Framework for Developing a Co-production Strategy in a Vertically Integrated Operation

By
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B.S. Materials Science and Engineering, Cornell University, 1996

Submitted to the Department of Materials Science and Engineering and the Sloan School of Management in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Materials Science and Engineering and Master of Business Administration

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ABSTRACT

The Boeing Company is consolidating its operations for their wing components in order to be more profitable during lower production volumes due to higher utilization rates. In order to support higher production rates moving forward and to mitigate capacity/capability constraints, Boeing will be working more closely with the supply base to implement a new strategic outsourcing relationship -- co-production. Critical elements of a successful supply chain design for Boeing include optimizing the total value stream and validating the capacity and capability of this value stream. The challenge exists to develop this co-production strategy that achieving the strategic objectives.

The framework consists of identifying the main objectives for co-production such as risk mitigation and level employment. Next, analysis of the operations based on the main objectives is performed. This involves developing a baseline cost and capacity model of the wing components. Finally, a preliminary co-production scenario is tested and used to validate the effectiveness of co-production in achieving the strategic objectives.

The results show that even with the increased asset utilization, the operations are still very costly. When certain product families are compared on a cost per foot basis, an interesting relationship develops where shorter parts are much more costly than longer parts. Another finding is that the required utilization of certain tools is quite high and is beginning to become at risk for meeting demand. A co-production strategy is shown to be favorable in achieving many of the strategic objectives.

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Finally, I’d like to thank the Leaders for Manufacturing (LFM) community and especially the LFM class of 2005 for making the last two years unforgettable.
NOTE ON PROPRIETARY INFORMATION

In order to protect proprietary Boeing information, the data presented throughout this thesis has been altered and does not represent the actual values used by The Boeing Company. The dollar values have been disguised and names have been altered in order to protect competitive information.
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1.0 Introduction

This thesis explores the issues involved in developing a strategic outsourcing relationship within a vertically integrated company and the motivations behind it. It is based on a six month internship at the Boeing Company in Portland, OR and Frederickson, WA. The internship focused on the framework for developing a co-production strategy for the Machined Structures organization in Frederickson, WA. The thesis also addresses the organizational change issues of implementing the strategy and looks at co-production within an outsourcing framework.

In this chapter, general background on the commercial aircraft industry will be provided as well as Boeing’s future direction in commercial aircraft manufacturing. The concept of co-production will be defined. Lastly, the objectives for this thesis and the thesis structure itself will be outlined.

1.1 Commercial Aircraft Industry

The Boeing Company is synonymous with commercial aircraft and yet in the last few years, competitor Airbus has sold more aircraft than Boeing. Prior to September 2001, the commercial aircraft industry was riding high with Boeing delivering more planes than ever before with 527 planes in 2001 (McClenahen, 2005). However, after September 11th, 2001 the commercial aviation industry faced its greatest turning point in history. Many airline companies declared bankruptcy as their spiraling costs were leading to a decline of their financial health. Forecasts for new planes were cut and as a result, Boeing saw a 28% decrease in delivered planes from 527 in 2001 to 381 in 2002. In recent years the trend has continued as Boeing has only managed to deliver 281 planes in 2003. During the same time period of 2001 to 2002, Airbus only saw a 7% decrease in deliveries. During 2003, Airbus delivered 305 planes marking the first time Airbus had delivered more planes than Boeing.

The Boeing Company is set to introduce the 787 in 2008 which will be a dramatic new airplane in its fuel efficiency and flight experience. For comparison, Boeing’s last major
product launch was the 777 back in 1990. The significant changes with the plane are the materials being used, mostly composite as opposed to aluminum as with used on previous generations, and the manufacturing process and its heavy reliance on partner suppliers. These changes, if demonstrated to be successful, may have a dramatic effect on Boeing’s existing manufacturing process and assets. Boeing is betting its business on the new plane and the new manufacturing model where individual parts and airplane sections are fabricated by partners and Boeing is responsible for the assembly and integration of those parts. Even Boeing’s 2016 Vision has “Large-scale systems integration” listed as one of their core competencies, with no mention of manufacturing (2001).

### 1.2 Machined Structures Organization - Skin and Spar

The Fabrication (Fab) Division within Boeing Commercial Airplanes is responsible for providing internal parts such as interior stowbins and partitions as well as external parts such as the wings. Within the Fab Division, three manufacturing sites collectively used to be called the Machined Structures organization. These three sites are located in Auburn, WA, Frederickson, WA and Portland, OR. The primary customers for the Machined Structures are the airplane programs in Renton and Everett, WA. The narrow-body airplane (737 and 757) final assembly resides in Renton, WA and the wide-body airplane (747, 767, and 777) final assembly resides in Everett, WA.

Within Machined Structures, Skin and Spar, which is responsible for the aluminum wing products, has recently undergone significant consolidation activities in order to reduce its capital footprint and increase asset utilization. With this increased asset utilization, Machined Structures hopes to realize reduced costs and higher productivity. As a result, though, some internal secondary sourcing will no longer be possible or practical from a flexible manufacturing perspective. Skin and Spar’s responsibilities include complex high precision metal machining, wing structure fabrication, chemical processing and other secondary processing operations. A sample of Skin and Spar’s products can be seen in Figure 1.1.
1.3 Co-production definition

The term, co-production, as used in this thesis is defined as partnering with an external supplier or suppliers to produce a percentage of the internal work statement. In more traditional terms, this is essentially outsourcing a portion of the internal production work. The volume of the co-production would depend on the strategic reasons and thus would be dictated by the contractual terms and conditions with the suppliers. Examples of strategic reasons for implementing a co-production system would be capacity risk mitigation, stable employment, sharing of best known production methods, development of the supply base, reductions in capital expenditures and flexible manufacturing.

1.4 Thesis outline

An introduction for this thesis was presented in Chapter 1.0. In Chapter 2.0, a direct observation of the current reality will be presented of the Skin and Spar operations. Chapter 3.0 will describe what the strategic goals are for the Fabrication Division and how co-production will enable them. The development of the co-production framework and process will be discussed in Chapter 4.0 with the analysis of the impacts of co-production on asset utilization and capacity will be described in Chapter 5.0. Organizational processes and
strategic alignment impacts will be analyzed in Chapter 6.0. The thesis will wrap up in Chapter 7.0 with follow-on work and conclusions on how to apply this framework to other areas within the Fabrication Division.
2.0 Data Analysis - State of Skin and Spar

Before even starting to suggest products for co-production, it is necessary to get a feel for the products, costs, factory, and operations. For example, what are the major products? What do the costs look like? What are the raw materials used? What type of products is the factory designed to handle? What is the current capacity and utilization? These questions are important in devising the co-production strategy and ensuring that the strategy is in alignment with the organization and operations. In this chapter the current reality of the Skin and Spar operations will be shown with respect to cost and capacity. Interesting observations about the cost data will be revealed as well as an explanation of why the data trends the way it does.

2.1 Factory Observations

The Skin and Spar operations are housed in a single factory that takes up over 900,000 square feet or approx 20.6 acres as seen in Figure 2.1. The factory is responsible for producing the wing components which are comprised mainly of skins, chords, spars, webs, and stringers as previously seen in Figure 1.1. Some of these components are extremely

![Figure 2.1 Skin and Spar factory](image-url)
long, well over 100 feet and thus require very large machines and equipment to transport and process them. For example, the skin mills as seen in Figure 2.2 have beds well over 100 feet in order to accommodate the largest and longest products. However, not all of the parts are 100 feet long. Some parts are only a few feet in length and yet are still processed on the same equipment that is used to process the long parts. Besides being equipped to produce all length parts for the different airplane programs, the factory is also equipped to handle all of the processing steps to produce a finished part.

Figure 2.2 Wing skin mill

The factory takes in raw stock material and does all of the milling and secondary operations including chemical processing and paint. The secondary operations are everything after the initial milling steps used to create the basic form. Sanding, forming, and shotpeening are just some of the secondary operations that are performed within the building. After the secondary operations, the other major processes are the chemical and paint processing areas. Once the finished products are completed, they are assembled on a kit and then shipped to the airplane programs where they will integrate the kits into an assembled wing.
2.2 Raw Materials

All of Skin and Spar's wing components are made out of aluminum alloys since weight is an important factor for commercial aircraft. Aluminum is used because of its high strength-to-density ratio and corrosion resistance. Aluminum has a density that is approximately one-third as much as steel or copper (Rooy, 1990). Other elements can be combined with aluminum to form alloys in order to change the material's properties. Boeing uses a variety of different aluminum alloys in their products because of their slightly different properties (Figure 2.3). The nomenclature for aluminum alloys consists of four digits where the first digit represents the alloying element used. The second digit in general indicates any alloy modification. The last two digits identify the specific aluminum alloy. In Boeing's case, they use primarily 2xxx and 7xxx types of aluminum alloy which correspond to alloys in which copper and zinc are the principal alloying elements respectively (Rooy, 1990). 2xxx series alloys do not have as good corrosion resistance as other alloys but they do have high strength-to-weight ratios. 7xxx series alloys on the other hand, exhibit high strength and are often used in high stress applications.

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Aluminum Alloy Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2024 2224 2324 7055 7075 7150</td>
</tr>
<tr>
<td>T Chord</td>
<td>X   X   X</td>
</tr>
<tr>
<td>Webs</td>
<td>X   X</td>
</tr>
<tr>
<td>Stringers</td>
<td>X   X   X</td>
</tr>
<tr>
<td>Spars</td>
<td>X   X   X</td>
</tr>
<tr>
<td>Skins</td>
<td>X   X   X</td>
</tr>
<tr>
<td>Double Plus Chords</td>
<td>X</td>
</tr>
<tr>
<td>Channel Vents</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 2.3 Aluminum alloys used in products

In addition to specifying the alloying element to change the aluminum properties, different temper treatments can be used to further modify the material's properties. Boeing uses T3 and T7 temper treatments. T3 is cold worked after solution heat treatment in order to increase the strength of the material. T7, in comparison, is solution heat treated beyond the
point of maximum strength to provide enhanced resistance to stress-corrosion cracking (Cayless, 1990).

2.3 Machining

Machining is the most critical piece in Boeing’s operations requiring extremely high precision and one that requires large capital equipment. Machining is the collective term used to describe a large number of manufacturing processes such as milling, drilling, sawing, turning, and grinding that are designed to remove unwanted material (Black, 1989). This unwanted material is usually in the form of chips (Figure 2.4).

![Figure 2.4 Example of machining](image)

Removing the unwanted material is not as simple as it sounds. There are many parameters that go into machining the raw materials into finished products such as the raw material properties and geometry, cutting tool parameters (tool geometry and material properties), cutting parameters (speed, feed, and depth of cut), workholding devices, and cutting fluids (Black, 1989). The parameters directly or indirectly influence the cutting force and power, size and properties of the product, tool wear, and surface finish.

Machining aluminum alloy can be done quickly and economically. In general, the cutting force required is proportionally to the tensile strength of the material but the force required
can vary greatly between different metals with similar material properties (ASM International, 1989). As a result, cutting forces are usually less for aluminum alloys versus steel. In fact, cutting forces for most aluminum alloys decrease as the cutting speed is increased (ASM International, 1989). Not only does machining at high speeds reduce the cutting forces, but chips break free more easily. Aluminum lends itself to high speed machining applications since the overall effect of speed on cutting force is so small. The two levers used to enable high speed machining are the cutting speed which is directly related to the spindle speed and the feed rate. These two in combination with the cutting depth and cutting tool will help determine the removal rate. Ideal parts for high speed machining are ones that have long straight cuts that do not require a lot of cutting tool changes. Many of Boeing’s wing components fall into this category such as the wing skins and stringers.

Another additional advantage of high speed machining is that heat generated during machining does not have the opportunity to migrate through the part. Most of the heat is removed with the chip. This is particularly beneficial for aluminum alloys because its thermal expansion coefficient is higher than that of most other machined metals (ASM International, 1989). Heat that is not removed with the chip can be further removed with cutting fluid. Dull cutting tools can also contribute to heat generation and therefore are kept sharp to prevent unnecessary heat formation.

Other parameters to consider for machining are the depth of cut and the feed. The depth of cut should be as great as possible so that the part spends as little time as needed on the tool. However, this is dependent on the machine capabilities and the part strength. Increasing the depth of cut increases the cutting forces and may have a negative impact, if increased too much, on the overall quality of the finished product where parts can distort or slip. Feed rates largely depend on the surface finish of the piece required. Rough cuts are typically done with high feed rates whereas finish cuts with a smooth surface finish are done with lower feed rates.

High speed machining is utilized in Boeing’s operations to help keep the part costs down and decrease the lead time required to produce finished parts from the raw materials. There are
many knobs that can be adjusted which influence the product's material properties as well as the machining total cost of ownership. Many of these parameters have been optimally set only after many years of experience between engineering and operations.

2.4 Long versus short parts

Given the current assets are largely designed to work with long parts; analysis on all the products were performed in order to give a better sense of the percentages of different part lengths. The data was calculated looking at the products within the Enterprise Resource Planning (ERP) system and matching it up with forecasted demand. Work is defined as the standard hours of processing, which is the sum of the setup and run times for all the processing done to the parts within the factory. The standard hours are the basis for the scheduling as well as the financial accounting system.

As seen in Figure 2.5, the factory has 15% of its work under 25 feet, 12% between 25 and 40 feet, 44% between 40 and 60 feet leaving only 29% over 60 feet. The factory spends approximately 25% of its time on parts that are under 40 feet or less. Now with a better sense of the overall work statement as broken out by length, looking at product costs will give another perspective in which to understand the situation.

<table>
<thead>
<tr>
<th>Skin and Spar</th>
<th>% of Work (2004-2010) by Length Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>15%</td>
</tr>
<tr>
<td>40</td>
<td>12%</td>
</tr>
<tr>
<td>60</td>
<td>44%</td>
</tr>
</tbody>
</table>

Figure 2.5 Work % by different product lengths
2.5 Product costs

As with any outsourcing exercise, determining the product costs are just one portion of the data used to make a decision. Implementing a co-production strategy is no different in that although lower costs might not be an objective, there will no doubt be a financial impact caused by implementing this strategy. The product costs are determined by using the ERP system that Boeing uses for its financial calculations when it charges the airplane programs. These cost values are determined by taking the product’s standard hours and multiplying it by an overall processing center rate. This processing center rate takes into account direct labor, fringe, non-labor, shared materials, and overhead costs. The rate varies quarter to quarter depending on the volume of products and the total number of standard hours for that quarter.

Since product costs most likely scale with the product length, another metric needs to be used to compare costs. For example, a long part requires more milling time than a short part and as a result its standard hours are greater. However, due to economies of scale, the standard hours do not scale directly by length. Making conclusions on these costs lead to nothing more than a realization that long parts costs more than short parts. There needs to be a metric that can capture the cost of the parts without being directly related to the length. This metric is a normalized cost metric where the cost of the part is divided by the length. This way the cost per foot captures the true length independent cost of the products and allows products of different lengths to be compared to each other. Once the cost per foot is calculated for the parts, these costs are then averaged together for a group of parts based on their lengths. For example, costs per foot for all parts with lengths up to 25 feet are averaged together. The same averaging is done for parts between 25 feet to 40 feet, 40 feet to 60 feet, 60 feet to 80 feet, etc. The average cost per foot is then plotted by the different product length groups as seen in Figure 2.6.

From the figure, something surprising jumps out in that fact that the under 25 feet group costs much more per foot than any of the other groups. As the parts get longer, economies of scale predict that the average cost per foot would decrease as seen in the decreasing average cost between 25 feet to 80 feet but the large drop between 25 feet and 40 feet seems
unusually high and difficult to attribute to scale economies. There also seems to be an increase in average cost for parts between 80 feet and 120 feet. This data suggests the accounting system is unfairly burdening the smaller parts or that the parts over 25 feet enjoy significant economies of scale when compared to parts under 25 feet.

![Average Cost per Foot by Length Group](image)

**Figure 2.6 Average cost per foot by length group**

In order to gain further insight into the data, further analysis needs to be performed. The cost data so far does not take into account the different types of product families. A more accurate picture would be to look at the average cost per foot by product type. Many of the product families have significantly different processing in terms of the equipment or number of milling steps needed. As a result, separating out the product types will give a more realistic picture of the product costs.

Figure 2.7 now portrays the average cost per foot broken out by the different product types across the different length groups. Overall a few things can be concluded from the data. First, some product types are inherently more costly than others such as double plus chords and channel vents. In the case of double plus chords, the product design makes it more complex than some of the other products and as a result has a high average costs per foot.
The complexity of the double plus chords requires machining at many different angles and with many different cutting tools. As a result, the machining costs of the double plus chords is significantly higher than other products with mostly straight cuts. Secondly, stringers exhibit a similar relationship as previously seen in Figure 2.6 where the average cost per foot decreases as the length of the part goes up.

![Average Cost per Foot for all Products](image)

Figure 2.7 Average cost per foot by product family and length group

### 2.5.1 Stringer Cost Analysis

To further understand this cost relationship, stringers will be examined more closely. Besides the average cost per length for stringers, the external supplier costs for a limited number of stringers will also be added to the figure. This is a nice comparison to see if this cost relationship is somehow inherent in the industry versus being only at Boeing.

Figure 2.8 more clearly shows the escalating cost per foot with shorter stringers but what is even more interesting is that external suppliers do not exhibit this same behavior. The figure suggests that purchasing stringers 25 feet and under will save a lot of money. However, co-producing short parts shifts additional overhead burden onto the longer parts since overhead
costs are allocated to internally produced parts. This shift in overhead costs will unfairly tax the larger airplanes with long parts as compared to the programs that have more co-produced parts. Additionally, the reader might be curious why the costs follow this relationship with such a dramatic change at 25 feet and under. A model in Appendix A is presented and compared against the observed cost relationship.

<table>
<thead>
<tr>
<th>Length Group</th>
<th>Average Cost per Foot for Stringers</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>Boeing Stringers</td>
</tr>
<tr>
<td>80</td>
<td>Supplier Stringers</td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.8 Stringer cost per foot for internal and external

To further explore the reasons why the costs exhibit this relationship, the stringer process flow will be examined. On the process flow map, the processes that have the greatest delta between the cost per foot for the short and long parts will be noted with an amount annotated to the process area. Since the costs of the parts are calculated from the standard hours, the work centers that do not vary the hours by the length will be noted with circles. This will give an indication as to why short parts are perhaps being burdened with too much of the costs since these costs are the same regardless of length.

As you can see in Figure 2.9, the major contributors to the delta between long and short parts are from routing or machining, unloading, deburring, sanding, and shotpeening. Many of these operations are secondary ones that do not have standard hours that vary by product
length. Looking at the setup and run times for some of the operations reveals that these times in fact are relatively independent of the length of the product. For example, the chemical processing tank takes the same amount of time regardless of the length of the part. However, since most of the equipment is designed for long parts, some of the processes can actually batch process the shorter parts. In the case of the chemical processing, many smaller parts can fit within the same tank run and therefore would only require one run time to output multiple parts.

Figure 2.9 Stringer product flow analysis

The proper way to attribute the cost would be to only associate the cost based on what the percentage the product had of the standard hours. For example if 5 parts took a total of 15 minutes of setup and run time, then each part should only be associated with 3 minutes of time from a cost accounting perspective. However, the problem with that is the ERP system used to track the costs is primarily being used for scheduling. If the time associated with those parts is changed to accurately reflect the costs, then the scheduling time, three minutes, would no longer reflect the actual time of 15 minutes to run the parts. As a result, the scheduled time would be incorrect by 12 minutes. The management has consciously made the decision to use ERP for scheduling to avoid this problem although it might cause the cost
2.5.2 Summary of Cost Data

The analysis of the product cost data and the implementation of the ERP system reveals some interesting findings that can be summarized in a few key points.

- Small parts are being overburdened with the cost
- ERP system is used primarily for scheduling followed by cost accounting.
- Based on the current accounting system, Boeing is not competitive at short parts.

2.6 Capacity Data

Given all of the consolidation activities happening in the Machined Structures organization, analyzing the capacity situation of the factory was another essential piece of data to understand the state of affairs. Another reason to look at the capacity data is to help determine which products should be co-produced over others. If the factory doesn’t have enough capacity to produce a certain stringer, then that stringer might be the ideal candidate to co-produce so that the factory does not need to spend money on capital equipment.

The challenge with gathering the capacity data is that all of the capacity charts produced by the Industrial Engineers (IEs) have a built in set of assumptions. These assumptions such as utilization and throughput are often calculated but never checked against actual production data. As a result, these capacity charts are often misleading in that they give a false sense of capability that is not an accurate picture of the production reality.

One way to get a true sense of the operations is to superimpose the actual production data on the capacity graphs to understand if the operations are meeting their projected capacity or if they need more resources and hours than they had originally planned for. An example of this can be found in Figure 2.10. The graph has number of hours on the left axis and time on the
other axis. The total number of standard hours for all of the products to be run on the tool is indicated by the shaded regions with each shade representing a different airplane type. The horizontal lines with labels of 5\1 or 5\2 etc. indicate the number of days and shifts required to meet that number of hours of production work. If more days such as the weekend or more shifts are allocated, then the capacity of the area is increased. As indicated on the graph, the projected capacity is only slightly above a 5\1 to start and ending closer to the 5\2 line. Boeing has a goal of not going above a 5\3 unless absolutely necessary. So if you consider the theoretical capacity data only, this figure would indicate that there are no capacity constraints in this work area.

![Work Center 1](image)

**Figure 2.10 Capacity graph with the demonstrated performance added**

However, the story is very different if the demonstrated capacity of the same area is overlaid on the same figure. This data is the number of hours required to process the planned work and is shown as the black line. As depicted on the figure with a black line, the number of hours required is much higher than the predicted hours and in fact reaches close to a 6\3. Using the demonstrated performance data in conjunction with the theoretical capacity data gives a very good sense of potential capacity issues moving forward especially if there is only one internal site producing the parts and volumes are forecasted to increase.

Analyzing all of the different work centers using this methodology reveals that most of the work centers are not accurately depicting the capacity situation. The demonstrated
performance data is on average much lower than the theoretical data. To get a better sense of the true nature of the problem, a sensitivity analysis is done to show all of the work centers at various demonstrated utilization percentages. These various utilization percentages allow for an accurate picture of work centers that are not performing as well as planned. The data in Figure 2.11 is not actual data and the numbers in the figure are purely hypothetical. The peak load percentage is the peak production requirement hours divided by the total number of planned production hours. The three groupings of demonstrated performance show the effects of reducing the planned production hours by 5%, 10% and 15% respectively. As the demonstrated performance level drops, the peak load percentages continue to increase.

<table>
<thead>
<tr>
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<tr>
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<td>80</td>
</tr>
<tr>
<td>9</td>
<td>78</td>
</tr>
</tbody>
</table>

Figure 2.11 Utilization sensitivity analysis

This data combined with the fact that many work centers are not performing at their theoretical capacity indicates that the true reality for the operations is more like one of the reduced demonstrated performance level scenarios as opposed to the theoretical demonstrated performance level.

2.6.1 Capacity Data Summary

The capacity data at the Skin and Spar operations revealed some very worrying gaps in their performance. These can be summarized in the following:

- Demonstrated capacity does not match the theoretical planned capacity
- Sensitivity analysis of the load percentage shows a very serious problem given the current work statement and demonstrated performance level.
3.0 Strategic Objectives of Co-Production

Outsourcing is becoming more and more a decision companies are being faced with in this global economy in which vertically integrated companies find their industries are traversing through the double helix of vertical and horizontal integration (Fine, 1998). As Fine describes, the forces that are pushing towards a horizontal or outsourcing configuration are entry from niche competitors, challenge of keeping ahead of the competition, and bureaucratic rigidities (1998). These forces tend to weaken or slow large, vertically integrated companies.

Outsourcing will be briefly reviewed in this chapter as well as the factors in making vertical integration decisions. Co-production will be explained and the reasons why Boeing is pursuing co-production as a strategy for their metal wing components.

3.1 Outsourcing

The definition of Outsourcing from The American Heritage Dictionary is “The procuring of services or products, such as the parts used in manufacturing a motor vehicle, from an outside supplier or manufacturer in order to cut costs.” (2000)

Although the common belief is that outsourcing is done strictly to cut costs, companies do it for a number of reasons ranging from costs to gaining access to different technologies. Costs are often used as the justification but for companies to have a successful outsourcing strategy, they need to ensure that it is “aligned with the company’s direction and goals.” (Blumberg & Miller, 2002) The basic decision of whether or not to vertically integrate can be examined from a framework of four factors (Beckman & Rosenfield, 2005). These factors are:

- Strategic factors
- Market factors
- Product and technology factors
- Economic factors
Strategic factors deal with core capabilities and whether or not the company still has a competitive advantage in retaining that capability. Market factors are those pertaining to the market structure and industry dynamics. Product and technology factors looks at how integrated the product architecture is and how integral the manufacturing technology is. Lastly, economic factors are the tangible factors such as product costs, investment costs, transportation costs, and transaction costs.

3.2 Co-production

Co-production as previously defined in Chapter 1, is essentially outsourcing a portion of the internal work statement. In fact, co-production falls within the first level, collaborative relationships, of the strategic outsourcing relationship continuum (Blumberg & Miller, 2002). Co-production is in the same category as cross-licensing and collaborative development.

Figure 3.1 The strategic outsourcing relationship continuum (Blumberg & Miller, 2002)

Boeing’s co-production strategy can be analyzed using the same framework for outsourcing decisions. This will help determine the primary considerations when deciding to co-produce.
3.2.1 Strategic Factors

Are making wing components core to Boeing’s business? Could Boeing be successful if they were to outsource all of their wing components? Recalling from Chapter 1, Boeing is doing exactly this on their next generation airplane, the 787. The company also lists large-scale systems integration as one of their core competencies with no mention of manufacturing of metal wings. However, the answer is not as simple as referring to Boeing’s stated competencies.

Most people in the Machine Structures organization firmly believe that no other company has the capability to do what they do. This may be true but only to a certain degree and even that is not given. There are probably not many companies that have the equipment long enough to handle a 747 wing skin or stringer, but there are many companies that have the capability to handle short parts including many companies that can handle parts up to 60 feet.

So from a strategic factor perspective, Boeing’s core competency is not making wing components although making long parts could be considered a core competency due to the fact that no other companies seem to have this capability. However, as part of the co-production activities, a comprehensive industry capability assessment is being performed in order to accurately determine co-production opportunities.

3.2.2 Market Factors

What does the wing component market look like? As it turns out, there are quite a number of players in excess of 20 with capabilities that are suited for Boeing’s products. With plenty of suppliers, Boeing has a lot of power in determining the terms and conditions on which it will co-produce with these suppliers.

Another concern the market and Boeing have are dependencies on human or fixed capital. Co-production by design removes most of Boeing’s concerns of becoming dependant on any of the suppliers since Boeing will continue to retain the capability and knowledge internally. Suppliers are concerned that their assets might need to be dedicated. Many of the assets are
standard industry equipment with relatively minor modification. Many of the jigs to attach to the tools though are product specific. This concern is alleviated due to the fact that Boeing is looking to partner with suppliers and thus is looking to have long terms contracts of 5 to 10 years.

3.2.3 Product and Technology Factors
From both the product architecture and technology perspective, there are no strong barriers to co-producing. The wing components are of a modular architecture in that have been designed and specified and each component performs a unique task. Parts are not specific to the individual aircraft but rather a model type. Also all of these parts have been in production for many years already. Parts that are produced to specification should perform as designed.

Manufacturing technology should also not be a problem since all of the machines and tools can be bought from common suppliers in the industry. Boeing does very little of its own technology development in the Machined Structures organization and relies on supplier technology development for its own advances. Machining capabilities should be comparable if not better at the industry partners since Boeing is more likely to upgrade their old capital equipment rather than purchase brand new equipment. Co-production suppliers on the other hand can afford to have the latest equipment since they are not purchasing expensive tools sized to handle very long parts.

3.2.4 Economic Factors
Economic costs for co-production go beyond the product costs. Other costs such as investment, transaction, and transportation costs need to be considered. Although investment and transaction costs need to be considered, they can be well estimated and not as dependent on the supplier selected. However, depending on the supplier location, transportation costs could be a significant cost of co-producing, easily negating any savings from reduced product costs. Transporting products over 50 feet require specialized equipment and start to incur
high transportation costs. Now imagine if the supplier is overseas. The transportation cost and logistics becomes a daunting issue.

### 3.3 Boeing’s Co-Production Strategic Reasons

Outsourcing is very popular with companies today who are looking to reduce manufacturing costs. Why then is Boeing looking to co-production instead of outsourcing? The difference lies primarily in Boeing’s objectives and current situation. Boeing has an extremely long history of producing wing components and large capital assets to produce them. The industry is not prepared in knowledge or equipment to handle all of Boeing’s production volume today. Nor would Boeing accept the risk of outsourcing all of its wing components. Based on those facts alone, Boeing is not going to consider outsourcing in the traditional sense. However, co-production can achieve Boeing’s following objectives:

- Stabilize employment levels
- Get the best value out of current assets and future capital
- Mitigate capacity risk and provide surge capacity capability
- Share best practices
- Develop supply base

#### 3.3.1 Stabilize Employment Levels

One of the original reasons for co-production was to help stabilize employment. Since the aerospace industry in the past has been very cyclical, Boeing has been forced to layoff workers in the down cycles and hire during the up cycles (Figure 3.2). This causes huge disruptions in employee morale and productivity. Boeing has just been through a down turn in 2002 and now they are forecasting increasing demand. Co-production would allow them to meet this increasing demand by leveraging the existing supply base instead of adding capital and workers only to be forced to layoff workers during a down swing. Co-production in a sense would allow them to stabilize their work force but still meet the demand variability.
Another one of the original reasons is to better utilize Boeing’s existing capital. For example, instead of buying new equipment to support higher demands, Boeing would shift production of a non-core part to any external supplier so that the equipment could be used to support critical, more valuable products. Co-production is enabling Boeing to use their limited capital resources in the most productive way in terms of value creation.

3.3.3 Mitigate Capacity Risk

After the consolidation of the Fab Division’s wing components factories, there will only be one factory now capable of producing all of Boeing’s commercial airplane wings. Co-production enables Boeing to mitigate this single source risk with another viable supplier. Assuming both suppliers are not producing at their limit, they each have some reserve capacity that they could use to increase production. For example if Boeing’s chemical tank line suffered a major problem, their production would halt without co-production. However, with co-production, they could shift some of the volume to the partner supplier. If on the other hand, the supplier runs into some problems, Boeing could increase its production to compensate. Having these two sources gives the airplane programs a more reliable source for their parts.
3.3.4 Share Best Practices

It is a continuous challenge for companies to gain a different perspective on doing things after being successful with a certain way. Best known methods are turned into processes and these processes are reinforced through training. Engineer after engineer is trained on these methods and changing or even thinking differently becomes very difficult. Through co-production, Boeing is able to compare different best known production methods and processes so that it can gain a new perspective and improve upon its manufacturing process.

3.3.5 Develop Supply Base

The final strategic objective of co-production is to develop the supply base. As previously mentioned, the wing component industry does not have enough knowledge and capacity to seamlessly handle all of Boeing’s product volume. There are actually no suppliers currently that Boeing could rely on to continue producing its products if Boeing were to exit the industry. This poses a potential problem for Boeing as the metal wing technology is potentially headed for obsolescence. The 787 will use composite materials instead of metal technologies and if successful, could signal an end of products designed with metal wings. However, due to the long product lifecycle, metal wings will still be in production for many years to come.

The implications of this are that metal wing demand will eventually wane enough that it does not justify Boeing to maintain its large assets. However, once Boeing decides to stop producing metal wing components and outsource them, no supplier will want to invest in the capital and resources to produce these parts. Boeing will also have very little power at that time to gain favorable terms and conditions. However, by co-producing now during a period where production volumes are increasing, Boeing is able attract suppliers to make the investments. Once the suppliers have been producing the parts for many years, they are in the position to continue producing parts until the product’s end of life. Co-production allows Boeing to develop the supplier capability in order to mitigate any impacts from technological obsolescence.
4.0 Co-production Framework

In this chapter a framework on developing a co-production model will be presented. The framework will not cover implementing the work transfer process as this is not specific to co-production. The framework can be summarized in five steps:

1. Determine co-production feasibility and strategic objectives
2. Analyze operations
3. Determine potential suppliers
4. Evaluate suppliers
5. Determine co-production terms and conditions

4.1 Determine co-production feasibility and Strategic Objectives

The most important thing in the framework is to understand the reasons for the project and determine if a strategic outsourcing relationship makes sense. Using the framework described by Beckman and Rosenfield will help answer the question of whether or not a strategic outsourcing relationship fits (2005). There are many different possible objectives that come to mind when outsourcing or co-production is mentioned so it is vital that these objectives be well defined at the start of the process. These objectives will play a role in subsequent steps of the framework. Making sure all of the stakeholders of the project agree to the reasons will ensure that there are no conflicting priorities during later steps and that everyone is focused on the same objectives. With that said, it is critical to document and communicate these objectives to all of the stakeholders. In the case of this internship, a co-production definition document was created that outlined the mission, objectives, and the scope. This document was ratified by the team and the different stakeholders.

4.2 Analyze Operations

Analyzing the operations is the second step in the framework. It is critical to develop a baseline of the operations. This could be from many different perspectives such as cost, quality, capacity, or tool utilization. The analysis should be focused on the attributes that are
most directly related to the objectives stated in the first step. For example, the Fab division is trying to best use their assets and as a result, cost and capacity are targeted to help understand how to best achieve that objective. Analyzing the operations and developing a baseline will help target products to achieve the objectives. It will also allow calculating the impact from co-production. This will help determine the right mix and quantity of products to co-produce. An example of this analysis is in chapter 2.

As part of the analysis, the raw materials and process steps need to be analyzed because they can influence the co-production mix. For example, a new type of aluminum alloy is requiring some changes to the secondary processing steps due to the different material properties and as a result is not a good candidate for co-production until the process is stable. In addition, products that do not have contour or need forming area ideal candidates at the beginning of co-production because they require less inspection equipment and have fewer process steps. In order to minimize the risk of the partner suppliers during the initial ramp of production, low risk and high yielding products are ideal products.

4.3 Determine Potential Suppliers

Once the objectives have been defined and communicated as well as data analysis on the operations, determining potential suppliers is the next major step. It helps if the objectives document also has a section on assumptions and boundary conditions. This will help ensure that the supplier list has only potential suppliers on it. The initial list should have a wide range of capable suppliers.

4.4 Evaluate Suppliers

Once the list of capable suppliers has been identified, evaluating them and deciding on which supplier or suppliers to co-produce is a difficult task. The first step is to focus on the key selection criteria. These criteria should accurately reflect the team’s strategy and objectives. In addition to these key selection criteria, a number of other critical criteria should be considered and included such as financial health, production, productivity, and company
culture. Next, evaluate and rank these criteria in order of satisfying the objectives. Using relative weights and scores assigned to the criteria will allow for an objective selection. With the list of key selection criteria developed, supplier evaluations can begin.

Depending on the number of capable suppliers, the process of evaluating them can take a long time. Utilizing best known methods and tools will help evaluate suppliers more efficiently. First, evaluate the key criteria first with supplier self evaluations. This will help narrow down the large list of suppliers. Secondly, based on these evaluations and other data sources, select the most promising suppliers for a comprehensive site evaluation. For the site evaluation, utilize agreed upon criteria for evaluating the supplier. For the criteria, specify characteristics or levels associated with the scoring to ensure consistent and objective evaluations across the team members and suppliers.

Select a supplier or suppliers according to the selection criteria. Sometimes it helps to visualize the supplier evaluation scores. The criteria for the supplier evaluations for wing components can be grouped into two categories; strategy and execution (Sargeant, 2004). Many of the criteria in the ability to execute category are directly related to the supplier’s machining capabilities and processes. Understanding the supplier’s machining capabilities from a quality and cost perspective is critical in partnering with a capable supplier. The alignment with strategy category looks more to the long term partnering aspect of the relationship and ensures that the partner’s own values, strategies, management, information systems, and machining technology development are aligned with Boeing’s own strategy and systems.

Suppliers can be plotted against these two categories as seen in Figure 4.1. Suppliers in the upper right quadrant are the most desirable in terms of satisfying the execution and strategy criteria. Partner D in this case is the most desirable scoring the highest in both categories of execution and strategy. In cases where there is no clear supplier, then a supplier may be chosen that is stronger in the category that is most important. For example, if partner D was not available then partner C and E would have comparable overall scores with each being stronger in either the execution or strategy category. Since Boeing is looking for a long-term
partnership, the supplier with a higher alignment with strategy might be favored with hopes that the partners ability to execute would only increase in the future. Once a supplier is selected, ensure that the team and key stakeholders ratify the decision.

Figure 4.1 Supplier performance matrix (Sargeant, 2004)

4.5 Determine Co-Production Terms and Conditions

After selecting the supplier, the co-production terms and conditions need to be finalized. The terms and conditions should be arranged so they are in alignment with the strategic objectives. Co-production scenarios can be as simple as a constant percentage regardless of volume or they can be complex varying with volumes and products. It is important to obtain financial and legal review of the contracts that include performance guarantees. One of the Fab Division’s sites has in place a poorly designed contract in which co-production volumes on a specific part are determined by the overall part family volume. In some cases, there is no demand for the co-produced part but there is for other parts in the same family and as a result of the contract, Boeing is required to purchase the co-produced parts that it has no demand for. The terms and conditions should be designed very carefully and should be setup to align with the strategic objectives.
4.6 Implementation

After completing the framework, the next step is to implement the co-production strategy by transferring the work. Since the work transfer process has been described in depth by Murdoch (2004) in her thesis, “Development of a Robust Work Transfer Process”, it will not be covered in this thesis.
5.0 Results

Although co-production has not been implemented for wing components, some of the impacts of implementing such a strategy can be estimated. In this chapter, examples of the capacity relief and improved asset utilization will be shown.

5.1 Capacity Mitigation

As previously discussed, one of the main objectives of co-production is to mitigate capacity risks and provide surge capacity. The work centers as shown in chapter 2 are being over utilized and are predicted to be operating above peak capacity. Implementing co-production would allow some relief to the capacity risk. As shown in Figure 5.1, many of the work centers show an improvement in the peak load percentage by co-producing a percentage of the work. For example, in work center 1, the peak load percentage is reduced from 101% down to 95% by implementing co-production. This particular scenario shows 50% co-production on Model 1 stringers. Products were chosen largely because of their length but also for their ease of manufacturing and machining. For example, new aluminum alloy products were not considered due to the lack of experience in production. Also, products that are relatively easy to machine were selected as a method to mitigate the risk of starting a new supplier.

<table>
<thead>
<tr>
<th>Work Center</th>
<th>Util %</th>
<th>Load % @ Peak As-is</th>
<th>Load % @ Peak To-Be</th>
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<tbody>
<tr>
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<tr>
<td>10</td>
<td>80%</td>
<td>93%</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Figure 5.1 Peak load percentage before and after co-production
Work centers 7 through 10 do not show an improvement because the co-production package is still being considered. The expectation though would be a reduction in the peak load percentage and the actually amount would depend on the number and type of skins that are co-produced. Work centers 1 through 10 are associated with different products and not consecutive process steps.

5.2 Best Value of Assets

Another strategic objective of co-production is to best utilize the current assets. Instead of purchasing new capital equipment to support increasing demand, co-producing products can free up some equipment to avoid having to purchase new equipment. Figure 5.2 predicts how co-producing a percentage of the work statement reduces the number of machines from four mills to only three mills. Now with the availability of this extra mill, the purchase of an additional mill can be avoided. As seen in Figure 5.3, the free mill can then be used for another product increasing the number of machines from one to two mills. This particular scenario demonstrates the flexibility that co-production allows the factory to have to achieve the best use of its assets.

![Figure 5.2 Capacity data showing a reduction in equipment requirements](image)

Figure 5.2 Capacity data showing a reduction in equipment requirements
Figure 5.3 Capacity data showing additional capital equipment
6.0 Organizational Processes

In this chapter the organizational processes will be analyzed using a framework of three lenses: strategic, political, and cultural. The strategic lens will look at how the formal structure and strategy of the organization impact the project. The political lens will look at the different interests and goals explicitly or inexplicitly stated that drive individuals or organizations that have a stake in the project. The cultural lens will look at how the cultural norms of the organization impact the project. Lastly, recommendations will be given to address some of the organizational issues surrounding co-production.

6.1 Organizational Structure

In order to properly evaluate the project from a strategic standpoint, the structure of the organization needs to be evaluated. The Boeing Company produces most of its wing components in their Fab Division. This division is essentially structured around manufacturing functional expertise such as machined products, interiors, structural composites, etc. as well as business functions that support the business division like human resources, communications, and finance.

Another organization, Supplier Management and Procurement (SM&P), is responsible for products sourced externally. SM&P falls under the same management that is responsible for the Fab Division. SM&P’s charter is to be the official interface between Boeing and the suppliers handling issues such as pricing, contracts, or supplier development. Within SM&P, different groups handle emergent offloads versus products already offloaded.

Even though the current organizational model is formed around internal versus externally procured parts, most of the critical SM&P parts are managed by the internal Fab Division. The logistics of forecasting, budgeting, ordering, inspecting, and delivering are all handled by supply chain analysts within the Fab Division. One strategic reason for this is because the airplane programs, Fab Division’s customers, want bundled kits of wing components and a one stop shop for their parts. Having to manage the externally produced parts and the Fab
parts would be an unnecessary tax on resources. It is much easier to have Fab handle this responsibility especially since in general they are delivering almost complete kits and they are the product experts.

In addition to these formal organizations, Fab Division has an executive staff member to manage and implement a divisional co-production strategy. This staff member also has an indirect reporting structure to SM&P since SM&P are stakeholders to division implementing any co-production strategy. Much of the communication between Fab and SM&P occurs primarily through co-production meetings between SM&P and this co-production staff member. This staff member also has individual manufacturing site level meetings to determine and implement the co-production strategy.

### 6.2 Strategic Lens

The overall strategy for the Fab Division is to produce parts for the airplane programs such as the 747, 737, or 777. The Frederickson site specifically is concerned with producing high quality wing products in a timely fashion. This is in contrast to SM&P’s strategy of procuring high quality parts at low cost. Another aspect of SM&P’s strategy is to develop or grow good suppliers. One of their goals is to consolidate the number of suppliers across different airplane sections first and then across different programs where possible. As a result, SM&P is primarily concerned with reducing costs while Fab Division wants high quality timely parts.

The co-production strategy will impact both organizations because it converts a portion of the internally produced Fab products to outsourced SM&P products. As a result, both organizations have a vested interest in controlling the process and ensuring their objectives are met. In the past, the organizations did not have a close working relationship. The Frederickson site would only ask for SM&P’s help when they ran into problems internally. In those cases, Frederickson would be at the mercy of SM&P’s decision since they would often be in a time crunch. The co-production strategy would change this mentality since Frederickson is looking to SM&P proactively and wants to build partnerships with SM&P.
and the chosen suppliers. These activities would take place well before any capacity need necessitated it.

The co-production strategy is being pursued by Fab Division to help with their consolidation activities of moving from two plants to only one. Their immediate goals are to provide capacity risk mitigation, level employment, and smart asset utilization. Some of Fab’s more strategic goals are to develop the supply base while leveraging increasing airplane rates, potentially lower production costs, share best practices, and look at possible country offset participation. Offsets are the practice of placing manufacturing work in specific countries so that those countries buy the finished product.

Since the main thrust behind the co-production strategy is coming from Fab, most of the control and work is being done by Fab. This is in contrast to how SM&P has worked in the past where they were responsible for determining the suppliers and arranging the contracts. They would include the Fab but the control and process was dictated by them solely. As a result of this, the co-production team which includes Fab and SM&P members has been careful to make sure that managers from both organizations read and sign the co-production team charter and objectives. It’s evident that SM&P will have very different objectives as will Fab, but to ensure that the team is successful, they’ll need to put aside their individual objectives and focus on the goals of the team. As a result, the team has focused on having the team members agree on the team objectives.

6.3 Political Lens

Looking at the organization from a political lens reveals some challenges that the internship faced. First analyzing the stakeholders and mapping out their level of support allows for a quick visual on who needs to be influenced and what some potential ways to influence them are. In terms of stakeholders, The Fabrication Division and SM&P upper management are key stakeholders. The next levels of stakeholders are the individual site or group managers followed by the individual functional area managers and lastly the engineers and workers. As seen in Figure 6.1 the stakeholder map with fictitious names shows the formal reporting
structure as well as an indication of their support for the project. A double plus indicates strong support, a single plus for support, a zero for neither support or against, a negative for against, and a double negative for strongly against.

Figure 6.1 Stakeholder map analysis for co-production project

Another useful tool is the stakeholder analysis (Figure 6.2) which shows the stakeholder’s support level as well as where they need to be in terms of support for the project to be successful. This helps identify which stakeholders need to be influenced and by how much. The combination of both these tools really shows who is in support of the project and who needs to be influenced further. It also shows who can influence others in the organization and who might oppose the project.

In this particular case, the figures reveal that Paul Stub is the key individual who is against the project and yet needs to be influenced enough to moderately support the project. The stakeholder map also shows that he is directly in charge of several individuals that are actually in support of the project. Unfortunately, the co-production activities for the Frederickson site wing products directly involved him and his direct reports. The tool does not give a sense of the resistance that he applied and only through direct contact with him or
his reports did it become obvious. For example, many of direct reports would say things to suggest that they would be fired if they supported this project. Others would say that they are getting conflicting priorities and as a result would follow the priorities of their direct manager, Paul Stub who was against the project.

<table>
<thead>
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<th>Neutral</th>
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<td></td>
</tr>
<tr>
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Figure 6.2 Stakeholder analysis

In trying to understand the motivation behind the resistance to the co-production project, one needs only to look at the political lens. Paul Stub was in charge of the plant that made wing products. His source of power could be measured by how large an organization he was in charge of or by how much product was produced by his facility. Co-production, on the other hand, would ultimately reduce the size of his organization and the amount of products being produced. As a result, co-production as he viewed it was going to reduce his political power. There might be other factors but one could argue that this is probably the most likely reason for the resistance especially since his management and direct reports supported the project.

Even though Paul’s manager supported the project, the manager actually was not able to exert enough power to change Paul’s behavior. The resistance to co-production lasted several months until upper management dictated co-production be implemented. It was also
only after gathering enough data and evidence to suggest not pursuing the strategy would be a mistake. It was clear that no amount of data would change the plant manager’s mind but that power from above would need to be exerted to change it. It was only after the situation became critical did upper management step in and move the project along.

Although there have not been any projects in the past that have looked to implement co-production, there have been similar outsourcing projects that have looked at the products costs and have reached similar conclusions. Even external consulting companies have also reached similar conclusions. However in each of the cases, the plant manager has managed to ignore the recommendations and data and has even managed to bury the data intentionally or unintentionally so that future teams have difficulty in finding it.

6.4 Cultural Lens

Looking at the co-production project through a cultural lens reveals some interesting observations. What is the symbolic meaning of the project? For some, co-production represents losing their job. They see it as work being outsourced never to return and with it their jobs. Others view it as an opportunity to gain more power. Let’s look at it from the different stakeholder’s point of view starting at the union level.

The union is concerned that co-production represents lost jobs. The Fab Division has already closed one plant down in their consolidation activities and morale for most workers there are very low. Now management tells them that they are going to send a portion of the work out and partner with suppliers in a co-production strategy. Most workers are going to feel threatened by this. Additionally, workers will need to teach their trade to suppliers so that the suppliers can produce the parts. This requires a high level of trust between the union and management so that these actions are not seen as only teaching before being fired. Management needs to stress the benefits of co-production and that jobs won’t be lost because of it.
Individual engineers and analysts in the plant have mixed feelings about co-production. For most, it represents change and forward thinking. The supply chain and business analysts realize that the factory needs some capacity help and that the health of the operation isn’t the greatest. So to them, this co-production strategy represents change for the better and a feeling of hope for the future. To the industrial engineers, co-production represents a power change from the very important industrial engineering group to the supply chain group. In the past, the industrial engineering group would own all of the product metrics and factory capacity, but as more and more products move towards co-production, the supply chain group will have more responsibility in the factory.

The plant manager sees co-production representing a loss of power and authority. As previously discussed, co-production would remove some products from the factory and with that some political power. Also due to co-production, there would be less of a need to purchase new capital equipment which would decrease the budget.

The site manager and the division executives see co-production as a chance to leverage external capability to help keep Fab Division’s employment level and manufacturing healthy. It also represents the future as Boeing is changing its business model to one of large scale systems integration where they rely on supplier partners to provide parts for the airplane. Boeing is also changing from metal wings to composite wings for their next generation 787 plane.

Besides looking at the symbolism of co-production, another thing to consider is the cultural norms, values, and basic assumptions of the organization. For many this is producing wing components. The Fab Division is consolidating its wing operations to one factory and as long as Boeing is still making metal airplanes, then they’ll need metal wings. Many believe that this need will continue for another 10-20 years.

Another basic assumption of the plant is that no other supplier can make long wing parts. They assume suppliers aren’t capable without any real data. This makes it very difficult to change behavior as they don’t see an alternative to Boeing producing wing components.
However, SM&P sees things differently and believes that there are many suppliers that have very good capabilities.

From a cultural norm perspective, many of the plant’s operations centered on the industrial engineering group’s responsibilities such as capacity planning, product scheduling, and capital equipment purchases. As a result, they were always in the power position and had a pulse on the factory. As previously mentioned with the co-production strategy, more of the power will shift to the supply chain group who handles all of the co-produced parts.

Co-production does not fit within the cultural norms of the plant. The strategic reasons do not help the powerful become more powerful nor do they align with what the organization was designed to do -- make wings.

6.5 Recommendations

After analyzing the organization and the impact that the co-production project will have through the three lenses, one can realize the difficulty that the project has in becoming a reality. From a strategic standpoint, there is actually a lot of support from SM&P in ensuring that the project is successful since it will only make SM&P more powerful and further reinforce their reason for existence. However, the division will have to work on ensuring that their objectives are being met and that they control the process and who they partner with. After all, it is the factory that will ultimately be responsible to the airplane programs.

From a political standpoint, it’s clear why the plant manager opposes the project and why it’s so difficult to gain resources to work on it. It also became evident that pressure would need to be applied from the top down in order to get any work accomplished and to gain some momentum. And lastly, culturally, co-production is against everything that the plant has stood for previously. The factory represents the best manufacturing that Boeing has to offer and what other suppliers can not achieve. Now co-production is saying that other suppliers can do what Boeing can do and that the factory is not so unique after all.
In order for co-production to be successful, it is important to understand these three lenses and apply the perspectives gained from each. Strategically, understanding and communicating are the best strategies for making the project succeed. Having clear team goals, processes, requirements, stakeholders, and responsibilities will allow the team to align the strategic differences between the many stakeholders. Politically, the team needs to understand the dynamics amongst the various stakeholders and determine which members might be hindering the project. Tools such as the stakeholder map can help to determine this. Since there is such strong support for the project from a high level, going to those supporters would be the recommended approach to apply a little pressure from above. This method needs to be done carefully as it could cause some political repercussions. And lastly, the team needs to be aware of the culture impacts that this project has. The team needs to communicate the strategic and tactical goals of the project with all stakeholders to ensure that everyone understands the motivations for the project. This will help diffuse some of the symbolic undertones that come from the project. By accomplishing these items, the project should be able to overcome these obstacles and successful stand on the technical merits of the project.
7.0 Conclusions and Suggestions for Future Work

In this thesis, a framework for developing a co-production strategy is proposed that ensures alignment with the strategic objectives of the business unit. The framework consists of five steps summarized below:

1. Determine co-production feasibility and strategic objectives
2. Analyze operations
3. Determine potential suppliers
4. Evaluate suppliers
5. Determine co-production terms and conditions

Determining the reasons for co-producing is not always as easy as it sounds. Stakeholders often have their own reasons and aligning the team and stakeholders on a uniform set of objectives can be challenging. Boeing’s reasons for co-producing were investigated and can be summarized in the following:

1. Stabilize employment levels
2. Get the best value out of current assets and future capital
3. Mitigate capacity risk and provide surge capacity capability
4. Share best practices
5. Develop supply base

Boeing’s initial objectives are to stabilize the employment levels and get the best value out of the current assets. Currently, employment levels fluctuate with demand levels and this disruption lowers employee moral and productivity. Obtaining the best value out of the current assets and reducing future capital equipment purchases is another key objective. Co-production can help address both those objectives. The other reasons such as mitigate capacity risk and developing the supply base were known benefits but wasn’t until after the preliminary analysis on the operations that highlighted the importance of these additional benefits. Developing the supply base became a critical long term goal so that the Fab
Division ensures a reliable low cost supply of metal wing components in the future if composite wing technology becomes the dominant design going forward.

The capacity mitigation objective is a convincing argument for co-production after analyzing the capacity data. Performance of the factory is not demonstrating near what the capacity charts are predicting and only after a complete capacity and sensitivity analysis does it become clear that co-production is needed to help mitigate this capacity issue.

Besides the operations performance, the product costs are also analyzed. Product costs are determined by using ERP which multiplies a cost rate by the number of standard hours. Unfortunately ERP is setup to accurately record the scheduling times and not necessarily record accurate cost times. As a result, the accounting system seems to overburden the short parts with more of the costs than it does the long parts. This translates into the smaller airplane programs absorbing more of the overhead costs. Additionally, supplier prices are drastically lower than Boeing’s production costs as calculated by ERP.

Based on hypothetical co-production scenarios, many of the strategic objectives are addressed. One scenario shows freeing up a mill so that it can be used for another product that would have required additional capital to support the demand. The scenarios also show a reduction in the peak load percentages for many of the work centers thus mitigating some capacity risks. Co-production has been shown to be an effective strategy for realizing Boeing’s objectives.

7.1 Future Work

Many issues are uncovered in this thesis as a result of developing a framework for co-production. The first issue is the cost accounting used to determine the product costs. To properly determine the costs of the products, a true activity-based cost methodology should be applied. This would allow true comparisons of product costs and performance against competitors or the industry. The ramifications of true cost accounting would extend beyond
the factory and would allocate the appropriate costs to the airplane programs. This could have profound impacts on the final airplane costs.

Another area for future work is to address the gap in demonstrated performance and predicted performance. Although this is not directly related to co-production, the large discrepancy and the impact it has on all facets of factory operations makes it critical to understand and remove.

Lastly, as with any new initiative, there will always be challenges or unforeseen issues that need to be addressed. Co-production is no different. Many of the challenges are related to the business processes and production systems. A majority of the problems stem from the fact that the ERP systems were not designed to handle the co-production scenario where one of the suppliers is external and the other is internal. Information on product costs, scheduling, and forecasting are all tied to the ERP system. If ERP can not store two sets of values for the same part number, then the costs, scheduling, and forecasting will be inaccurate. Understanding all of these complications is critical for a smooth implementation of co-production.
8.0 References


Appendix A:

The relationship shown in Figure A.1 between the length of the part and the average cost per foot shows higher costs for shorter parts with decreasing cost per foot as the lengths increase. In order to better understand this relationship, an analysis of the cost components of the product is performed in Appendix A.

![Average Cost per foot for Stringers](image)

Figure A.1 Stringer cost per foot

The product costs as a function of length can be estimated by taking the costs of the machining, labor, and raw materials where machining and raw material costs depend on length. Thus the equation looks like the following.

$$$(L) = $machining(L) + $labor + $raw(L) \quad (1)$$$

The cost of machining can be further broken down into tooling, depreciation, repair, and power costs.

$$smachining(L) = $tooling + $dep + $repair + $power \times time(L) \quad (2)$$

However the time can be further broken out into setup and runtimes where runtimes are dependent on the length of the product.

$$smachining = $tooling + $dep + $repair + $power \times (Setup + Run \times L) \quad (3)$$

Substituting equation (3) back into equation (1) now gives

$$$(L) = $tooling + $dep + $repair + $power \times (Setup + Run \times L) + $labor + $raw \times L \quad (4)$$
Dividing equation (4) by the Length now gives the equation in terms of cost per foot.

$$\frac{\$L}{L} = \frac{\$tooling}{L} + \frac{\$dep}{L} + \frac{\$repair}{L} + \frac{\$power \times setup}{L} + \frac{\$labor}{L} + (\$power \times Run) + \$raw \quad (5)$$

Equation (5) shows that most of the cost components are not dependent on the actual length of the product such as the repair costs or depreciation costs. The cost components that are dependent on length are the raw material costs and the power costs due to the run times. However, when these components are divided by the length, they become constants. All of the components that do not depend on length now have a factor of $1/L$. So for products that have a large $L$, these terms become small relative to a product with a short $L$.

Taking equation (5) with a constant value for the length dependent terms and plotting it against $L$ (Figure A.2) with values ranging from 10 to 90 gives a relationship that is very similar to the one seen in Figure A.1. In order for the theoretical model to be as accurate as possible, the $L$ values were the actual average lengths for the different groups. The average stringer lengths were 10.87 feet for up to 25 feet, 32.35 feet for 40 feet, 49.33 feet for 60 feet, 68.41 feet for 80 feet, and 90.77 feet for up to 120 feet. This analysis has demonstrated that the relationship seen with the length versus cost per foot is expected based on the cost components and their dependence on length.

![Theoretical Average Cost per Foot](image)

**Figure A.2** Theoretical cost per foot by length graph