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An Integrated Outsourcing Framework: Analyzing Boeing's Outsourcing Program for Dreamliner (B787)

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Abstract

This paper analyzes the outsourcing model which Boeing devised to develop its latest commercial airplane model: Dreamliner (B787). The development of this airplane which seemed to be very promising in the beginning turned into the longest delayed program in the history of the company. In this paper, we propose an integrated outsourcing framework through which we try to find the root causes of the delays and the resulted extra costs. The proposed framework shows how the interaction of all influential factors in four outsourcing dimensions (who, what, to whom, and how) determines the performance of an outsourcing program.

Keywords: Outsourcing; Supplier Management; Boeing; Dreamliner

1. Introduction

On the 29th of January 2003, Boeing revealed the general specification of its latest airplane design. The new airplane was a fuel efficient jetliner made of mostly composite materials – an innovative and unparalleled design which the commercial aviation industry had never seen the like of it. The plane was eventually dubbed Dreamliner or Boeing 787 (B787). The Dreamliner, with its appealing and unique features, turned into the most successful release in the history of commercial aviation industry with a record number of 500 orders within the first three years of the program's official launch. Later on, Dreamliner's orders even exceeded 900 at some point[1]. However, the Dreamliner came to be known as the longest delayed program in the company's history with more than undesirable consequences, including huge extra costs, lost and delayed revenues, loss of customers' and investors' confidence, not to mention a reshuffle of the top management.

When the first signs of the problems were observed in 2007, the company started to pour money and resources into the program. At that time, the top management was under the impression that they could contain the problem to a six month delay (considering some cushion for then unforeseen problems). A six month delay might not look unacceptable for a mega project to develop an extremely complex product. Nevertheless, only the six-month delay resulted in around $1 billion of extra costs and an estimated reduction of $3.5 billion in revenues for the consecutive year (Gates, 2007). However, as the subsequent events showed, the roots of the problems were so deep that they caused more than three years of delay and many times more extra costs.

In this paper we try to analyze the Boeing's challenges in this program, which seem to have roots in the outsourcing model the company established for developing this airplane. Similar to many other challenging cases in the past, this case supports the idea that outsourcing is a double-edge sword which can ultimately offer either significant positive business achievements or huge negative business impacts, depending on how it is designed and implemented.

Outsourcing literature is rich with papers which try to demonstrate the interaction of influential factors in an outsourcing program – either to explain the outcome or to prescribe an approach. Most of these papers, however, focus on limited number of factors. In reality, each outsourcing program is influenced by a network of many influential factors. In some cases, focusing on a selected number of factors could be misleading – as we will show for the Dreamliner case. In this paper, we offer a framework which can help us to identify all the influential factors from a holistic point of view. Using the existing results in the literature, one

[1] The number of outstanding orders is a changing figure due to new orders and cancelations.

can then analyze the interaction of these factors to understand/design an outsourcing program – again we demonstrate it for the Dreamliner case.

In this paper, we first introduce our framework while reviewing the related literature. We then provide the case background and our observations in this case. Using this framework, we analyze the Dreamliner case to find the root causes of the problems. Managerial insights are provided at the end.

The authors acknowledge that the analysis of a case ex post is much easier than doing so ex ante. We want to emphasize that this analysis by no means undermines the efforts of executives and managers at Boeing and the decisions they had to make under very a turbulent business environment. It is partly through their visions and daring that we can enjoy such advancements in the commercial aviation field.

2. Related Literature and Conceptual Framework

Outsourcing of a specific business activity can be referred to as the process of transferring the responsibility of performing a function from internal employee groups to external non-employee groups (Zhu et al, 2001). Due to its potential benefits, outsourcing has become one of the key business strategy themes for companies in the last few decades over which the evolution of outsourcing can be classified into three periods (Hätönen and Eriksson, 2009): the era of cost cutting by (domestic) outsourcing via arms-length relation (1980s), the era of capability enhancement by (international) strategic sourcing via strategic alliances (1990s), and the era of organizational transformation by (global) transformational outsourcing via collaborative development (2000s).

The evolution of outsourcing has been accompanied by augmentation of outsourcing variants. This resulted in quite an extensive literature which looks at outsourcing from different perspectives. In order to gain a comprehensive perspective, capable of capturing all related factors, we propose a general framework with four outsourcing dimensions. These outsourcing dimensions are in fact four questions the answer to which can fully characterize all the influential factors in any outsourcing program. These outsourcing dimensions (questions) are: (a) *who* wants to outsource and what are the capabilities of the outsourcing firm? (b) *what* is being outsourced and what are the characteristics and complexity of the product or service being outsourced? (c) _to whom_ should a firm outsource and what are the required qualifications of the suppliers? and (d) _how_ outsourcing is being done and how effective and efficient they are?

Throughout the rest of this section we briefly review the literature related to our case and show that the existing results can be viewed from the perspective of this framework. In fact, each paper in the literature tries to explain the relationship between two or more factors in different outsourcing dimensions. For each paper we specify the dimension(s) under discussion in a bracket.

Because of the vastness of the outsourcing literature, for the sake of brevity, we focus only on the outsourcing of design (or R&D) and New Product Development (NPD), which is related to the case under study in this paper.

Nowadays, many companies have developed competencies in managing NPD projects to play mainly the role of system integrators. There are others who have kept the development of few critical components or subsystems in-house and outsourced the development of the rest to suppliers. All these companies can then enjoy the benefits of outsourcing of NPD which include: access to a larger pool of resources (either financial or talent) [who & to whom], greater focus on core competency and customer requirements [who], reduced costs through lower labor and talent costs [to whom], global growth through access to critical local information and markets [to whom], more employee flexibility [who] through transferring the responsibility of new employees to suppliers (Rundquist, 2008), potential profit margin benefits (Calantone and Stanko, 2007) [who], and lead-time reduction [what].

There are a variety of challenges in outsourcing in general and the outsourcing of design and NPD in particular. In the past, firms usually prefered to keep NPD processes in-house since its outsourcing would be associated with future vulnerability of the firm because of either intellectual property concerns (Munsch, 2004; Roy and Sivakumar, 2011) [who], or dependency concerns (McIvor, 2005) [who]. However, due to its abovementioned benefits, outsourcing of design and NPD is becoming more common over time.

For a stronger focus on core competencies, firms are encouraged to consider outsourcing everything which is not a core competency (Windrum et al, 2009). However, distinguishing core from non-core compentencies or equivalently determining the scope of outsourcing [what] is not an easy task. McIvor et al. (2010) proposed a framework which helps to identify what should be outsourced and what should not. Depending on the relative capabilities of the outsourcing firm [who & to whom] and criticality of the processes to be outsourced [what], the authors propose four outsourcing options: I) collaborative outsourcing (low capability, critical); II) retain in-house (high capability, critical); III) transactional outsourcing (low capability, not critical); and IV) outsource or spin-off (high capability, not critical).

Design and NPD processes require the interaction of cross-functional teams and as such having effective and efficient communication is both critical and challenging. The required interaction can be escalated by the complexity of the product or service (Zhao and Calantone, 2003) [how & what]. To facilitate communication, in electronic industry, extended enterprises have been formed where Original Equipment Manufacturers (OEMs) have extended their collaboration with companies that manage production, product introduction, and even product design for the more complex and technologically advanced parts of a product or module (Johansen, 2005) [how & what]. In fact, the modular nature of products in some industries has let companies outsource detailed design of components under their general design requirements. Such a practice [how] has been observed in Japanese car companies (Dutton, 1992), Chrysler (Minahan, 1998), and Apple (Magee, 1992). When a modular design is possible, the challenge of dealing with the complexity of the product reduces to the challenge of managing the interfaces of the proruct sub-systems [how].

In the conventional NPD, we usually observe co-located teams relying on designers and engineers located in engineering centers. In contrast, nowadays, NPD has more globally distributed teams using an entirely digital NPD process to facilitate distributed, collaborative engineering (Eppinger and Chitkara, 2006) [how]. It seems, however, that there is no established model that describes how this virtual network operates or should be managed (Monroy and Vilana Art, 2010) [how & to whom]. When it comes to NPD outsourcing of complex products, co-location of outsourcing firm and suppliers is advised in general design and integration phases Tripathy and Eppinger, 2011) [how].

Another challenge in outsourcing of NPD is the structure of supply chain. To address the challenging task of managing a network of suppliers, often delegated sourcing strategy is applied (Cousins and R. Spekman, 2003) [to whom & how]. This structure has become popular in the aerospace and automotive industries since the mid 1990s. In delegated sourcing, a few key suppliers known as first-tier suppliers are each responsible for the delivery of an entire sub-assembly as opposed to an individual part. The outsourcing firm delegates authority to the first-tier suppliers to manage the manufacturing of the associated components of the sub-assembly. Such a structure can be applied when a modular design is feasible. In this approach a first-tier supplier is, in essence, a strategic partner. This firm designs the sub-systems and develops a hierarchical network of its own suppliers (Mazaud and Lagasse, 2007) [to whom]. Such a dual responsibility for the first-tier suppliers is extremely critical in success of such outsourcing programs. Any shortcoming in qualifications and technical strengths of the first-tier supplier is potentially transferred to the outsourcing firm and can result in delays and other negative impacts [to whom].

An influential factor amplifying these outsourcing challenges is the complexity of the product [what]. Complexity could pose challenges in capacity estimation when launching new products. This could possibly lead to over commitment situations (Yu et al, 2010) [what & to whom]. Moreover, complexity of products can cause challenges in having a modular design which is critical in outsourcing of design and NPD (Langlois, 2003) [what]. To outsource the design and NPD of complex products, when learning by doing matters, the OEM should retain some component specific knowledge in-house (Zirpoli and Becker, 2011) [what & who]. Through empirical analysis of 323 projects, Hui et al. (2008) have argued that, due to high interdependency of activities within stages of complex projects, outsourcing firms suffer from lack of domination over the activities and as such face challenges in control and monitoring [how & what]; leading to poor performance. In outsourcing the NPD of a complex product it is difficult to clearly define the outsourced function or state a clear performance measure (Tadelis, 2007). Moreover, for a complex product, the detailed specification of the product might evolve as the development program proceeds, which prevents the outsourcing firm from having a well-defined contract. Lack of clarity in the contract is often a source of renegotiations and change in contract terms, which can result in considerable hidden costs (Tadelis, 2007) [how & what].

Complexity of product can also influence the type of relation between the outsourcing firm and its supplier. One extreme type of relation known as arms-length or contractual (Kamath and Liker, 1994) [how] is where suppliers manufacture simple parts, either standard across the industry or designed by the outsourcing firm. At the other end of the relation spectrum is partnership in which the supplier is fully integrated into the product development processes of the outsourcing firm.

The contract/relation between the outsourcing firm and suppliers should also provide proper incentives for the suppliers to exert enough fund and effort [how]. For outsourcing the NPD of complex products where the scope and performance measures cannot be clearly defined from the outset, these incentives usually cannot be properly induced through direct payments. In these cases, other mechanisms such as revenue sharing contracts or royalty payments can be used (Quinn, 2000) [how].

There is a similarity between our conceptual framework and the classification of literature proposed by Hätönen and Eriksson (Hätönen and Eriksson, 2009) with the primary difference that our framework is to be applied for analysis of an outsourcing program while Hätönen and Eriksson's classification tries (among other results) to categorize the subjects of the published articles in the general field of outsourcing. Furthermore, one of our contribution is to highlight that the interactions of the factors in different dimensions (questions) are extremely critical in the analysis of an outsourcing program. Hence, these dimensions should be analyzed (questions should be answered) in accordance with each other. Each of these four dimentions can be characterized by different factors as is depicted in figure 1 (see also table 1 for the state of each of these factors in the Dreamliner program). The nature of these factors in each dimension and their interaction can identify the level of success of an outsourcing program. In our analysis section , we will show how these interactions resulted in delays and extra-costs in the Dreamliner's oursourcing program.

We chose the factors in each outsourcing dimension (figure 1) based on the existing results in the literature[2] and the observations in our case. In fact, each case has its own influential factors with different levels of importance. What we want to emphasize in this framework is that, in any outsourcing program, we need to look at the four outsourcing dimensions and characterize the influential factors of each dimension in that specific case. Then, the interaction of all these factors should be considered and analyzed to get a complete picture of the performance of the outsourcing program. As we will show in our case, considering only a limited number of factors could be misleading.

[2] See for example the references mentioned in this section. Monroy and Vilana Art (2010) enumerates ten outsourcing success factors.

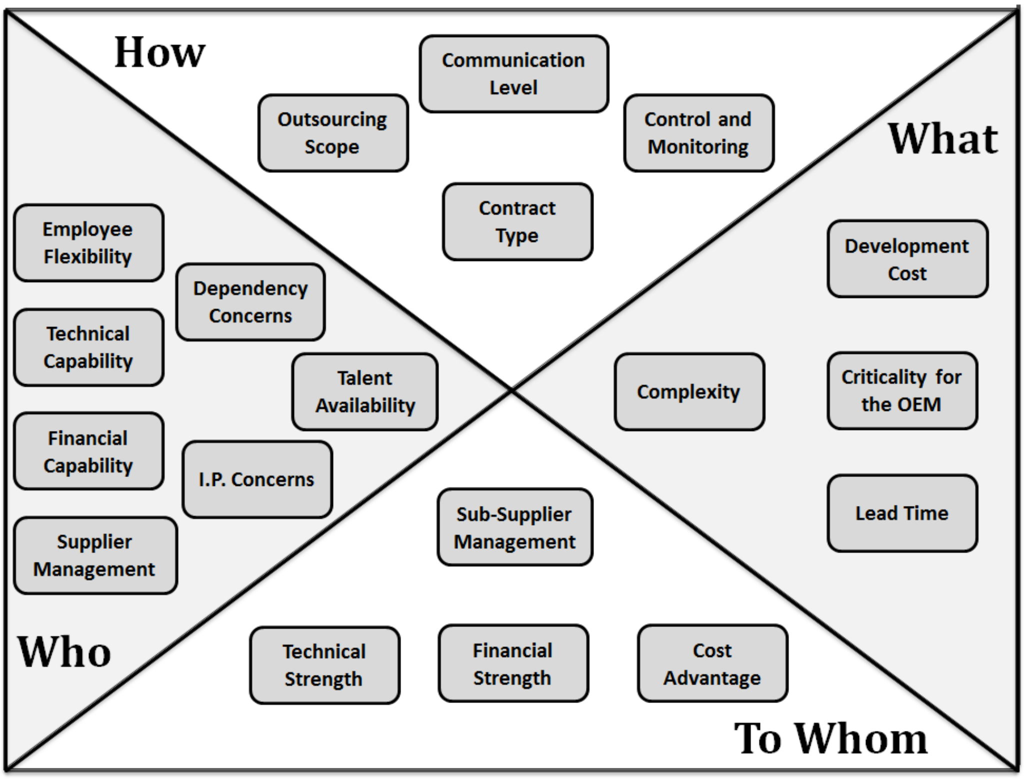

Figure 1 – Four outsourcing dimensions and their typical associated factors

3. Methodology

In this research we performed an in-depth study of theoretical results in the literature (focused on outsourcing of R&D and NPD). Based on this study we proposed our conceptual framework. We also carried out a case study to show how our framework can be applied in practice. For our case study, we used two sources of data/information: qualitative interviews and published materials. Specifically, we conducted semi-structured interviews with industry experts and analysts as well as Boeing's union representatives. In parallel, we carefully compiled and analyzed all publicly available data/information including published news, comments, analyses in media and the company website. Over time, we could gather sufficient information from interviewees and publicly available materials by realizing saturation in new information. Through the gathered information and our conceptual framework, we tried to analyze the root causes of this costly and well publicized delay and its impacts. Our analysis is based on the related events which have happened by the end of October 2011.

Despite repeated attempts, probably due to extensive delays and escalation of public criticisms, none of the key decision makers at Boeing and at the first-tier suppliers were willing to be interviewed. This can be viewed as one of the main sources of data limitation in our case study.

There have been many news reports and company media releases since the program was first announced in 2003, some supported and some criticized the many controversial issues that surrounded the program. To the best of our knowledge, there has not been any publication which has a comprehensive and analytical look at the delayed program to date. This article could be a first attempt at such a comprehensive and analytical look.

4. Case Background

In this section we provide background information on the Boeing Company, its products, the Dreamliner design, and the Dreamliner program. This background information, which is presented according to our conceptual framework, provides the context for our analyses which proceed.

4.1. Who: Boeing, an Extraordinary Company

The Boeing Company is one of the nation's largest exporters by value (Reed, 2009). It was founded in 1916 and it is the world's largest and most diversified aerospace company as of 2010. Boeing designs, manufactures, and supports commercial jetliners, defense systems, satellites, and launch vehicles. At the end of 2009, with customers in 90 countries, $34.1 billion of the company's sales was from the commercial airplane division, contributing to approximately 50% of Boeing's annual revenue[3].

4.2. What: Dreamliner, an Extraordinary Design

The Boeing 787 is a mid-sized, wide body, twin engine commercial jet airliner. At the time of launch, the Dreamliner was rated as the most efficient commercial airplane ever made by Boeing

3 http://www.boeing.com/companyoffices/aboutus/brief.html

and would be 20% more fuel efficient than similar sized airplanes[4]. The change from the traditional hydraulic systems to electrical architecture, higher usage of composite materials (derivatives of carbon fiber), use of advanced technologies for a better in-flight experience, and reduced airplane maintenance costs were some of the very notable features of this plane (Hale, 2006).

The usage of composite materials in the Dreamliner's structure was not Boeing's first experience with these exotic materials. The company owns a facility dedicated to this purpose called Composite Manufacturing Center. What differentiated the Dreamliner's design from Boeing's other models such as B707 and B777, was the extent to which these materials were used. The extensive use of composite materials makes the Dreamliner 30,000 to 40,000 pounds lighter than similar aircrafts. It also let Boeing design the structure of the plane from very few large body parts (sections) which could reduce the assembly time and use much fewer fasteners.

4.3. How: Dreamliner Development Program

Boeing not only introduced a revolutionary product, but also revolutionized the way it developed the new airplane. The company decided to outsource the manufacturing of the airplane more extensively. Boeing also outsourced, for the first time, the design, engineering, and integration of the majority of airplane parts including different sections of the fuselage, the horizontal tail, and the wings. Although Boeing had the proper capability and expertise within its own engineering team, the company offloaded the design and engineering phase to suppliers, while limiting its role mainly to the provider of the general design and the assembler of the sections delivered by the suppliers. More than 90% of engineering, manufacturing and the integration of the Dreamliner were outsourced to outside suppliers[5]. The vertical fin remained the only major part which was designed and manufactured directly by Boeing.

Boeing named its major suppliers the G*lobal Supply Partners* (GSP) since participation of a supplier necessitates investing its own funds and resources to perform the engineering

4 http://www.boeing.com/commercial/787family/programfacts.html

5 Boeing originally outsourced more than 70% of the design and manufacturing of the Dreamliner to suppliers. Later on, the company sold of its Wichita and Tulsa plants, increasing outsourcing, according to industry experts, to more than 90%.

development and integration. These major supply partners were also called *risk sharing partners* since they agreed to receive part of the revenue of selling each airplane as their payment (Drew, 2009a). So, they accepted to share Boeing's risk in success or failure of the program.

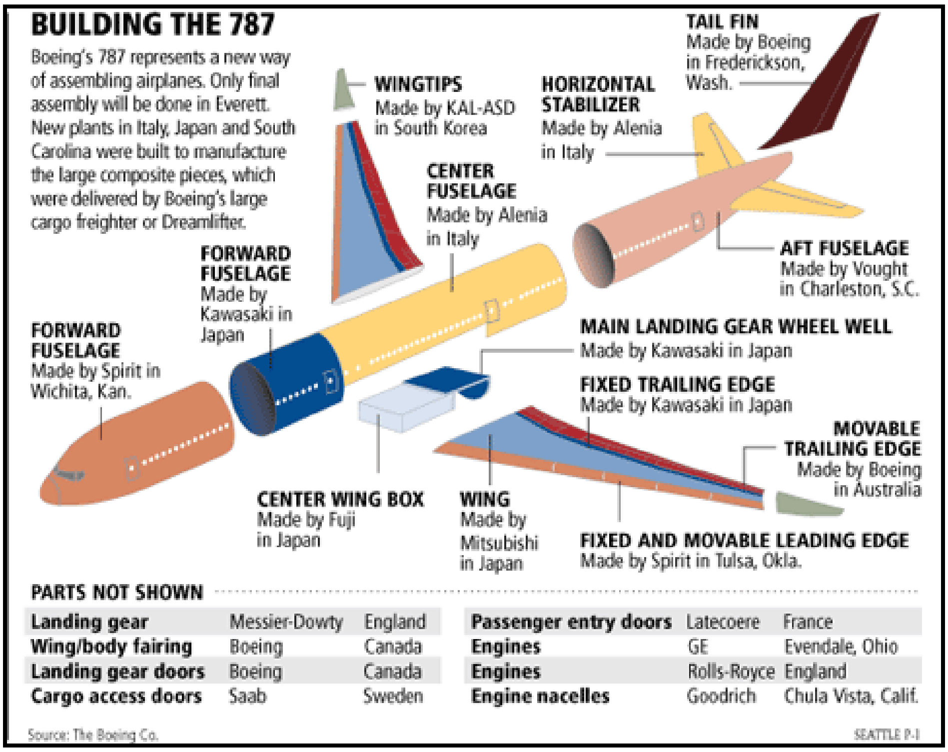

Figure 2: Outsourced parts of the Dreamliner and their suppliers
Source: Seattle Post-Intelligencer

4.4. To Whom: First-Tier Suppliers

The major partners chosen by Boeing were Spirit AeroSystems (USA), Alenia Aeronautica (Italy), Kawasaki Heavy Industries (Japan), Vought Aircraft Industries (USA), Fuji Heavy Industries (Japan), and Mitsubishi Heavy Industries (Japan) (Lott, 2010). Figure 2 shows the sections outsourced to each supplier.

4.5. What Happened

By convincing suppliers to invest their own funds and resources, Boeing managed to cut the development costs to around 55% of the originally estimated $10 billion budget for the program (Lunsford and Micheals, 2004). As a result, the GSP model was received very well by the industry experts, analysts, and even investors. As such, Steven Schaffer, vice president and general manager of the GSP at Boeing Commercial Airplanes, was named the supply chain manager of the year (2007) by the Purchasing Magazine. All in all, everyone seemed to be excited about the brilliance of the program design.

The events that followed this initial hype, however, proved that neither the outsourcing model nor its implementation was free of major flaws. Starting in 2007, Boeing faced a series of problems in its Dreamliner program, which led to a series of delay announcements. Figure 3 shows the timeline of these delays and the announced reasons.

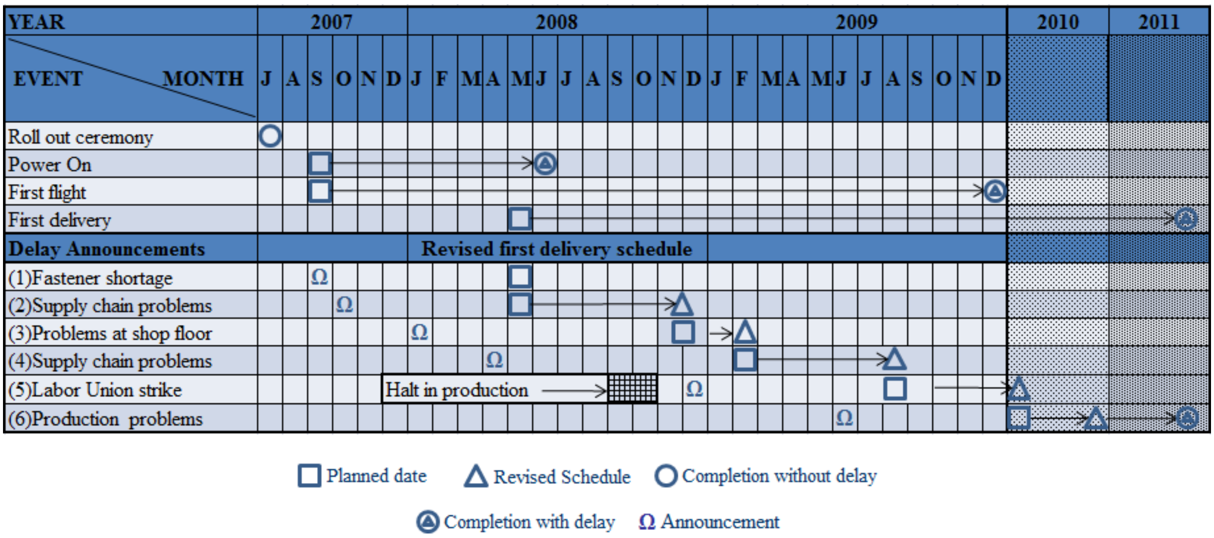

Figure 3: Dreamliner program timeline

Boeing managed to display the first assembled Dreamliner in its roll out ceremony, as it was scheduled, in July 2007. Boeing insisted on having the roll out on July 8th 2007 since the digits of this date symbolize the airplane name (07/08/07⇔787). The B787 which was displayed to the public in this ceremony was not as complete as it looked. Most of the parts delivered to Boeing's assembly facility were incomplete. Engineers and technicians at Boeing had to use temporary fasteners to pull the parts together for the show. In fact, Boeing rushed the suppliers to deliver the parts even if they were not complete so that it could keep its promise for the symbolic roll out date. After another 5 delay announcements, finally, the first Dreamliner took off the ground in December 2009.

The impact of these delays, which were accompanied by huge extra costs, had many tangible and intangible impacts on Boeing. As an example, we can look at the possible impact of this program on the Boeing's stock performance. Figure 4 shows Boeing's stock performance compared with its industry average (Aerospace and Defense) from 2004, when the program was launched, till fall 2010 (both Boeing's stock price and the industry average are normalized to an index of 100 at the beginning of 2004).

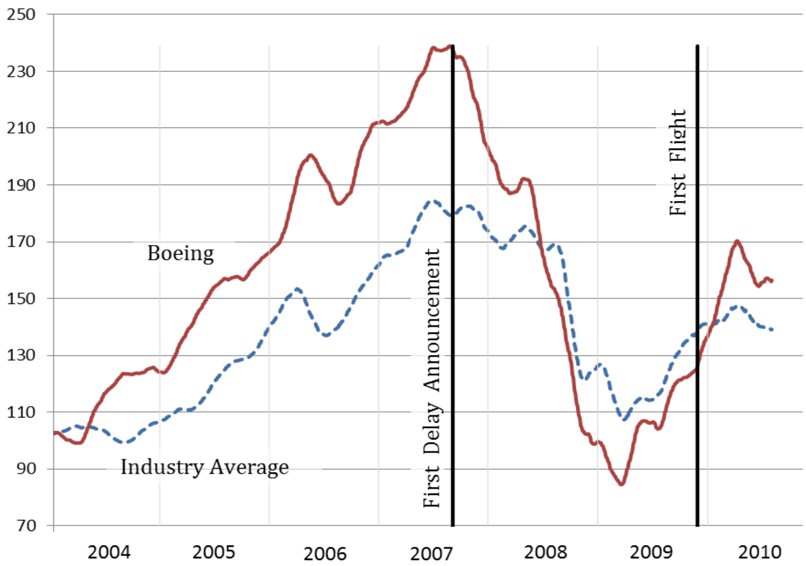

Figure 4: Being's stock performance compared with the Aerospace/Defense industry average

Boeing's stock increasingly performed better than the industry average since the launch of the program till the roll out date. This was the period of time when the program was mostly praised and received a record number of orders. The superiority of Boeing's stock started to decline after the first delay announcement. This decline continued and in mid 2008 Boeing's stock started to actually perform weaker than that of the industry average until late 2009 when the maiden flight (first take-off) happened and Boeing's stock managed to gain part of its old strength. Although Boeing's stock price might have been affected by internal factors other than the Dreamliner program, Figure 4 shows that there is a strong correlation between the success and failure of this program and Boeing's stock price.

5. Observations

In this section we introduce highlights of Boeing's challenges in B787 development program and company's responses to them. For brevity's sake, we do not discuss all the documented problems.

5.1. Fasteners problems

One of the first supply chain problems that surfaced in this program was a shortage of fasteners. In 2007, there was a general shortage of fastener production capacity in the industry (Glader and Lunsford, 2007). This problem was even worse for the Dreamliner program. The new composite design needed about 80% fewer fasteners. In addition, the airplane was in the development phase. So, the orders were for very few numbers of airplanes. The relatively small volume of fastener orders from the Dreamliner program did not stir an enthusiastic response from the suppliers who preferred to exploit their limited capacity in larger orders. Hence, it was natural for the fastener manufacturers to give lower priorities to smaller orders. This situation posed serious threats to the Dreamliner program (Wallace, 2007).

Following the fastener delay, Boeing and Alcoa planned to develop ways to speed up production. Alcoa's plan was to add up to its existing capacity at Mexico and Hungary and also to open up a new plant in China (Ostrower, 2009). However, the problems with fasteners continued to haunt the Dreamliner program. On a second occasion, the delay was caused by improper installation of the fasteners. Due to unclear specifications of how to install these fasteners, close to 3% of the fasteners installed had to be removed and reinstalled. In response, Boeing emphasized that they would improve their quality management systems and the training of workforce on fastener installation (Gates, 2008a).

5.2. Travelled work

Suppliers, who could not complete their parts according to the specified requirements, passed on incomplete or substandard sections of the airplane to Boeing's final assembly facility at Everett, WA. Workers at Everett had to incorporate additional effort to finish the incomplete work. They named this type of extra work "travelled work." This was compounded by the problem of mechanics at Everett having to encounter parts for assemblies sometimes without proper paper work or even assembly instructions in another language which required translation (Lunsford, 2007).

Boeing had to include travelled work into its already tight production schedule, which resulted in further delays. For example, flaws in manufacturing of the mid fuselage structures by Alenia Aeronautica, the Italian supplier, made Boeing to issue a "stop work" order to the supplier. Boeing realized the problem after Alenia had manufactured 23 mid fuselage sections. To fix the problem, Boeing had to apply patches to the defective areas (Drew, 2009b).

5.3. Problematic sub-suppliers

In GSP model, Boeing for the first time outsourced the sub-systems to its supply partners, and these partners in turn outsourced different tasks of their contracts to sub-suppliers. The subsequent events showed that Boeing was not ready to deal with this more complicated supply chain, nor these sub-suppliers were all able to meet Boeing's high standards.

For instance, Vought Aircraft Industries, a supply chain partner in charge of building the rear fuselage of the Dreamliner, offloaded the production of floor grids to IAI (Israel Aircraft Industries). However, IAI failed to deliver the integrated floor grid of the first Dreamliner on time. Under pressures from Boeing, Vought shipped the first rear fuselage to Everett which had only 16% of its structure completed and none of the systems installed. To solve the problem, IAI was directed to supply unassembled floor grid pieces and as such, after about one year, the fuselages from the Vought plant were 98% complete by structure and had 87% of the systems installed, before being delivered to Everett for final assembly (Gates, 2008b).

Another instance rose when Boeing outsourced the Brake Control Monitoring System (BCMS) to General Electric (GE), who in turn subcontracted the design of the software to Crane Co. The delivered software caused serious feedback problems at Everett due to the improper test and verification of the software by HCL, an Indian subcontractor of Crane. Crane accepted the responsibility and spent many times its initial budget to rework the job. After the problem was resolved by Crane, Boeing realized that the temperature generated in the brakes was higher than expected during the taxi testing of the first Dreamliner. They needed to redesign the BCMS; requiring an additional investment by Crane. This time, however, Crane was not willing to pour more money into this project. In a legal battle, Boeing was directed to pay $18.9 million for the redesign cost. It was then decided that Boeing would work directly with Crane rather than with GE as intermediary (Ostrower, 2009).

5.4. Delays and Shortage of Financial Resources

The supply partners in GSP model were expected to have the financial strength to afford the development cost and to wait for the Dreamliner deliveries before they receive their compensation. The extensive delays, however, exhausted the financial abilities of some of the supply partners to support the reworks and extra costs of the program. Entering a period of global economic downturn added to the problems of financially troubled suppliers. On the other hand, Boeing, who had time constrained obligations to its customers, was pushing the supply partners to increase their investment in the program to expedite the production. This was, of course, beyond the means of some of the supply partners.

For example, Vought and Global Aeronautica[6] built two facilities in Charleston, South Carolina, dedicated to Dreamliner program. To resolve the supply chain problems and increase the production capacity, these facilities needed additional investments. However, Vought and Global Aeronautica, who had already invested heavily in the program and did not receive any income due to the extended delays, were hesitant to pour more money into these facilities. Therefore, Boeing was left with no choice but to buy the facilities[7].

5.5. Labor union strike

A 58-day strike by 27,000 Boeing workers caused further delays in the already delayed Dreamliner program. One of the major issues in this dispute (the second time in three years) was the employees' concern about their job security, which had been intensified by the extensive outsourcing in the Dreamliner program. While Boeing's employees felt that they were losing their jobs to outside suppliers, at the same time, they were asked to use their considerable experience and expertise to fix all the unfinished works which the inexperienced suppliers failed to complete (travelled work).

The strike, which was the longest in 13 years, cost Boeing $100 million per day in deferred revenue. The strike ended when the machinist union secured a four year contract in which Boeing offered a 15% pay rise over the four year period of the contract. Boeing included this extra pay as an incentive in the contract to gain flexibility and prevent further obstruction by the workers to its future outsourcing plans (Lunsford, 2008).

After the two month strike, Boeing decided to open a second assembly line in South Carolina to ramp up production for its delayed Dreamliner program. The company decided to open the

[6] Global Aeronautica was a 50%-50% joint venture between Alenia Aeronautica and Vought Aircraft Industries.

[7] Dominic Gates, interview with authors, Jun.4, 2010.

new facility to isolate the program from potential disruptions by its unionized workforce in Washington State. The South Carolina plant had the advantages of no labor union problem, relatively lower labor cost, and being closer to the two other Dreamliner production facilities (which originally belonged to Vought and Global Aeronautica). In this way, Boeing wanted to ensure Dreamliner production remains continuous without any labor disruption to meet the production goal of manufacturing 10 airplanes per month by the end of 2013 (Ostrower, 2010).

6. Analysis

Many interconnected factors played influential roles in turning the Dreamliner outsourcing program into an operational and financial nightmare. Using our conceptual framework, we try to show how the interaction of these factors led to the delays and extra costs. Table 1 shows the influential factors for each of the four dimensions of outsourcing, as well as the status of associated factors in the Dreamliner program.

Who	
Technical Capability	Very strong, possibly stronger than all other suppliers (except in a few subsystems which have always been outsourced such as engines, avionics …)
Financial Capability	Very strong, Boeing managed to pay an estimated $30 billion of extra costs during almost three years of delays
Supplier Management	Boeing was experienced in outsourcing the manufacturing but novice in outsourcing the detailed design of the airplane sections
Talent Availability	Boeing owned one of the largest and richest collection of experienced engineers and technicians in this industry
IP Concerns	Since Boeing intended to play to role of a system integrator, it was not very strict about keeping in-house its know-how of airplane detailed design
Dependency Concerns	Through its revenue sharing contracts, Boeing was not very concerned about its dependency on supply partners
Employee Flexibility	Boeing’s workforce was strongly unionized. Boeing intended to create more flexibility

What	
Complexity	Extremely complex product
Criticality for the OEM	What is outsourced was very critical
Development Cost	Very high initial investment was required
Lead Time	Usually very long for this type of product
To Whom	
Technical strength	Evidence suggests that some of the suppliers where not up to the task
Financial strength	Supply partners were financially strong to make the initial investment as long as the program was not delayed
Sub-Supplier Management	Problems with sub-suppliers shows that some of the supply partners were not particularly good at managing sub-suppliers
Cost advantage	Suppliers were NOT located in cheap labor or talent locations
How	
Outsourcing scope	Extensive outsourcing of design and manufacturing
Contract type	Revenue sharing
Communication level	The communication level was less than needed for the outsourcing of NPD of an extremely complex product
Control and Monitoring	Less than enough control and monitoring

Table 1 – The status of influential factors of four elements of outsourcing in the Dreamliner program

The GSP model can perfectly be justified by certain combination of the factors mentioned in table 1. However, we will show in this section, how the interaction of other factors can, and did, result in delays and extra costs. The combination of the following four factors could have persuaded Boeing to follow GSP model.

1. The very high initial cost of development program,
2. Boeing’s desire to reduce the risk of initial investment,
3. Boeing’s desire to play the role of a system integrator, with greater employee flexibility,
4. The availability of supply partners with reasonable technical capability and resources, who are willing to invest their own funds in the development of the program and wait for a share of revenue as their compensation.

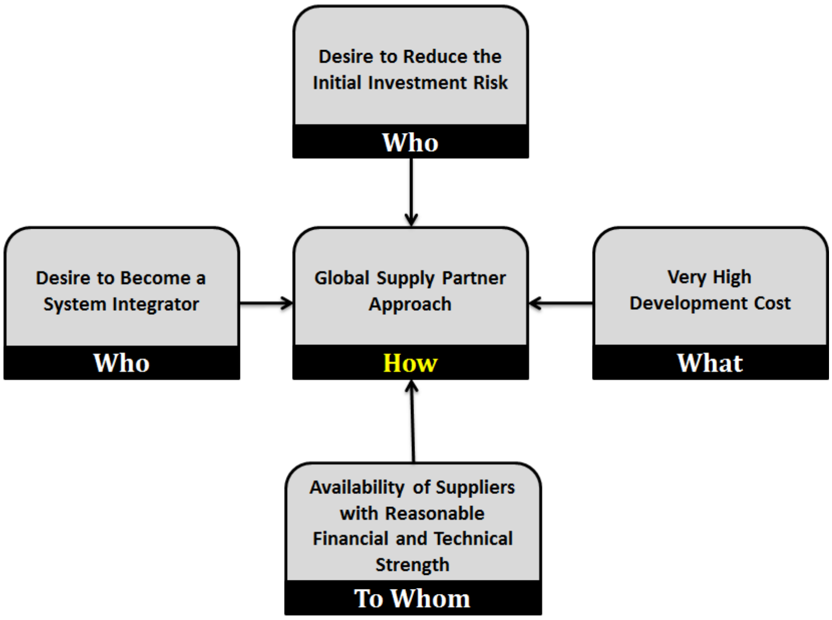

Figure 5 - Factors which persuaded Boeing to follow the GSP model

Figure 5 shows how these factors are related to four outsourcing dimensions. The combination of these four factors makes the GSP model almost the best model for the development and production of the Dreamliner. However, there are other factors which should be considered before we can have a holistic view of the outsourcing program. Below, we try to identify main factors whose interactions caused serious problems for the program. We look at these factors from two perspectives

- Core competency point of view
- Delay/extra-cost point of view

6.1. Core Competency Point of View

The old debate about what processes should be outsourced and what should be kept in-house applies to Boeing too. However, it is not always easy to identify the core competency processes which should be kept in-house. The approach chosen by Boeing suggests that the company considered its main core competency to be its ability to manage the development program as a system integrator. However, the case evidence shows that Boeing was not very accurate in evaluating its core competency.

Historically, Boeing has shown great ability in managing mega-projects of developing new airplanes. In the Dreamliner program, Boeing kept this project management role, as well as the assembly of the final product, in-house and outsourced pretty much everything else. The Dreamliner development project, however, was not similar to the projects that Boeing had previously experienced. There were many features of the Dreamliner program which made it quite distinct from its predecessors: (a) the supply chain structure was multilayered and more complex, (b) suppliers were responsible for the integrations of the major sections of the airplane, (c) and above all, the detailed design of the airplane sections was done by the suppliers. Many of the supply chain problems which delayed the program were clear evidence that Boeing was not specifically experienced in managing such a project, which means the project management in this program could hardly be Boeing's core competency.

Prahalad and Hamel (1990), in their seminal paper, argue that "core competencies are the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies." The real core competency of Boeing, which resulted in its successful introduction of many different airplane models in the past, seems to be Boeing's know-how to perform all the detailed design, engineering, and assembly of all the parts with partial outsourcing of manufacturing process. Boeing's another core competency is its ability to absorb all the learning which happens when the detailed design and engineering are done internally.

Granstrand et al (1999) argue that companies should try to create a portfolio of competencies to remain competitive. However, they emphasize, building a new competency should not result in the destruction or weakening of other "distinctive" or "core" technological competencies. Boeing's attempt to create a core competency in system integration could come with the cost of weakening its real core competencies as we discussed above. This weakening in core competencies, in turn, could result in the following negative impacts. See also figure 6.

Intellectual Property Concerns

Boeing, due to outsourcing detailed design, had to share with suppliers some of the unique design knowledge and techniques which had been accumulated at Boeing through designing and developing airplanes for almost a century. For example, a proprietary manual, "How to Build a Commercial Airplane", which was developed by Boeing engineers for over five decades, was shared in large part with Tier-1 suppliers developing the Dreamliner (Nolan, 2009).

Dependency Concerns

Boeing limited its access to the detailed design of subsystems, under GSP model. Since the suppliers spent their own funds to design and develop the sections, they naturally retain details of these designs as their own property.

> "That means Boeing will have to depend on suppliers for any changes or modifications in future, for the parts that will go onto the 787. Boeing has no idea what went into the design, because they don't own the design. It is on their (suppliers') computers, the design principles and the calculations are all with them (suppliers) and they own it legally and intellectually,"

explains Stan Sorscher[8].

Future troubleshooting could also be a more complicated task, especially if the problem involves two or more sections developed by different suppliers. As an example, in July 2009 Boeing announced that the joint between the center wing box and the wing faced a stress related problem. Mitsubishi Heavy Industries had developed the wing and Fuji Heavy Industries had developed the center wing box and Boeing had developed the interface. Since neither of the suppliers owned the interface and nor did Boeing have access to the design of the parts, Boeing had to re-test the already completed Dreamliner and bear the cost of over runs (Gates, 2009). Similar problems might happen if Boeing wants to make any modification or extend the features of the airplane.

Transferring the learning process

The ownership of the design and manufacturing of high value-added parts and processes can be considered as the source of core competency for a company. Aerospace industry, and in particular commercial aviation, has a very steep *learning curve* due to the extreme complexity of the products. That is, the first airplane of a new model costs many times more than the tenth airplane, for instance, since the processes can be improved dramatically by learning how to do things properly. By outsourcing the engineering, manufacturing, and integration of the major sections of the Dreamliner to outside suppliers, Boeing let this learning process, and the corresponding high value-added functions, transfer to those suppliers.

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[8] Stan Sorscher, interview with authors, July 26, 2010.

Weaker future innovation capability

The ability to innovate products depends on the ability to innovate the related processes. In other words, when a company deals with the manufacturing processes of a product, the ability to innovate related new processes lies within that company. These new processes, in turn, could enable the company to manufacture the next generation of that product (Pisano and Shih, 2009). A good example could be Boeing's ability to introduce the Dreamliner as a composite airplane. This could be due to Boeing's past experience with the composite materials. Thus, when Boeing outsourced almost all the detailed design and manufacturing of the airplane structure to outside suppliers, the ability of future innovations in making airframe structures from composite materials was also transferred to these suppliers. This can limit Boeing's competitiveness in introducing future generations of composite airplanes.

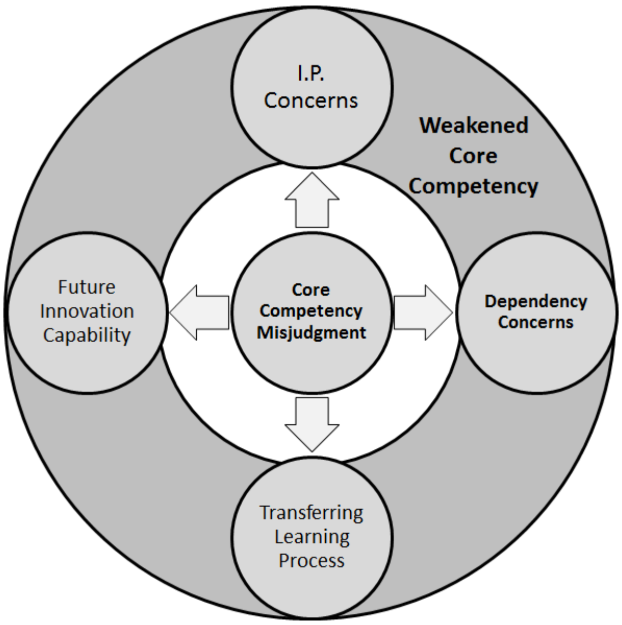

Figure 6 - Factors which could result in weakened future competitiveness

6.2. Delay/Extra-Cost Point of View

There are several factors whose interactions in the Dreamliner program resulted in the extensive delay and huge extra costs. Figure 7 shows the interaction of the main factors in the four outsourcing dimensions. Blow, we briefly explain these interactions.

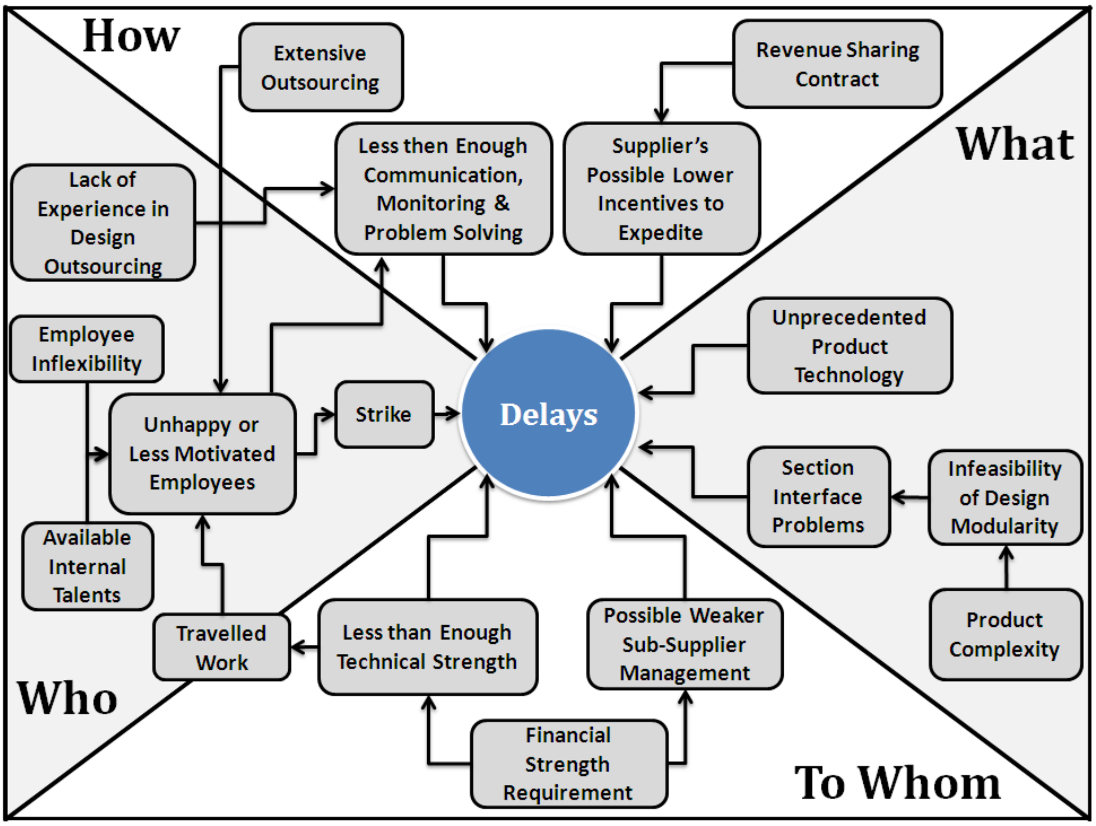

Figure 7 – How the interaction of different outsourcing element can be problematic

Less Than Enough Monitoring and Communication

Although Boeing had enough experience in how to outsource manufacturing, it was relatively inexperienced in outsourcing detailed design. After decades of designing airplanes, Boeing had developed practices which were keys in turning it into a successful airplane designer and developer. Boeing was so used to knowing and implementing these practices that it failed to understand that these are not common knowledge among its supply partners. As Lynn Lunsford[9] metaphorically puts it, these practices have become part of Boeing's DNA. For instance, it has been a common practice in Boeing that all parts of detailed design are reviewed by a *Designated Engineering Reviewer* (DER) to guarantee the consistency of different parts of the detailed design. Boeing did not articulate this practice to its suppliers and it was surprising for Boeing that some of the suppliers had failed to have their designs approved by a DER. Since Boeing

[9] Lynn J Lunsford, interview with authors, July 15, 2010.

expected its supply partners to perform this task, many of Boeing's DER had already been either retired or laid off[10]. So, Boeing was not able to address the problem very quickly.

Boeing's lack of experience in outsourcing design resulted in an insufficient level of monitoring and communication with supply partners. Outsourcing the design of an extremely complicated product to multiple parties needs a whole new level of monitoring and communication which is not comparable to what Boeing used to have. Furthermore, the product design was also unprecedented due to new materials and technologies, which brought along its own surprises to the project. This was another source of uncertainty which necessitates a more rigorous control and monitoring mechanism for the project. This fact was reminded to Boeing by a senior advisory group which consists of retired Boeing's managers whom the company invited back in 2010 to analyze Boeing's challenges. This is how Joseph Sutter[11], the unofficial leader of the advisory group, addresses the problem of improper monitoring and communication with suppliers in the Dreamliner program:

> "You better damn well have a high percentage of Boeing guys there (at supplier locations) looking over their shoulders" (Sanders, 2010).

Human Resource Related factors

The successful development of an airplane depends heavily on having experienced and skillful workers, technicians, and engineers especially in an industry whose learning curve is very steep. So, it is not just a good design which leads to a successful product, it is also the learning process which happens throughout the development program. This learning process is feasible when the technical teams possess the proper skills and understand this culture.

Being in this business for almost a century, Boeing has nurtured generations of skillful employees, who developed and manufactured many successful airplane models. Boeing's workforce and the accumulated knowledge which resides with them seem to be the company's real core competency.

[10]Lynn J Lunsford, interview with authors, July 15, 2010.

[11] Joseph Sutter is the most renowned living veteran of Boeing and is considered as a legendary figure in the aerospace world. He was the head of the design team of the world's first Jumbo-Jet, B747.

Boeing workforce proved their competency again, in the Dreamliner program, by fixing all the unfinished travelled work which suppliers failed to complete during the early stages of the program. As another piece of evidence, among the very few sections of the Dreamliner which was delivered, relatively, on time and on budget was the vertical fin which was designed and manufactured by Boeing's employees.

In the Dreamliner program, however, Boeing weakened the role of its experienced employees by relying mostly on its global supply partners. This approach not only put this valuable resource on the side, but also created a sense of job insecurity among the employees; one of the major concerns in the machinists strike in 2008.

> "One of the biggest issues of the strike was the continued outsourcing of the company and it remains an issue that it is our work (which is going out to suppliers),"

says Connie Kelliher[12], IAM[13] spokesperson.

Problem Solving

In many of the reported supply chain delays, it seems that the problems surfaced at a very late stage, when it was very difficult to deal with them. The fastener shortages as well as the defects in the mid fuselage are both examples of the problems which could have been detected and resolved much sooner. However, they surfaced when there were no other choices but to delay the program and spend a lot more money than it was really needed. The reason could be either lack of a proper monitoring system, or lack of a proper problem solving culture which reacts to the signals of trouble in a timely manner. In our studies we found evidence showing that there has not been a close relationship between the top management and the body of the company. The most obvious evidence could be two labor union strikes in three years (in 2005 and in 2008).

Lack of trust and/or a good relationship between top management and the body of the company could be a barrier that prevents a smooth and timely flow of information from those who can detect the problems to those who can make the decisions to resolve the problems.

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[12] Connie Kelliher, interview with authors, July 19, 2010.

[13] IAM District 751 is the International Association for Machinists and Aerospace workers of Washington State District representing active and retired aerospace workers at Boeing Industries in Washington State.

Another reason for poor problem solving could be lack of a mechanism which encourages the supply partner to share, as soon as possible, any trouble which could cause a delay. In such situations, the suppliers usually tend to postpone the sharing of the unpleasant news.

> "Many of the delays on the 787 program have come strictly because suppliers, who were supposed to raise their hands for help, were reluctant to do so. They had to deal with their egos and legal reasons,"

says Lynn Lunsford[14].

Suboptimal supplier selection

In the GSP model, only those suppliers could participate who had the financial capability of investing their money up front in the program and willing to wait until Boeing sells the airplane before they receive any payment. This was a strong and limiting prerequisite. Therefore, the technical capability of suppliers received secondary priority. This could potentially result in suboptimal selection of suppliers from a product development point of view, which is supported by the existence of a few very problematic supply partners in this program.

Supply Partners' Incentives

One inherent problem within this supply chain model is that when the program starts to deviate from its schedule, it can deteriorate the participants' incentives in doing their best. Assume a scenario in which the program is delayed because of problems at one supplier. Now if another supplier spends a lot of resources to deliver on time, it will not gain anything. In fact, in this case, it would be in supplier's best interest to spend as little as possible and be just slightly better than the worst supplier, who would endure all the blames and bad publicities. If every supplier knows the progress of all other suppliers, in a "perfect information" situation, this behavior would not hurt the program. However, due to suppliers' imperfect information, each one of them decides about its effort level based on guessing the progress level of the others. This behavior can seriously hurt the program. Not all suppliers necessarily behave in this way, however, the general setup works against suppliers' incentive to do their best. What intensified this problem in

[14] Lynn J Lunsford, interview with authors, July 15, 2010.

the Dreamliner program was that the supply partners owned the design of the outsourced section. So, they had strong bargaining powers and could not be replaced easily.

Hidden Costs

> "Back in 2003, the odds were against the program … As a result, the only way you get this thing (the Dreamliner program) going is if you promise to limit the development costs to a tiny fraction of what they should have been. The only way to do that was to develop an extremely unrealistic supplier model,"

says Richard Aboulafia[15].

In 2003, Allan Mullaly (then CEO of Boeing Commercial Airplanes) managed to get the project through, against some opposition from the Board of Directors. To do so, Mullaly had to reduce the financial risk of the project by reducing the required upfront investment and spreading the risk among various supply chain partners. What the company overlooked was the fact that the new GSP model devised a much more complicated supply chain and engaged the company in a program with little previous experience. This meant the program had to endure a much higher level of operational risks. That is, the new GSP model had considerable expected *hidden cost*. The history of the program suggests that Boeing underestimated the operational risks in the program schedule and resources. On the other hand, the operational risks and financial risks are not independent of each other. When the company faced all the realized operational risks, they brought back all the financial risks along with them and all the expected hidden costs surfaced.

6.3. Consequences

The interaction of the abovementioned factors resulted in Boeing's longest delayed program with the total investment mounting to almost 3 times the initial expected budget (Gates, 2011). The delays resulted in (a) poor stock performance (see figure 4), (b) deferred revenue, (c) penalty payments to customers for late delivery, (d) unscheduled (direct or indirect) payments to suppliers who delivered their sections on time (e) order cancellations, and (f) a drop in Boeing's credit worthiness by credit rating agencies (Siew, 2009). These delays, on the other hand, caused the program to enter a period of national and global economic downturn, which in turn became a

[15] Richard Aboulafia, interview with authors, June 22, 2010.

problem for suppliers who invested heavily in the program and did not receive any payments. Therefore, the suppliers' financial problems become another source of trouble for the supply chain. See figure 8.

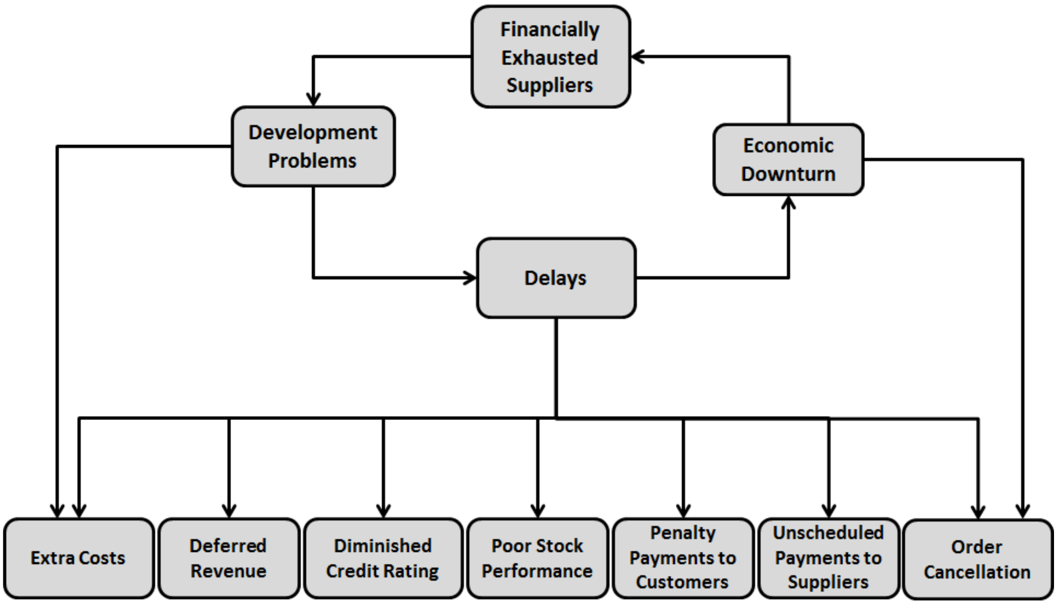

Figure 8 – The consequences of the development problems and delays

Observing these consequences, Boeing might revise its GSP model for its future programs.

> "We outsourced too much. ... We didn't consider the extent of the risk we'd take on by going outside," said Jim Albaugh, CEO-Boeing Commercial Airplanes (Gates, 2010). "We will make sure the voice of the engineers is much more involved in the decision making as we go forward."

7. Conclusion and Insights

One can hardly find a major development program in aerospace industry which has been delivered in time or on budget. Due to extreme complexity of the products and very high standards of this industry, each development program has its own surprises. The extended delay and huge extra costs of Dreamliner program, however, was unprecedented in the history of Boeing. As we discussed, the interactions of many different factors resulted in these delays and extra-costs.

We first highlighted that the new outsourcing model can be fairly justified by looking at factors such as high initial development costs and the tendency to reduce the initial investment risk. However, after mapping all major factors, we analyzed the root causes of delays and extra costs within a network of interconnected factors.

Our conceptual framework is built upon the existing outsourcing literature which mostly focuses on the impact of different factors on the outsourcing performance in a relatively isolated way. Our framework, instead of focusing on limited number of factors, tries to focus on the interaction of all influential factors in four dimensions of outsourcing (Who, to Whom, What, How). In spite of its simplicity, this conceptual framework is sufficiently comprehensive to analyze complex outsourcing programs.

Although this case study focuses on the outsourcing of the detailed design and engineering of a commercial airplane, the insights can be applicable to a wider range of outsourcing situations which have similar characteristics. In fact, the following managerial insights can be concluded from this case study.

1- *Safeguard the real core competencies*: An accurate evaluation of company's core competencies is needed before an outsourcing strategy can be laid out. An outsourcing program should not threaten company's core competency. As we showed in this case, Boeing's decision to outsource almost all the detailed design and manufacturing weakened its core competency and resulted in extended delays and extra cost.

2- *Appreciate the value of in-house detailed design and manufacturing*: In an industry with a very steep learning curve, detailed design and manufacturing present precious core competencies that is worth maintaining. Companies who are really good at manufacturing tend to be good at innovation, whereas companies who outsource their manufacturing often find that innovation has followed (Plambeck and Taylor, 2005). Moreover, Outsourcing the detailed design can cause unexpected problems down the road with respect to intellectual property.

3- *Consider all the influential factors*: There are many factors which play influential roles in the success or failure of an outsourcing program. Therefore, an outsourcing decision should not be made based on only few selected factors which support a certain course of action. A Holistic consideration of these factors and their possible interactions is needed, in particular when dealing with an extremely complex product.

4- *Be mindful of changes*: Outsourcing of a complex product or service requires certain capabilities and processes in the outsourcing firm. A major change in what is being outsourced, therefore, might require different sets of competencies. Building competencies in outsourcing detailed design and becoming a system integrator is not a trivial task and need time and effort. Since core competencies are built through a process of continuous improvement and enhancement, it may take a decade or longer to build a new core competency (Prahalad and Hamel, 1990). The transition from fully in-house detailed design to fully outsourcing of detailed design needs time and special consideration. We believe some of the major challenges in this program might have been eased by

   a. making more gradual changes, i.e. outsource the detailed design of very limited number of sections to most capable and reliable suppliers, while performing the rest of the detailed design and engineering in-house,
   b. making much stronger preparation for addressing the potential challenges of implementing a new approach (GSP model) or technology (composite airframe), e.g. a much stronger control/coordination over the supplier partners,
   c. considering (more thoroughly) the potential surprises in the schedule and budget of the program.

5- *Consider the hidden cost of outsourcing*:
It often appears to be cheaper to outsource a process, and it usually ends up being more expensive. Although any outsourcing program brings certain benefits, there are associated hidden costs which inevitably come along with the benefits. These hidden costs can be viewed as the risks of outsourcing program. It is essential to try to identify and quantify the potential hidden costs, utilize ways to minimize them, and have some contingency plan. Based on the existing results in the outsourcing literature, exhibit 1 shows main factors which increase the expected hidden cost in an outsourcing program.

The expected hidden costs of an outsourcing program are increasing in these factors:

- Product complexity [what]
- Geographical distance [to whom]
- Cultural and legal differences [to whom]
- Cultural differences [to whom]
- Regulatory differences [to whom]
- Contract vagueness which could be due to [how]:
    - Lack of clear performance measure
    - Lack clear definition of project scope
- Difficulty or lack of monitoring [how]
- Lack of OEM’s experience in outsourcing what is to be outsourced [who]
- Lack of suppliers’ technical capabilities [to whom]
- Misalignment of suppliers’ incentives with OEM’s goals [how & to whom]
- Closeness of outsource function to OEM’s core competency (IP transfer) [who & what]
- Rate of evolution in what is outsourced (change in product features or processes) [what]

Exhibit 1 – Hidden cost factors

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References

Calantone, R.J., Stanko, M.A., 2007. Drivers of Outsourced Innovation: An Exploratory Study. Journal of Product Innovation Management 24 (3), 230–241.

Cousins, P.D., Spekman, R., 2003. Strategic supply and the management of inter-and intra-organisational relationships. Journal of Purchasing & Supply Management 9 (1), 19-29.

Drew, C., 2009a. A Dream Interrupted at Boeing. http://www.nytimes.com/2009/09/06/business/06boeing.html?pagewanted=1&_r=1 (accessed 2 February, 2010).

Drew, C., 2009b. Boeing Halts Production of Flawed Dreamliner Part. http://www.nytimes.com/2009/08/15/business/15boeing.html (accessed 18 January, 2010).

Dutton, B., 1992. US car companies: Changing fast enough. Manufacturing Systems 10 (1), 12-13.

Eppinger, S., Chitkara, A.R., 2006. The New Practice of Global Product Development. MIT Sloan Management Review 47 (4), 22-30.

Gates, D., 2007. 787 delay could wind up costing Boeing $1 billion. http://seattletimes.nwsource.com/html/boeingaerospace/2003973238_boeing25.html (accessed 30 December, 2009)

Gates, D., 2008a. Boeing finds problems with fasteners on 787 test planes. http://seattletimes.nwsource.com/html/businesstechnology/2008351743_boeing05.html (accessed 6 May, 2010).

Gates, D., 2008b. Boeing expertise speeding up 787 partners. http://seattletimes.nwsource.com/html/boeingaerospace/2004470059_charleston11.html (accessed 6 May, 2010).

Gates, D., 2009. Boeing 787 wing flaw extends inside plane. http://seattletimes.nwsource.com/html/boeingaerospace/2009565319_boeing30.html (accessed 11 February, 2010).

Gates, D., 2010. Albaugh: Boeing's 'first preference' is to build planes in Puget Sound region. http://seattletimes.nwsource.com/html/businesstechnology/2011228282_albaugh02.html (accessed 1 August, 2010).

Gates, D., 2011. Boeing celebrates 787 delivery as program's costs top $32 billion. http://seattletimes.nwsource.com/html/businesstechnology/2016310102_boeing25.html (accessed 1 November, 2011).

Glader, P., Lunsford, J.L., 2007. Boeing's Nuts-and-Bolts Problem: Shortage of fasteners tests ability to finish Dreamliners. Wall Street Journal, 19 June, A8.

Granstrand, O., Patel, P., Pavitt, K., 1997. Multi-Technology Corporations: Why They have Distributed Rather Than Distinctive Core Competencies. California Management Review 39 (4), 8-25.

Hale, J., 2006. Boeing 787 from the Ground Up. http://www.boeing.com/commercial/aeromagazine/articles/qtr_4_06/article_04_1.html (accessed 31 January, 2012).

Hätönen, J., Eriksson, T., 2009. 30+ years of research and practice of outsourcing -Exploring the past and anticipating the future. Journal of International Management 15 (2), 142-155.

Hui, P., Davis-Blake, A., Broschak, J.P., 2008. Managing Interdependence: The Effects of Outsourcing Structure on the Performance of Complex Projects. Decision Science 39 (1), 5-31.

Johansen, K., 2005. Collaborative Product Introduction Within Extended Enterprises. Dissertation No. 943. Linköping, Sweden: Linköping Studies in Science and Technology.

Kamath, R.R., Liker, J.K., 1994. A Second Look at Japanese Product Development. Harvard Business Review 72 (6), 154-170.

Langlois, R.N., 2003. The vanishing hand: the changing dynamics of industrial capitalism. Industrial and Corporate Change 12 (2), 351-385.

Lott, S., 2010. The dream becomes a reality. http://www.aero-mag.com/features/18/20103/269/ (accessed 6 May 2010).

Lunsford, J.L., 2007. Jet Blues: Boeing Scrambles to Repair Problems with New Plane; Layers of Outsourcing Slow 787 Production. Wall Street Journal, December 7, A1.

Lunsford, J.L., 2008. Outsourcing at Crux of Boeing Strike; As Job Security Emerges as Issue for Both Sides, Delays in 787 Dreamliner Become Union Rallying Point. Wall Street Journal, September 8, B1.

Lunsford, J.L., Micheals, D., 2004. A New Friction Puts Airbus, Boeing on Course for Fresh Trade Battle. Wall Street Journal, June 1, A1.

Magee, J.F., 1992. Strategic alliances: Overcoming barriers to success. Chief Executive, 81 (November), 56–60.

Mazaud, F., Lagasse, M., 2007. Vertical sub-contracting relationships strategy, the Airbus First-tier suppliers' coordination. Working paper: Groupement de Recherches Economiques et Sociales. (www.gres-so.org), 1-22.

McIvor, R., 2005. The Outsourcing Process, Strategies for Evaluation and Management. Cambridge University Press, New York.

McIvor, R., Humphreys, P., McKittrick, A., 2010. Integrating the critical success factor method into the business process outsourcing decision. Technology Analysis & Strategic Management 22 (3), 339-360.

Minahan, T., 1998. Platform teams pair with suppliers to drive Chrysler to better designs. Design News 53 (10), s3-s7.

Monroy, C.R., Vilana Art, J.R., 2010. Strategic positioning of global manufacturing virtual networks in the aeronautical industry. Technology Analysis & Strategic Management 22 (5), 631–647.

Munsch, K., 2004. Outsourcing design and innovation. Industrial Research Institute 47 (1), 27-30.

Nolan, D., 2009. Is Boeing's 787 Dreamliner a Triumph or a Folly? http://blogs.hbr.org/cs/2009/12/is_boeings_787_dreamliner_a_tr.html (accessed 6 May, 2010).

Ostrower, J., 2009. Paris Air Show: Realising the 787 dream. http://www.flightglobal.com/articles/2009/06/05/327485/paris-air-show-realising-the-787-dream.html (accessed 12 April, 2010).

Ostrower, J., 2010. Dreamliner production challenges lie ahead. http://www.flightglobal.com/articles/2010/01/05/336571/dreamliner-production-challenges-lie-ahead.html (accessed 13 June 2010).

Pisano, G.P., Shih, W.C., 2009. Restoring American Competitiveness. Harvard Business Review 87 (7), 2-14.

Plambeck, E.L., Taylor, T.A., 2005. Sell the plant? The Impact of Contract Manufacturing on Innovation, Capacity, and Profitability. Management Science 51 (1), 133-150.

Prahalad, C.K., Hamel, G., 1990. The Core Competence of the Corporation. Harvard Business Review 68 (3), 79-91

Quinn, J.B., 2000. Outsourcing innovation - The new engine of growth. Sloan management Review 41 (4), 13–28.

Roy, S., Sivakumar, K., 2011. Managing Intellectual Property in Global Outsourcing for Innovation Generation. Journal of Product Innovation Management 28 (1), 48–62.

Rundquist, J., 2008. World-class or good enough – The choice of partner when outsourcing new product development in medium-sized firms. International Journal of Innovation and Technology Management 5 (4), 423-445.

Sanders, P., 2010. Boeing Brings in Old Hands, Gets an Earful. Wall Street Journal, 19 July, B1.

Siew, W., 2009. S&P cuts Boeing's credit rating by one notch to A. http://www.reuters.com/article/2009/07/29/boeing-ratings-sandp-idUSN2927930820090729 (accessed 20 May, 2010).

Tadelis, S., 2007. The Innovative Organization: Creating Value Through Outsourcing. California Management Review 50 (1), 261-277.

Tripathy, A., Eppinger, S.D., 2011. Organizing Global Product Development for Complex Engineered Systems. IEEE Transactions on Engineering Management 58 (3), 510-529.

Wallace, J., 2007. Aerospace Notebook: Fastener shortage holding back 787. http://www.seattlepi.com/business/332205_air19.html (accessed 13 February, 2010).

Windrum, P., Reinstaller, A., Bull, C., 2009. The outsourcing productivity paradox: total outsourcing, organizational innovation, and long run productivity growth. Journal of Evolutionary Economics 19 (2), 197–229.

Yu A.S.O., Figueiredo, P.S., Nascimento, P.T., 2010. Development Resource Planning: Complexity of Product Development and the Capacity to Launch New Products. Journal of Product Innovation Management 27 (2), 253–266.

Zhao, Y., Calantone, R.J., 2003. The Trend Toward Outsourcing In New Product Development: Case Studies In Six Firms. International Journal of Innovation Management 7 (1), 51-66.

Zhu, Z., Hsu, K., Lillie, J., 2001. Outsourcing — a strategic move: The process and the ingredients for success. Management Decision 39 (5), 373–378.

Zirpoli, F., Becker, M.C., 2011. The limits of design and engineering outsourcing: performance integration and the unfulfilled promises of modularity. R&D Management 41 (1), 21-43.