right', BusinessWeek, May 8th, 2006

components manufactured throughout Europe and North America are shipped to France and Germany for final assembly. Unlike Boeing, which was known to be more rooted in a mass-production and assembly-line system, Airbus found itself having a just-in-time lean production system through the way it is structured. Airbus's lean production system was considered as the inception of the aerospace's industry's journey to leanness[30]. With the right mixes of products, market strategies, and production system, Airbus made inroads into the large commercial aircraft market and attained the first place in deliveries in 2003 and 2004.

In 2001, Airbus formally became a standalone and integrated company. Although the dissolution of its original consortium structure might mean less direct government subsidies, it is expected to further enhance Airbus's competitiveness position. Airbus should be able to attain cost savings through more efficient and coordinated management and production systems; the restructured organization also will give Airbus better position to invite new partners and seek funding from financial markets.

Although everything has seemed rosy for Airbus over the past few years, the climate of competition has started to change since 2003. After having come a long way from its production crisis in the 1990s, Boeing gradually shed its well-known past as a cyclical company. The company's financial performance had significant improvement in 2005 over 2004: the revenues grew by 5 percent, operating earnings grew by 40% and the operation margin went up by 1.3 percent[31]. Boeing's stock has also leaped by nearly 50% in the past year. It implemented disciplined production processes through the adoption and continuous improvement of lean production principles, in conjunction with ramping up its production rate over the next two years. Currently it is able to raise the production rate without rehiring more of the people it had laid off

[30] 'Leaning on Lean Solutions', Aerospace America, June, 2005
[31] Boeing's Annual Report 2005

since 2001. After several years of exploring various options such as the Sonic Cruiser, its newly-launched 787 Dreamliner program seemed to right airplane matching the emerging interest in point-to-point transportation being evidenced by the airline industry. The net new orders for the 787 Dreamliner reached 1002 for 2005 alone. On the other hand, Airbus's A380 program experienced serious production problems, which has already forced Airbus to announce a delay of delivery for the second time in July, 2006. Shares of EADS, Airbus's parent company, dropped 26% right after the news of production problems and the delay broke out; according to EADS's estimation, the delay will cause $2.5 billion loss in operating profit between 2007 and 2010. The delay crisis and Airbus's slow response to it exposed not only technological but also management coordination problems. Moreover, the newly-launched A350 program, which aims to compete directly against Boeing's 787 Dreamliner, has suffered from criticism from the customers right after Airbus came out with information about its details of size, range and economics.

The battle between Airbus and Boeing will definitely not come to an end in the near future. Airbus is currently redesigning its A350 and might even develop an entirely new A350 in order to counter Boeing's 787 and 777 models. The commonality feature shared by Airbus's other aircraft lines give Airbus an advantage in terms of lower costs and shorter development lead time. Meanwhile, Boeing has already launched its new 787-8 family in November, 2005, which is expected to go head-to-head against Airbus's A380. For the future market, Airbus forecasts that the next 20 years will see demand for 16,600 new passenger aircraft with more than 100 seats, including over 1200 with more than 450 seats, in addition to 700 new and 2400 converted freighters. Boeing also predicts the growing air travel will be followed by the need to expand the existing fleet and the need to replace older airplanes with newer, better ones, which creates a market for 27,210 new airplanes worth $2.6 trillion to be delivered over the next 20 years. From the customers' point of view, they do not want to declare a final winner in this battle, either. Intense competition between Airbus and Boeing gives airline companies increasing bargaining power in new purchase negotiations. Most of the major carriers still prefer to maintain a mixed fleet of aircraft from both manufacturers.

Chapter 3. Literature Review

The "Lean" manufacturing approach, which can be traced to Toyota and also known as the "Toyota production System (TPS), has resulted in legendary success by Japanese auto manufacturers. Lean principles have helped the Japanese automobile manufacturers to achieve higher quality, lower cost, and faster time-to-market. Furthermore, Japanese lean manufacturers have made significant efforts to diffuse lean principles across their supplier networks over the past several decades, which have fostered the evolution of a new structure of buyer-supplier relationships. Previous studies have shown that much of the competitive advantage enjoyed by Japanese can be attributed to this new buyer-supplier structure (Womack *et al.*, 1991; Dyer and Ouchi, 1993). This structure works well because it offers a rational framework for both buyers and suppliers to determine costs, prices, and profits and also provides mechanism to make the two parties willing to cooperate for mutual benefit. Many of these Japanese-style lean supply chain management principles and practices have been emulated by North American and European manufacturers in order to enhance their competitive advantage. The most important ones include establishing collaborative relationships with suppliers, delegating more design and manufacturing responsibilities to suppliers, integrating suppliers early into product development stage and developing knowledge-transfer network among suppliers.

In recent years, the business environment has largely been reshaped by the globalization of production, increased customer demand for higher product quality as well as variety, and rapid advances in information technology. In the emerging business environment, an increasing number of companies are adopting lean principles, including lean supply chain management principles and practices, to cope with the increasing level of technological and product complexity, competition and market uncertainty. Also, many emerging business relationships reinforce and elaborate lean principles. For example, the ideas of an extended enterprise, virtual corporation and supply chain coordination echo the basic lean principle of collaboration and strategic alliance with suppliers, aimed at enhancing product quality, lowering cost, synchronizing production and removing inefficiencies across the supplier network. Also, the accelerated adoption of information technologies (e.g., e-commerce, XML internet, wireless network) has stimulated many innovative practices, especially in retailer industry and computer industry, to eliminate existing inefficiency in the supply chain channel and also to achieve better visibility across the supplier chain, enabling the supplier network much more responsive to rapidly changing customer needs.

3.1 Lean supply chain management principles and practices across industries

Lean supply chain management principles and practices will be elaborated in the following three sections. Section 3.1.1 delineates the basic foundation and structure of Japanese-style supplier relationship management. It also compares the supplier relationships management in the traditional mass-production culture with the Japanese-style model. Section 3.1.2 focuses on supplier development practices that are commonly applied by Japanese lean manufacturers to achieve continuous improvement. Section 3.1.3 emphasizes the importance of information sharing among entities cross supplier networks and discusses the application of the state-of-the-art information technologies and systems enabling the creation of a new supply chain management framework.

3.1.1 Supplier relationships management

In this section, the Japanese automobile manufacturers are used to illustrate lean principles and practices in supplier relationships management, which are then compared with the western mass-production practices that are typically represented by both U.S. and European automobile manufacturers. There are a number of reasons for directly focusing on the Japanese auto producers. First, in an average car, there are over 15,000 components and as many as 20,000 parts that have to function well when integrated together. This interdependence feature makes coordination through the supplier network a significant technical and organizational challenge facing the automobile industry. Second, it was the Japanese automobile manufacturers (e.g., Toyota and Nissan) that took the lead in diffusing lean principles to their suppliers and in creating a new framework for managing buyer-supplier relationships. Third, many of the principles and practices adopted by large Japanese automobile assemblers to strengthen relationships with their suppliers have been emulated by their Western counterparts and benchmarked by other industries (Liker *et al.,* 1996). Fourth, there are abundant previous studies focusing on how Japanese automobile assemblers manage their relationships with their suppliers to develop sustained competitive advantage in an increasingly competitive global automobile market (Liker *et al.*, 1996; Dow and McGuire, 1999).

Supplier relationships management in the traditional mass-production industrial culture

In the 1980s, western mass-production automobile manufacturers were managing their part production using either of the following two approaches. Some of them, such as GM, produced more than 60% of the parts in-house. The others, such as Saab, outsourced the majority of their part production and only kept in-house the production of the most important parts. Producing everything in-house required enormous investment dedicated to either manufacturing facilities or to the coordination of many parts divisions driven by "push-based" rather than "pull-based" production. As a consequence, production flexibility is decreased, for example resulting in excess production during periods of low automobile demand. Therefore, many vertically-integrated mass-production manufacturers had turned to outsourcing approach in order to take advantage of the lower prices and greater flexibility offered by outside suppliers.

Under the traditional mass-production subcontracting system, automobile assemblers would typically call in the suppliers and ask for bids once the detailed engineering drawings at the parts level have been completed. The winning supplier would be determined on a lowest-price bid basis. The auto manufacturer would generally believe that keeping a large supplier base would be beneficial. Bidding from a larger pool of suppliers would encourage more intense competition, which the customer company could exploit in order to negotiate lower costs, higher product quality and better delivery times. In addition to enhancing the customer's bargaining power, having a large supplier base would offer back-up production capacity when facing accidental disruptions in supply. (Maloni and Benton, 1997: 420; Sheffi, 2005).

Since quoting a lower price is the key to winning the contract under the mass-production subcontracting system, suppliers are typically motivated to offer a price below their actual cost, only to ask for a cost adjustment later from their customers. Under this arrangement, suppliers are usually not able to share any cost savings with their customers. They are generally unwilling to expose to their customers any information about their own costs and profits. By creating "grey areas", suppliers believe that they can retain their bargaining power when negotiating any follow-on cost adjustments with the customers and can thus prevent the customer from requiring further cost reductions. The customers, therefore, have very limited knowledge of their suppliers' production operations and capabilities. The only information communicated between the customers and their suppliers is the price of the part or component in question.

As a general rule, under this system, the winning bidder is only awarded a short-term contract (e.g., one year ahead or even for a shorter period). The winning supplier is not guaranteed follow-on contracts for new products despite their excellent performance on the current contract for an existing product. When the supplier does not meet the quality or performance requirements set up by the customers, the most-often taken approach is to drop the supplier immediately. If the market demand slumps or does not reach the planned production volume, it is quite possible that the customer would lay off the current supplier and turn to another offering a lower bid in order to cut down the costs. Such a practice undoubtedly reinforces suppliers' belief that the information, such as on detailed production processes and internal efficiency gains through improved operations, should be held back from the customers who could not be trusted.

In the conventional mass-production system, the buyer-supplier relationships can be best described as arm's-length, short-term, transactional, and built on price competition with other suppliers where suppliers are selected on the lowest-bid basis. There is hardly any trust, cooperation or open communication between the buyers and the suppliers. Suppliers have no or very little involvement in their customer's product design and development processes. Correspondingly, customers have very restricted visibility into their suppliers' production operations. Each entity in the supply chain works independently and does its best to ensure the protection its proprietary corporate data. Customer companies and their suppliers are locked-in in a zero-sum game (Taylor, 2004), where profits accruing to one party (e.g., customer, suppliers) are seen as coming at the expense of the other party.

Supplier relationship management in lean-production system

In contrast with conventional mass-production manufacturers, Japanese lean manufacturers usually keep much smaller supplier bases and adopt single or dual sourcing purchasing policies. They usually organize their supplier network into a well-defined tiered hierarchy structure. At the top of the tiered hierarchy are a handful of first-tier suppliers. First-tier suppliers are usually equipped with excellent technological capabilities and are assigned full responsibilities for designing and manufacturing a whole subsystem, rather than discrete parts that are later assembled into a finished automobile. Manufacturers also authorize their first-tier suppliers to manage their own respective suppliers, which are second-tier or lower-tier suppliers. First-tier suppliers can further delegate the management responsibilities to their own suppliers and thus form another tiered structure at a lower level. With much smaller supplier bases and a tiered structure, Japanese lean manufacturers can thus focus their scarce communication and management resources on a handful of first-tier suppliers and develop longer-term dedicated relationships with their most important first-tier suppliers. This characterizes the well-known "Japanese-style" partnership model of buyer-supplier relationships.

The Japanese-style partnership arrangement is defined as an "exclusive" supplier-buyer relationship that aims to maximize the efficiency of the entire value chain in which the costs and profits are visible for each entity involved. Based on the previous studies, the key features of the Japanese-style partnership include:

1. Suppliers and buyers consistently practice win-win behavior and respect the fairness principle.

2. Strategic practices are taken in order to reinforce the trust between buyers and suppliers.

3. Both suppliers and the buyers make a long-term commitment to their relationships.

4. Suppliers are involved in the product development at a very early stage.

5. There is intensive and frequent technical or cost information sharing between the customer and suppliers.

6. Clearly defined rules and mutual assistance/education are the key drivers of enhanced efficiency, quality and productivity in the supply chain.

In contrast with the zero-sum game played in many conventional supplier-buyer relationships, the supplier and customer in Japanese-style partnerships adopt a win-win attitude when collaborating with each other in order to enlarge and share the total value that is created by both sides. The customer and the supplier is expected to respect each other's right to make profit and also to recognize that higher profits should not be derived by one party at the expense of the other.

To force both sides to exercise win-win behavior, trust between the supplier and the customer is required. However, Japanese-style partnership is not built on blind trust only; the trust is established through mutual interdependence and the agreed-upon rules of the game (Kamath and Liker, 1994). In order to strengthen their interdependent relationship, both the Japanese suppliers and their customers deliberately create weakness for themselves, ensuring that no entity, even the stronger one, can damage the relationship without suffering significant loss (Nishiguchi and Anderson, 1995). In the Japanese-style buyer-supplier networks, the customer usually selects only one or two suppliers for each component, which is known as sole or dual sourcing. Each supplier is awarded more business than in the conventional buyer-supplier transaction, in which the customer selects multiple suppliers per part. Japanese lean manufacturers also delegate to their suppliers more responsibilities in designing and manufacturing a whole subsystem or component. Therefore, Japanese lean manufacturers may be conjectured to have relatively less technical knowledge about certain parts or systems, compared with the mass production manufacturers who exercise a tight control over detailed engineering design at the lowest part level. One possible exception to such a plausible conjecture is Toyota, generally known as having detailed engineering knowledge on all aspects of the car at the system, subsystem, component and parts levels.

On the other hand, suppliers in the Japanese-style partnership are often required to make investments in equipment, personnel or facilities dedicated to a specific customer only. These investments can be risky for the suppliers, because they are expensive, tailored to only one customer and sometimes of no use outside the transaction with this specific customer. However, such asset-specific investments cement even closer relationships between the customer and its suppliers, ensuring that neither party can easily walk away from the relationship. Other trust-building practices include the customer owning some part of the stock of its suppliers, having guest engineers from its suppliers, and transferring its own employees to supplier sites. These practices create shared vulnerability and enhance the sense of coexistence for both parties, which help stabilize buyer-seller relationships.

Long-term commitments are highly valued in Japanese-style partnership. Unlike the short-term contracts in conventional supply-buyer relationships, suppliers are usually awarded business for the whole model life cycle or guaranteed four years of business at least (Womack *et al.*, 1990). If the winning supplier has excellent performance, it is very likely that this supplier will win the contract for the next new model. In fact, Toyota and Nissan even offer "open-ended" contracts to their partners, using long-term business to encourage the partners to perform well. Furthermore, instead of using the price proposed through a bidding process as the sole criterion, Japanese lean manufacturers take into consideration the suppliers' long-term performance in supplying previous models when selecting their suppliers. During the business downturns, the

Japanese lean manufacturers usually do not drop the current suppliers and look for another offering a lower-bid. Some of them would work with their suppliers to reduce costs, enhance supply chain efficiency or seek other business opportunities. There are several economic advantages a long-term and stable supplier-buyer relationship can offer. Knowing that their business with the customer can last for the whole product life cycle and even extend to the new model, suppliers are more willing to make long-term customer-specific capital investments or develop new products for the next model in advance. The manufacturer can also reap the long-term cost benefits from the suppliers' improved production efficiency as their production experiences accumulate with time (Dyer and Ouchi, 1993). Although the initial investments for establishing a long-term supplier-buyer partnership can be expensive, economies of scale can be realized by the large amount of business over time between the two parties, which drives down per-unit production as well as transaction costs (Dyer, 1997).

Darwinistic price competition among suppliers has been a main feature of buyer-supplier relationships in the conventional mass-production culture, where the market serves as the principal coordinating agent and where the customer firms incur substantial transaction costs. In contrast, in Japanese-style customer-supplier partnerships, supplier interfaces are governed by clear rules where both the customer company and the suppliers are motivated to improve their operational efficiency and lower their transaction costs. Sharing cost savings is the best example. In the Japanese automobile industry, powerful assemblers institutionalize certain mechanisms to work with suppliers to achieve cost savings jointly. The suppliers can keep an agreed-upon percentage of the cost savings. The rest would be shared with their customers in exchange for long-term commitments from their customers. If the suppliers achieve more cost savings than the original target, the suppliers can keep all of the excess cost savings. Therefore, both parties can benefit from this arrangement and are willing to work jointly to cut down the total value chain cost. The suppliers are also more incentivized to take an active role in conducting value engineering to reduce their costs and improve their operational performance. Japanese lean manufacturers often offer assistance in various forms when their suppliers fail to meet production or quality requirements. The customer sometimes assigns on-site guest engineers to solve the problems, working side by side with the suppliers' engineers. A variety of educational activities, such as shop-floor demonstration and seminar, are also offered and self-learning supplier associations are supported by some Japanese manufacturers, aimed at achieving continuous improvement across the supplier network. Further details on supplier development and continuous improvement will be discussed in Section 3.1.2.

Early involvement of suppliers in the production development stage is another important feature of Japanese-style partnership. Due to rapid proliferation of product models and changes in the functionality of the products that are offered to customers increasingly demanding new features in the products they buy, companies have progressively reached out to their suppliers for expertise for designing and manufacturing the parts and components making up their products. In the conventional mass production culture, the suppliers were basically expected to manufacture specific components according to the detailed engineering specifications handed down by the customer companies. By contrast, the customers in Japanese-style partnership only provide early general model specification and performance requirements to their key suppliers early in the product development stage and let the suppliers develop the detailed design on their own. In some cases, the first-tier suppliers, especially the ones equipped with outstanding technological capabilities (e.g., Nippondenso), are selected to start participating in planning the new model even before the concept development stage (Kamath and Liker, 1994). The customers seek inputs from their partnering suppliers early in the product development process since these suppliers are usually more knowledgeable about their specialized products and the related production issues and can provide valuable suggestions from the manufacturing perspective. Some suppliers can even influence on the determination of product specifications. The ability to delegate more component/subsystem design and manufacturing responsibilities to suppliers frees up both capital and personnel resources in the customer organizations while providing access to the suppliers' expertise in certain components/subsystem. It also enables the customers to concentrate on developing their own core competitive capabilities. By developing the new model jointly with the suppliers, manufacturability problems, such as difficulty in connecting two components/parts together, can be identified and avoided very early in the design phase. This prevents the manufacturing problems from flowing down to the supply chain. As a result, early supplier integration only eliminates the enormous costs incurred by reworking and redesigning the parts later when problems are discovered but also enhances the overall product quality. Meanwhile, because the suppliers work jointly with the customers so early in the product design and development stage, they develop better understanding of the customers' needs so that they can respond more effectively with tailor-made solutions to the highly individualized needs of their customers. The customers can then benefit from the ensuing greater supplier specialization by having their unique needs met without incurring the additional cost of developing such expertise internally and by reducing coordination costs (Clark, 1989).

The last, but the most significant, aspect of Japanese partnership is the intensive, open and frequent communication between the supplier and buyer. Well-established communication channel must be in place first so that Japanese-style partnership practices, such as joint problem-solving, supplier development and joint product development can be implemented.

Unlike the mass-production supplier-buyer transactions, each entity in Japanese-style partnerships is required to disclosure extensive technical and costs/profits data to the focal firm. Without intensive information sharing, it is impossible for the suppliers and customers to jointly identify and eliminate the inefficiencies existing in the supply chain or to offer assistance to each other on production/operation problems.

Japanese lean manufacturers gain various benefits from having close ties to their suppliers, such as decreased inter-company inefficiencies, enhanced product quality, stable market demands from long-term commitments from each other, better product design, decreased defects and the resulting cost savings. Their legendary success has proven that the key to developing a competitive supply chain system is not the lower purchase prices but the way the customer manages its relationship with its suppliers.

3.1.2 Knowledge sharing across supplier network and supplier capability development

Extensive previous research has suggested that in order to sustain its competitive advantages, a firm should be continuously engaged in learning and should regularly upgrade or adapt its capabilities in response to the changing business external environment (Teece, *et al.*, 1997). Some research has further pointed out that the inter-organizational learning - learning within a network through collaboration with other network members – might have a even more critical influences on a firm's innovation and competitive advantages than individual firm-level learning (Powell *et al.*, 1996). It was also noted that a firm's supplier network, including its customers and suppliers, can become its primary source of innovation and whether the knowledge-sharing mechanisms are effective within a firm's supplier network directly impact its competitiveness within its industry (von Hippel, 1988).

Generally, a firm's knowledge can be divided into two types – explicit knowledge and tacit knowledge (Kogut and Zander, 1996; Nelson and Winter, 1982). Explicit knowledge is 'knowledge that has been or can be articulated, codified, and stored in certain media. The most common forms of explicit knowledge are manuals, documents, procedures, and stories capturing lessons learned'[32]. Explicit knowledge can be communicated externally 'without loss of integrity once the syntactical rules required for deciphering it are known' (Kogut and Zander, 1992). Opposite to explicit knowledge, tacit knowledge is difficult to codify, document, communicate, describe, replicate or imitate (Nelson and Winter, 1982). Nonaka and Takeuchi (1995) defined tacit knowledge as a 'non-linguistic, non-numerical form of knowledge that is highly personal and context specific and deeply rooted in individual experiences, ideas, values and emotions'. However, tacit knowledge can be a sustainable competitive advantage for an organization (Nonaka, 1994).

Supplier development is defined as the undertaking of improving suppliers' capability through transfer of both explicit knowledge and implicit knowledge (Sako, 2004). For decades, Japanese lean automobile manufacturers, such as Toyota, Honda and Nissan, have made considerable financial and resource commitments in supplier development activities across their supplier networks. The ultimate goal of supplier development activities is to enhance suppliers' overall capability of continuous improvement (Kaizen) by putting in place processes for accumulating, acquiring, creating and exploiting new knowledge. From previous studies on the supplier development activities of the Japanese lean manufacturers, several distinctive features of high-performance knowledge-sharing networks can be identified.

Supplier development activities are aligned with the company's subcontracting practices and

[32] http://en.wikipedia.org/wiki/Explicit_knowledge

supplier management philosophy.

As mentioned in the previous sections, lean production involves just-in-time delivery, which allows only items needed by the downstream to flow down from the upstream process and reduces inventory buffers; it also highly emphasized quality control and allows multi-tasked shop-floor operators to stop production line in case of problems, preventing defects from flowing downstream; improvement ideas on any aspect of the company are continuously requested from the employees in order to achieve *Kaizen* (continuous and incremental process improvement). In order to support its lean production system, it is necessary for a lean manufacturer to work with lean suppliers that are also highly reliable in meeting strict product quality and delivery requirements. Lean manufacturers' decision to devote resources to create lean suppliers among their suppliers instead of simply switching to other lean suppliers can be attributed to the common feature of lean manufacturers' sub-contracting philosophy - long-term commitment and cooperative partnerships with their suppliers. From a long-term relationship with their suppliers, lean manufacturers enjoy several benefits, including economies of scale, as well as reduction in transaction and production costs, relation-specific assets, long-term interpersonal relationships, and mutual obligations and responsibilities. Simply substituting the original suppliers for the lean ones not only results in loss of these benefits but also damage to company's reputation, making it hard to attract lean suppliers who also value long-term supplier-customer relationship (MacDuffie and Helper, 1997). Furthermore, through creating a greater number of lean suppliers, the customer company enlarges the pool of qualified sourcing choices in the market (MacDuffie and Helper, 1997), which also increases the company's bargaining power when negotiating on costs and prices.

In addition to the common features shared by lean manufacturers, the approaches to supplier development are driven by the individual company's purchasing and supplier-relation management philosophy and therefore differ from company to company. For example, Toyota's purchasing philosophy evolved from Japanese 'life-long' employment philosophy (Nishiguchi and Anderson, 1995), stating that "once nominated as Toyota suppliers, suppliers should be treated as part of Toyota; Toyota shall carry out business with these suppliers without switching to others and shall make every effort to raise the performance of these suppliers." (Toyota Motor Corproation, 1988) Based on this creed, Toyota started various initiatives aimed at creating a "Toyota family" with strong belief of "co-existence and co-prosperity" (Kyoson Kyoei) among the members of its supplier network. This philosophy not only established suppliers' long-term loyalty and identities as members of the Toyota family but also laid out the foundation of Toyota's various supplier development processes and organizations. Unlike Toyota's hand-on approach, Honda's purchasing philosophy emphasizes free competition, equal partnership and suppliers' managerial self-reliance. Honda's supplier development activities aim to help suppliers become global competitors with broad customer bases while maintaining their responsiveness to Honda's requirements. By doing so, Honda can avoid the financial strain resulting from its suppliers' over-dependency on business with Honda during business downturns (MacDuffie and Helper, 1997; Sako, 2004).

Developing supplier capabilities requires huge investments in time, labor, and money. In order to avoid unnecessary waste and ensure the effectiveness of supplier development activities, it is important that the customer company should establish its supplier development approaches to ensure that its activities are consistent with the company's overall supplier management philosophy and business strategies.

There are distinctive internal organizational structures and routines in place for transferring

knowledge and tightening the bond among suppliers.

Previous research found that only after an organization has purposefully designed routines in place to facilitate knowledge acquisition, storage, diffusion, and adaptation can it be effective at learning at either individual-firm or network level (Nelson and Winter, 1982; Levitt and March, 1988; Dyer and Nobeoka, 2000). Therefore, in order to facilitate highly effective knowledge transfer and implementation across supplier networks, distinctive internal organizational structure, corporate governance and well-executed supplier development processes are required. The successful cases of supplier learning networks enabled by Japanese automakers share the features of commitment from a well-established internal organizational structure and routines designed for knowledge transferring.

Toyota adopts a bifurcated structure for supplier development activities, separating purchasing function from supplier development activities. There are two internal units at Toyota in charge of supplier development; one is Toyota's purchasing planning division and the other one is its operations management consulting division (OMCD).Unlike Toyota, Honda and Nissan combined their supplier development with purchasing functions. Honda's core supplier development activity –BP– is carried out by the Purchasing Technical Center (corresponding to Toyota's OMCD). At Nissan, its Engineering Support Department is in charge of supplier development activities. "Free" and "individual-based" assistance is directly offered to the suppliers by these internal organizations. For example, The consultant/engineer teams in OMCD offer "free" "direct" "on-site" assistance to both Toyota's internal factories and Toyota's suppliers (Winfield and Hay, 1997; Dyer and Nobeoka, 2000; Sako, 2004), ensuring that the same set of TPS processes, principles and method flow down Toyota's supplier network consistently. The OMCD usually sends its consultant teams directly to the suppliers' facilities to jointly work on the problems with the suppliers' employees.

In addition to one-to-one direct assistance, the supplier development group represents another example of the commonly-observed supplier development process adopted by Japanese lean automakers, with a primary objective to encourage lateral learning among suppliers themselves. Kyohokai, Supplier Association by Purchasing Planning Division and Jishuken Group (supplier self-learning group) by OMCD are two well-known processes adopted by Toyota. Supplier Association aims to develop ties among suppliers and to achieve and reinforce competitiveness and continuous growth through further information sharing and mutual communication with Toyota Motor Corporation[33]. The Supplier Association also offers various training courses, presentations on the "best-practice" and tours to the best-practice plants. Besides the monthly general meeting of members within the Supplier Association, there are also specific committees that are formed focusing on several different topics (e.g., cost, quality…etc) respectively (Sako, 1996). These committees enable suppliers with common concerns to have more interactions with each other and increases the amount of knowledge related to certain topics that are transferred or cumulated within the supplier network (Dyer and Nobeoka, 2000). Jishuken Group, organized by OMCD, is a voluntary supplier self-study group within Toyota's supplier network. The suppliers are grouped in such a way that the members in the same group are geographically close to each other, while direct competitors are not included in the same group. Geographic proximity facilitates suppliers' visits to each other's factories. Avoidance of direct competitors in the same group ensures that suppliers feel comfortable with opening their internal business information to the other members of the same group. Under the supervision of OMCD's engineers, each year the suppliers in each Jishuken group decide on an improvement target related to an area of

[33] http://www.kyohokai.gr.jp/khktowa/kyohokaioutline/e_outline.htm

common interest. The "Kaizen" ideas are then put forward by the members in the Jishuken group and implemented at the factory of an appointed hosting member. Toyota puts great pressure on Jishuken group to meet the planned targets, ensuring that the learning activities should result in concrete improvements (Dyer and Nobeoka, 2000; Sako, 2004).

A similar supplier association can be found in Nissan as well. Capability Enhancement promotion Committee, consisting 25 core suppliers, is the supplier association established by Nissan's Engineering Support Department. There are three meetings each year at the levels of company president and manufacturing directors. Smaller supplier group meetings are also held regularly within the proximate regions. The purpose of these meetings is to share information, create consensus and presenting successful Kaizen examples.

Multiple processes are provided to achieve multilateral transfers of both tacit and explicit knowledge.

All of these supplier development activities take place in various forms, ranging from one-to-one direct assistance to the formation of lateral learning groups across suppliers, from classroom teaching and presentations on best practices to shop-floor demonstration and experiments. The employment of multiple knowledge sharing paths ensure that all types of knowledge, both explicit and tacit, can be transferred in the most suitable way possible so that the knowledge can be diffused most efficiently (Dyer and Nobeoka, 2000). For example, For example, classroom teaching and presentations of best practices can diffuse explicit knowledge efficiently; however, tacit knowledge is found most effectively transferred through shop-floor practices. Multiple learning avenues also enable multi-lateral learning among suppliers themselves, maximizing the efficiency of acquiring and transferring knowledge within the supplier network. Furthermore, by pursuing supplier development activities through multiple pathways (e.g., joint shop-floor problem-solving teams at suppliers' facilities, Jishuken group), the customer company can gain multiple accesses to its suppliers' inner operation and cost structures (Sako, 2004). This would strengthen the customer company's capability in setting reasonable target costs (Sako, 2004) and enlarge the customer company's knowledge about components not produced in-house.

The finding that is perhaps the most noteworthy is that teaching through the hands-on practice of participating in routines, rather than the representation of routines in classroom or lecture format, results in more complete and effective transfer of tacit knowledge. Sako (2004) has argued that the Jishuken is more effective than the supplier group processes adopted by Nissan and Honda because the know-how of the problem-solving process is concretely experimented and demonstrated on-site in a hand-on manner, rather than simply through presentations of the successful cases or tours to the best-practice factories. Dyer and Nobeoka (2000) have found that the reason why PDA(Plant Development Activity, a Toyota's endeavor in replicating Jishuken in United states) is considered more valuable than the BAMA (Bluegrass Automotive Manufacturers Association, the counterpart of Kyohokai organized by Toyota in United States) is that the "PDA core group activities involve learning that is context specific, that is, hands-on and on-site." Winfield and Hay (1997) have also found that the Toyota's suppliers in the UK have largely linked together both experimental trail and seminar-related learning to explain new process changes to their workforce, reflecting the belief that through involving workforce in the change process actively in practical settings rather than by following top-down teaching, the changes can be communicated more effectively.

Supplier development strategies are integrated into the supplier selection process.

Absorptive activity refers to the ability of an organization to pick up new ideas and adapt to them and is considered the most critical factor deciding whether an organization can absorb new knowledge effectively and implement a planned change successfully (Levinson and Asahi, 1996). The indicators of an organization's absorptive capacity include the effective communication mechanism among the members, reward systems that prize flexibility and innovation and prior related knowledge existing in the organization (Cohen and Levinthal, 1990). Levinson and Asahi (1996) have also suggested that organizational culture can facilitate or hinder organizational change and/or organizational learning. Therefore, factors such as suppliers' absorptive capability, managerial attitude and firm identity should be considered when selecting supplier in order to ensure the success of supplier development endeavors.

In MacDuffie and Helper's case studies (1997) on Honda's BP program, it was found that Honda selected the participants of its BP program according to the following criteria: highly motivated to learn, responsive to Honda's needs, willing to open their operations completely to Honda, willing to take risks, willing to take initiative in investment of new technologies and organizational/human capabilities and willing to promise that no layoff would happen as a result of Honda's BP programs. Winfield and Hay's case studies (1997) on Toyota's suppliers in the UK have also revealed the fact that Toyota selected its suppliers because they were equipped with an already existing preemptive attitude favoring learning and adopting changes, as well as their perceived potential compliance with Toyota's requirements.

The scope of learning is broadened and deepened over time.

Because of the interdependency feature among many processes within a company, changes in manufacturing processes might affect different aspects of an organization. Implementation of the lean production system not only involves the changes in the shop-floor practices (e.g., Kanban, JIT...etc) but also calls into consideration the evolution of the company's management philosophy, culture and capabilities. Therefore, in order to replicate complete lean capabilities in suppliers, the supplier development activities should not only focus on shop-floor techniques but also on many other aspects of the company, such as product development, finance, business plans, and strategic planning.

The history of Japanese automakers' supplier activities shows a broad trend over time evolving from narrowly-focused problem-solving tools and methods to supplier integration into product development and aligning supplier capabilities and strategies with the focal company's high-level management strategies and processes (Sako, 2004). For example, Purchasing Planning Division in Toyota teaches TQC (Total Quality Control) techniques to the middle-level management personnel of Toyota's suppliers. It helps suppliers to integrate their shop-floor processes into their high-level management policies, emphasizing overall capability enhancement. Moreover, as it has been found in the UK, Toyota's suppliers tend to implement changes as a "whole package", rather than focusing on a certain selected area. It has been suggested that the training given by Toyota to its suppliers is not only targeted at the mid-level and top management personnel but is aimed all the way down to the suppliers' team leaders (Winfield and Hay, 1997).

Incentive mechanisms, as well as clear rules and norms are established in order to motivate learning and to prevent opportunistic behavior in the learning network.

Supplier development capabilities require not only the efforts of the customer company but also commitment, as well as investment, by the suppliers that are recipients of the customer company's efforts. To maintain suppliers' motivation in participating supplier development activities, incentives, such as Honda's 50-50 sharing rule for cost savings, are often provided by the customer. Furthermore, companies have a tendency to protect their own proprietary data from the outside entities and are not always willing to share information with external entities. Some companies, such as Toyota, would use withdrawal of their business from a supplier as a form of punishment if that supplier enjoys the benefits of knowledge transfer within the supplier network but is unwilling to share its own internal knowledge with others.

3.1.3 Supply chain integration, collaboration, and supply chain innovation enabled by information sharing and information technologies

The importance of supply chain integration and collaboration

Today, companies across many industries are faced with a much more complex, dynamic, and competitive marketplaces than before. There are several factors contributing to this phenomenon, among which are globalization, faster product life cycle, elevated and demanding customer requirements, and e-business environment (Porter and Stern, 2001; Tan, 1999; Meyer, 2000). Due to globalization and crumbling trading barriers, companies have found that their competitors, suppliers, partners, and customers could be anyone from any country. Customers' expectations are getting much higher than before and companies have to continuously enhance the quality and variety of their products and shorten the time-to-market to strengthen their competitive advantage. By lowering the barriers to entry and providing improved access to customers, the emergence of the e-business environment has brought even more players into the marketplace, particularly many small start-ups. Companies with less capital can now enter the market and compete with the large players in the same marketplace, which means that competition is becoming much more intensified. Furthermore, e-business speeds up the rate of changes in the external market environment and companies have to accelerate their pace of decision-making accordingly (Golicic *et al.*, 2003). Companies can be said to have entered a "hyper-competitive" marketplace where the complexity, uncertainty and competition will continue increasing (Merrifield, 2000; Patterson *et al.*, 2003). In this new environment, producing products of good quality at a reasonable cost will no longer be a sufficient strategy to boost competitiveness; an enterprise has to have a much more innovative, efficient, flexible and robust business architecture and supply chain strategies in order to survive and prosper (Herman, 2002).

In response to the uncertainties and complexities of today's dynamic global market, strategic alliance and partnerships with suppliers have emerged as an important development in recent years. Through outsourcing non-core manufacturing and distribution operations to partnering suppliers, individual companies have made attempts to achieve leanness and flexibility while at the same time expanding their resources and capabilities without heavy capital investment. Furthermore, in some of industries, such as biotechnology and pharmaceuticals, the networks formed by strategic alliances and partnerships, instead of individual companies themselves, have become the primary sources of innovation for product development (Powell *et al.*, 1996; Levinson and Asashi, 1996); participation in many research and development partnerships has become critical for these companies to bring the most promising products to the market (Herman, 2002). However, with more entities participating in the supplier network, various types of inefficiencies, such as delays, errors and wastes, might increase as well. In order to eliminate the inefficiencies across the multiple echelons in the supply chain, closer coordination among suppliers and customers is imperative. Previous sections have emphasized the importance and benefits of collaborative and mutually-beneficial buyer-supplier relationships based on trust, respect, strategic contractual arrangement, long-term commitment and shared inter-organizational vision. One of the most important benefits is that partnership or alliance enables a more open and effective channel for information sharing and communication cross the supply network, which pave the way to enhanced supply chain coordination.

Previous literature has pointed out that the unwillingness to share information and lack of coordination across the supply chain result in sub-optimization in the supplier network, where each entity acts only locally, striving to optimize its own profits instead of working towards the optimization of the performance of the entire supplier network. The bullwhip effect is one of the most well-known examples. The bullwhip effect, which first came to attention in connection with an analysis of Procter and Gamble's diaper products, is the phenomenon in which the fluctuations in orders amplify in magnitude as they move further upstream along the supply chain (Hau 1997; Sheffi, 2005). Lack of information visibility and the failure of coordination across the supplier network are the main reasons contributing to the bullwhip effect. Because the entities within the same supply chain do not share information, temporary order fluctuations from the downstream customer might be misinterpreted by the upstream manufacturers as permanent demand growth or a decrease in future demand. Consequently, the manufacturers would overly expand or shrink their production and orders to their upstream suppliers with the anticipation that the future demand will follow this trend. The same pattern repeats itself and the variations of the demand will continue to be amplified while moving up along the upstream supply chain reaching all the way to producers of raw materials. The presence of the bullwhip effects has led to increased costs due to the basic misalignment between supply and demand, inventory hedging/duplication, shipping delays, poor delivery times, and related reasons (Chopra and Meindl, 2003).

In addition, failure to communicate with suppliers effectively and poor supply chain integration can result in serious quality issues. While the order fluctuations are increased upstream along the supply chain, errors are accumulated downstream. In most cases, it can be found that the last link of the supply chain is usually the least efficient one due to all of the errors accumulated from the upstream processes along the supply chain (Sharman, 2002). These errors may be due to the supply of incorrect materials, defects in specifications or installation instructions, poor design interfaces, and other reasons. If these errors are not detected or ignored due to miss-communication or lack of communication, their correction will become labor-intensive and costly once they flow along the supply chain. Womack *et al.* (1990) have noted that repairing the finished cars with defects at the end of the assembly line is enormously time-consuming and usually fails to fix all of the problems, as the errors have been accumulated all along the supply chain and have remained hidden under layers of parts and upholstery. The previous section has pointed out that early integration of suppliers into production development can avoid defects in product design and, quite importantly, can help generate improved product specifications very early in the process. Moreover, many problems in product development can be avoided or minimized through better communication among supply chain partners and through the streamlining of organizational boundaries to facilitate better management of information flows.

Therefore, along with outsourcing, collaboration with supplier partners and managing the supply chain as an integrated system represent essential ways of enhancing customer satisfaction and improving overall channel efficiency (Davis, 1993). The benefits of supply chain integration can be concluded as follows (Patterson *et al.*, 2003):

1. Minimizing the bullwhip effect;

2. Maximizing the efficiency of conducting activities along the supply chain;

3. Minimizing inventories along the supply chain;

4. Minimizing cycle times along the supply chain;

5. Achieving an acceptable level of quality along the supply chain;

6. Achieving better product design.

In the future, the competition will focus not only on the capabilities of individual companies but also the overall performance of their supplier networks. The true competitiveness should be achieved through the right combination of the best financial and technological resources from external suppliers, along with coordination of all of value-added activities in the supply chain. In addition, innovation is another crucial factor deciding a company's success (D'Aveni, 1994). Continuous innovation and corporate renewal are both considered as significant strategies for generating and maintaining competitive advantages (Merrifield, 2000). As one of the most viable strategies of supply chain innovation, adoption of information technologies has received significant attention in recent years. From many cases of applying information technologies in supply chain management across industries, it has been proven that the implementation of appropriate information infrastructure can impact buyer-supplier relationships, interorganizational business processes, the firm's marketing strategies and even the overall supply chain or organizational architecture. The following few paragraphs will discuss in more detail on how information technologies enable innovation in a firm's business model and supply chain strategy to create greater value.

How do information technologies enable innovations in business processes and in supply chain management?

Information technology consists of the information technology infrastructure, systems, applications and tools used to collect, convert, store, protect, process, transmit, and retrieve information [34] ; it also includes tools for analyzing information and related aids in decision-making (Chopra and Van Mieghem, 2000). The rapid advances in information technologies over the past two decades have not only reshaped the business environment but have also proven to be an enabler of enormous value creation if exploited well. How to leverage the power of information technologies to transform a firm's business model and supply chain strategies has received considerable attention in the literature. It has been pointed out that information technologies can create significant value through enhancing transactional efficiency, facilitating better marketing and customized services, achieving better supply chain operational efficiency, and enabling supply-chain integration and collaboration, as well as enabling business process reengineering and supply chain restructuring.

1. Enhance the efficiency in buyer-customer transactions

The first time industries evidenced important benefits from their investments in information technologies was through the introduction of E-Commerce (electronic commerce). In the beginning, E-commerce referred to information technologies that facilitated electronic inter-organizational business transactions, such as EDI (Electronic Data Interchange). EDI, which is a technology introduced more than 20 years ago, enables

[34] http://en.wikipedia.org/wiki/Information_technology#_note-Explanation

effective computer-to-computer communication among organizations with minimal human intervention. The documents or data transmitted are conveyed in commonly understood and standardized formats that are agreed-upon by the participating organizations[35]. With rapid recent advances in the Internet and WWW (World Wide Web) technologies, the content of E-Commerce has been broadened and now encompasses any applications that rely on the Internet technology to improve the efficiency and effectiveness of business transactions[36] (Meyer, 2001).

The business transactions that can be executed include (Chopra and Meindl, 2003; Sharman, 2002):

- Placing purchasing orders to suppliers;
- Issuing shipment notices to customers;
- Providing product information and test results to the customers;
- Providing product specifications to the suppliers;
- Allowing customers to place orders and track the orders;
- Contracting; and,
- Invoicing.

All of these business transactions are still the traditional business processes; however, information technologies replace the originally paper-based and labor-intensive business transactions typically involving phone calls and fax with electronic and automated processes

[35] http://www.doli.state.mn.us/edi_1.html ; http://www.anu.edu.au/people/Roger.Clarke/EC/EDIIntro.html
[36] http://www.webopedia.com/TERM/e/electronic_commerce.html

via information networks. The automation of business transactions has significantly reduced "clerical" error rate and transaction costs (Chopra *et al.*, 2001; Sharman, 2002), including costs related to handling proposals and quotations, processing orders, personnel processes and so on (Chopra *et al.* , 2001). These information technologies can be served as a catalyst for gaining efficiencies across organizational boundaries. Sine the Internet supports real-time data processing and electronic data retrieval and storage, the transactions can happen at any time and any place within seconds. Furthermore, the Internet supports real-time processing and unlimited data types (e.g., graphic files, CAD design files), which speed up the processing time and expand the types of document that can be transmitted (Chopra *et al.*, 2001).

The enhanced efficiency of transactions among entities in the supplier network shortens the turnaround time of these business procedures and decreases overall lead time. Large e-companies have already started taking aggressive approaches to transform their business transactions into electronic ones. For example, one of Simens' initiatives in electronic procurement and sales, click2procure, created a companywide virtual on-line procurement marketplace particularly designed for purchasing highly standardized goods and materials such as office supplies. By the end of 2001, the procurement volume handled through click2procre reached more than one billion euro (Goller and Heinzel, 2002).

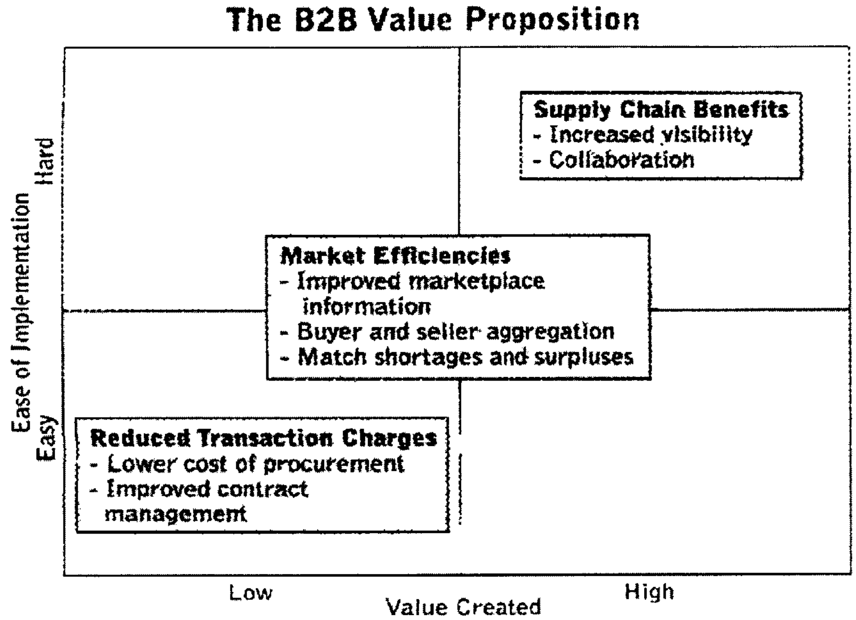

Figure 3.1. 1. The B2B value proposition

The reduction in transaction costs only scratches the surface in terms of the potential benefits information technologies can bring to supply chain management. Chopra *et al.* (2001) have argued that the value created by E-Commerce through reduced transaction costs are limited, as shown in Figure 3.1.1. Sharman (2002) also has pointed out (see Figure 3.1.2) that only one sixth of the total supply chain management costs are due to transaction and overhead costs; the majority of the costs are incurred because of poor supply chain coordination (e.g., suboptimization due to unwillingness to share information) and inefficient supply chain operations, including transportation, handling, and inventory. The discussion provided immediately below discusses how information technologies can create greater value and achieve future cost reductions by enabling better marketing strategies, supply chain efficiencies, supply chain collaboration and innovations in supply chain design.

Figure 3.1. 2 Overall supply chain cost breakdown

2. Facilitate better marketing and customized service

With the advances in Internet-related technologies and the consequent emergence of on-line stores, more consumers have switched to on-line purchasing from traditional store shopping. As a result, many retailers or manufacturers have already started to exploit the benefits brought by on-line business. The on-line catalogs enabled by Web technologies make it easy for the sellers to publish or update their product portfolios and product prices. Instead of mailing the product portfolios to all customers, the retailers only have to update the product information through a single data entry and all of the customers can see the changes from the website. The flexibility of changing prices and product portfolios facilitates dynamic pricing and dynamic revenue management similar to airline yield management. Dell dynamically changes prices and delivery times of certain products based on the customer demand, as well as its inventory positions; by doing so, Dell not only decreases its inventory costs by dynamically offering promotions on products with excess inventory but also maximizes its revenue that can be extracted from its available resources (Chopra and Meindl, 2003).

On-line marketplaces offer another opportunity for increasing revenues through the ease of changing prices and service customization. On-line virtual stores have the flexibility of modifying the store "layout" by routing the customers to different web pages or allowing different functionalities according to the personal profiles of the customers (Chopra and Van Mieghem, 2000). This functionality facilitates service and price discrimination, which are hard to achieve at traditional physical retailer stores. The customers can choose the levels of services they would like, such as delivery times offered by Amazon.Com, according to their willingness to pay. Based on the buying power of customers, on-line auction sites can also change prices dynamically in order to increase revenues (Chopra and Meindl, 2003; Chopra and Van Mieghem, 2000). Furthermore, the time gap between the customer placing orders on-line and the delivery of the products allow the manufacturers to postpone the final assembly of the product until the demand is realized and, hence, offer a higher level of product customization. For example, Dell allows the customers to choose from the websites the parts they would like to go into their computers and assemble them after the customers place the orders.

Information technologies also help the company get a better understanding of the characteristics of the market demand. Some Japanese retail companies, such as Seven-Eleven in Japan, are extremely sophisticated in using their IT systems to collect and utilize data on customer needs and habits (Earl, 1998). Seven-Eleven has successfully increased its revenues through utilizing data-mining technology to analyze the factors influencing demand patterns for different products and change its store-shelf layout accordingly. From the data on the age and gender of customers collected by its store cashiers, Seven-Eleven found that it would be most convenient to put ladies' stockings next to the beer because these stockings are purchased most often by the husbands on their way home from work[37].

3. Achieve better supply chain operational efficiency

A variety of recently-developed information technologies have largely expanded the pool of available information reflecting the real-time status of people, items or processes in the supply chain. This facilitates supply chain managers to get a better understanding of the choke points and improve or eliminate the error-prone processes in the existing supply chain (Herman, 2002). Wireless information technology, in particular, is believed to offer great opportunities for enhancing the operational efficiencies of supply chains. Wireless networks give elements in the supply chain (e.g., people, products) their specific "identity", which allows them to be monitored and tracked. As a result, real-time visibility is gained into the location and status of individual sales items. Many enterprises have already started to utilize wireless technologies to enhance the efficiency of supply chain activities, including materials handling, inventory tracking and management, asset tracking, replenishment, and warehousing (Shankar and O'Driscoll,2002). Aviall, a Dallas-based aircraft parts distributor has attained about $1- million- per-year savings in time and labor costs through applying wireless technology to automate the inventory replenishment process in customer warehouses. Wal-Mart, as a pioneer in applying information technologies in supply chain management, has started in recent years an RFID (Radio Frequency Identification) pilot project which tracks the products of several manufacturers, such as Gillette (Gillette was acquired by P&G in January, 2005), all the way from from the individual manufacturers to its own distribution centers to the retail store backrooms to the store shelves Wal-Mart anticipates that the RFID-enabled processes can improve its global supply chain

[37] "Chain reaction", The Economist, Jan 31, 2002

visibility, store on-shelf product availability, detection of shrinkage and self-checkout at stores (Shankar and O'Driscoll, 2002).

4. Enable supply-chain integration and collaboration via improved information visibility and information-sharing efficiency

The previous paragraphs have stressed the importance of supply chain integration through the establishment of alliances and the sharing of information with supplier partners as a viable strategy to achieve greater supply chain efficiency and higher customer satisfaction. It has been demonstrated in many industries that information technology can act as an enabler facilitating collaboration among supplier networks. Both CRP (Continuous Replenishment) and VMI (Vendor Managed Inventory), which represent two important elements of the overall ECR (Efficient Customer Response) vision of the US grocery industry, provide a good example of how information technology facilitates collaboration between vendors and customers to improve channel performance (Clark and Stoddard, 1996). In CRP systems, retailers share data on warehouse shipments or Point-of-sale (POS) data with vendors. Vendors, with better knowledge of product movements at retailers, can then determine accurate order quantities to ship and replenish the inventory at the retailers on a just in time basis (Kinsey, 2000). VMI system is a further extension of the CRP system. It requires the manufacturer to take full responsibility for managing the retailer's inventory. Using the information on product movement shared by the retailer, the manufacturer generates demand forecast and order quantities. The CRP system and VMI system have already proven their potential to effect large reductions in inventory levels at both manufacturers and retailers, decrease stock-out levels and bring about higher production cost savings (Clark and Stoddard, 1994). Although CRP or VMI system can be implemented with traditional data transmission media, both of them require continuous flow of information between the vendors and the customers to support just-in-time delivery. Manually handling such a big volume of information would involve many human errors, a risky approach that can result in stock-outs. Using EDI for data transmission, which has facilitated efficient and accurate data transmission, is viewed as a key enabling technology contributing to the success of CRP and VMI systems.

One of the most important impacts the Internet has had on supply chain relationships is the unprecedented connectivity it has enabled -- being interconnected to both suppliers or customers via the Internet (Golicic *et al.*, 2002). Since the Internet has the characteristics of open access and low entry costs, more supply-chain members can share information via the Internet and remain connected with one another without financial and technological barriers. With open, quick, and effective media for sharing and accessing data across the supplier network, supply-chain partners can collaborate and synchronize their operations in terms of production planning, delivery scheduling or inventory management, with a common view of the current status of business processes and market demand. The Internet technologies can also facilitate collaborative product development between firms, especially when product development activities become increasingly more globalized and the transparency of the communication network becomes particularly important for achieving effective internationalization product development activities.

The emerging Internet-related technologies, such as XML and XML-based web service technology, are believed to bring the next revolution of connectivity in the near future. XML (Extensible Markup Language), recommended by W3C[38], is a standard way to define data

[38] W3C stands for World Wide Web Consortium, an organization that develops interoperable technologies (specifications, guidelines, software, and tools) and a forum for information, commerce, communication, and collective understanding. For more details on W3C, please refer to http://www.23.org/

structures around different subject domains. The standardized data structure of XML documents facilitates the sharing of data across different systems located in different organizations and geographical regions that are connected via the Internet. XML separates the data definition from the data presentation and, hence, can enable machine-to-machine data communication among a variety of dissimilar devices, including PCs, wireless smart sensors and tags, and GPS devices. Moreover, the XML-based web services technology makes possible automatic invocation of the right services or functions provided by the applications located on the other machines on the Internet. This means that software integration or "system-to-system" integration among supply chain partners become much easier. These emerging information technologies offer the companies flexibility of interconnecting systems that may be different from those employed by their partners, which facilitates not only bilateral collaboration but also encourages multilateral collaboration among suppliers, manufacturers, service providers, distribution channels and customers (Sharman, 2002).

5. Innovative business process reengineering and supply chain restructuring

As shown in Figure 3.1.2, significant cost reductions can be achieved through supply chain innovation and restructuring. Many companies have started explore the potential of information technologies to innovate their business processes and supply chain structures. The employment of both CRP and VMI in the grocery industry, discussed above, provides an important example. The use of CRP and VMI has completely changed the traditional order processes, shifting the order and replenishment responsibilities traditionally assumed by the retailers to the wholesalers or manufacturers. As mentioned earlier, it is infeasible and problematic to handle such large amounts of data transmission in the CRP or VMI systems manually instead of through the use of EDI. It is true that a large percentage of retailers and manufacturers have achieved cost savings through applying EDI to manage their order transactions without making processes changes required by CRP or VMI system. However, Clark and Stoddard (1996) have shown that a merger of technological innovation (e.g., adoption of EDI) and process reengineering generates the maximum achievable benefits.

Dell is another successful case showing that information technology can serve as an enabler innovating a firm's business model and supply chain structure. Utilizing the Internet and WWW technologies, Dell achieves direct contacts with the end customers and compresses its supply chain by eliminating the traditional reseller link. As mentioned before, through direct access to the end customers, Dell can use dynamic pricing to steer end customers' demands to the products with components that are available immediately, which helps Dell achieve large inventory cost savings. The direct sale model also enables Dell to offer customization by letting the end customers directly choose from Dell's website the specific components that go into the final products. Furthermore, Dell's direct access to the end customer allows Dell to offer delivery directly from its supplier partners to the end customers. For example, Sony, which has a long-term relationship with Dell, ships its monitors directly to Dell's customers. This brings about considerable cost savings in terms of warehousing and decreases the delays associated with having to stock additional inventories. However, the most significant benefit results from the merger of the direct sale model through WWW and the adoption of common platforms and components shared by the various products Dell provides. By combining these two strategies, Dell is able to postpone the manufacturing and fulfillment until the demand from the end customers is realized. This postponement not only eliminates the finished-good inventory but also enables Dell to exploit economies of scale through aggregating demand forecasts over common components (Chopra and Van Mieghem, 2000).

The Information technologies will continue to drive the evolution of the business model and supply chain strategies of companies in the future. The wireless technologies, such as RFID (Radio Frequency Identification) and GPS (Global Positioning System), greatly enhance the visibility and current status of the people, processes or products within the supply chain and provide much more extensive data to help customer companies make the right decisions on a real-time basis. The traditional linear supply chain is hence gradually transformed into a more proactive web-enabled supplier network that behaves like a neural network and can quickly respond to the customers' needs. In addition, the improved efficiencies of data transmission and the flexibility of interconnecting systems located in different organization facilitate the adoption of more agile business models. The emerging technologies, such as XML and web services, can provide a "plug-and-play" business application architecture, where, with defined and standardized interfaces for business processes and data transmission, enterprises can easily extend their capabilities by connecting to external resources offered by their partners and can also disengage unqualified suppliers easily as well. In summary, information technologies have proven an important enabler of more collaborative, agile and responsive supplier networks, largely enhancing the competitiveness of the customer companies in a dynamic and hyper-competitive global market.

Chapter 4: Comparative Analysis of Supply Chain Management Strategies and Practices Adopted by Boeing and Airbus in the 787 and the A380 Programs

4.1 Overview of the Airbus A380 and the Boeing 787 programs

4.1.1 Airbus A380

Overview

The 555-seat double deck Airbus A380 is the most ambitious civil aircraft program to date. The launch of A380 program revealed Airbus's ambition in terminating Boeing's long-term dominance in the long-haul jumbo jet market since the early 1970s with its famous 747. With the addition of the A380 platform, Airbus has rounded up its product line family and now covers all large commercial airliner market niches.

The development of A380 started in the mid 1990s. Based on market analyses prior to that, Airbus predicted that the volume of future air travel passengers would triple within 20 years. The rapid growth of the Asian economy and unabated urbanization during the past decade have been taken to support Airbus' market forecasts. The emerging, urban-based, middle-class population with rising disposable income in the developing Asian countries (e.g., China and India) has driven up the demand for air travel. The main travel destinations for this new customer group, as tourists, have been the major cities in the West. Accordingly, Airbus has predicted that the hub-to-hub tourist passenger traffic will be growing at a staggering rate in the future, which could already be observed by examining the top fast-growing international aviation routes throughout Asia, between Asia and the United States, and between Asia and Europe. However, with air traffic capacity constraints, increasing fuel prices, severe limits on expansion of runways, and the new security approaches after 9/11, the existing aviation facilities in the major hub cities will face serious congestion in the near future. The A380, with its 35% more capacity than the largest currently-operating aircraft, Boeing 747, has been positioned as a desirable solution to help airlines cope with the rising air traffic demands and enable them to improve the utilization and efficiency of their fleets without increasing the number of flights.

Currently, the A380 aircraft is sold in two models: the basic one is the 555-seat A380-800 in a three-class configuration or up to 853 passengers in a single-class economy configuration. The other model is A380-800F, which is a 590-ton MTOW aircraft with a range of 10,410km (5620nm) that will be able to carry a 150-ton payload and is due to enter service in 2008, with FedEx as the launch customer. Potential future models will include the shortened, 480-seat A380-700, and the stretched 656-seat A380-900.

Design features

Key design aims include the ability to use existing airport infrastructure with little modifications to the airports, and direct operating costs per seat 15-20% less than those for the 747-400. The A380 is marketed as an economic and environmentally-friendly solution to the growing air traffic. It is designed to have 10-15% more range but burn 13% less fuel than the 747. The A380 is the first long-haul plane to consume less than 3 litres of fuel per passenger seat over 100km[39]. Further, the A380 is billed to generate half as much noise on take-off as its competitor. The cabin design of the A380 promises unprecedented customer amenities: with 49% more floor space and 35% more seating capacity than the 747-400, Airbus is ensuring more space for each

[39] http://www.airbusa380.com/

passenger. Table 4.1.1 gives a detailed comparison between the A380 and the 787-400.

How they compare – A380 versus 747			
	A380	747-400ER	% difference
Length	72.7	70.7	+3%
Wingspan (m)	79.8	64.4	+24%
Wing area (m²)	845	541	+56%
Height (m)	24.1	19.4	+24%
Maximum take-off weight (t)	560	413	+36%
Range (km)	15,000	14,200	+6%
Maximum fuel capacity (l)	310,000	241,000	+29%
Accommodation (typical 3-class)	555	416	+33%
Installed thrust (lb)	280,000	252,000	+11%
Cargo payload – Freighter (t)	150	113	+33%
List price ($million)	272-292	198-227	+37% to +29%

Table 4.1. 1 Comparison of A380 and 747[40]

The cockpit design of the A380 follows the same cockpit layout, characteristics and operating procedures as the A320 and A330/A340 platforms, providing advantages in terms of crew training, crew transition, cross-crew qualification and fixed fleet flying[41] [42]. However, it also incorporates new features that benefit from innovation in technologies for displays, flight management systems and navigation. The improved A380 cockpit will have eight 15-by-20 cm (6-by-8-inch) interactive, physically identical and interchangeable LCDs, including two Primary Flight Displays, two navigation displays, one engine parameter display, one system display and two Multi-Function Displays. These LCDs provide the digital Head-Up Display (HUD), which increases pilot situational awareness, particularly during the approach and landing phases[43].

The A380 is the first commercial airplane that adopts the EHAs (electrohydrostatic actuators) flight control technologies, marking a step forward to the "all-electric airplane" in the aerospace industry. EHAs are electrically powered but use small hydraulic pumps and reservoirs

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[40] 'Changing the game- Will the world look different after the A380?' A Flight Group Special Report, June 2005 (www. Flightinternational.com)

[41] Aerospace-Technology.com : http://www.aerospace-technology.com/projects/a380/

[42] http://www.airbus.com/en/aircraftfamilies/a380/flight_deck.html

[43] http://www.airbus.com/en/aircraftfamilies/a380/flight_deck.html

that transform electrical power into hydraulic power. The advantages of EHAs include large savings in terms of both weight and space (e.g., a reduction in the size of components, generation equipment, tubing, and the amount of fluid required), as well as in terms of easier installation. The A380 incorporates two rather than three Eaton Corporation hydraulic systems with an increased hydraulic pressure of 5,000lb/in^2 instead of a standard 3,000psi. Higher-pressure hydraulics also helps to reduce the size of pipelines, actuators and other components for overall weight reduction. The A380 further adopts variable-frequency (VF) power generation, which will enable more reliable power generation at lower maintenance costs and less weight, compared with the current systems[44]. Furthermore, the A380 will be the first civil air transport aircraft capable of flying with total hydraulic failure, using electricity to operate only the flight control surfaces. It can operate with only one electrical generation source, or only one hydraulic source, which increases the fault tolerance of the aircraft[45].

The other important innovation is the extensive use of composite materials, which comprise 25% (by weight) of the A380, compared with 10% in the A320 and 16% in the A340-500/600. A new material, Glare, that is highly resistant to fatigue, is used in the construction of the panels for the upper fuselage. The aluminum and fiberglass layers of Glare do not allow propagation of cracks. Glare is also much lighter than conventional materials and represents a weight saving of about 500kg in the construction[46].

Supply chain and production

44 "A380: More Electric
45 'Changing the game- Will the world look different after the A380?', A Flight Group Special Report,June 2005 (www. Flightinternational.com)
46 http://www.aerospace-technology.com/projects/a380/

Major structural sections of the A380 are manufactured by the prime contractors in France, Germany, the United Kingdom and Spain; however, components for the A380 airframe are also manufactured by industrial partners in Australia, Austria, Belgium, Canada, Finland, Italy, Japan, South Korea, Malaysia, Netherlands, Sweden, Switzerland and the United States. The five largest suppliers, by value, are Rolls-Royce, SAFRAN, United Technologies, General Electric, and Goodrich. The final assembly of the A380 takes place in Toulouse, France, after which the aircraft is flown to Hamburg (Germany) for preparation before delivery.

Customers and orders

As of August 2006, 16 customers had committed firm offers for 159 A380s, with an additional 75 optional orders. These have included: Singapore Airlines (the launch customer with an order for 10 aircraft), Lufthansa (15), Emirates (41), Air France (10), Qantas (12), Malaysian Airlines (6), Virgin Atlantic (6), International Lease Finance (10), Kingfisher Airlines (5), Qatar Airways (2), Federal Express (10), Korean Air (5), Thai Airways (6), Etihad Airways (4), China Southern Airlines (5) and United Parcels Service. Of these, 25 are for the cargo version. These reported sales figures involve the production of the A380 over four years. Over the next 20 years, Airbus forecasts a demand for 16,000 A380-sized passenger airliners and freighters.

Challenges facing A380

Current production delays and technological issues such as the wake vortex can have a serious impact on the long-term success of the A380.

- **Wake turbulence**

The turbulence created by the wake of the A380 engine sparked another trans-Atlantic conflict. The A380 may generate more wake turbulence than the other existing aircraft models. The ICAO (International Civil Aviation Organization) has set up an interim rule that requires the trailing airplanes to stay twice as far behind the A380 as behind other planes.[47].

The regulation is intended to provide adequate protection from the powerful turbulence churned up by the A380's wings and engines. However, greater aircraft separation would take up two landing slots and largely reduce the frequency of aircraft landings[48]. At large airports, even slightly increased minutes of spacing between some planes can negatively affect airport throughput during peak periods. The A380, which has been promoted as the solution to congested hub airports, has also been argued to become much less appealing because of the increased separation[49].

Further flight testing will be required in order to determine whether the vortices produced by the A380 are substantially larger and whether the greater spacing is needed. It is expected that ICAO will issue final guidance on the issue in November 2006[50]

- **Production delay**

In June 2006, Airbus management announced that it would face an additional six-month delay in delivery of the A380, which was the second time since 2005. After three months, in September, 2006, Airbus announced yet another delay. Although Airbus has not finalized its updated delivery schedule since then, the delay announcement has caused serious impact. The announcement caused a 26% drop in the share price of Airbus's parent, EADS, and led to the

[47] "Guidance Material in Regard to Wake Vortex Aspects of A380 Aircraft", ICAO, June, 2006.
[48] "Airbus Faces a New Delay in Delivery of Its Biggest Jet", The New York Times, June 14, 2006.
[49] "Airbus A380 faces dispute with US aviation officials", AFX News Limited, October 5, 2005
[50] http://en.wikipedia.org/wiki/Airbus_A380#_note-3

departure of EADS Co-CEO Noël Forgeard, Airbus CEO Gustav Humbert, and A380 program manager Charles Champion. The launch customer Singapore airline has been reported to be seeking compensation from Airbus, and Emirates from Dubai, Malaysian Airlines and ILFC are reported to be investigating the possibility of canceling their orders.

The delay arose because of the complexity of wiring up the aircraft with a wide variety of the customized equipment, such as in-flight entertainment and communications units, provided by customers for installation. The A380's electronic systems are highly integrated, so even a small change would cascade down through the whole system and create the needs for more adjustments than previously estimated[51].

4.1.2 Boeing 787 Dreamliner

Overview

In late 2002, Boeing abandoned its Sonic Cruiser project, which intended to achieve 15 to 20 percent faster speed (between Mach 0.95 and Mach 0.98) at the same fuel burn rate as the 767 and the A300[52]. It announced the redirection of its efforts to the 7E7 project, later named the 787 Dreamliner, which can fly at a lower speed than the Sonic Cruiser but has better fuel efficiency. The development of the 787 was Boeing's response to the greater demand for a cheaper aircraft to operate and maintain in the post September 11th market.

In contrast with the A380's massive capacity, which is designed for a hub-and-spoke airline route system, the 787 Dreamliner is targeted at rapid, direct, point-to-point connections with capacity of only 250 passengers. The launch of the 787 Dreamliner shows Boeing's belief in the potential of the so-called "the middle of the market". This market segment is currently served by

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[51] "Airbus Faces a New Delay in Delivery of Its Biggest Jet", New York Times, June 14, 2006
[52] http://www.boeing.com/news/feature/concept/background.html

the aircraft models such as the 767, A300/A310 and A330, which can support intercontinental range (approximately 2000 to 6500 nautical miles) and carry around 180 to 250 passengers. The airplanes in this segment allow the airlines to offer greater flight frequency and more direct connections between different city pairs[53], which are services travelers nowadays are more and more willing to pay for[54]. The relaxation of Extended-Range Twin Engine Operations (ETOPs)[55] also makes the smaller airplanes like the A330 more appealing. The 787 Dreamliner, which is designed for operating in this segment but at higher speed and with better fuel-efficiency, seems to have a strong business case here. Facing the largely shrinking sales of the 767 due to the strong performance of the A330, Boeing is hoping to win back dominance of this \$60-billion-a-year jetliner market from Airbus.

The 787 platform currently comes in three variants, all of which will use the same engine type. The 787-8 Dreamliner will carry 217 passengers in a three-class configuration with a range of up to 8,500 nautical miles (15,700 kilometers). The 787-3 Dreamliner, a version of the 787-8 optimized for shorter flights, will carry 289 passengers in a two-class configuration with a range up to 3,500 nautical miles (6,500 kilometers). The 787-9 Dreamliner, a longer version of the 787-8, will carry 257 passengers in three classes, with a range of 8,300 nautical miles (15,400 kilometers). One point worth underlining is that the long-range one can carry a fewer number of passengers than the short-to-medium range one, which is opposite the traditional aircraft design practice favoring a larger passenger capacity over longer ranges.

Design features

The 787 Dreamliner is designed to offer 20% less fuel burn and 10% lower seat mile costs

[53] http://www.msnbc.msn.com/id/3226089/
[54] "The A380 Debate", Morgan Stanley Research, September 5th, 2006
[55] Extended-Range Twin Engine Operations (ETOPs) are regulations preventing twinjets from realizing their full potential range.

than current-generation aircraft[56]. It is also advertised as being 20% less expensive to operate and about 30% less expensive to maintain than the Airbus A330[57]. The important contributors to its high fuel-efficiency include the "more-electric" design and the extensive use of composite materials to replace the conventional aluminum alloys.

The "more-electric" architecture of the 787 Dreamliner, which replaces bleed air and hydraulic power with electrically powered compressors and pumps, is its most notable technological breakthrough. It marks the very first time for the industry to eliminate bleed air from the engines. Also, the use of electric motors to pressurize the cabin marks yet another milestone in the industry's evolution toward the "all-electric airplane". As mentioned earlier, a "more-electric" architecture can greatly reduce the aircraft's overall weight and improve its maintainability.

Another significant technological advancement in the 787 is the large increase in the use of lightweight composite materials in its airframe structure. It is estimated that over 50% (by structural weight) of the primary airframe structure will be made up of the composite material carbon fiber. In total, if titanium alloys are included, about 61% of the 787's airframe will be made from materials that will be highly corrosion-resistant as well as highly fatigue-resistant. This not only reduces the aircraft's overall weight of the aircraft but also greatly lowers the maintenance cost. Thanks to composites' durability feature, the line maintenance interval, the base maintenance interval, and the interval for heavy structural inspection will be significantly lengthened, as shown in Table 4.1.2 [58]), which means a 30 % reduction in airframe maintenance costs.

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[56] "Evolution and Revolution", Aviation Week & Space Technology, March 28th, 2005
[57] "High-Stakes Bet on a Giant Plane Trips up Airbus", Wall Street Journal, June 15th, 2006
[58] http://www.newairplane.com/787/en-US/innovativeFeatures/LongTermValue/LowerMaintenanceCosts (Boeing Co.)

	767	Competitors (e.g., A330)	787
Line Maintenance Level (hours)	500	700	1000
Base Maintenance Level (months)	18	18	36
Heavy Structural Inspection (years)	6	6	12

Table 4.1. 2 The comparison of maintenance costs

Boeing has selected two engine types, the General Electric (GE) GEnx and Rolls-Royce Trent 1000, to power the 787. The traditional bleed air heating and de-icing systems have been replaced with electrical systems. Two engine types are extremely quiet and fuel-efficient, contributing up to 8% of the total efficiency improvement of the 787. The most significant innovation on the engine design is the "interchangeability" between two engine types. It is the industry's first time to apply a standard engine interface, which allows greater flexibility for the airplane owners to change the engines according to their needs. The increased standardization of the airframe design offering makes the 787 a more valuable asset for the airplane lenders.

Supply chain and production

Beyond the "revolutionary" as well "evolutionary" technological features of the 787 Dreamliner, Boeing has also revolutionized how the aircraft is developed and produced in the 787 program. The majority of the systems and assemblies are designed, developed and tested by principal industrial partners in the USA, Japan and Europe. Boeing will be responsible for only about one-third of the overall production of the entire aircraft and plans to complete the final assembly process in three days.

Customer and orders

The 787 program, initially known as 7E7 program, was launched in April 2004 with a record firm order of 50 units from its launch customer, All-Nippon Airways. Since its launch, 32 customers, including Monarch, have logged 420 orders and commitments. Of these, 377 are firm orders valued at $59 billion at current list prices, making the Dreamliner the most successful commercial airplane launch in history[59].

4. 2 Overview of the participating companies

There are four companies in total participating in this research. The following table gives an overview of these participating companies (The names of the companies are not disclosed according to the confidentiality agreement.):

	Company X	**Company Y**	**Company Z**	**Company W**
Product category	aerospace composite materials and specialty chemicals	Systems	Systems	Systems
Annual sales	$10-15 million	$5-10 billion	$4-5 billion	$3-4 billion
Supplier status in the A380 program	Third-tier supplier	A major Airbus supplier	A major Airbus supplier	A major Airbus supplier
Supplier status in the Boeing 787 program	Third-tier supplier	A Boeing partnering supplier	A Boeing partnering supplier	A Boeing partnering supplier
Certified or preferred by Airbus?	Yes	Yes	No	Yes
Certified or preferred by Boeing?	Yes	Yes	No	Yes

Table 4.2. 1 Overview of the participating companies in this research

59 http://www.boeing.com/news/releases/2006/q3/060818c_nr.html

4.3 Comparative analysis of supply chain strategies of Airbus and Boeing in the A380 and 787 programs

4.3.1 Partnership, collaboration and integration across supplier networks

The elevated cost consciousness of the airlines and fierce competition in the post September 11th air passenger market have forced aircraft producers to lower their prices, while offering better products, in order to attract customers. Under the pressure of shrinking profit margins, more and more aircraft manufactures, especially the two largest producers of large commercial airliners Boeing and Airbus, have adopted "risk-sharing partnerships" with their suppliers, hoping to achieve cost reductions across the entire supply chain. The supply chain strategies applied in both of the 787 and the A380 programs perfectly exemplify this trend.

Compared with the early aircraft development programs, both Airbus and Boeing have become much more aggressive in spreading costs and risks through partnerships with their suppliers. Suppliers in both A380 and 787 programs were asked to absorb "non-recurring" costs, thus greatly shifting the market and manufacturing risks to the suppliers. For the A380 project, Airbus has established "risk-sharing partnerships" with more than 30 of its major suppliers (e.g., Alenia, Eurocopter, Fokker, Gamesa, Labinal, and Saab), that will cover about US$3.1 billion, which is about 25 percent, of the project's total non-recurring costs[60]. According to the interviewees in this research, for the 787 program, Boeing has asked its partnering suppliers to carry all of the non-recurring costs, but in return gives back to the suppliers the intellectual property (IP) rights on the components and systems they provide, which marks a reversal of

[60] "The Emerging Airline Industry", AT Kearney, 2003

earlier practices.

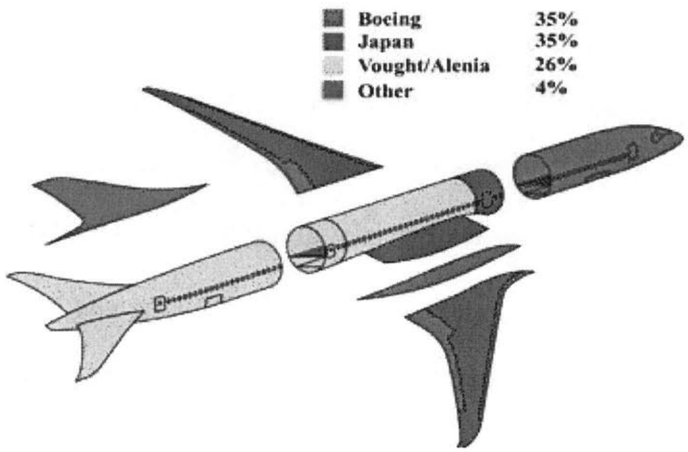

Figure 4.3. 1. The workshares distribution in the 787 program

The most significant transition is that suppliers are taking up much more responsibilities in product design, development and manufacturing than ever. Airbus has discovered its partnership architecture and modular outsourcing strategies through its consortium structure. However, Boeing is reaching to the next level in the 787 program. In the 787 program, Boeing is fast adopting a revolutionary business model similar to the so-called "system integration" model, involving its risk-sharing partners throughout the design, development and manufacturing processes for all major components and subassemblies.

With the 787 program, Boeing delegates the major responsibilities of the development and manufacturing to its first-tier suppliers and assumes the central role of system integrator. This marks the first time for Boeing to outsource the entire wing design and manufacturing to external suppliers (The details will be discussed in the later sections): Japan's Fuji Heavy Industries is responsible for center wing box and installation of the wells; Mitsubishi Heavy Industries manufactures the wing box; and Kawasaki Heavy Industries is responsible for the manufacture of the mid forward section of the fuselage, the fixed section of the wings and the landing gear well. Global Aeronautica, a joint venture company between Vought Aircraft Industries from Dallas and Alenia Aeronautica from Italy, is responsible for the manufacture of the mid section and rear section of the fuselage including the tailplane, representing a 26% share of production. French company Latecoere will supply the passenger doors. Goodrich will provide the nacelles and thrust reverser[61]. Boeing, on the other hand, will only take about 33% to 35% of the 787 work share. The figure 4.3.1[62] illustrates the construction workshares of Boeing and its partners in the 787 program. During the product development stage, Boeing only provides high-level interface definition; it is the responsibility of the first-tier partnering suppliers to develop the detailed interface designs working together with the other major suppliers, where Boeing will act as the referee in the case of any conflicts. This means that there are substantially increased multilateral communication flows among the peer first-tier suppliers, as well as between each partnering supplier and Boeing. All lateral design and engineering interactions among the partnering suppliers, as well as the design interactions between each supplier and Boeing, is orchestrated through the use of the common information technology infrastructure electronically connecting all of the parties together.

In order to reduce final assembly down to three days, Boeing has adopted a higher-level of integration at the supplier level, by significantly reducing the number of the parts and components, subassemblies or sections that go into the final assembly stage. In addition, major suppliers have been selected to provide complementary components or systems that would enable them to synergize their technical capabilities, resulting in much more efficient and effective design solutions. For example, Hamilton Sundstrand was awarded contracts including the environmental control system, electrical system, cabin pressurization, auxiliary power unit,

[61] http://www.aerospace-technology.com/projects/dreamliner/
[62] http://www.aerospace-technology.com/projects/dreamliner/

ram air turbine and the other systems. The wide scope of the contracts allows Hamilton Sundstrand to subcontract the design work within each workpackage and across its divisions[63]. This means that the first-tier suppliers are moving upward in the value chain and assuming more the role of the system integrator. First-tier suppliers, therefore, can offer more integrated and interconnected solutions, decreasing the number of the components comprising the airplane. The first-tier partnering suppliers are also given full control of their own lower-tier supplier networks. The 787 program will be the first time when a first-tier supplier is given control of the selection of second and third-tier suppliers in a Boeing commercial aircraft program.

Most of the interviewees in this study also mentioned that compared with Boeing's previous commercial airplane programs, collaboration between Boeing and its vendors or between Boeing and its partnering suppliers in the 787 program has reached a high water mark, a significant departure from past practices. In the 787 program, the conventional "build-to-print" buyer-seller relationship model is essentially scrapped, in favor of the new "design-and-build" partnership at all levels.

Compared with the 787 program, the outsourcing strategy adopted by Airbus in the A380 program, which is the older of the two development programs covered in this research, seems more in the mold of the traditional model. Although Airbus has embraced partnerships since its inception among the core national "champions" in the respective European countries brought together under the Airbus umbrella in the early 1970s, the core technologies related to complex or key airframe components have typically been kept pretty much in-house within the core respective companies. This model has remained essentially unchanged in the development of the recent Airbus aircraft platforms despite the fact that it has been increasing its outsourcing

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[63] "Evolution and Revolution", *Aviation Week & Space Technology*, March 28, 2005, Vol. 162 Issue 13, p46-47

contents in recent years. For example, Airbus has its own international joint design team located in Wichita (U.S) and Filton (U.K.), working together to design a large A380 wing component, while Airbus' Korean suppliers are manufacturing the wing panel according to the engineering design specifications handed down by Airbus.[64] Airbus has been noted to only outsource key components in the older models (Pritchard, 2001). In the A380 program, Airbus has exercised the control of all component interface definitions. The Airbus suppliers work in parallel, with limited lateral communication among them.

4.3.2 Global outsourcing

In view of the diversity of the national origins of many of the suppliers supporting both the Boeing 787 and the Airbus A380 programs, it is not hard to see that the commercial aircraft industry has become truly international, dispersed globally into a vast supplier network. More and more new entrants have been emerging from Asia, Latin America or Eastern Europe and competing against the incumbent aerospace manufacturers from North America and United States. Further, the strong economic performance of these "non-traditional" regions (e.g., China, India, and Russia) and their increasing importance as future customers for airliners force large OEMs and their suppliers to shift more manufacturing or R&D activities to these regions under "industrial offset"[65] agreements[66]. Booming economies and the increasing affluence of the emerging middle class in the Asian developing countries (e.g., China and India) are key drivers of the rapid growth in the demand for air travel. Large Asian and Middle-Eastern carriers (e.g.,

[64] http://www.wingsoverkansas.com/news/article.asp?id=590

[65] Industrial offset refers to a compensatory trade arrangement where the exporter grants concessions to the importer. In the commercial aircraft industry, these concessions typically take the form of production-sharing agreements (Pritchard and MacPherson, 2005).

[66] "Restructuring the Global Aerospace Industry: The shifting Roles of Suppliers", AT Kerney, 2003

Singapore Airlines, All Nippon Airways, and Emirates Airline), are replacing U.S. and European carriers as the key customers, emerging as the major customers ordering new airplanes in large numbers. Sourcing from Asian countries by using indigenous aerospace suppliers is therefore becoming an important strategy on the part of the large commercial aircraft producers in order to attract customers in these countries, typically nationally-owned airlines, as major new customers. Meanwhile, the technological maturity and excellence of Japanese and Korean suppliers and the improving production quality of suppliers from less developed Asian countries also make Asia an appealing sourcing option. A close review of both the A380 and 787 programs reveals a striking finding: the aerospace manufacturers from the Asian-Pacific region have a much stronger presence in these two programs than ever before. In the next few sections, a detailed comparative analysis will be given on the outsourcing strategies of Airbus and Boeing in the Asian region and on the roles that Asian suppliers play in the Boeing 787 and Airbus A380 programs.

Boeing

As mentioned earlier, an increasing number of aerospace manufacturers are embracing the "system integration" production mode. Following this trend, as well as the accelerating globalization, Boeing has gradually expanded the portion of its foreign sourcing in recent years. The foreign content of the Boeing 727 program in 1960s was only 2 percent. For the 777 in the 1990s, the foreign content rose up to 30 percent. In the 787 program, the foreign content might jump to as high as 70 percent (Pritchard and MacPherson, 2005).

- ***Boeing and Japan***

In particular, Boeing depends greatly on Japanese airframe and composite technologies. Boeing has had long-standing, mutually-beneficial relationships with the Japanese aerospace and aviation industries. For decades Boeing had held an unparalleled dominance as a seller in the domestic Japanese market for large commercial aircraft: through June 2005, the Japanese airlines have ordered 796 Boeing airplanes worth more than $70 billion (in 2004 dollars); in the past decade, Japanese airlines gave more than 80 percent of their orders to Boeing[67].

The partnership between Boeing and Japanese aerospace industry started in the 1970s. The Japanese Aircraft Development Corporation (JADC) is a consortium of Japanese aerospace companies that have been receiving aid from Japanese Ministry of Economy, Trade and Industry with the goal to revitalize Japanese aerospace industry. The important members of JADC-Mitsubishi Heavy Industries (MHI), Kawasaki Heavy Industries (KHI), and Fuji Heavy Industries (FHI) - have worked with Boeing since the 767 program. The components supplied by these three companies in connection with the 767 program included fuselage panels, aerodynamic fairings, landing-gear doors and inspar ribs, which are equal to approximately 15 percent of the total value of the 767 airframe. MHI, KHI and FHI had a higher level of participation in the 777 program, compared with the earlier programs, in terms of the design, manufacturing, and testing of the airframe. These Japanese aerospace manufacturers are partners supplying about 20 percent of the 777 airframe, including fuselage panels and doors, the wing center section, the wing-to-body fairing and the wing inspar ribs. The government of Japan reportedly provided 2 billion yen ($16 million) for the 777 project, as well as loans from the Japan Development Bank (JDB) and the Export-Import Bank for development and for aircraft imports[68].

In the Boeing 787 program, Japanese partners take up a significant percentage of the

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[67] http://www.boeing.com/companyoffices/aboutus/boejapan.html

[68] "High-stakes Aviation: U.S.-Japan Technology Linkages in Transport Aircraft", Committee on Japan, National Research Council, 1994

workshare, about 35%, in designing and manufacturing airframe structures[69]. The JADC has already signed formal contracts with the Boeing Commercial Airplane Company to conduct research and development work on new technologies, including composites for the 787. The Japanese government will be subsidizing the 787 program up to $3 billion (Pritchard and MacPherson, 2004). The entire manufacturing process for the final assembly of the wing will be created by Mitsubishi Heavy Industries, Fuji Heavy Industries and Kawasaki Heavy Industry. It is the first time Boeing subcontracts the whole wing production to the external suppliers. The Japanese aerospace manufacturers are thus playing a significant role in the design and production of the 787 Dreamliner.

Table 4.3.1 shows the evolution of Boeing's foreign outsourcing since the early models, such as the 727 program. From the 767 program onwards, more and more of the key airframe components have been outsourced to foreign partners. This trend manifests the fact that Boeing approaches outsourcing internationally in order to gain greater access to new markets, spread the risk, seek more financial resources and lower its spending on research and development. This table also shows the increasing importance of Japanese suppliers.

Airframe	**727**	**767**	**777**	**787**
Wing	US	US	US	Japan
Center Wing Box	US	Japan	Japan	Japan
Front Fuselage	US	Japan	Japan	Japan/US
After Fuselage	US	Japan	Japan	Italy
Empennage	US	US	Foreign	Italy/US
Nose	US	US	US	US

Table 4.3. 1Outsourcing Trends for Boeing Airframe (Pritchard and MacPherson, 2005)

[69] http://en.wikipedia.org/wiki/Boeing_787#_note-787_flyingredef

- ***Boeing and China***

Boeing started its reach into the Chinese commercial aerospace market since 1970s and has established long-standing and mutually-beneficial relationships within China. Its activities in China range from subcontracting, joint ventures, technical training and assistance to facilitating cooperative programs between the U.S. and Chinese aviation/aerospace authorities. Since the beginning of the Boeing-China relationship in 1972, Boeing has provided 565, or about 61 percent of the 924 commercial jetliners operating in China, while only 251 or 27 % of them have been provided by Airbus[70]. According to Boeing's own forecasts, China will be the world's second largest market for new commercial airplanes after the United States, with a projected demand for 2,600 aircraft valued at $213 billion over the next 20 years[71]. Boeing also projects that single-aisle aircraft, such as the Boeing 737, will represent the highest level of demand projected at 1,678 airplanes; the demand for intermediate twin-aisles (e.g., the Boeing 767 and the Boeing 777) is projected to reach roughly 568 units[72]. In order to solidify its dominant position in this lucrative market, Boeing's active participation in the Chinese aviation and aerospace industries represents a proactive long-term strategy.

A major aspect of Boeing's activities in China is its increasing investment in establishing long-term supplier relationships and contracts, involving collaborative ties and joint-ventures with the local aerospace manufacturers. The most recent supplier contracts signed in June 2005 in Beijing are worth $600 million, including work in the 737, 777 and 787 programs. Adding up these new contracts, the active supplier contracts between Boeing and China's aerospace

[70] http://www.boeingchina.com/en/aboutboeing/bg.shtml#4
[71] "Boeing Current Market Outlook 2006", Boeing Co. http://www.boeing.com/commercial/cmo/pdf/CMO_06.pdf
[72] "Boeing Current Market Outlook 2006", Boeing Co. http://www.boeing.com/commercial/cmo/pdf/CMO_06.pdf

suppliers are valued at $1.6 billion in total[73]. Figure 4.3.2 illustrates the parts of the 737 aircraft that are produced by suppliers from China. In the 787 program, China's aerospace manufacturers have much higher visibility than in the previous programs and, for the first time, they produce essential composite parts and structures for Boeing's commercial aircrafts: Chengdu Aircraft Industries has been awarded a contract as the single source for the rudder, Shenyang Aircraft Industries will produce the vertical fin leading edge, and Hafei Aircraft Industries in Harbin is responsible for the upper and lower wing-to-body fairing panels. Figure 4.3.3 shows the role Boeing's Chinese partners play in the 787 program. China's aerospace manufacturers also have won work packages from the 787 program through Boeing's supplier network, serving as the lower-tier suppliers supporting Boeing's 1st-tier suppliers in the 787 program. One point worth mentioning is that the 787 program is the first program where China's aerospace manufacturers have started sourcing from the U.S. aerospace suppliers. The breadth and depth of China's involvement in the 787 program is unprecedented.

[73] http://www.boeingchina.com/en/aboutboeing/bg.shtml#4

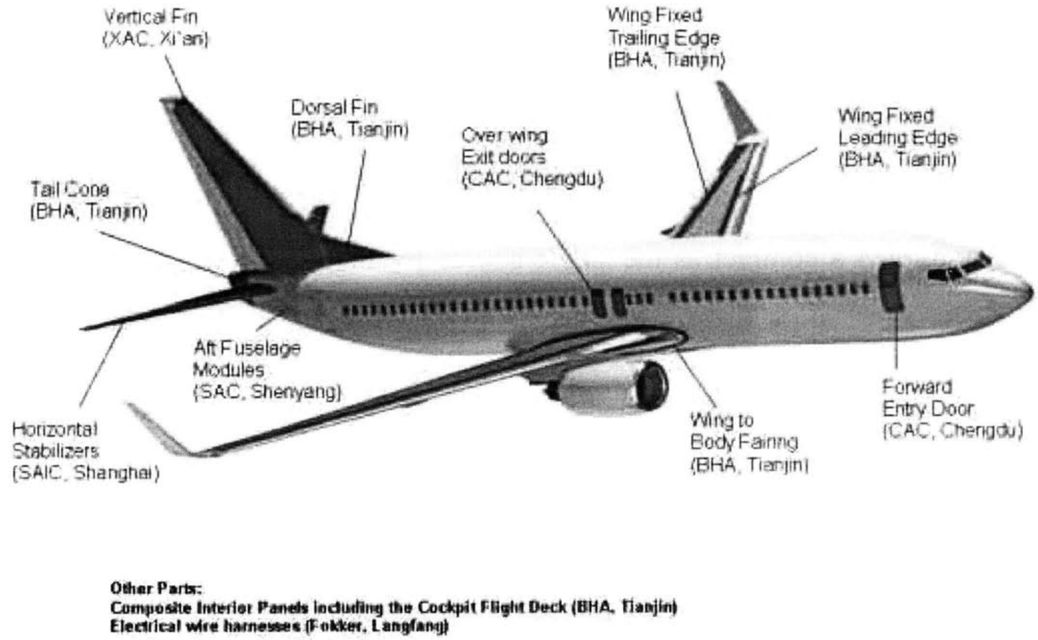

Figure 4.3. 2. China's role in the 737 program[74]

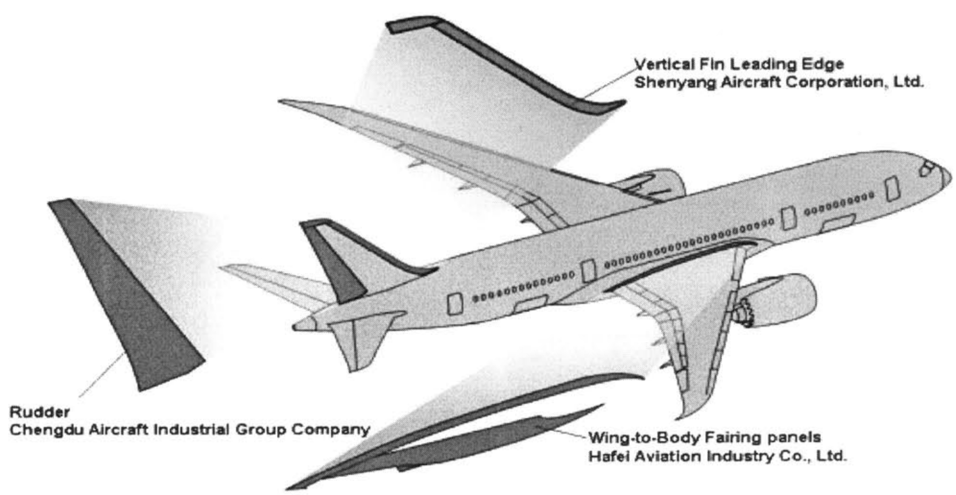

Figure 4.3. 3. China's role in the 787 program[74]

In addition, Boeing has started collaborative initiatives, such as joint ventures, with the local aerospace manufacturers in China. For example, Taikoo Aircraft Engineering Co (TAECO), where Boeing holds a 9% interest, is a joint venture for aircraft heavy maintenance, modification

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[74] http://www.boeingchina.com/en/aboutboeing/bg.shtml#5

and repair; BHA Aero Composites Co. -- which is a supplier to Boeing, Fisher and Goodrich -- is actually a joint venture among Boeing, Hexcel and AVIC I, where Boeing has a 40% interest.

Since 1993, Boeing has made enormous investments in transferring its technical expertise and operational experience to China's aviation industry and the regulatory authority, aimed at improving flight safety, reliability and efficiency. Boeing has also made significant investments in production quality control initiatives to help improve product quality. Boeing has a resident team in China, offering direct technical assistance/support to the Chinese factories. This team provides free educational training to China's aviation professions on a wide spectrum of topics, not only on technical matters (e.g., pilot techniques, maintenance engineering) but also on regulation development and managerial skills in air traffic management, executive management, airline management and airline marketing. Boeing has continued to expand its training facilities in order to address the needs of the growing Chinese aviation professions. In short, Boeing has been an important contributor to the development of China's aviation and aerospace industry.

Nonetheless, Boeing is facing a decade of downturn in the China's market and the major competitor is Airbus. Several factors, including Boeing's own problems and political issues between the United States and China, contribute to this trend and will be discussed in detail later.

Airbus

Compared with Boeing, Airbus's relationships within the Asian-pacific area started much later and the activities involved have not been as multifaceted, either. However, recognizing the huge potential of the Asia-Pacific market, Airbus has pursued an aggressive strategy over the past decade to strengthen its ties with Asia-Pacific countries and expand its marketing and outsourcing activities in this region.

- **Airbus and Japan**

Due to Boeing's strong dominant position, which is supported by the strong political ties between Tokyo and Washington D.C and the closely-knit industrial cooperation between Boeing and Japan, Airbus has only gained a 4% share of the Japanese market, while it owns 62 % of the airplane market in Europe, 49 % in North America and 55 % in the Asia-Pacific region. With its high population density, congested airports and saturated international and domestic routes, Japan is undoubtedly a potential market targeted by Airbus' 555-seat superjumbo A380 and Airbus has been making great efforts to win orders from Japanese airlines.

In the A380 program, Airbus forged stronger partnerships with the Japanese aerospace industry. In 2001, Airbus set up a Japanese subsidiary. A host of Japanese suppliers, including Mitsubishi Heavy Industries, Fuji Heavy Industries and Japan Aircraft Manufacturing Co., were contracted as suppliers of airframe assemblies. It is estimated that business related to the A380 program will bring around US $4.6 billion to the Japanese industry in the coming years[75]. This reflects Airbus' intention to leverage Japanese aerospace manufacturers' technological capabilities and convince Japanese airlines to place orders for Airbus aircrafts.

Despite its efforts, Airbus is encountering tremendous difficulties in the Japanese market. So far, no Japanese airline has placed any order for the Airbus A380. The three giant Japanese aerospace manufacturers have so far declined Airbus' contract offers of work in the A350 program, claiming that their production capacity is fully committed to the 787 program, A350's

[75] http://www.airbus.com/en/worldwide/airbus_in_japan.html

targeted competitor.

- **Airbus and China**

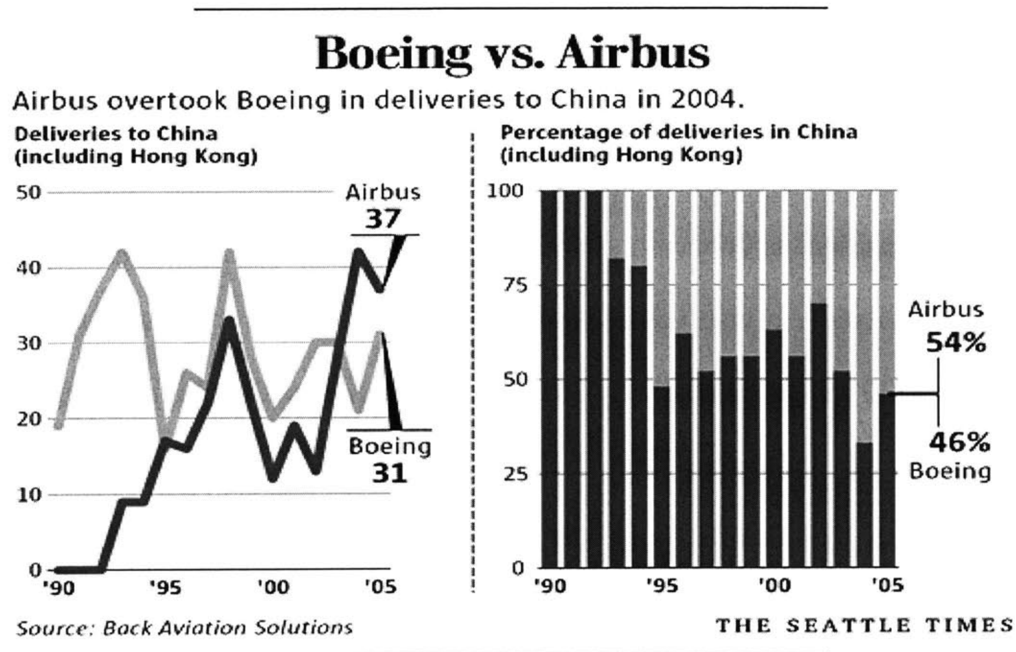

Figure 4.3. 4. Deliveries of Airbus and Boeing to China[76]

Like Boeing, Airbus has also seen the potential of the Chinese market, with its fast growing demand for air travel spurred by its staggering economic growth. The upcoming 2008 Summer Olympics in Beijing, of course, stands as a symbol of the Chinese "coming of age" in the early 21st century. It might be surmised that the Airbus A380 could be seen as a great choice for airlines to operate on routes connecting mega-hub cities like Beijing, Shanghai, and Guangzhou to the other major cities around the world.

While Airbus is still struggling in the Japanese market, it seems to be facing much smoother

[76] "Boeing stumbles in race for China" , Seattle Times, June 5, 2005

sailing in China. The sales of Airbus aircraft in China climbed to 219 in 2005 from 56 in 2004. Its deliveries to Chinese customers have seen gradual growth over the past decade and pose a potentially serious threat to Boeing's traditional dominance in the Chinese market (Please see Figure 4.3.4). In 2005, Airbus overtook Boeing by delivering six more aircraft to Chinese customers. It plans to expand its training and parts centers in the next couple of years to respond to the growth of its business in China[77]. However, Airbus' increasing sales in China did not take place overnight nor without much effort on its part. In return for China's commitment to more orders, Airbus has intensified its cooperation with China since 2002, signing contracts worth $300 million in U.S dollars[78]. It also vowed to double its procurement of local content from Chinese suppliers to $120 million annually by 2010. In the summer of 2006, Airbus announced that Tianjin will be the site for Airbus' first final assembly plant outside Europe; the plant is exclusively dedicated to the manufacturing the A320 aircraft and is expected to roll out assembled airplanes by 2008[79].

Although Airbus has signed a deal with AVIC I on subcontracting projects worth US$100 million in the production of the upper and lateral panels of the A380 nose landing gear bay[80], Airbus' outsourcing in China is still focused on the older models. Chinese suppliers' presence in the A380 program is much more limited, compared with their role in Boeing's 787 program. However, it is expected that Chinese suppliers will play a more important role in Airbus' planned A350 program, as Airbus has established an Engineering Center in Beijing that will initially concentrate on design work in connection with the A350 program[81].

[77] http://www.iht.com/articles/ap/2006/09/14/business/EU_FIN_COM_Germany_Airbus.php
[78] http://english.people.com.cn/200410/11/eng20041011_159649.html
[79] "Airbus may hit an air pocket over china", BusinessWeek, April 24, 2006
[80] http://english.people.com.cn/200406/14/eng20040614_146268.html
[81] "Airbus may hit an air pocket over china", BusinessWeek, April 24, 2006

Summary

The differences between Airbus' and Boeing's outsourcing activities in the Asian-Pacific region mainly echo the quite different overall outsourcing philosophy of these two companies. Taking the position of a system integrator on the 787 program, Boeing had delegated the entire responsibility for wing design and production to its Japanese partners, while it also has assigned a significantly greater share of the work to the Chinese suppliers. In contrast, Airbus, while it also engages in industrial offset agreements, it has typically elected to do so in connection with the older Airbus aircraft models (Pritchard and MacPherson, 2005). This is probably a main reason explaining why Airbus seems to be facing many more difficulties in Japan than in China. Decades of technology development through extensive involvement in Boeing's projects have helped the Japanese companies to establish a leadership position in wing design and composite technology. Now, Japanese companies, with government support, have set their sights on becoming a major force in aircraft manufacturing in competition with the U.S. and European producers. The fact that Airbus is still keeping in-house the development of its cutting-edge technologies[82], such as composite materials and wing design, makes their cooperation with Airbus apparently less appealing.

Although China is also eager to develop its aviation industry, it has a more urgent need: more jobs for local people. Hence, the one willing to offer more local job opportunities and develop local human resources is more likely to be received with greater favor. Furthermore, the friendly political relationships between China and E.U., along with Airbus' own strong "PR machine" (as noted by one of the interviewees for this research) has also helped further Airbus' sales in China. Meanwhile, Boeing's long-term dominance in Asia may have led to some

[82] "As Competition Heats up, Jobs Fly into China", Seattle Times, June 7th, 2005

complacency on its part, perhaps causing it to overlook the fact that services and good personal relationships are the keys to winning the customers' heart.[83] This is also another possible factor contributing to Airbus' growth in Chinese market.

The other notable aspect is that Boeing's activities in China are much more education-oriented than those by Airbus, reflecting Boeing's commitment to enhancing the capabilities of Chinese suppliers as potential future partners. Airbus' relationships with Chinese suppliers are still more of a traditional "build-to-print" subcontractor relationship rather than stressing knowledge transfer. However, this might change in the near future with its expanding investments in China.

4.3.3 Supplier selection and supplier certification

According to the interviews conducted in connection with this research, Boeing and Airbus have similar processes and requirements in selecting and evaluating their suppliers. All of the suppliers that have been interviewed reported that they were chosen on a best-value basis. The first-tier major partnering companies have been selected at the concept development stage for both programs. Some interviewees mentioned that they have maintained good contacts with the engineering teams of both companies over years and that they typically are notified by Boeing and Airbus when they are planning new aircraft development programs. This supports the more general finding that both Airbus and Boeing integrate their first-tier suppliers early into the product development phase and value their expertise in terms of the parts, components and systems they provide.

[83] "Boeing stumbles in race for China", Seattle Times, June 5, 2005

This practice, however, does not seem to reach down to lower-tier suppliers. One of the third-tier suppliers interviewed, who is a common supplier to both programs providing aerospace composite materials and specialty chemicals, reported that it was selected at a later, preliminary design review stage, for the 787 program and during the detailed design review stage for the A380 program. However, it was also learned that if relatively new materials technologies are involved, the supplier would be invited to provide inputs early in the program ensure both lower costs and manufacturability.

The selection processes for the first-tier suppliers were found to be quite similar in both the A380 and 787 programs. The suppliers are called upon for a workshop, where the system integrator (e.g., Boeing) explains its vision and requirements for the new program. Then the suppliers enter the so-called "plateau" phase, when both the customer and the suppliers finalize the detailed specifications for the new model. The requests for proposal (RFPs) are then issued. Subsequently, the suppliers submit their proposals in response to these RFPs, which are then evaluated by the customer company, focusing on the bidding company's suitability and capabilities as a supplier, vendor, or institutional partner.

Most of the interviewees benefited from being recognized as certified or preferred suppliers by Boeing and Airbus. For the first-tier suppliers, the most common benefits include a long-term commitment by the customer company, early involvement in product design and development, and being selected as sole source supplier. Another notable benefit derived by these suppliers is that they enjoy cost savings in purchasing raw materials by "piggy-backing" on large purchase contracts signed by the customer company involving large-volume discounts.

4.3.4 Contractual arrangements

The companies interviewed for this research reported that they are operating under a firm fixed-price type contract on both the Boeing 7897 and the Airbus A380 program. Typically, the contract with the partnering suppliers is written in such a way that, for example, if total non-recurring costs amount to $50 million, this is amortized over the total number of planes expected to be sold (e.g., 500). This comes to $100,000 per airplane. Thus, if total sales exceed 500, the partnering supplier would enjoy $100,000 per airplane as a benefit for having shared in the risk of developing the aircraft in the first place. If the aircraft does well in the market place, so does each of the risk-sharing partner supplier companies.

This practice, adopted by Boeing in connection with the 787 program, reflects the growing trend where key suppliers are asked to share more of the financial risks associated with developing a whole new aircraft. One of the companies interviewed indicated that the same terms and conditions are flowed down to their own lower-tier suppliers in connection with the Boeing 787 program, meaning that increasingly the lower-tier suppliers, too, can be expected to shoulder pretty much the same type of risk-sharing (and reward-sharing) responsibilities as the major partnering suppliers. The larger trend seems to be both a basic shift in the responsibilities assigned to suppliers and a fundamentally different method for effecting cost reduction throughout the supplier network, where direct top-down pressure for cost reduction is replaced by an incentive mechanism for reducing costs.

An important parallel development is that, unlike in the past when the system integrator (e.g., Boeing) would "own" all engineering drawings, under the new and evolving contractual regime the major partnering supplier would exercise intellectual property rights over the engineering drawings. The interviews have indicated that ownership rights for engineering drawings are not accorded to the lower-tier suppliers, while they are expected to participate in risk-sharing arrangements. One major reason as why this would seem acceptable to the lower-tier suppliers is the fact that they would enjoy "life-of-program" single-source sourcing subcontracts with their customers, which provides an important benefit to them in terms of a reliable and predictable long-term revenue stream as long as they are capable to perform to the customer's expectations (e.g., cost, quality, delivery).

One of the suppliers interviewed indicated that the practices just outlined would give Boeing an important cost advantage by allowing the suppliers at all levels the benefit of scale economies as they can look forward to a long-term relationship over the life-of-the-program and make long-term investments in both process improvement and technological innovation to reduce costs. Combined with Boeing's practice of allowing its suppliers to benefit from lower cost raw material inputs by "piggy-backing" on its own high-volume discount-based raw material purchase contracts (e.g., titanium), these contractual practices set into motion a new set of arrangements leading to mutually-beneficial relationships throughout the supplier network. The interviews have indicated that Airbus, for example, is not engaged in allowing its suppliers to benefits from reduced cost inputs by "piggy-backing" on high-volume discount-based purchases of raw materials, such as titanium.

It is finally worth pointing out that the firm fixed-price contractual arrangement involving the major partnering suppliers on the Boeing 787 program, with its built-in risk-sharing provisions, provides the needed incentives for them to work together closely in coordinating and managing the myriad engineering interfaces among the products and systems for which they are individually responsible in order for them to reduce their own costs. That is, Boeing seems to have externalized the cost of coordination (transaction costs) among its major suppliers, as well as the coordination costs between its major suppliers and their respective lower-tier suppliers. Nevertheless, Boeing would have to maintain extensive visibility into its entire supplier network to keep track of the various transactions, involving its "drop-ship" arrangements with suppliers with which it would have directly contracted, managing various nonconformance-related issues, and resolution of conflicts.

4.3.5 Information technology and infrastructure

In order to support collaborative business model with their partners, both Boeing and Airbus have aggressively deployed information systems facilitating communications among different partners or units around the world and streamlining inter-organizational processes. Most of the companies participating in this research responded that they have already utilized EDI (Electronic Data Interchange) for exchanging business documents (e.g., order placement, request for proposals, shipment notice) and technical data (e.g., technical specifications, routine or complex engineering drawings, tooling requirements, testing requirements), with their customers. Airbus and Boeing have already installed the so-called "supplier portal" information systems to facilitate the exchange of information on business processes with their suppliers. A supplier portal is a password-protected, web-based platform where the customers can distribute services/contents or exchange documents through a common entry point to their own information system[84]. With only a web browser installed, the supplier can access the data, documents or software applications necessary for doing business with its customer. The tasks that can be finished electronically through the supplier portal include managing inventory levels, managing

[84] "General Terms and Conditions of Access to and Use of Airbus Private Part of Supplier Portal (GTCs)", slides from Airbus

purchase orders, viewing and printing updated drawings and specifications[85]. One notable aspect is that EDI is also largely used for business transactions and for flowing down technical requirements or contractual terms and conditions between the first-tier suppliers and their own lower-tier suppliers. The adoption of EDI has been a common practice in the aerospace industry.

In the 787 and A380 programs, international partners play a significant role early in the product design phase. Both Airbus and Boeing have employed information technologies to set up virtual collaboration environments supporting development activities by suppliers in multiple countries. Airbus Concurrent Engineering (ACE) System is the information infrastructure developed under the ACE project, aimed at combining "best-in-class" tools and methods to enable simultaneous and interactive engineering within its extended enterprise[86]. Digital Mock-Up (DMU) technology, which allows full visualization of complete product designs in three dimensions, is a key element of Airbus Concurrent Engineering System used widely in the A380 program. It provides a 3-D virtual product development environment where designs can be reviewed, simulated and shared virtually among engineers located in different regions and time zones. Furthermore, 3-D virtual development environment can integrate engineers across functions; designers, sourcing specialists and production planners can collaboratively explore and validate design and manufacturing decisions, ensuring manufacturability and maintainability[87]. Airbus even uses DMU to directly integrate its customers while developing order-specific variants of the A380 passenger and A380 freighter aircraft. For example, engineers in Toulouse and at customer sites can manage mock-up reviews. This enables the customer to collaborate on the development and layout of individual aircraft right from the

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85 http://www.boeing.com/companyoffices/doingbiz/supplier_portal/BSP_External.html

86 "Partnering for Success", John Hobday (Airbus Industrie ACE Partnership Manager) www.mscsoftware.com/support/library/conf/auc99/p00999.pdf

87 http://www.3ds.com/products-solutions/plm-solutions/enovia-vplm/overview/

beginning of development[88]. Digital mock-up also enables clash detection earlier in the development process, avoiding costly modification in the later processes.

Similarly, Boeing has already replaced 2-D blueprints with 3-D solid models. The 777 was Boeing's first digitally designed airplane. The innovation incorporated into 787 early during its 7E7 phase extended the use of the same digital models of the airplane from the design phase right through manufacturing to maintenance[89]. For the 787, Boeing deployed the latest updated V5 PLM (Product Lifecycle Management) application suite, developed by Boeing's IT partner, Dassault Systèmes. The V5 PLM application offers improved integration of CATIA[90], ENOVIA[91] and DELMIA[92] and is part of an overall approach to managing the international collaboration, known as the Global Collaboration Environment (GCE). In this virtual environment, Boeing and its partners are able to use V5 PLM applications to design, build and test every aspect of the 787 airplane and its manufacturing processes digitally before production begins[93]. With visual teleconferencing software (e.g., Microsoft NetMeeting) and 3-D digital models stored in a single database held on servers maintained by Boeing, engineers in Boeing can collaborate in real time with their counterparts from the partnering companies.

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[88] http://ec.europa.eu/research/aeronautics/projects/article_3628_en.html

[89] "Boeing Shows its Technology of the Digitally Designed 7E7", Seattle Times, September 24, 2004

[90] **CATIA** (**C**omputer **A**ided **T**hree **D**imensional **I**nteractive **A**pplication) is a 3D product lifecycle management developed by Dassault Systemes and marketed by IBM. For more details, please refer to the following websites:
http://www.catia.com/
http://en.wikipedia.org/wiki/CATIA
http://www-306.ibm.com/software/applications/plm/catiav5/

[91] ENOVIA a software providing a set of integrated solutions supporting virtual product modeling, lifecycle management, and decision. It is developed by Dassault Systemes and marketed by IBM. For more details on this product, please refer to the following websites:
http://www.enovia.com/
http://www-306.ibm.com/software/applications/plm/enovia/

[92] **DELMIA** (**D**igital **E**nterprise **L**ean **M**anufacturing **I**nteractive **A**pplication) is the brand for digital manufacturing and simulation solutions from Dassault Systemes. For more details about the product, please refer to the following website:
http://www.delmia.com/

[93] http://www.boeing.com/news/releases/2005/q2/nr_050613h-a.html

The 3-D design software and product lifecycle management software have transformed the traditional sequences from development to manufacturing. Before, research and development (R&D) team started to work on a product first. The production engineers have had to wait until the design was complete in order to figure out how to produce it. Then, the production could not start before the production process would be approved by the quality team. Under this practice, it was very common that the design would go through numerous iterations, where the production and quality teams would toss the design back to the engineering team to resolve various design-related problems. Now, however, the new information technologies and systems make it possible for the integrated product and process teams (IPPTs) -- including product development, manufacturing engineering and quality assurance – to collaborate throughout the design and development phase in terms of performing all the engineering tasks, examining the design together and catching and correcting any design errors before the engineering design process is completed. The enhanced cross-disciplinary collaboration speeds up the product's time to market and also enhances product quality.

Both Airbus and Boeing believe that RFID could provide major benefits for the entire aerospace industry. RFID data can give more accurate estimates of demands for parts; both manufacturers and suppliers are therefore able to decrease their parts inventory. Furthermore, information stored on RFID tags can facilitate monitoring and tracing the statues of parts, making maintenance easier and reducing the time required to solve in-service problems or generate inspection reports. Suppliers can also use the technology to verify that the parts they ship to Boeing and Airbus are genuine and decrease the number of unapproved parts that enter the supply chain[94].

[94] http://www.rfidjournal.com/article/view/934

Before the 787 program, Boeing had already started to apply RFID in aircraft tool management. All of its tools and toolboxes were equipped with RFID tags that contained past history, as well as shipping, routing and customs, information. Since 2000, Airbus also has used RFID tagging for its ground equipment and tools, which it loans to airline maintenance centers. The tags are used to track the items as they are sent out to the centers and returned. For the A380 and the 787 programs, both Airbus and Boeing have since applied RFID more extensively. Airbus has equipped its A380 with about 10,000 RFID chips on removable parts such as seats, life jackets, and brakes[95]. For the 787 program, Boeing plans to include unique identification and maintenance and inspection data conforming to industry standards developed for commercial aviation by the Air Transport Association[96]. The RFID tagged parts on the Dreamliner will be serialized end items such as line replaceable units (LRUs) and life-controlled parts, as well as on-board emergency equipment. Smart labels will be applied during the manufacturing process by the supplier prior to delivering the airplane to airlines[97].

Moreover, Boeing and Airbus have risen above competition and worked together for reaching consensus regarding standards for using global RFID technology on commercial airplanes. By working together, Boeing and Airbus can avoid unnecessary costs caused by conflicting requirements with their largely-overlapping customers and suppliers. They started a joint initiative with product-life-cycle management vendor Sopheon plc and Siemens Business Services to provide an industry-wide Internet portal to selected reference sources for RFID implementation. One notable aspect of this is that the partnership between Sopheon, Airbus, and Being implies that RFID will be gradually incorporated into product-life-cycle management

[95] " Airbus puts RFID on commercial jet," Supply Chain Management Review, March 2005, pp. 61
[96] The Air Transport Association has added an RFID standard to its SPEC2000, which is a comprehensive set of e-business specifications, products and services for the aviation parts industry. The standard requires the use of ISO 15693 passive, read-write tags that can operate at 13.56 MHz. (http://www.rfidjournal.com/article/view/934)
[97] http://www.boeing.com/news/releases/2005/q4/nr_051003g.html

applications, which presents new possibilities for using RFID in product development, maintenance, and end-of-life recycling of aircraft parts[98].

Boeing and Airbus's joint initiative in promoting an industry-wide standard for RFID usage will have significant influence on hundreds of the aircraft manufacturers' suppliers and even trickle down to lower-tier suppliers. The widespread adoption of RFID technology and the imposition of RFID tagging through contractual requirements across the aerospace industry is expected to accelerate in the near future.

4.4 Implications for supply chain management strategies

Adoption of system integration model through partnerships with suppliers

In recent years, aerospace manufacturers have been facing a mounting pressure to reduce their costs, not only because of the intensifying competitive pressures in commercial aerospace but also because of the increasing demand in defense aerospace for affordable weapons systems. System integrators (prime contractors), as well as their major suppliers, have therefore been studying other industries, such as automobiles, to learn from their experiences in developing close partnerships with their suppliers in order to aggressively lower their costs and spread their risks. They have thus started asking their suppliers to take on a greater and more integrated responsibility in both product development and manufacturing. In return, the suppliers are selected as sole-source suppliers on a best-value basis and are awarded long-term contracts or even strategic partnerships, often involving the provision of after-market customer support involving spare parts, maintenance, repair and overhaul (MRO) services (e.g., the GoldCare

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[98] http://www.informationweek.com/story/showArticle.jhtml?articleID=53701369&tid=5978

program for the 787). The manufacturers who see themselves as system integrators will function as coordinators that work closely with their suppliers to ensure the optimized combination of the resources in their extended enterprises and continuously improve the overall supply chain performance. They also provide collaborative environments where the supply chain partners are willing to share data, communicate with each other regularly and intensively and the interfaces across the supplier networks are streamlined.

As the system integrators (primes), and their major suppliers, increasingly outsource activities and functions they used to perform internally, they must find qualified suppliers that can assume such responsibilities so that they are able to optimize the portfolio of core competences they can orchestrate in order to enhance their competitive advantage. They, hence, approach the task of outsourcing by employing a number of criteria, including those noted below.

1. The R&D capabilities

Nowadays, suppliers, especially the first-tier ones, are expected to be integrated early in the product development stage or even take over the full responsibility for design and development, as in the case of the Japanese manufacturers and other major partnering suppliers in the Boeing 787 program. As a matter of fact, tier-one suppliers' involvement and contribution in the development phase are highly valued by manufacturers that want to achieve both product and process innovation by leveraging the technological capabilities of their suppliers. Hence, a supplier's ability to participate in the early development stages is undoubtedly a key differentiator in the market. The suppliers equipped with higher R&D capabilities will have more of an influence in shaping the customer company's product or performance specifications, as well as in delivering greater value to the customer in terms of a superior product at lower cost and higher quality, thereby enabling the customer company to evolve a stronger competitive advantage vis-à-vis its own competitors.

2. Ability to assume full supply chain management responsibilities

As more components or parts are outsourced to external suppliers, it would seem that manufacturers, acting as customer companies, will gradually have to yield control over the suppliers responsible for the design and production of these parts and components. The supply chain strategy adopted by Boeing for the 787 illustrates this point: the first-tier suppliers, serving as the major partnering suppliers, have full responsibility for managing their own supplier networks, including the selection of their own lower-tier suppliers, quality assurance, and implementation of just-in-time production systems. At the same time, of course, the suppliers themselves also have to make the necessary investments for improving their processes, enhancing their overall innovative capacities, and improving the capabilities of their own suppliers in order to meet the system integrator's (prime's) cost, quality and delivery requirements.

3. Strong financial backing

In order for them to take on the new and growing design and production responsibilities transferred to them by the primes, the first-tier suppliers have to demonstrate, to the satisfaction of their customer company, the fact that they enjoy a strong financial posture and are able to make the necessary capital and human resource investments in order to develop the needed capabilities. As the primes become increasingly dependent upon their first-tier suppliers, the financial strength of the suppliers becomes a key factor, among others, in deciding whether a particular supplier can be entrusted to meet the system-integrator's demanding requirements in these large and complex programs.

Globalization

From the profiles of the suppliers participating in the 787 and the A380 programs, it is not too difficult to see immediately that the commercial aerospace industry has already entered the era of global competition. No matter whether they are driven by the pressure to lower their costs or by the increasing need to enter into a variety of offset arrangements to spread financial risks and open up new markets, large system-integrators as well as their suppliers are shifting an increasing share of their workload to their lower-tier suppliers in countries such as China, India and Russia. Boeing has been making substantial investments in the Asia-pacific region over the past several decades and has by now established a dominant position in this region as a whole. Airbus, even though it has entered this market as an active player much later than Boeing, is also increasing its cooperation with companies in Japan and China. It has entered into discussions involving the transfer of a significant amount of work to China over the next decade or so. Both companies have also established cooperative programs or have taken outsourcing initiatives in Russia, Australia, Malaysia, and other countries.

To maintain or enhance their competitiveness, large aerospace companies must recognize the pattern of globalization and learn to globalize their own supply chain activities and design new business models and strategies. This involves a lot more than finding the best subcontractors from various countries, as Boeing's experience in China demonstrates. Many issues related to supply chain coordination and management across several regions would have to reckon with cultural differences and how best to manage these differences. How these challenges are addressed may well determine success in this new age of globalization. In this respect, there are some lessons that can be learned from past experience. One example is the effort made by the Boeing 787 wing team that made conscious efforts to develop a deeper understanding and appreciation of the culture of their Japanese teammates at MHI. This involved many meetings, seminars with experts on the Japanese culture, and Japanese language courses. These efforts were designed to ensure comfortable working relationships and, ultimately, working successfully in across-cultural environment[99].

Consolidation

The global competition and increasing financial and technological requirements to compete in the market means that the lower-tier suppliers, quite often with a smaller capital base, will be forced to be merged or acquired by larger companies in order for them to attain a sufficiently robust position to address market competition. It is predictable that the aerospace industry will see a round of worldwide acquisition and merger activities in the near future. However, loosely-coupled forms of collaboration among diverse organizations, large and small, could also emerge across many borders as a plausible alternative to a new wave of international consolidation in the aerospace industry.

Outsourcing dilemmas

1. Outsource or Make In-house?

Over the past 30 years, Boeing has gradually expanded the content of its outsourcing activities from simple structural parts to complex components, such as center wing box, as it has increasingly stressed its central "system integration" strategy. Driven by the motivation to reduce its own share of the total amount of the technical work that would be involved in launching the

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[99] " Wings around the World", Boeing Frontiers, March, 2006, http://www.boeing.com/news/frontiers/archive/2006/march/cover.html

787 program and also to reduce the overall financial burden it would be required to assume, Boeing shifted a significant amount of the workshare, including product development and production, to its major supplier partners and kept only 35% of the total workshare in-house. This strategy appears to have provided Boeing with significant technological and financial advantages in launching the 787 program.

Airbus, in contrast, is currently facing prolonged production-related technical difficulties in the A380 program, delaying delivery by two years while also causing a cut in projected earnings by as much as 4.8 billion euros ($6.1 billion) over the next four years[100]. The delivery crisis engulfing the A380 and the pending trans-Atlantic dispute concerning government loans for the A350 program, could not come at a worse moment for Airbus. Airbus is noted to be studying carefully Boeing's new business model and associated supply chain management strategies, as well as the information technology infrastructure that has been pivotal in the 787 program, as it considers other projects such as the A350 midsize plane and the A400 military jet[101].

Meanwhile, everything may not be as rosy with Boeing as it may seem. It has been pointed out that Boeing's strategy to aggressively adopt the "system integrator" role, with heavier reliance on suppliers for both finances and technology, may, in reality, reflect its internal weaknesses in terms of its basic technology base. Some have argued that for a considerable period of time in the past, Boeing has underinvested in R&D, capital equipment and manufacturing facilities compared with Airbus, its main competitor (Pritchard and MacPherson, 2004). While Airbus has continuously introduced technological advancements, especially in composite technology, it has been noted that Boeing's airframe design has changed very little

[100] "Airbus Denies Reports That Chief Executive Has Offered to Resign," The New York Times, October 8, 2006, p. YT 5.
[101] "Course Correction", Aviation Week & Space Technology, July 24, 2005

since the 747. Facing fierce competition with Airbus, Boeing is seeking to develop an aircraft with unprecedented composite content. Given the perception that Boeing lags behind its Japanese partners in aircraft composite technology, Boeing's reliance on these suppliers to tap their technological capability is seen as an economic and logical move (Pritchard and MacPherson, 2005).

However, by outsourcing most of the work packages to its external suppliers, it is speculated that Boeing might be accelerating the speed of hollowing out its core technological competence. The 787 involves various revolutionary aircraft technologies, especially in the design and manufacturing of the composite wing and the fuselage, whose related work packages have been virtually all outsourced by Boeing. The only challenge left for Boeing is its 3-day final assembly plan for the 787.

2. Outsourcing to foreign partners: industrial offsets

In the large commercial aircraft industry, industrial offsets represent a common practice to open up new markets or to secure market shares in selected national markets where airlines are typically government-owned, operated or heavily controlled. The use of offsets has, indeed, successfully driven sales for both Boeing and Airbus, especially in the Asia-Pacific market. The governments of the respective customer countries have provided, in return for these offset arrangements, not only access to their own internal markets but also access to new capital resources and an opportunity to spread the program risks. However, these perceived benefits might be counterbalanced by certain long-term negative consequences. Over the past few decades, Boeing has increasingly expanded the participation of Japanese aerospace manufacturers in various Boeing programs, under what maybe termed industrial offset arrangements whereby Boeing as a seller has enjoyed unparalleled dominance in the internal Japanese market. Over time, Japanese aerospace manufacturers have gradually acquired the wing manufacturing and assembly expertise embodied in the work packages from Boeing's programs over years. Wing production is considered as the most technology-intensive part in aircraft manufacturing and the technical experience and know-how required in connection with wing design and production represent a major barrier to entry in the commercial aircraft manufacturing sector[102]. Now, the Japanese firms, with government support, possess full capabilities for entering the industry as airframers (Pritchard and MacPherson, 2004; Lam, 2005). In fact, the Japanese government is pursuing the development of Japan's first passenger jet in a joint venture with Mitsubishi Heavy Industries. The proposed aircraft will be an "all-composite" regional jet that comes in 72- and 92- seat versions and aims to be at least 20 percent more fuel efficient than other competing regional jets[103]. By giving away its wing production entirely, Boeing might arguably have set the stage for even more competition in the future global market.

Another major concern about offsets is that the potential risks are less predictable and might offset the expected gains. Due to China's lower labor costs and the possible large deals in the future, Airbus has promised to significantly expand its investments in China, including a final assembly plant for the A320. However, as the main airframe structures and other components continue to be manufactured in Europe, the related supply chain coordination costs for transporting these components from Europe to China for final assembly might be higher than the cost-savings that can possibly be achieved through lower labor costs in China. In addition, some western aerospace manufacturers are still plagued with the quality issues in China, let alone

[102] "Japan's Economy Emerging from the Doldrums" http://www.econstrat.org/blog/?p=17
[103] "Japan looking to Build First Passenger Jet", Manufacturing.Net, September 6th, 2006

asking Chinese suppliers to shoulder the R&D responsibilities in developing new programs[104].

The deployment of information infrastructure

In order to support a collaborative environment, the manufacturer has to be responsible for orchestrating intensive communications and information sharing involved. Furthermore, while aerospace manufacturers are expanding their supply chain to the global markets, supply chain coordination becomes much more difficult to manage. Many aerospace manufacturers approach the task of managing their global supply chains by applying information technologies to streamline inter-organizational business processes and facilitate virtual collaboration among partners located all over the world. For the suppliers, it is imperative to be equipped with necessary electronic communication and collaboration technologies; otherwise, they will be considered not qualified to do business with their customers.

4.5 Conclusions

The elevated cost consciousness of the airlines and the intensive rivalry between Boeing and Airbus continue to boost up competition in the aerospace industry. In order to stay competitive, aerospace manufacturers are taking aggressive approaches to cut down costs and expand its capabilities while maintaining agility. In this research, the comparative analysis of the supply chain strategies adopted for the Boeing 787 and the Airbus A380 programs has identified several major trends that will have significant implications on the future supply chain model in the aerospace industry:

1. Both primes and their first-tier suppliers are taking the roles of system integrators

[104] "Airbus may hit an air pocket over China," Business Week, April 24, 2006

and seeking collaboration with their supply chain partners with a goal to spread out risks and costs across their supplier network, as well as to enhance their enterprise capabilities. Suppliers, especially the first-tier ones, are taking up more extensive and integrated responsibilities for the components they are supplying. Suppliers should see themselves as long-term partners, rather than simply short-term service providers. Therefore, in order to survive, it is crucial for a supplier to acquire enough size (through consolidation or strategic alliance) to acquire strong financial backing and make investments to enhance their technological capabilities.

2. Aerospace manufacturers are outsourcing more and more activities to suppliers located in non-traditional regions, such as Asia and Eastern Europe, either under various types of offset arrangements or based on the cost considerations. This means that the future supply chains in the aerospace industry will become highly international, where cross-national collaboration will become a common phenomenon.

The adoption of information technologies is imperative for coordinating data sharing and communications in a complex global supply chain where many entities from different organizations located in various geographical regions are collaborating. The enhanced collaboration enabled by information technologies can decrease the time-to-market and improve product quality. In the future, suppliers have to be equipped with enough information technology capabilities in order to do business with their customers.

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Appendix A. Questionnaire Survey

Part A. General Company Background information

A1.Please provide the information requested below on your company

Annual Sale Revenue: ______________________

Number of Full-Time Equivalent Employees: ______________________

A2.What are the primary (main) products of your company?

(Examples of "primary" products include flaps, fairings, pylons, actuators, stators, servovalves, brakes, injection molding services, etc)

A3.What are the specific products (parts, components, systems) that your company supplies in connection with Boeing 787 and Airbus A380 programs?

Boeing 787

Airbus A380

A4.What are major examples of the other products that your company supplies in connection with other programs of Boeing and Airbus?

Boeing

Airbus

A5.Please indicate the status of your company as a supplier in connection with the Boeing 787 and Airbus A380 programs:

Boeing 787:

Your company supplies Boeing 787 program as

A Boeing "partnering supplier"*

A supplier other than a Boeing partnering supplier ┐

*A Boeing "partnering supplier" refers to the key structural partner Boeing establishes partnership agreements with and is responsible for designing and manufacturing their respective "stuffed sections"** of the 787. Examples of Boeing "partnering supplier" include Goodrich Aerostructures, Vought, and Spirit Aerosystems.

**"Stuffed sections" are essentially a section of the airplane with the structural elements (e.g., floors, beams), and electronic components (e.g., wires, sensors) and sometimes even interiors (e.g., walls, carpets) fully installed.

Airbus A380:

Your company supplies Airbus A380 program as

A major Airbus partner companies (e.g., BAE systems) ┐

An integrating (higher-tier) supplier directly supporting Airbus or a major Airbus partner company ┐

A supplier other than an Airbus partnering company or integrating supplier ┐

A6. Please indicate who are ***<u>your most important direct customers</u>*** (in terms of *contract dollar value*) in connection with the Boeing 787 and Airbus A380 programs:

Boeing 787

Your most important direct customer is

Boeing ┐

A Boeing partnering supplier ┐

A Boeing supplier *other than* a Boeing partnering supplier ┐

Airbus A380

Your most important direct customer is

Airbus ┐

A major Airbus partnering company (e.g., BAE Systems) ┐

An integrating (higher-tier) supplier directly supporting Airbus or a major Airbus partner company ┐

***Note**: In the rest of this questionnaire, please answer all questions relating to your relationship* *with **__your most important direct customers__** with reference to the specific customers you have just identified.*

Part B. Supplier certification and relationship management

B1. Many aerospace companies have been using a formal documented process and performance standards to evaluate the capabilities of their major suppliers for the purpose of deciding whether to confer upon them a "certified" or "preferred" supplier status. Are you already a "certified" or "preferred" (or their equivalent) supplier of ***your most direct customer in connection with the Boeing 787 program or the Airbus A380 programs***?

Boeing 787:	┐ Yes	┐ No
Airbus A380:	┐ Yes	┐ No

If you are a "certified" *or "preferred" supplier of any of your most important direct customers in connection with the Boeing 787 and Airbus A380 programs respectively, please proceed to the following sub-question; otherwise, please skip to **__B3__**.*

Often, the "certified" or "preferred" suppliers are given "bronze", "silver" or "gold" designations, denoting a progressively higher set of exacting standards, process capability, and performance expectations. Have you been designated as a gold, silver, or bronze supplier by any of ***your most important direct customers in connection with the Boeing 787 and Airbus A380 programs,*** respectively? Please check one of the following as the most appropriate:

	Boeing 787	**Airbus A380**
Gold	┐	┐
Silver	┐	┐
Bronze	┐	┐

B2. *If you are not a "certified" or "preferred" supplier of any of your most important direct customers in connection with the Boeing 787 and Airbus A380 programs, please skip this question to **B3**.*

If you are a "certified" or "preferred" supplier to any of your most important direct customers in connection with the Boeing 787 and Airbus A380 programs, please check in the table below to indicate what benefits your company receives from these customers.

Possible benefits awarded to the certified or preferred supplier	**Your most direct customers in connection with**	
	Boeing 787	**Airbus A380**
Less frequent or number of audits are conducted on your company's process control, quality systems; reduced source or incoming inspections of your products	☐	☐
Given preference in making new contracts awards	☐	☐
Commitment to a long-term relationship (e.g., multiyear purchase agreements for a particular product for a fixed duration)	☐	☐
Sharing of cost savings	☐	☐
Financial assistance (e.g.,for purchasing special equipment or products for process improvement, IT/IS infrastructure)	☐	☐
Strategic management assistance (e.g., business strategies)	☐	☐
Technical or engineering assistance (e.g., improvement of your product design and performance, diagnosis of inefficiency in your supply chain)	☐	☐
Provision of enhanced worker training	☐	☐
Sharing of technology roadmaps	☐	☐
Early involvement in product design and development	☐	☐
Selection of your company as a sole source supplier	☐	☐

B3. In connection with the Boeing 787and Airbus A380 programs, how long a commitment have ***your most important direct customers*** made to purchase components, materials or services from your company?

	Boeing 787	Airbus A380
No commitment at all	˥	˥
Commitment of one year or less	˥	˥
Commitment of more than 1 year, up to 3 years	˥	˥
Commitment of more than 3 years	˥	˥

Note: Commitment refers to an explicit agreement (e.g., contractual, handshake) to purchase the product(s) in question from your company, which may or may not involve a specific purchase quantity.

B4. Please check below at what stage your company was selected as a supplier to support the Boeing 787 and Airbus A380 programs.

Program Phase	Boeing 787	Airbus A380
Concept development	˥	˥
Preliminary Design Review	˥	˥
Detailed Design Review	˥	˥
Prototype design and manufacturing	˥	˥
Testing and evaluation	˥	˥
Low-rate Initial Production	˥	˥
Full-production	˥	˥

Part C Supplier Selection, Order Placement, and Quality Management

C1. Please check below on what basis you believe your company was selected as a supplier by ***your most important direct customers in connection with the Airbus A380 and Boeing 787 programs***.

	Your most direct customer in connection with	
Selection Criteria	**Airbus A380**	**Boeing 787**
Lowest-cost	˥	˥
Best-value basis (e.g.,reliability, past	˥	˥

performance, flexibility and responsiveness, demonstrated business processes)		
Other	☐	☐
(Please specify)	________	________

What type of contract type does your company currently has with ***your most important direct customerss in connection with the Boeing 787 and Airbus A380 programs***?

	Your most direct customer in connection with	
Contract Type	**Airbus A380**	**Boeing 787**
Fixed-cost contract	☐	☐
Cost-plus contract	☐	☐
Other	☐	☐
(Please specify)	________	________

C2. Does your company have both complete autonomy and authority to manage your own subtier suppliers in connection with the Airbus A380 and Boeing 787 programs?

Airbus A380: ☐ Yes ☐ No

Boeing 787: ☐ Yes ☐ No

Please provide any further information or clarification below:

____

Part D. The Integration of Information Processes and Practices across Supplier Networks

D1. Please check below to indicate what extent your company utilizes electronic data transfer via email, web interface, B2B software or secured online marketplace to conduct the following types of document/data exchanges (two-way data/information flows) with ***your most***

important direct customers in connection with the Boeing 787 and Airbus A380 programs.

- Level 1: Most or all document/data exchanges are manual or paper-based
- Level 2: As much as a quarter to half of document/data exchanges are electronic-based
- Level 3: A majority or all document/data exchanges are electronic-based

Also check in a separate column whether your company utilizes internet-based e-business, procurement, collaboration and related services provided by third-party organizations (e.g., Exostar) in order to facilitate the electronic exchange of the information identified below between your company and ***your most important direct customers*** in connection with the Boeing 787 and Airbus A380 programs.

Boeing 787					**Airbus A380**			
	Level				**Level**			
Don't know	**1**	**2**	**3**	**Types of Data Exchange (Not Exhaustive)**	**1**	**2**	**3**	**Don't know**
				Business transactions:				
				Request for quote; request for proposal				
				Order placement				
				Contractual requirements (including requirements flowdown to subtiers)				
				Notification of parts receipt				
				Shipment notice				
				Invoice processing and payment				
				Technical data Interchange				
				Technical specifications (materials, processes)				
				Key characteristics (e.g., geometries, dimensions)				
				Special processes (e.g., heat treat, grinding, coatings, plating, shot peen)				
				Routine engineering drawings (e.g., paper, 2D, CAD)				
				Complex engineering drawings (e.g., solid models) involving complex parts, contoured surfaces, dimensionless tolerancing)				
				Supplier capabilities requirements (e.g.,				

				non-destructive testing, magnetic particle, radiography, ultrasonic)				
				Tooling requirements				
				Testing requirements				
				First article inspection requirements				

D2. Please check below to indicate what extent your company utilizes electronic data transfer via email, web interface, B2B software or secured online marketplace to conduct the following types of document/data exchanges (two-way data/information flows) with ***your own supplier***.

- Level 1: Most or all document/data exchanges are manual or paper-based
- Level 2: As much as a quarter to half of document/data exchanges are electronic-based
- Level 3: A majority or all document/data exchanges are electronic-based

	Level			
Types of Data Exchange (Not Exhaustive)	**1**	**2**	**3**	**Don't know**
Business transactions:				
Request for quote; request for proposal				
Order placement				
Contractual requirements (including requirements flowdown to subtiers)				
Notification of parts receipt				
Shipment notice				
Invoice processing and payment				
Technical data Interchange				
Technical specifications (materials, processes)				
Key characteristics (e.g., geometries, dimensions)				
Special processes (e.g., heat treat, grinding, coatings, plating, shot peen)				
Routine engineering drawings (e.g., paper, 2D, CAD)				
Complex engineering drawings (e.g., solid models) involving complex parts, contoured surfaces, dimensionless tolerancing)				
Supplier capabilities requirements (e.g., non-destructive testing, magnetic particle, radiography, ultrasonic)				
Tooling requirements				
Testing requirements				

First article inspection requirements				

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