
Managing New Product Development and Supply Chain Risks: The Boeing 787 Case

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To stimulate revenue growth and market response, Boeing decided to develop the 787 Dreamliner. The 787 Dreamliner is not only a revolutionary aircraft, but it also utilizes an unconventional supply chain intended to drastically reduce development cost and time. However, despite significant management efforts and capital investment, Boeing is currently facing a series of delays in its schedule for the maiden flight and plane delivery to customers. This paper analyzes Boeing's rationale for the 787's unconventional supply chain, describes Boeing's challenges for managing this supply chain, and highlights some key lessons for other manufacturers to consider when designing their supply chains for new product development.

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Introduction

Since the U.S. government deregulated air travel in 1977, more airlines have entered the market causing fierce price competition. As airfares continued to decline, the total number of U.S. passengers per year has risen from approximately 240 million to 640 million from 1977 to 1999. At the same time, U.S. commercial aircraft manufacturers have faced major competition from European companies. After losing market share to Airbus (owned by EADS) in the late 1990s, Boeing was under pressure to decide between two basic competitive strategies: reduce the costs (and the selling prices) of existing types of aircraft or develop a new aircraft to raise revenues through value creation.

In 2003, Boeing decided to focus on creating additional value for its customers (airlines) and their passengers by developing an innovative aircraft: the 787 Dreamliner. (Throughout this paper, we shall use the term "787 Dreamliner," "787," and "Dreamliner" interchangeably.) First, Boeing's value-creation strategy for the passengers was to improve their travel experience through redesigning the aircraft and offering significant improvements in comfort. For instance, relative to other aircrafts, over 50% of the primary structure of the 787 aircraft (including the fuselage and wing) would be made of composite materials (Hawk, 2005). As compared to the traditional material (aluminum) used in airplane manufacturing, the composite material allows for increased humidity and pressure to be maintained in

the passenger cabin, offering substantial improvement to the flying experience. Also, the lightweight composite materials enable the Dreamliner to take long-haul flights. Consequently, the Dreamliner allows airlines to offer direct/nonstop flights between any pair of cities without layovers, which is preferred by most international travelers (Hucko, 2007). Table 1 and Figure 1 (p. 75) compare the 787 aircraft with other popular aircrafts.

Second, Boeing's value-creation strategy for its key immediate customers (the airlines) and its end customers (the passengers) was to improve flight operational efficiency by providing big-jet ranges to midsize airplanes while flying at approximately the same speed (Mach 0.85).³ This efficiency would allow airlines to offer economical nonstop flights to and from more and smaller cities. In addition, with a capacity between 210 and 330 passengers and a range of up to 8,500 nautical miles, the 787 Dreamliner is designed to use 20% less fuel for comparable missions than today's similarly sized airplanes. The cost-per-seat mile is expected to be 10% lower than for any other aircraft. Also, unlike the traditional aluminum fuselages that tend to rust and fatigue, the 787's fuselages are based on composite materials, which reduce airlines' maintenance and replacement costs (Murray, 2007). Table 2 provides a summary of the Dreamliner's benefits for both the airlines and their passengers.

Due to the unique value that the 787 provides to the airlines and their passengers, the number of orders exceeded expectations. The Dreamliner is the fastest-

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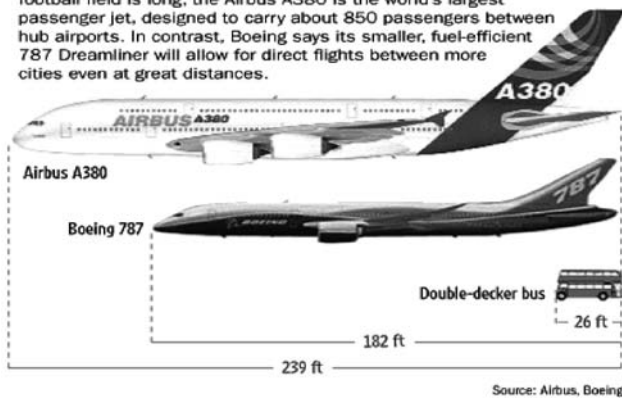
Table 1
Comparison of select Boeing and Airbus aircraft

Airline Family	Max. Range (nautical miles)	Max. Capacity (passengers) ²	Empty Weight (lbs)	Cruising Speed (mph)	Operations Strategy
737-800	3,000	189	91,000	514	Direct flights to multiple cities
747-8	8,000	467	410,000	570	Hub to hub
787-9	8,500	330	254,000	561	Direct flights to multiple cities
A380-800	8,200	555	610,000	561	Hub to hub

Figure 1
Dreamliner and A380 size comparison

Up, Up and Away

Weighing in at 280 metric tons and with a wingspan as wide as a football field is long, the Airbus A380 is the world's largest passenger jet, designed to carry about 850 passengers between hub airports. In contrast, Boeing says its smaller, fuel-efficient 787 Dreamliner will allow for direct flights between more cities even at great distances.



selling plane in aviation history with carriers attracted to its new largely composite design and innovative next-generation jet engines that will allow the wide-bodied plane to fly further on less fuel. The Dreamliner program has been considered a model endeavor combining novel technology and production strategies. As of November 16, 2008, Boeing (Too early to talk about delay here.) www.boeing.com) received orders from more than 50 airlines for a total of 895 Dreamliners. The overwhelming response from the airline industry about Boeing's 787 has forced Airbus to quickly redesign its competitive wide-bodied jet, the A350, to make it even wider, which was later re-released as the A350XWB as an "extra wide body" (Wallace, 2006). Boeing is currently the second-largest global aircraft manufacturer (behind Airbus) in terms of revenue and deliveries (though having received more orders than Airbus), the second-

largest aerospace and defense contractor in the world (behind Lockheed Martin), and the single-largest exporter in the United States. Sales in 2007 amounted to \$66.4 billion with a net income of \$4.1 billion.

Besides sales, the stock market responded favorably when Boeing launched its "game-changing" 787 Dreamliner program in 2003. As shown in Figure 2, between 2003 and 2007, Boeing's stock price increased from around \$30 a share to slightly over \$100 a share. However, Boeing announced a series of delays beginning in late 2007 and the market has reacted negatively (Figure 2). The negative market response is somewhat expected as publicity of Boeing's supply chain problems have become increasingly evident. As shown in Figure 2, Airbus shared a similar fate after announcing a series of delays for the delivery of its A380 in early 2006 (Raman et al., 2008). Despite significant capital investment and management effort, Boeing is currently facing continual delays (for more than two years) in its schedule for the maiden flight and plane delivery to customers as of this writing (Sanders, 2009c). After numerous failed attempts to get its 787's composite rear fuselage supplier back on track, Boeing finally decided to acquire Vought's South Carolina facility at a cost of \$1 billion on July 8, 2009 (Sanders, 2009a). This occurrence motivated us to examine the underlying causes of Boeing's challenges in managing its 787's delivery schedule.

In this case study, we shall examine Boeing's rationale for the 787's unconventional supply chain. The next section presents our analysis of the underlying risks associated with its supply chain. Then we describe Boeing's risk mitigation strategies to expedite its development and production processes. We conclude with some key lessons for other manufacturers to consider when designing their supply chains for new product development.

2. Measured in terms of typical seat configuration. For example, the total number of seats can be higher if more space is allocated to the economy-class cabin and less space to the first and business class cabins.

3. Other immediate customers include air freight logistics service providers such as Federal Express or DHL and aircraft operators such as Global Air.

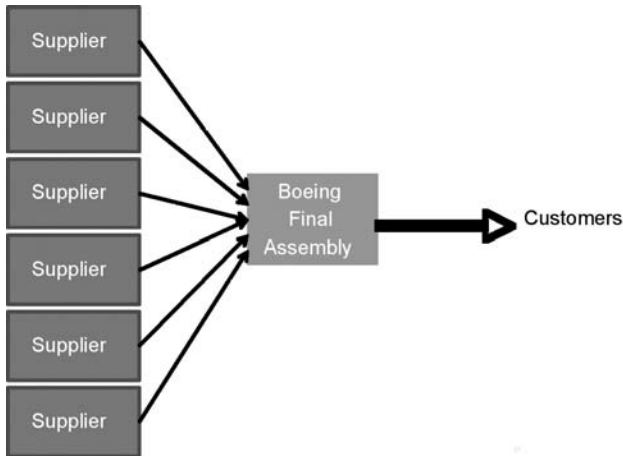
Table 2
Dreamliner features with benefits for airlines and passengers

Feature	Values to Airlines (Immediate Customers)	Value to Passengers (End Customers)
Composite material	<ul style="list-style-type: none"> • Faster cruising speed, which enables city-pair nonstop flights • Fuel efficiency (lighter material lowers operating cost) • Corrosion resistance (lower maintenance cost) • Stronger components that require fewer fasteners (lower manufacturing cost) 	<ul style="list-style-type: none"> • Faster cruising speed, which enables city-pair nonstop flights • Higher humidity in the cabin air is allowed, which increases comfort level
Modular design that allows for two types of engines (General Electric GENx and Rolls-Royce Trent 1000)	<ul style="list-style-type: none"> • Flexibility to respond to future circumstances (market demand) at a reduced cost • Simplicity in design allows for rapid engine changeover 	<ul style="list-style-type: none"> • Cost savings with cheaper and faster engine changeover may be passed on to passengers
Large and light sensitive windows	<ul style="list-style-type: none"> • Lower operating costs due to less need for interior lighting 	<ul style="list-style-type: none"> • “Smart glass” window panels work like transition lens—controlling the amount of light automatically—decreasing glare and increasing comfort and convenience
Redesigned chevron engine nozzle (serrated edges)	<ul style="list-style-type: none"> • Reduction in community noise levels 	<ul style="list-style-type: none"> • Reduction in interior cabin decibel level
Easy preventive maintenance	<ul style="list-style-type: none"> • Boeing provides service so planes are in operation for longer periods of time 	<ul style="list-style-type: none"> • Fewer delays due to mechanical problems

Figure 2
Historical stock prices of Boeing and Airbus compared to the S&P500



Figure 3
A traditional supply chain for airplane manufacturing



The 787 Dreamliner's unconventional supply chain

To reduce the 787's development time from six to four years and development cost from \$10 to \$6 billion, Boeing decided to develop and produce the Dreamliner by using an unconventional supply chain new to the aircraft manufacturing industry. The 787's supply chain was envisioned to keep manufacturing and assembly costs low, while spreading the financial risks of development to Boeing's suppliers. Unlike the 737's supply chain, which requires Boeing to play the traditional role of a key manufacturer who assembles different parts and subsystems produced by thousands of suppliers (Figure 3), the 787's supply chain is based on a tiered structure that would allow Boeing to foster partnerships with approximately 50 tier-1 strategic partners. These strategic partners serve as "integrators" who assemble different parts and subsystems produced by tier-2 suppliers (Figure 4). The 787 supply chain depicted in Figure 4 resembles Toyota's supply chain, which has enabled Toyota to develop new cars with shorter development cycle times

Figure 4
Redesigned supply chain for the Dreamliner program

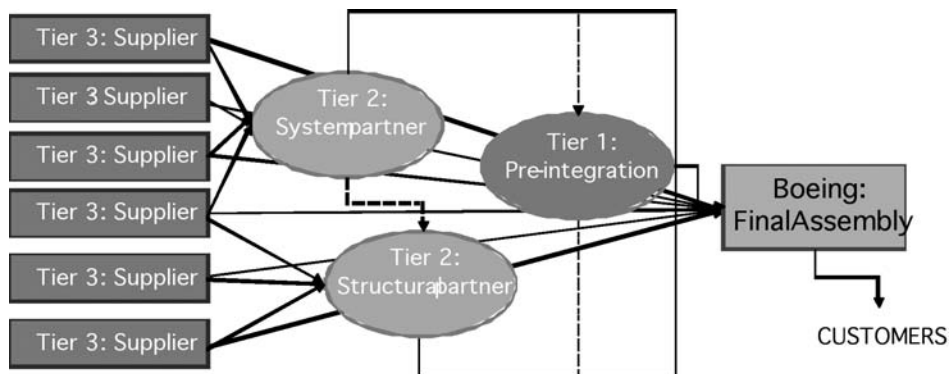
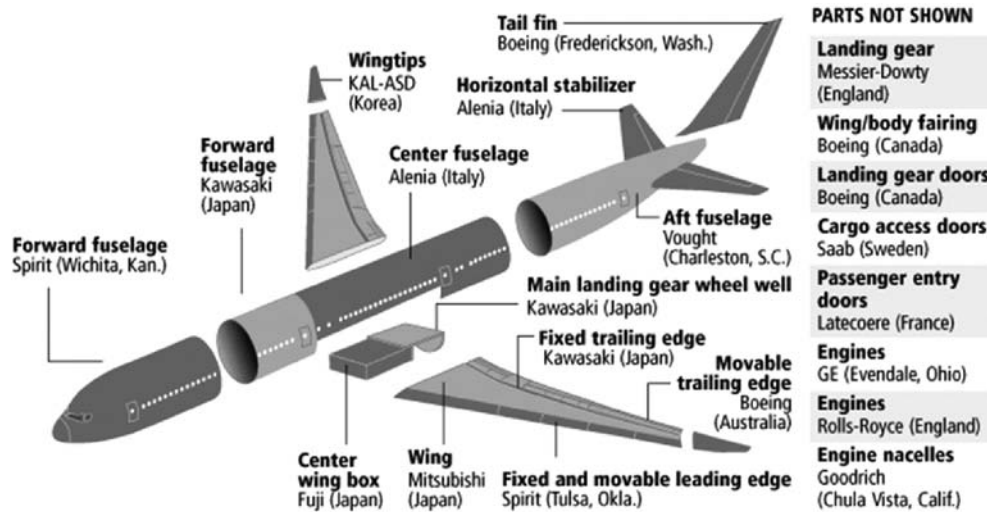


Table 3
Comparison of Boeing's strategy for its 737 and 787 programs

Component	737 Program	787 Program
Sourcing strategy	Outsource 35-50%	Outsourced 70%
Supplier relationship	Traditional supplier relationship (purely contract based)	Strategic partners with tier-1 suppliers
Supplier responsibilities	Developed and produced parts for Boeing	Developed and produced sections for Boeing
Number of suppliers	Thousands	Approximately 50 tier-1 strategic partners
Supply contracts	Fixed-price contracts with delay penalty	Risk-sharing contracts
Assembly operations	30 days for Boeing to perform final assembly	3-day assembly of complete sections

Figure 5
Dreamliner subassembly plan (Source: www.Boeing.com)



and lower development costs (Tang, 1999). Table 3 highlights the key differences between the 737's supply chain and the unconventional 787 supply chain. For instance, under the 787's supply chain structure, these tier-1 strategic partners are responsible for delivering complete sections of the aircraft to Boeing, which would allow Boeing to assemble these complete sections within three days at its plant in Everett, Washington (Figure 5). We now explain the rationale behind the 787's supply chain as highlighted in table 3.

Outsource more

By outsourcing 70% of the development and production activities under the 787 program, Boeing can shorten the development time by leveraging suppliers' ability to develop different parts at the same time. Also, Boeing may be able to reduce the development cost of the 787 by exploiting suppliers' expertise. As Boeing outsourced more, communication and coordination between Boeing and its suppliers became critical for managing the progress of the 787 development program. To facilitate the coordination and collaboration among suppliers and Boeing, Boeing implemented a web-based tool called Exostar that is intended to gain supply chain visibility, improve control and integration of critical business processes, and reduce development time and cost (Manufacturing Business Technology, 2007).

Reduce direct supply base, delegate more, and focus more

To reduce development time and cost for the Dreamliner, Boeing fostered strategic partnerships with approximately 50 tier-1 suppliers who will design and build entire sections of the plane and ship them to Boeing. By reducing its direct supply base, Boeing could focus more of its attention and resources on working with tier-1 suppliers (pre-integration stages) rather than with raw material procurement and early component

subassembly. However, unless the supplier relationship is managed correctly, reducing the supply base can increase supply risks because of the reduced bargaining power of the manufacturer (Tang, 1999). The rationale behind this shift is to empower its strategic suppliers to develop and produce different sections in parallel so as to reduce the development time. Also, by shifting more assembly operations to its strategic partners located in different countries, there is a potential savings in development cost as well (Figure 6).

Reduce financial risks

Under the 787 program, Boeing instituted a new risk-sharing contract under which no strategic suppliers will receive payment for the development cost until Boeing delivers its first 787 to its customers (slated to be ANA airlines). This contract payment term was intended to provide incentives for strategic partners to collaborate and coordinate their development efforts. Although this contract imposes certain financial risks for Boeing's strategic suppliers if delivery deadlines are missed, they are incentivized by being allowed to own their intellectual property, which can then be licensed to other companies in the future. Another incentive for the strategic partners to accept this payment term is that it allows them to increase their revenues (and potential profits) by taking up the development and production of the entire section of the plane instead of a small part of the plane.

Increase production capacity without incurring additional costs

Decentralizing the manufacturing process would allow Boeing to outsource noncritical processes. The intention is to reduce the capital investment for the 787 development program. Also, under the 787 supply chain, Boeing needs only three days to assemble complete sections of the Dreamliner at its plant. Relative

to the 737 supply chain, this drastic reduction in cycle time would in turn increase Boeing's production capacity without incurring additional investments.

The Dreamliner's supply chain risks

Although the 787 supply chain (Figure 4) has great potential for reducing development time and cost, there are various underlying supply chain risks. As described in Sodhi and Tang (2009 a), there are many types of supply chain risks ranging from technology to process risks, from demand to supply risks, and from IT system to labor risks. In this section, we shall present some of the risks and actual events that caused major delays in the Dreamliner's development program (Table 4).

The 787 Dreamliner involves the use of various unproven technologies. Boeing encountered the following technical problems that led to a series of delays.

- **Composite Fuselage Safety Issues:** The Dreamliner contains 50% composite material (carbon fiber-reinforced plastic), 15% aluminum, and 12% titanium. The composite material has never been used on this scale and many fear that creating an airplane with this mixture of materials is not feasible. Also, lightning strikes are a safety concern for wings made out of this composite material because a lightning bolt would potentially travel through the wing-skin fasteners (Wallace, 2006).
- **Engine Interchangeability Issues:** One of the key benefits of the 787's modular design concept was to

allow airlines to use two different types of engines (Rolls-Royce and GE) interchangeably. Due to recent technical difficulties and part incongruity, it would take 15 days to change engines from one model to the other instead of the intended 24 hours (Leeham Co., 2005).

- **Computer Network Security Issues:** The current configuration of electronics on the Dreamliner puts passenger electronic entertainment on the same computer network as the flight control system. This raises a security concern for terrorist attacks (Zetter 2008).

Supply Risks

Boeing is relying on its tier-1 global strategic partners to develop and build entire sections of the Dreamliner that are based on unproven technology. Any break in the supply chain can cause significant delays of the overall production. In early September 2007, Boeing announced a delay in the planned first flight of the Dreamliner citing ongoing challenges including parts shortages and remaining software and systems integration activities. Even using Exostar, a web-based planning system, to coordinate the supplier development activities, coordination is only possible when accurate and timely information is provided by different suppliers]For example, one of the tier-1 suppliers, Vought, hired Advanced Integration Technology (AIT) as a tier-2 supplier to serve as a system integrator without informing Boeing. AIT is supposed to coordinate with

Table 4
Boeing's 787 supply chain risks and consequences

Risk Factor	Potential Risk Caused by the 787 Supply Chain	Risk Consequence: What Happened at Boeing?
Technology	Infeasibility of material in flight tests, which is untested on this scale	Invisibility of development issues with tier-1 suppliers' partners resulting in major delays
Supply	Tier-1 suppliers outsource development tasks to tier-2 partners, which may not have technical know-how	Lack of knowledge about supplier selection by tier-1 partner, delay in development and manufacturing work
Process	Overreliance on tier-1 partners to coordinate their development tasks with their suppliers further down the supply chain	Need for increased coordination of supplier's activities required traveled work" by Boeing personnel
Management	Inexperienced management team without supply chain expertise	Management failure, need for reorganization at highest levels
Labor	Union dissatisfaction with Boeing's decision to outsource more	Union strike causing work stoppage
Demand (Customer)	Publicity of problems may cause problems with airline and passenger perceptions of Boeing	Delivery delays may cause financial penalties and cancellation of orders

other tier-2 and tier-3 suppliers for Vought (Tang, 2007). Additionally, due to cultural differences, some tier-2 or tier-3 suppliers do not often enter accurate and timely information into the Exostar system. As a result, various tier-1 suppliers and Boeing were not aware of the delay problems in a timely fashion, which makes it difficult for Boeing to respond to these problems quickly.

Process Risks

The underlying design of the 787 supply chain is likely to cause major delays because its efficiency depends on the synchronized just-in-time deliveries of all major sections from Boeing’s tier-1 strategic partners. If the delivery of a section is delayed, the delivery schedule of the whole aircraft is delayed. Unless Boeing keeps some safety stocks of different complete sections, it is likely that Boeing will face late delivery. Also, under the risk-sharing contract, none of the strategic partners will get paid until the first completed plane is certified for flight. As strategic partners recognize the potential of being penalized unfairly if they complete their tasks before other suppliers, the risk-sharing contract payment may actually entice these strategic partners to work slower, which undermines the original intent of the risk-sharing contract (Kwon et al., 2009).

Management Risks

As Boeing used an unconventional supply chain structure to develop and build its Dreamliner, it is essential for Boeing to assemble a leadership team that includes some members who have a proven supply chain management record with expertise to prevent and anticipate certain risks as well as to develop contingency plans to mitigate the impact of different types of risks. However, Boeing’s original leadership team for the 787 program did not include members with

expertise on supply chain risk management. Without the requisite skills to manage an unconventional supply chain, Boeing was undertaking a huge managerial risk in uncharted waters.

Labor Risks

As Boeing increased its outsourcing effort, Boeing workers became concerned about their job security. Their concerns resulted in a strike by more than 25,000 Boeing employees starting in September 2008. The effects of the worker strike were also felt by Boeing’s strategic partners. For example, anticipating that the strike at Boeing would trigger order cancellations and delivery delay of certain Boeing aircrafts, Spirit Aerosystems, a key supplier of Boeing, reduced its work week for employees who develop and manufacture various Boeing aircrafts. This reduced work schedule could potentially delay the delivery schedule of certain fuselage parts for the 787 (Rigby & Hephher, 2008).

Demand Risks

As Boeing announced a series of delays, some customers lost their confidence in Boeing’s aircraft development capability. In addition, there is a growing concern about the fact that the first 787s are overweight by about 8%, or 2.2 metric tons, which can lead to a 15% reduction in range (Norris, 2009). In response to Boeing’s production and delivery delays and the doubt about 787’s long range capability, some customers have begun canceling orders for the Dreamliner or migrating towards leasing contracts instead of purchasing the airplane outright. As of July 2009, the orders for the Dreamliner have been reduced from 895 (reported in November 2008) to 850 (reported in July 2009) (see Sanders, 2009b, for details).

Table 5
Boeing's reactive risk mitigation strategies

Risk Factor	Reactive Risk Mitigation Strategy
Technology	Modify design
Supply	Purchase company at the bottleneck stage (Vought Aircraft Industries)
Process	Send hundreds of engineers to solve issues with underperforming partners at their sites
Management	Reorganize top management—replaced program manager with supply chain expert
Labor	Concede to labor unions—increased pay and decreased outsourcing
Demand (Customer)	Paid penalties for delivery delays; public relations campaign to reassure customers

Boeing's reactive risk mitigation strategy

To manage various disruptions as presented earlier, we now present Boeing's reactive response for reducing the negative impact of the current problems and for avoiding further complications resulting in additional delays (Table 5).

To improve the safety of its composite fuselage, Boeing is redesigning its fuselage by using additional material to strengthen the wing structure; however, this additional material will increase the aircraft's overall weight. Boeing management has continued to assure its customers that it will work diligently to reduce the weight of the final version of the plane. Boeing is redesigning its installation process with the hope of reducing its changeover time from one engine model to the other. Finally, to ensure that the computer network is secure, a proper design is being required that allows for the separation of the navigation computer systems from the passenger electronic entertainment system.

Mitigating Supply Risks

After realizing that some tier-1 strategic partners did not have the know-how to develop different sections of the aircraft or experience in managing their tier-2 suppliers to develop the requisite components for the sections, Boeing recognized the need to regain control of the development process of the 787. For instance, knowing that Vought Aircraft Industries was the weakest link in the Boeing's 787 supply chain, Boeing acquired one unit of Vought in 2008 and then another unit in 2009 (Ray, 2008; Sanders, 2009a). These two acquisitions provide Boeing direct control of these two units of Vought and their tier-2 suppliers for the fuselage development. Further, as a result of continued production delays, some of Boeing's suppliers were in jeopardy of facing massive profit losses, which put completion of the entire Dreamliner program at risk. For example, in response to threats of work stoppage, Boeing paid its tier-1 strategic partner Spirit Aerosystems approximately \$125 million in 2008 to ensure that this partner continued its vital operations, Ray 2008).

Mitigating Process Risks

As a response to suppliers' inability to meet production deadlines, Boeing decided that it must send key personnel to sites across the globe to fill suppliers' management vacuum and address production issues in person. This proved to be an expensive endeavor as personnel was pulled from responsibilities on-site at Boeing to address supply and manufacturing issues at the sites of their outsourced partners. The strategy of relying on suppliers for subassembly proved to be too risky for Boeing in certain circumstances and resulted in Boeing having to perform the work themselves. For instance, Boeing sent hundreds of its engineers to the sites of various tier-1, tier-2, or tier-3 suppliers worldwide to solve various technical problems that appeared to be the root cause of the delay in the 787's development. Ultimately, Boeing had to redesign the entire aircraft subassembly process (Gunsalus, 2007).

While this hands-on approach would certainly help the process, it is very costly and time consuming, which defeats the underlying intents of the 787's redesigned supply chain as described earlier.

Mitigating Management Risks

To restore customers' confidence about Boeing's aircraft development capability and to reduce any further delays, Boeing recognized the need to bring in someone with a proven record of supply chain management expertise. In response, the original 787 program director, Mike Bair (with proven marketing expertise), was replaced by Patrick Shanahan, who had proven expertise in supply chain management. Shanahan is now responsible for coordination of all activities for Boeing's major plane families, which includes the Dreamliner. Moreover, Boeing has changed its top leadership by replacing its interim CEO, James Bell, with Jim McNerney in 2005.

Mitigating Labor Risks

To bring about an end to the strike after two months of shutdown, Boeing made concessions that would give workers a 15% wage boost over four years. On the key issue of job security, which had been the major impediment to reaching an agreement, Boeing agreed to limit the amount of work that outside vendors could perform. Therefore, Boeing's concept of outsourcing a significant amount of work to global partners could be endangered and production costs could eventually rise. In response to the wage increases and limits in outsourcing promised by Boeing, the machinists union conceded to withdraw charges filed with the Department of Labor regarding allegations of unfair bargaining practices at Boeing (Gates, 2008).

Mitigating Demand (Customer) Risks

As customers had begun to cancel their 787 orders and as the company's capability of developing the 787 was put into question, Boeing developed the following mitigation strategies. First, as a way to compensate its customers' potential loss due to the late deliveries of their orders, Boeing is supplying replacement aircrafts (new 737 or 747) to various concerned airlines such as Virgin Atlantic (Lunsford October 11, 2007 ; Crown, 2008). Second, to restore Boeing's public image, Boeing has improved its communication by sharing its progress updates on its website. In addition, Boeing is conducting a publicity campaign to promote the superior technology of the 787 and the overall value that the airplane will offer to airlines and passengers (Crown, 2008).

Boeing's potential proactive risk mitigation strategies

As Boeing makes its best effort to restore confidence in its capability of developing innovative aircrafts such as the Dreamliner, there are certain risk mitigation strategies that Boeing could have embarked on at the outset of the program to better manage potential risks proactively (Table 6).

Table 6
Alternative strategies for mitigating program risks

Risk Factor	Proactive Actions	Risk Affect
Supply chain visibility	Use IT to ensure transparency of entire supply chain	Avoided or reduced
Strategic partner selection and relationship	Use proper vetting of all strategic partners to determine their capability of completing tasks	Reduced
Process	Develop better risk-sharing opportunities and incentives for strategic partners	Reduced
Management	Establish proper working team with expertise in supply chain logistics	Avoided
Labor	Perform outreach and communicate with union heads about sourcing strategies	Avoided
Demand (customer)	Treat customers as partners and communicate better the potential for missing delivery deadlines	Avoided or reduced

Improve Supply Chain Visibility

As described earlier, Boeing's supply risk was caused by the lack of supply chain visibility. Without accurate and timely information about the supply chain structure and the development progress at each supplier's site, the value of Exostar has been compromised significantly. To improve information accuracy, Boeing should have required that all strategic partners and suppliers provide all information imbedded in the supply chain relationships instead of relying on alerts generated from the program only after they were directly affected. Also, Boeing should provide incentives for all suppliers to use Exostar to communicate accurate information in a timely manner.

Improve Strategic Supplier Selection Process and Relationships

Spending more effort on evaluating each supplier's technical capability and supply chain management expertise for developing and manufacturing a particular section of the Dreamliner would have enabled Boeing to select more capable tier-1 strategic suppliers, which could avoid or reduce potential delays caused by inexperienced tier-1 suppliers. Also, Boeing should require that they participate in the tier-1 partner's vetting process of tier-2 (or tier-3) suppliers. The additional effort of properly vetting key suppliers would certainly enhance communication and coordination and reduce the risks of potential delays, which would in turn reduce the development time and cost (Lunsford, 2007).

Modify the Risk-Sharing Contract

Although the delayed payment term associated with the risk-sharing contract was intended to reduce Boeing's financial risk, it did not provide proper incentives for tier-1 suppliers to complete their tasks early. If some strategic partners are incapable of developing their sections according to the plan schedule, the entire development schedule is pushed back. As a result of

these delays, Boeing incurred millions of dollars in penalties that it had to pay out to its customers (West, 2007). To properly align the incentives among all strategic partners, Boeing should have structured the contracts with reward (penalty) for on-time (late) delivery (Kwon et al., 2009).

Proactive Management Team

Boeing should have chosen the right people for the job at the outset of the program, allowing them to anticipate and avoid the risks associated with its novel supply chain structure. Also, identifying the sources of potential problems and having the right person (or team) in place would mitigate many of the risks and allow Boeing to respond more quickly and effectively when problems occurred. For example, Boeing could have either avoided or anticipated various types of supply chain risks as described in Section 3 had they appointed persons with proven supply chain management expertise to serve on the original leadership team. By having a leadership team with all requisite skills, Boeing would have had the requisite expertise and authority to respond to the delay problems more effectively.

Proactive Labor Relationship Management

Dissatisfaction among Boeing's machinists was caused by Boeing's strategy to increase its outsourced operations to external suppliers. Had the union's general disapproval of Boeing's outsourcing strategy been taken into account, Boeing may not have decided to outsource 70% of its tasks. Even if this outsourcing strategy was justified financially, Boeing could have managed its labor relationship proactively by discussing the strategy, by offering job assurances, and by obtaining buy-in from unions. This proactive labor relationship management would have created a more mutually beneficial partnership, which could have avoided the labor strikes.

Proactive Customer Relationship Management

Recognizing the risks associated with innovative product development, proactive customer relationship management is critical to help customers set proper expectations when placing their orders. Better communication with customers throughout the development process can enable a company to manage customers' perceptions throughout the entire product development process. Setting proper expectations about the delivery schedules of its 787 Dreamliner may have encouraged the airlines to manage their aircraft replacement schedule differently, say order more 737s and 747s and fewer 787s. Without setting an aggressive delivery schedule to its customers, it was plausible for Boeing to reduce the penalty caused by the delayed delivery schedule. Through continuous engagement and open communication about the challenges and Boeing's contingency plans, it would have been plausible for Boeing to manage its customers' perception and its reputation better.

Afterthoughts

By examining the inherent risks associated with Boeing's supply chain and by analyzing Boeing's reactive mitigation strategies presented earlier, we have developed the following insights that other manufacturers may consider when managing their supply chains for efficient new product development.

Assembling a Leadership Team with Requisite Expertise

On the surface, it appears that Boeing's fundamental problem was caused by its attempts to simultaneously take on too many drastic changes. These changes include unproven technology, unconventional supply chains, unproven supplier's capability to take on new roles and responsibilities, and unproven IT coordination systems. However, one plausible reason for Boeing to take on so many drastic changes may be because the 787 leadership team underestimated the risks associated with all these changes. Had Boeing constructed a multi-disciplinary team with expertise to identify and evaluate various supply chain risks, it might have been possible for Boeing to anticipate and avoid potential risks, and to develop proactive mitigation strategies and contingency plans to reduce the impact of various supply chain disruptions.

Obtaining Internal Support Proactively

Partnerships between management and labor are essential for smooth operations for companies to implement any new initiatives including new product development programs. Although their interests are often misaligned, better communication of business strategies with union workers is a proactive step towards avoiding costly worker strikes. Also, aligning the incentives for both parties proactively is more likely to reduce potential internal disruptions down the road.

Improving Supply Chain Visibility to Facilitate Coordination and Collaboration

Besides the need to perform due diligence in key supplier selection to ensure that the selected supplier has the requisite capability and the commitment for success, a company should consider cultivating stronger commitment in exchange for accurate information in a timely manner. Overly relying on IT communication is highly risky when managing a new project. To mitigate the risks caused by partners further upstream or downstream, companies should strive to gain complete visibility of the entire supply chain. Having clear supply chain visibility would enhance the capability for a company to take corrective action more quickly, which is more likely to reduce the negative impact of a disruption along the supply chain. See Sodhi and Tang (2009b) for a discussion of the importance of timely response to mitigate the negative effects of supply chain disruptions.

Proactive Management of Customer Expectation and Perception

Due to the inherent risks associated with new product development, it is critical for a company to help its customers set proper expectations proactively, especially regarding the potential delay caused by various types of risks as highlighted in Table 3. Setting proper expectations at the outset would reduce potential customer dissatisfaction down the road. During the development phase, it is advisable for the company to maintain open and honest communication with its customers regarding the actual progress, technical challenges, and corrective measures. Such efforts would possibly gain customer trust, which would improve their loyalty in the long run.

Conclusion

Boeing's Dreamliner program involves dramatic shifts in supply chain strategy from traditional methods used in the aerospace industry. In addition, Boeing boasted about its novel manufacturing techniques and its technological marvels. Such dramatic shifts from convention involve significant potential for encountering risks throughout the process. Boeing's ongoing issues with meeting delivery deadlines are a direct result of its decision to make drastic changes in the design, the development process, and the supply chain associated with the Dreamliner program simultaneously without having the proper management team in place. Further, this team did not proactively assess the risks that were later realized and did not develop coherent strategies for effectively mitigating them. Although it may be impossible to identify all potential risks and create contingency plans for all eventualities before a project begins, Boeing could have done many things differently. It is instructive for managers in any industry to view the issues that Boeing faced and analyze how these issues were handled so that they can learn from mistakes that were made before engaging in similar supply chain restructuring.

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COMMENTS ON THE CASE STUDY

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The analysis and write-up of the Boeing 787 case study by Christopher S. Tang and Joshua D. Zimmerman reflects a consistent and high quality academic analysis of undertakings in the market place.

This case study analyzes the errors, omissions, mistakes that have been made by an organization seeking to bring goods and services to market in an expedited manner. This is not a unique situation and we can extrapolate and learn from both the business undertakings of Boeing 787 project and the Supply Chain case study of how to improve and avoid repeating many of these errors.

Boeing applied some good concepts and ideas in an effort to bring the 787 Dreamliner to market. They assessed and applied strategies that have worked in other industries in an effort to respond to pressures and dynamics in the market place. Some of these concepts worked well and others were disappointing.

The concept of using new materials in the aircraft and leveraging a Tier 1 supplier support system borrowed from the

automobile industry has inherent risks in concept versus application. The realities of cutting edge design and real world application resulted in additional resource commitment by Boeing.

Expecting Tier 1 suppliers to naturally align with Boeing expectations was clearly unrealistic. Engineering design challenges and resolutions clearly required additional unplanned resources and escalated costs for the overall project.

What we have seen is that this trend practiced by Boeing is not unique. We have seen a trend by many organizations to manage expenses in response to the economic crisis.

This is not a new phenomenon when we consider the large number of western companies that have chosen to "outsource" key tasks, services and activities to emerging markets and lower cost countries in an effort to remain competitive.

We have also seen many companies surge forward to enact and manage projects with limited attention paid to the potential impacts that can be reasonably identified by solid risk assessment processes.

Many organizations fail to take the time to establish a solid understanding of the potential downside impacts associated with the performance problems of vendors or contractors in the supply chain. This is not as complex and challenging as presented. Discussions on the nature of 'win-win' are not always as clear as the controlling organization views them.

Organizations also fail to consider the impacts of missing customer commitments, managing brand and reputation issues and also being sensitive to the many stakeholder focus areas and concerns.

The costs of a failure, setback or disruption are geometrically more costly than having a solid risk management and response and recovery capability in place. The contingency planning or "what if" capabilities of an organization often can be the difference between a successful project or the costly reactive efforts required to salvage a project.

Transferring risk and reward is a practice that is often attempted but frequently misunderstood. This cannot be accomplished by a series of meetings in the board room of a major organization. This is not a trend or new concept.

This is a very complex and iterative process requiring attention from key managers on both sides to understand, negotiate and accept risk and reward situations.

It may be necessary to also have traditional purchaser-supplier relationships in specific cases in the supply chain. This may be very germane to smaller, boutique or specialty services or product suppliers. In short- one size does not fit all- no matter how much pressure is applied!

This requires dialogue. Creating an environment that breeds success can only be accomplished by candid and aggressive communication. Be prepared to manage exceptions where cultures, size, cash flow and unique services may clash.

The key factor is establishing and embedding a culture of organizational resilience in all organizations. This is an organizational culture where all levels of the organization have input to the success of the organization's undertakings. This is a sense of change that is promulgated from top management but is accomplished by the managers and workers in the firm. Again, this may not apply to all supplier organizations.

The culture of resilience is both internal and external. The job security issues at the forefront of the Boeing machinist union is shared by many other constituencies.

Lessons learned from the Asian tsunamis and the US 2006 Gulf Coast disasters should be considered by all organizations. Significant community wide, regional or industry challenges need to be recognized, assessed and addressed at the outset of the project and evaluated for potential risks.

The cost of a project delay, outage, setbacks, mistakes or disasters have significant impacts on the organization, the employees, their families, key suppliers and contractors and the health of the community.

Sure Boeing made some mistakes as analyzed by Christopher S. Tang and Joshua D. Zimmerman. Boeing also attempted to become more efficient and competitive. Boeing pushed the envelope and continued to be creative and address challenges in the industry. They may have just applied a bureaucratic approach to the 787 Dreamliner project which may have undermined the strategic intent of the project structure.

The ideas and intention were all commendable. The challenge is there was a lack of understanding of the importance of both understanding and managing the complexities of the supply chain and the overall inherent risks of a mismanaged supply chain.

Organizations need to be more resilient, nimble and responsive in this global market. This can only be achieved by understanding what has worked and what has been lacking. Understanding the strengths of the key suppliers and their imperatives and limitations is a solid first step to resilient, successful organizations.

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