# Strategic Sourcing of Serial Production Processes in Jet Engine Manufacturing

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## Abstract

Fabrication of an individual jet engine component at Pratt & Whitney can go through upwards of 40 manufacturing processes, from an airfoil's single crystal casting to thermal plasma spray coatings and wire EDM-drilled cooling holes. Many of these processes are extremely specialized, requiring special equipment, environmental controls, and expertise to produce at the precise tolerances required in aerospace.

Utilizing contract manufacturers is an attractive and cost-effective option when lower unit process costs outweigh the associated transaction costs. However, it is not clear that Pratt & Whitney is utilizing an integrated and cost-efficient strategy when making sourcing decisions. Decisions are made locally, by individual production areas with little visibility into overall company impact. Furthermore, outsourcing arrangements established to temporarily supplement capacity end up persisting and becoming longer term or permanent arrangements.

Based on research with Pratt Whitney, this project arrives at a methodology to operationalize continuous analysis of transaction costs in order to arrive an efficient sourcing decision.

Thesis Supervisor: Dr. Roy Welsch
Title: Professor of Statistics and Engineering Systems

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## Acknowledgements

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# Chapter 1: Introduction

Contract manufacturing plays a critical role in jet engine manufacturing, where complex and specialized manufacturing processes are required to achieve the high-performance design characteristics demanded in the industry today. At Pratt & Whitney, an individual component can go through over of 40 production processes before it becomes a finished part and can be integrated into the engine.

The decision about whether to make or buy a part is therefore, not a one-time phenomenon, but a decision that must be made at almost every step of the manufacturing process. There are multiple inputs which inform this decision, including cost, quality, inventory and lead time, among others. This project has two primary objectives:

1. Develop a business process and system of governance which operationalizes analysis of transaction costs and facilitates strategic management of the make-or-buy decision.
2. Develop a total cost metric which captures the various transaction costs associated with outsourcing individual manufacturing processes to contract manufacturers.

This study will show that it is possible to create a simple analysis tool which can provide a total cost metric, encapsulating each of the various business considerations.

## 1.1 Thesis Organization

Chapter 2 provides relevant background information about the aerospace industry and Pratt & Whitney's role within it, as well as an overview of relevant supply chain and contract manufacturing considerations.

In Chapter 3, we review relevant literature related to transaction cost economics and total cost analysis. I also provide an overview of Pratt & Whitney's Vendor Assist business process as it exists today. This establishes the motivation for this project.

Chapter 4 provides a detailed explanation of our approach and methodology to developing a total cost metric and the business process and governance which operationalize continuous strategic analysis of sourcing decisions.

Chapter 5 explores the resulting analysis tool and limitations therein. We also discuss deployment of the business process and tools.

Finally, in Chapter 6 we conclude with potential future improvements and adaptations that build upon this project.

# Chapter 2: Background

## 2.1 The Aerospace Industry

The United States has the largest aerospace industry in the world [9], accounting for almost 2% of GDP [13]. Advancement and competition in the aerospace industry is driven by innovation and technical performance. Therefore, it is no surprise that the aerospace industry plays a significant role in advancing science and technology [9]. The industry is characterized by long design cycles, requiring manufacturers to anticipate market demands sometimes decades in advance, and make significant investments into product development early in the process. Indeed, Pratt & Whitney spent 20 years and $10 billion dollars developing their GTF engine (geared turbofan), which entered into service in 2016 [14] and now has a backlog of over 8,000 orders [15].

Development of commercial aircraft requires analysis of market data and assumptions about future trends. Once a new design concept reaches the offerability milestone, the airframer solicits launch customers. If the market reception is favorable and the concept receives enough support from launch customers, the design will go forward into final development and production.

For defense products, the US military provides detailed mission specifications and design requirements. Contenders then develop solution proposals to meet the mission and compete to win the contract. These contracts are often long term and very valuable. However, due to reductions in US military spending (sequestration), defense contracts are much harder to come by [9]. Thus, diversification in commercial and military product offerings is a key strategic advantage.

For both commercial and defense markets, integration of the airframe with the powerplant, or engine, is critical. Therefore, development often occurs in tandem. The engine typically makes up about 20% of the value of the aircraft, reference Table 2.1. An aircraft is offered with either an exclusive engine (such as the 737 Max with the CFM Leap-1B engine), or the option between typically two different engines provided by different manufacturers (such as the A320neo with the option of either a Pratt & Whitney PW1100G-JM or CFM Leap-1A).

*Table 2.1: Distribution of aircraft value across different components [9]*

| | **Commercial** | **Defense** |
|---|---|---|
| **Airframe & Integration** | 50% | 30% |
| **Powerplant** | 20% | 20% |
| **Avionics & Systems (including weapons)** | 30% | 50% |
| **Total Aircraft Value** | 100% | 100% |

Aircraft engines are often sold at a loss. Most of the value associated with selling an engine comes from aftermarket service contracts and provision of spare parts.

## 2.2 Pratt & Whitney

Pratt & Whitney is one of the oldest aerospace companies in the US. It was founded in 1860 in Hartford, Connecticut [16], where it is still headquartered today. As of April 2020, it is a wholly-owned subsidiary of the Raytheon Technology Corporation conglomerate of aerospace companies, along with Collins Aerospace, Raytheon Intelligence and Space, and Raytheon Missiles Defense [17]. After the Raytheon-UTC merger, Raytheon Technologies Corp. is the 2nd largest firm among US manufacturers of aircraft, engines, and parts, reference Figure 2-1.

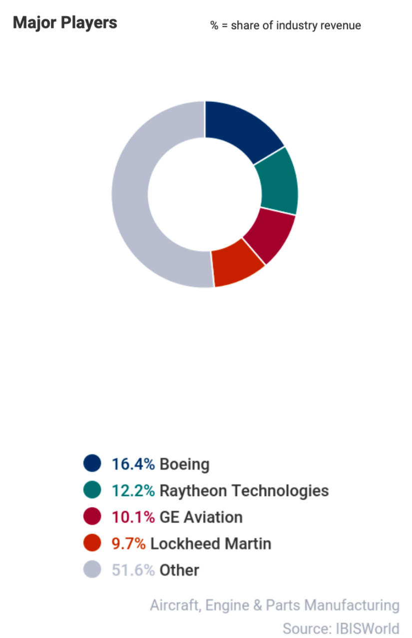



*Figure 2-1: Major players in the US aircraft, engines, and parts industry [1]*

Pratt & Whitney manufactures jet engines and auxiliary power units for commercial and military aircraft, in addition to providing aftermarket service. Their primary customers include airframers (such as Boeing and Airbus), airlines, other aircraft operators (such as FedEx and UPS), aircraft leasing companies, and governments, domestic and foreign [18]. Figure 2-2 provides a relative comparison of Pratt & Whitney's business segments in 2019.

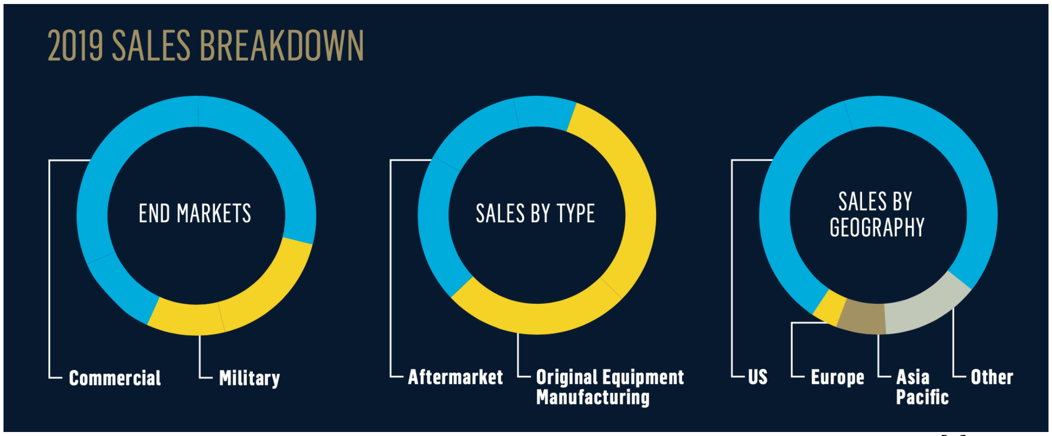



*Figure 2-2: Pratt & Whitney 2019 business segments and markets overview [2]*

There are three primary competitors in the commercial turbofan manufacturing industry: GE, Rolls Royce, and Pratt & Whitney. Collaborations between these competitors is a common means of pooling technology and distributing development costs. Pratt & Whitney partnered with GE in Engine Alliance to develop an engine for Airbus's A380. Additionally, Pratt & Whitney participates in a partnership with Germany's MTU and Japanese Aeroengine Corporation to develop the popular V2500 product line, this partnership is called International Aero Engines (IAE). While GE and Safran SA combined to form CFM International, which directly competes with Pratt & Whitney in powering the A320neo. Figure 2-3 depicts the relative market importance of each of these competitors.

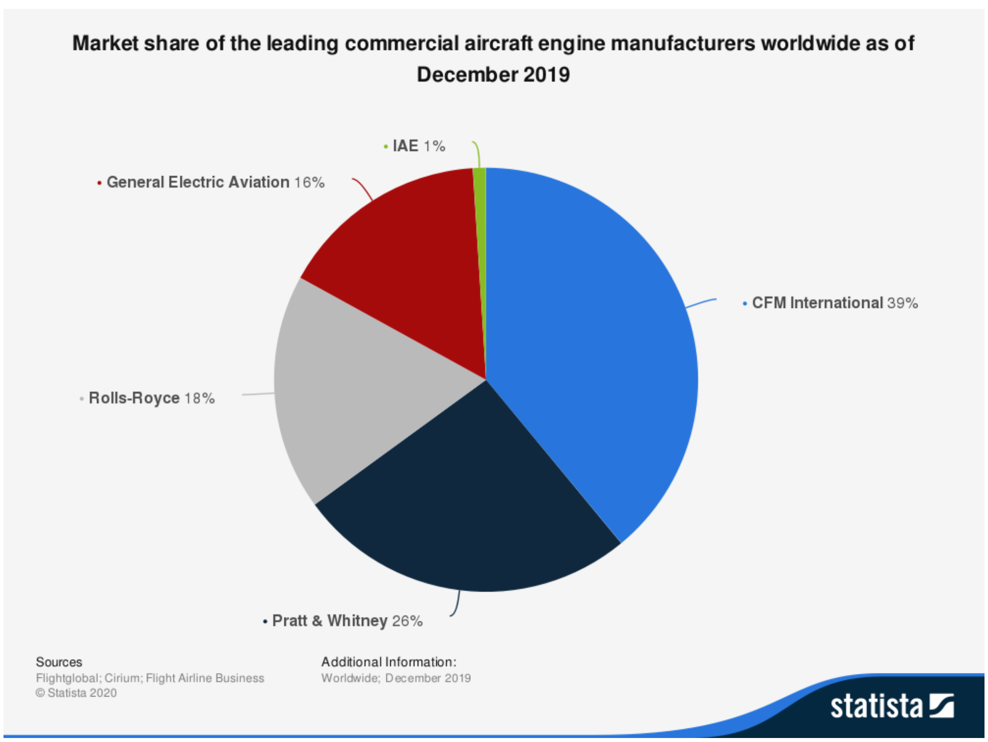



*Figure 2-3: Market share of leading aircraft engine manufacturers [3]*

The markets for commercial and military engines are very different, not only in the customers they serve, but also in the way business is awarded, regulatory oversight, mission requirements and design features. At Pratt & Whitney, the design and development of commercial and military engines are managed by separate business units, however manufacturing is centralized, supporting both business segments.

While Pratt & Whitney has a long history of designing and manufacturing jet engines, only a handful are relevant to their current manufacturing operations. Figures 2-4 and 2-5 describe the production-relevant commercial and military engines.

**Pratt & Whitney Commercial Engines**

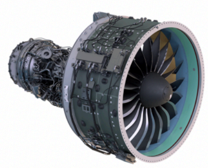
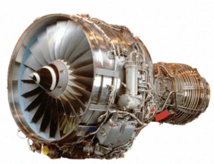
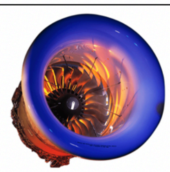
| | Name | Used on Aircraft | Engines per Aircraft | Fan Diameter (in) | Takeoff Thrust (lbs) | Production Support | Comments |
|---|---|---|---|---|---|---|---|
| Geared Turbofan (GTF)  | PW1200G | Mitsubishi Regional Jet | 2 | 56 | 15K-17K | OEM & Spares | Geared fan innovation allows different parts of the engine to rotate at more efficient speeds (fan slower than compressor & turbine). This results in reduced fuel consumption, noise, and emissions. |
| | PW1700G | Embraer 2nd generation E-Jet | | 56 | 14K - 17K | | |
| | PW1900G | | | 73 | 19K - 23K | | |
| | PW1500G | Airbus A220 | | 73 | 19K - 25k | | |
| | PW1100G-JM | Airbus A320neo | | 81 | 24K - 33K | | |
| | PW1400G-JM | Irkut MC-21 | | 81 | 28K - 31K | | |
|  | V2500 | Airbus A319, A320, A321<br>Boeing MD-90<br>Airbus Corporate Jets<br>Embraer KC-390 | 2 | 63.5 | 23K - 32K | Spares | Designed and manufactured by International Aero Engines, a global partnership of aerospace leaders including Pratt & Whitney, Japanese Aero Engine Corporation and MTU Aero Engines. |
|  | GP7200 | Airbus A380 | 4 | 116 | 70K | Spares | Joint venture between GE and Pratt & Whitney. This engine is a combination of GE90 and PW400. |
|  | PW400-94 | Boeing 747<br>Boeing 767<br>Boeing KC-46<br>MD-11<br>Airbus A300<br>Airbus A310 | 2 - 4 | 94 | 52K - 62K | OEM & Spares | |

*Figure 2-4: Pratt & Whitney's production-relevant commercial engine products [4]*

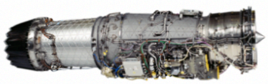
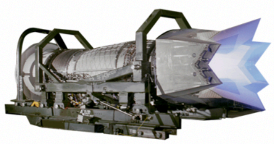
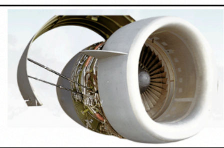
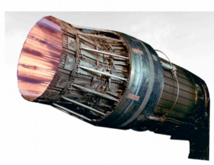
| Pratt & Whitney Military Engines | | | | | | |
|---|---|---|---|---|---|---|
| | Name | Used on Aircraft | Engines per Aircraft | Thrust Class (lbs) | Production Support | Notes |
|  | F135 | F-35 Lightning II  | 1 | 40K+ | OEM & Spares | Vertical & conventional takeoff & landing configurationations. Incorporates 5th gen stealth tech. |
|  | PW800 | B-52 CERP  | 8 | 18K | Development | Currently competing for B-52 Commercial Engine Replacement Program (CERP) contract. |
|  | F119 | F-22 Raptor  | 2 | 35K | Spares | Features stealth technology and vectored thrust for enhanced maneuverability. |
|  | F117 | C-17 Globemaster III  | 4 | 40.4K | Spares | |
|  | F100 | F-15<br>F-16  | 2 | 29K+ | Spares | First production delivery in 1989. Since then, delivered over 3,800 engines operated across 23 air forces. |

*Figure 2-5: Pratt & Whitney's production-relevant military engine products [5]*

At the end of 2019, Pratt & Whitney employed over 42,000 people around the world [19]. This figure is likely somewhat smaller today due to workforce reductions in the wake of the COVID-19 pandemic and associated downturn in commercial air travel [20]. In April 2020, passenger air traffic suffered a 95% decline in demand due to the effects of global quarantines [21]. This created an industry-wide slump which caused airlines to ground significant portions of their fleets, delay deliveries of new aircraft, delay discretionary MRO activity, and even cycle engines from parked aircraft for short term mitigation of costly maintenance. These cost-cutting tactics had a significant impact on Pratt & Whitney's revenue stream. Analysts currently predict that commercial air travel will not return to pre-pandemic levels until 2023 [1]. However, the market for jet engines may take longer to recover due to the wide availability of used engines and engine parts [22].

Pratt & Whitney's manufacturing operations are organized into 5 Module (Mod) Centers: Blades, Disks, Hot Section, Cold Section, and Assembly. These relate to the different components which make up an engine (reference Figure 2-6). Each Mod Center supplies parts for the entire model mix, including military and commercial products (Figures 2-4 and 2-5). Each Mod Center operates multiple factories across the US and internationally. Figure 2-7 depicts this relationship between factories and Mod Centers.

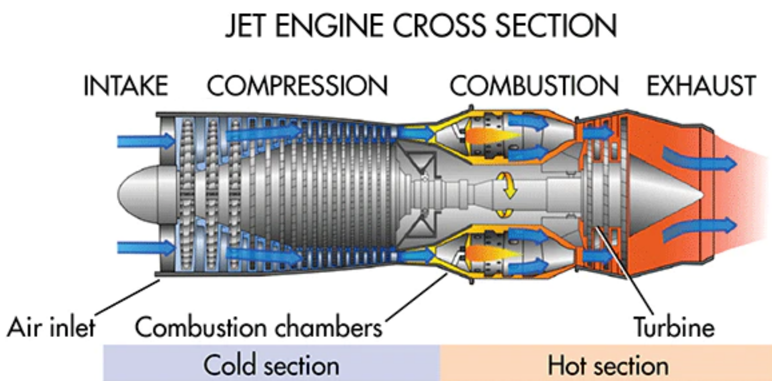



*Figure 2-6: Cross-Section of a Jet Engine [6]*

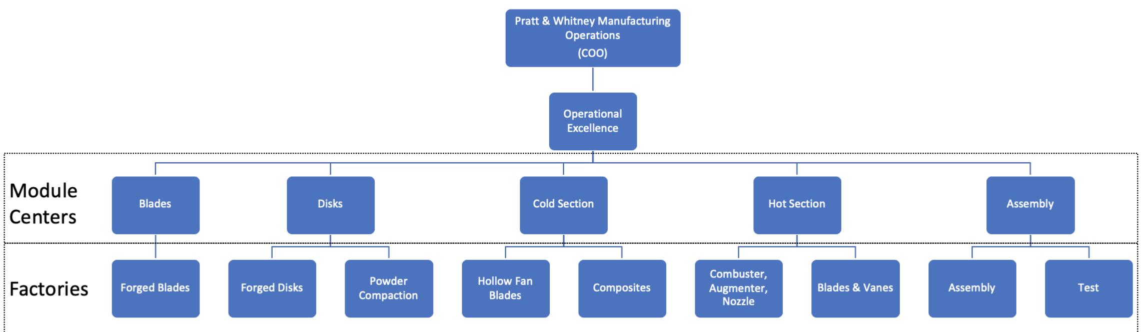



*Figure 2-7: Pratt & Whitney's Operations Organization (illustrative only, not a comprehensive list of all factories)*

## 2.3 Supply Chain

The supply chain which supports the aerospace industry is vast. According to the Aerospace Industries Association (AIA), 35% of aerospace jobs come from end-use manufacturers, while 65% come from the supply chain [13]. Most of the supply chain is made up of small and medium-sized firms. Figure 2-8 shows how industry output is divided between the supply chain and OEMs.

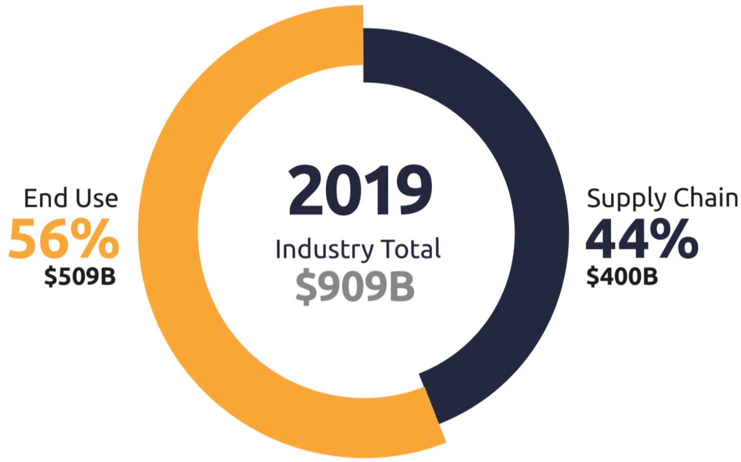



*Figure 2-8: 2019 US aerospace & defense industry output [7]*

Contract manufacturers (CMs) play a key role in supplying OEMs with unique capabilities. CMs focus on providing a subset of specialized manufacturing services that can achieve the design features and tolerances required for high performance aerospace applications. By specializing in certain manufacturing processes, they are able to achieve economies of scope. Additionally, because CMs provide their services to the industry at large, and potentially other advanced manufacturing industries as well (see Figure 2-9), they are often able to achieve economies of scale. Thus, CMs can be a more cost-effective option than OEMs creating similar capabilities internally.

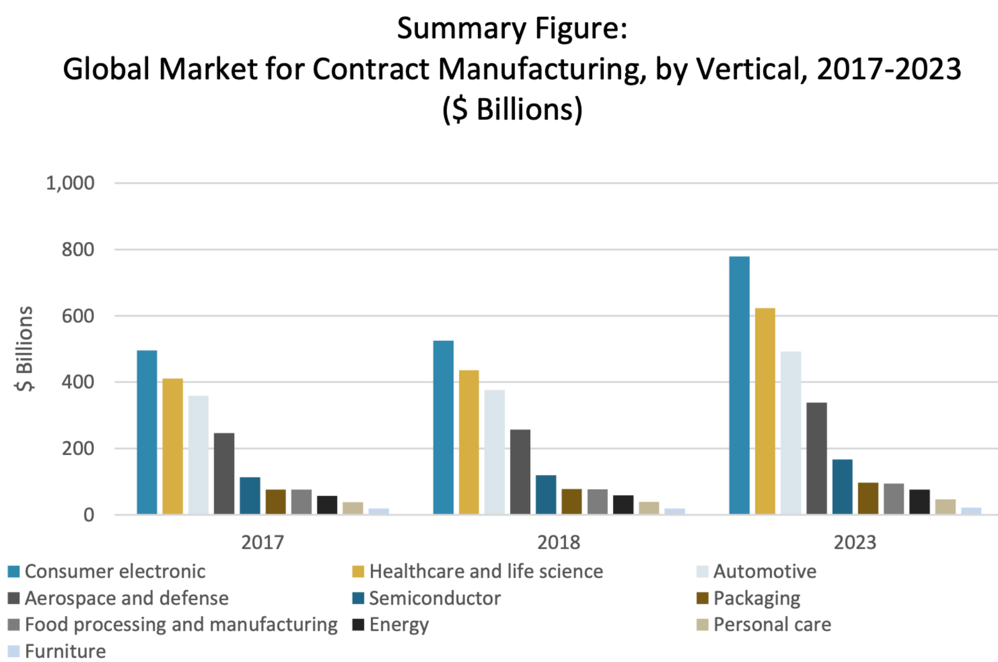



*Figure 2-9: Contract manufacturing across industries [8]*

Beyond cost effectiveness, outsourcing to a CM creates other benefits for OEMs as well. Outsourcing can offer financial flexibility and the benefits of risk sharing. By utilizing a supplier who has invested in specialized equipment or capability, the OEM can avoid the necessity of large capital investments, this is especially important when the rate of technological innovation and advancement creates a high risk of obsolescence for certain equipment. Additionally, outsourcing can improve focus on internal core competencies and provide access to capabilities which do not exist internally [23].

However, outsourcing does not come without risks. These risks include loss of confidentiality, potential competition from suppliers, and loss of research and development strength [24]. Maintaining control of the production process can improve agility in introducing design changes and innovations. Additionally, it is not always more cost effective to outsource. Cost effectiveness and efficiency in outsourcing manufacturing processes is the focus of this project.

Aerospace and Defense makes up one of the largest markets for contract manufacturing (reference Figure 2-9), accounting for $257 billion globally in 2018, and $64.3 billion in North America alone [8]. Prior to the COVID-19 pandemic, the global market for contract manufacturing was expected to grow by 5.6% annually through 2023 [8]. The impact of the pandemic has pushed firms to be more efficient with resources and the net effect on contract manufacturing has yet to been seen. The services offered by CMs has ballooned over the past few years to include all aspects of the production process, from design, engineering, manufacturing, logistics, and maintenance [8].

While the general trend points to increasing levels of outsourcing, especially in the consumer electronics industry, there are compelling cases for vertical integration. For example, in 2018 aerospace giant Boeing announced insourcing as a key initiative to reduce costs [25] and Elon Musk attributes Tesla’s ability to innovate and disrupt, to its structure of being “absurdly vertically integrated” [26].

# Chapter 3: Literature Review and Project Motivation

## 3.1 Literature Review

According the prominent economist and Nobel laureate, Oliver Williamson, "the decision to outsource a technologically separable good or service, or to integrate (produce one's own needs) turn(s) on transaction cost differences" [27].

Transaction Cost Economics (TCE) is one of the most prolific and widely referenced theories of organization in operations and supply chain management research [28]. It builds upon the foundations of Ronald Coase and the theory of the firm, which establishes the firm and market as two alternative means of production and defines the border between them [29]. One of the core tenets of TCE is that buyer-supplier transactions can occur internally within a firm (i.e., a manufacturing process is performed by an internal production area) or externally across firms (outsourcing) and there are transaction costs with either mode of governance [28]. The focal point for analysis is then the make-or-buy decision and the objective is to employ the mode of governance which maximizes efficiency [30]. TCE focuses on two polar modes of governance, market (buy) and hierarchy (make).

Building on this objective of choosing the most efficient form of governance, there are many methods of evaluating the efficiency of various options. There is ample and rich literature on strategic supply chain management, especially on the topics of globalization and cost analysis methodologies. Such methodologies include Total Cost of Ownership (TCO), Total Landed Cost (TLC), and Total Value Contribution (TVC). Each of these approaches expands upon the most basic unit-cost analysis to include other cost or value factors that are relevant to the sourcing decision. In their 2020 Journal of Operations Management article introducing the concept of TVC [10], Gray, Helper, and Osborn provide a comparison of these various analysis tools, which is provided in Table 3.1.

*Table 3.1: Comparison of sourcing approaches [10]*

| Approach | Factors considered | Advantages | Disadvantages |
| --- | --- | --- | --- |
| Piece-price/lowest quote | Unit price | Very easy to understand<br>Very easy to implement<br>Requires little data<br>Objective; clear incentives for decision makers | Does not consider nonprice cost elements[a]<br>Does not consider revenue-generating factors<br>Does not consider risks |
| Total landed cost (TLC) | As above, plus: Shipping and handling costs; trade compliance costs; inventory costs | Easy to understand<br>Conceptually easy to implement (can be tedious)<br>Considers more cost elements than piece-price<br>Objective; clear incentives for decision makers | Does not consider all nonprice cost elements<br>Does not consider revenue-generating factors<br>Does not consider risks |
| Total cost of ownership (TCO)[b] | As above, plus: Design and development costs; startup/switching costs; training costs; operating costs; software costs; governance costs (e.g., monitoring); supply chain support costs; retirement/disposal costs | Provides a framework for identifying relevant factors<br>Tends to result in lower total costs than piece-price, TLC<br>Information gathered has secondary uses | Anchors decision makers on cost<br>Does not explicitly consider revenue-generating factors or factors related to risk<br>Difficult and time-consuming to fully implement |
| Total value contribution (TVC) | As above, plus risk: Costs of shortages, disruptions, and downtime; risk of brand damage; risk of loss of IP<br>As above, plus revenue: Social/environmental performance; product and service quality; other factors affecting demand/willingness-to-pay<br>As above, plus the value of options: Capacity for future growth; innovation capabilities; the potential to learn from suppliers; factors that affect the firm's social license to operate<br>As above, plus the potential to identify factors not listed here through a cross-functional process | Conceptually correct<br>TVC process anchors on customer value, not cost<br>Provides a framework for identifying relevant factors, and an implementation process<br>Information gathered has secondary uses | Subjectivity in the decision factors considered<br>Difficult to quantify differences between options<br>Difficult and time-consuming to fully implement |

[a]Any factors not included in the selection stage may be included in a prequalification stage on a pass/fail basis; this applies to all factors and all approaches.
[b]We acknowledge that best-in-class TCO models can include some risk and value factors, as well as the cost categories listed here.

However, there is very little research on strategies to operationalize continuous evaluation of the make-or-buy decision for production processes. This is specifically the realm of contract manufacturing. By focusing on business processes and analysis tools, we contend that it is possible to institutionalize continuous reevaluation of sourcing decisions and associated transaction costs. This idea introduces the principal motivation and hypothesis of this project.

***Hypothesis:*** *Total cost analysis can be used to operationalize strategic sourcing decision.*

## 3.2 Pratt & Whitney Vendor Assist Process

The Pratt & Whitney business process by which contract manufacturing work is outsourced is called Vendor Assist. It differs from the standard procurement process used to purchase parts in that it is more flexible and requires fewer steps to execute. This provides the Mod Centers with agility in planning their production schedules. Tactically, the process is well defined, with standard work established for each step in the process, including engineering evaluation of the outsourcing proposal, a process for soliciting and evaluating bids from different suppliers, and mature quality controls. However, there exists an opportunity to improve the associated business oversight. For example, it was difficult to answer the questions "what are we outsourcing and should we be doing it?" This visibility was difficult to provide because of rapid growth in this initially obscure cost category, with no mechanism for integration across Mod Centers. The Vendor Assist cost category increased significantly over the last 5 years; Vendor Assist spend grew at an annualized rate of 28%, compared to 16% annualized growth in volume outsourced (see Figure 3-1). Additionally, there was a perception among Pratt & Whitney leadership that they should be able to perform most manufacturing processes more efficiently internally, but there was no systematic way of evaluating this assertion.

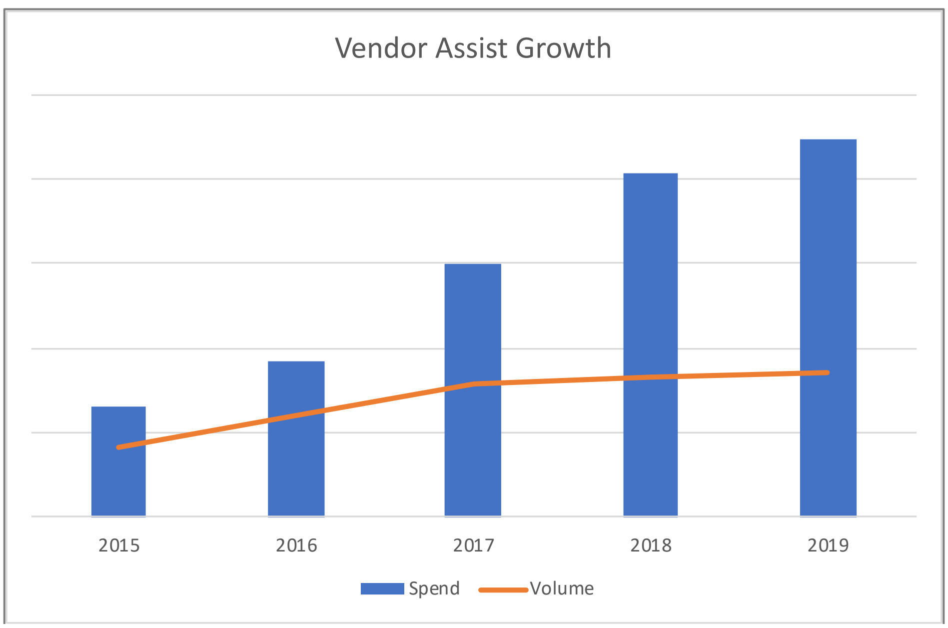



*Figure 3-1: Growth of Vendor Assist spend and volume from 2015 - 2019*

The decision on whether to make or buy a production process for an individual part is held locally, by factory leadership. There was very little integration across Mod Centers. As a result, if multiple Mod Centers were outsourcing the same type of process, the opportunity to invest in that process capability and create a center of excellence was overlooked, let alone the opportunity to consolidate vendors and negotiate bulk discounts. Furthermore, if one Mod Center had capabilities or capacity needed by another, there was no systematic way to gain that insight.

There are three primary reasons a Module Center might choose to outsource:

1. They do not have the capability to perform the process. Usually this is due to a lack of equipment or expertise. This results in "permanent outsourcing." Within the Vendor Assist business process, this is considered Permanent Vendor Assist (PVA).
2. There is insufficient capacity to perform the process. This can be either a long-term situation, for which it requires capital investment to meet current and future planned rates; or a short-term situation, such as planned equipment down-time or for one-off developmental parts. In either situation, this is considered a Temporary Vendor Assist (TVA).
3. Finally, it might be desirable to maintain a second source of supply for risk mitigation purposes. This is also considered a TVA.

The distinction between permanent (PVA) and temporary (TVA) outsourcing is an important one. Essentially the difference is that PVA part-processes are outsourced due to lack of capability, while it is lack of capacity for TVA. Our estimation of transaction costs will be relevant to both types of order, however our ability to compare outsourcing costs with internal equivalent costs will be limited to TVA only. Due to the lack of manufacturing capability, estimating PVA costs would require extensive analysis into non-recurring capital expenditures in addition to assumptions about unit costs and overhead. This is beyond the scope of this study. As depicted in Figure 3-2, the bulk of Vendor Assist orders fall into the TVA category (about $^2/_3$).

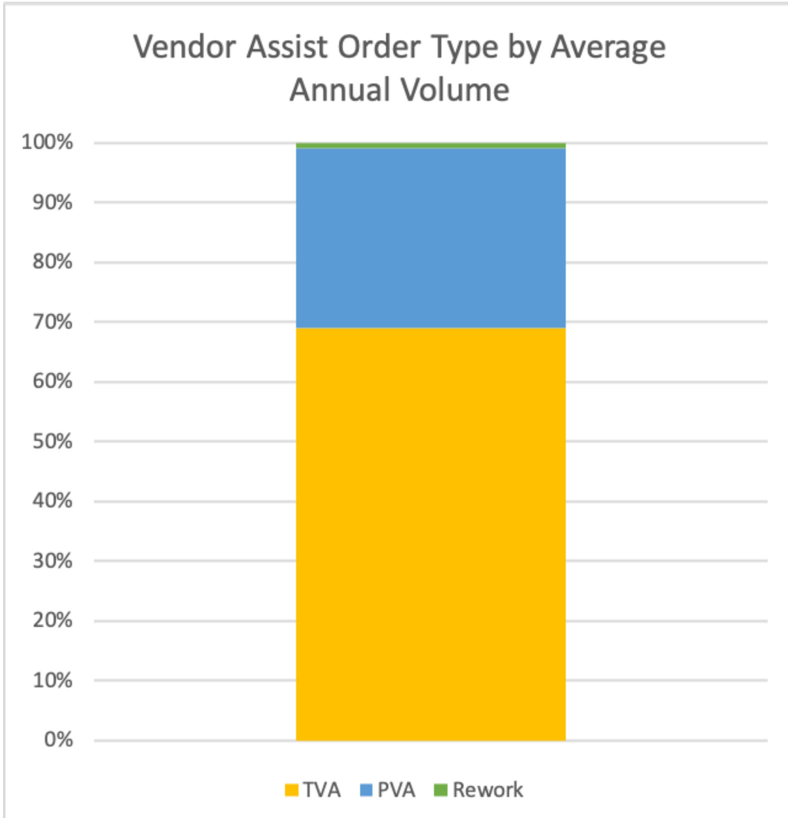



*Figure 3-2: Vendor Assist order type by volume*

While the term Temporary Vendor Assist may lead you believe that these arrangements are short lived, that is not the case. Of the 2020 Vendor Assist orders, almost 70% of part-processes had been outsourced continuously since 2018 and 25% had been outsourced for the last 5 years (since 2016).

You might observe from Figure 3-2 that Rework is an additional Vendor Assist order type. This represents less than 1% of the total volume of Vendor Assist. This is typically to resolve non-conformances which require processes that cannot be performed internally.

A comparison of unit costs between performing a process internally versus externally is almost always the basis by which outsourcing is either justified or vilified. However, this method of analysis fails to capture relevant transaction costs. In order to operationalize this deeper level of analysis, we focus on data that is readily available in any purchase order. By scraping relevant data from the purchase order, it is possible to automate estimation of transaction costs and institutionalize regular management reviews. Furthermore, it is undesirable to create a "black box" tool which would be difficult to understand and interpret. In order to ensure that operations leaders would feel comfortable using whatever tool we develop, it must be simple, understandable, and transparent. Microsoft Excel is widely used and prolific at Pratt & Whitney. Therefore, to promote adoption, we will create an Excel-based tool to estimate these transaction costs. These considerations lead to the definition of our overall strategy.

***Strategy:*** *Automate estimation of transaction costs using accessible tools and data readily available in existing reports, then institutionalize management reviews of Vendor Assist business impact.*

Additionally, where it is necessary to make assumptions about various inputs, we endeavor to apply more conservative estimates, resulting in relative underestimation of transaction costs. Most of our analysis occurs on a per-unit basis, while batch-ordering is the norm for Vendor Assist. We arrived at this strategy of conservative estimation to offset any economies of batch size.

# Chapter 4: Approach and Methodology

## 4.1 Production Process Categorization

It is first important to identify which processes are routinely outsourced. In serial production, each subsequent manufacturing process changes the configuration of the part and adds value. Most metallic engine components will follow a similar general process:

1. Pre-Forming

2. Forming

3. Heat Treating

4. Machining

5. Finishing

6. Coating

7. Inspecting

Often, machining and inspecting processes occur multiple times throughout the value chain. For example, conventional machining occurs to obtain the net shape of the part after forming and airfoils receive laser-drilled cooling holes after coating as well; basic inspections occur after almost any process. In order to refine historical data, it is first necessary to define categorical relationships for the relevant production processes. These are provided in Table 4.1. While this captures all of the relevant major categories, the processes associated with them are illustrative and not comprehensive.

*Table 4.1: Categorization of manufacturing processes*

| Manufacturing Process Categories | | |
|---|---|---|
| **Category** | **Sub-Category** | **Process** |
| Forming | Forging | Die Forging |
| | | Cold Forging |
| | | Seamless Rolled Ring Forging |
| | Casting | Investment Casting |
| | | Die Casting |
| | | Sand Casting |
| | | Single Crystal Casting |
| | Hot Isostatic Pressing | Hot Isostatic Pressing |
| | Additive Manufacturing | Powderbed Fusion |
| | | Directed Energy Deposition |
| | | Vat Photopolymerization |
| Heat Treatment | Heat Treatment | Brazing |
| | | Furnace |
| | | Induction |
| Machining | Conventional | Turning |
| | | Milling |
| | | Drilling, Reaming, Boring, Honing |
| | | Broaching |
| | | 5-Axis |
| | Non-Conventional | Electric Discharge Machining (EDM) |
| | | Laser |
| | | Waterjet |
| Chemical | Chem Machining | Chem Stripping |
| | | Chem Milling |
| | | Etching |
| | Chem Inspection | Flourescent Penetrant Inspection (FPI) |
| Surface Treatment | Coating | Thermal Spray |
| | | Vapor Deposition |
| | | Diffusion Coating |
| | Plating | Electroplating |
| | | Immersion Plating |
| | Finishing | Peening |
| | | Blasting |
| | | Lapping |
| | | Burnishing |
| Welding | Welding | Electron Beam Welding |
| | | Diffusion Bonding |
| | | Laser Beam Welding |
| | | Plasma Arc Welding |
| | | Gas Tungsten Arc |
| Testing & Inspection | Inspection | CMM |
| | | Surface Laser |
| | | Sonic Inspection |
| | Testing | Non-Destructive Testing |
| | | Balance Testing |
| Composites | Composites | Ceramic Matrix Composites (CMC) |
| | | Organic Matrix Composites (OMC) |

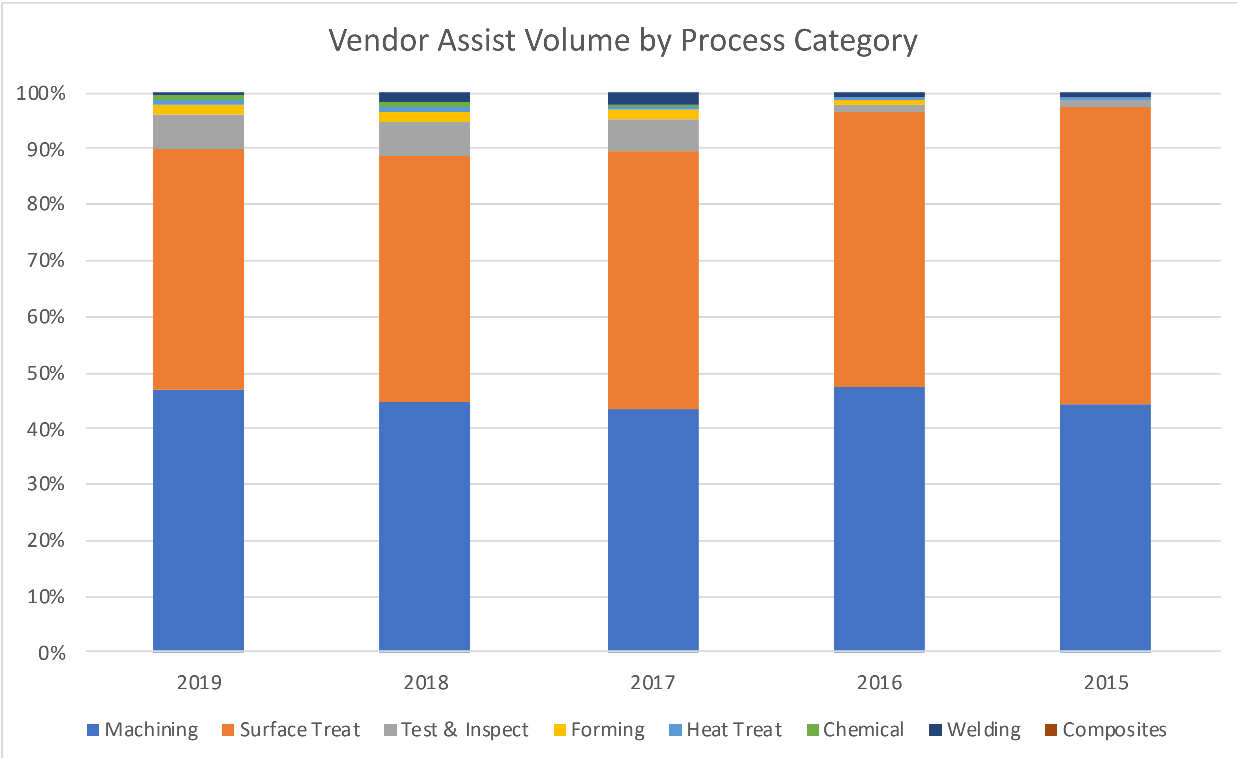



*Figure 4-1: Volume of Vendor Assist orders by manufacturing process category*

However, not all of these processes are routinely outsourced. After defining this categorization, we can take a look at the relative volume of outsourcing (Figure 4-1). Machining processes make up 47% of outsourcing volume, followed by surface treatment processes at 43%. We can also see that Test & Inspection is a growing process category for outsourcing.

The cost of each of these processes is not equal. Figure 4-2 depicts the average unit cost for each manufacturing category. Indeed, there is a wide gap between the unit cost of manufacturing for composite processes and chemical.

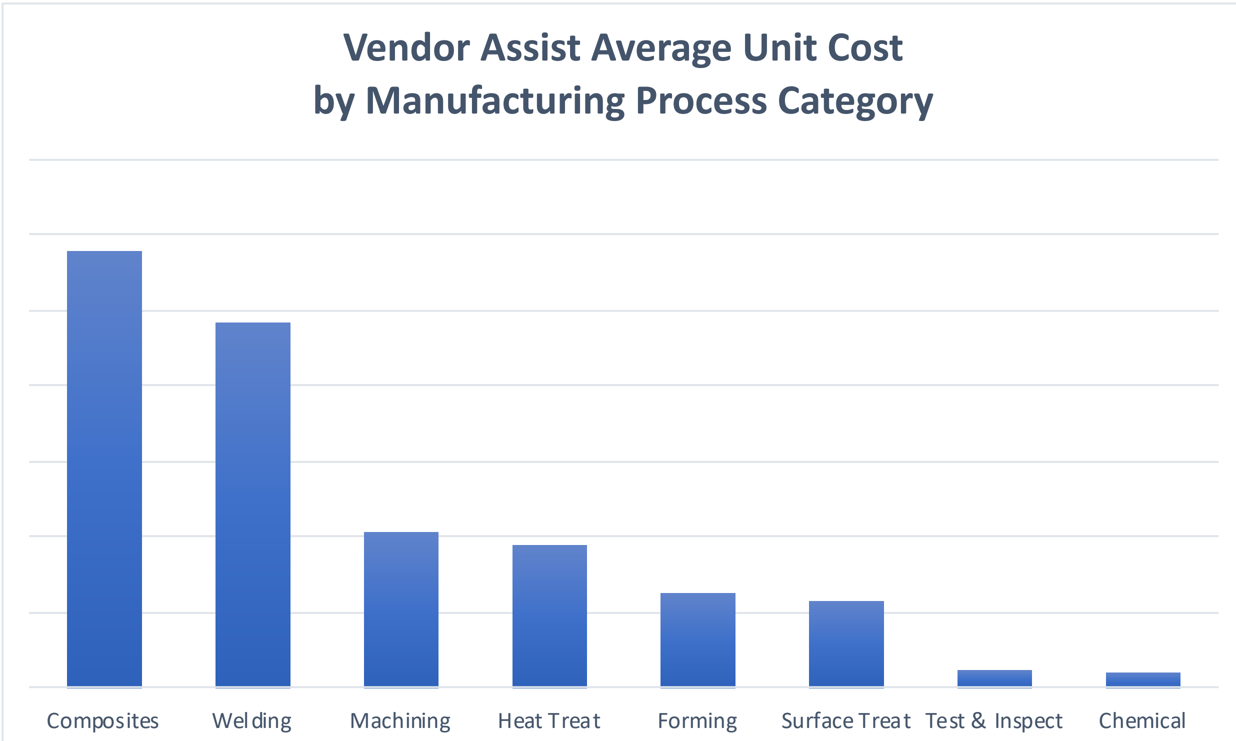


*Figure 4-2: Average unit cost of Vendor Assist by manufacturing process category*

## 4.2 Business Process and Governance

Paraphrasing the words of Peter Drucker, "you can't manage what you can't measure." Metrics drive behavior and they are an integral part of business oversight. As described previously, at Pratt & Whitney, the Vendor Assist cost category had grown from a relatively insignificant source of cost, to becoming a major lever for cost reductions (reference Figure 3-1). While the Mod Centers developed forecasts for annual Vendor Assist spend, they were never accountable to any financial targets. This lack of oversight contributed to the astounding year-over-year growth observed over the last 5 years. Therefore, the logical first step in managing this process is to develop financial targets and metrics.

Working with Mod Center leaders across Pratt & Whitney, we defined their 2020 Vendor Assist plan. Because this was a new activity, it required review of historical trends, combined with forward-looking rate and production forecasts. Additionally, it was necessary to revise this plan midway through the year due to volume reductions in the post-COVID-19 business environment.

Recall that one key element of our strategy is to make decisions about the analysis tool and its deployment which promote adoption. With regard to developing the business process and governance, this means leveraging existing business practices and working within the existing culture.

At Pratt & Whitney, defining a process requires developing standard work. Standard work, being one of the lean manufacturing principles, is prolific and widely used at Pratt & Whitney. As mentioned previously, robust standard work exists for the Vendor Assist process, detailing tactical steps, such as how to write work instructions for a vendor, obtain bids, contract with a vendor, manage compliance and quality requirements, etc. However, the standard work for assessing the business impact of sourcing decisions, falls short when it comes to short term outsourcing to CMs. Each Mod Center managed their Vendor Assist decisions differently. These decisions were not often revisited and there was little accountability for bringing temporarily out-sourced work back in-house. Therefore, what would start as a temporary sourcing plan would eventually become the baseline sustaining plan.

To address these gaps, we can start by mapping out the Vendor Assist process as it stands today. The major process steps are illustrated in Figure 4-3.

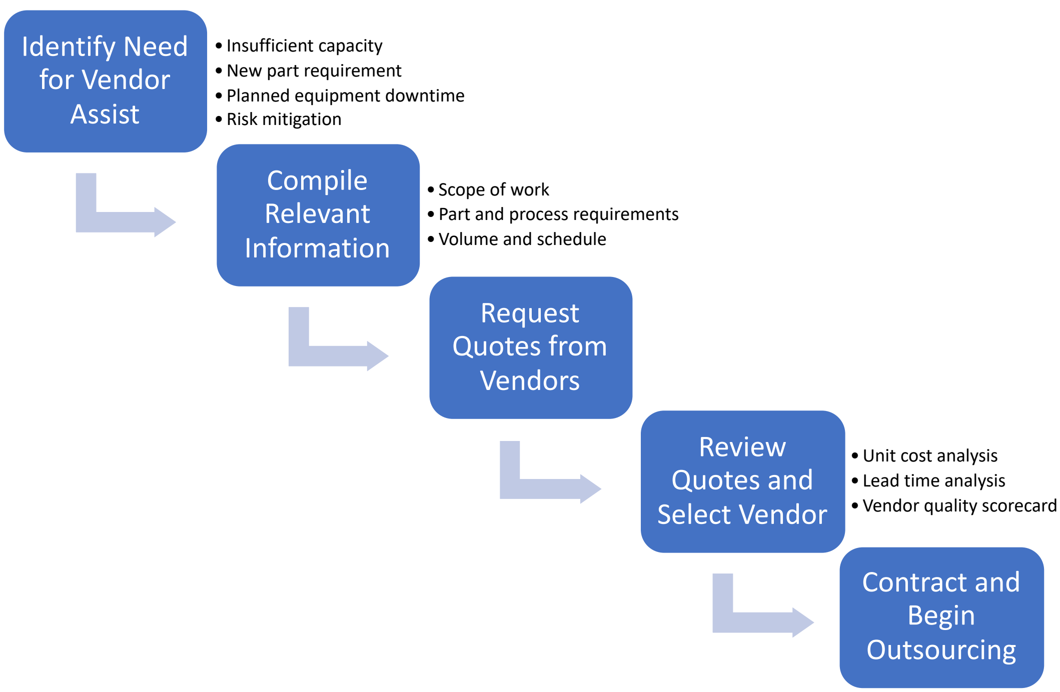



*Figure 4-3: Vendor Assist process steps*

Vendor Assist was designed to be a nimble process, with fewer bureaucratic hurdles to enable quick turn-around production flexibility. We do not want to impede this process by adding a management oversight step, because often Vendor Assist is pursued when few other options exist to answer the demand within the required time-frame. Therefore, our strategy will be to employ regular management reviews.

The cadence of business at Pratt & Whitney is monthly. Most major leadership reviews occur on a monthly basis. There are established monthly venues for reviewing production plans, cost reduction opportunities, and various other initiatives. Therefore, we instituted monthly management reviews for each Mod Center as well as an integrated review at the COO level. This would provide awareness and accountability of what is being outsourced and how that impacts performance to financial targets and utilization of existing assets. Additionally, at the integration review, Mod Center leaders are expected to identify available capacity for processes which are outsourced by other Mod Centers. We developed the standard that this should be part of the monthly review; previously it would occur informally based on individual networks. While this is still an acceptable means of coordinating this activity, it is subject to gaps. The monthly management review establishes the expectation and provides accountability.

Figure 4-4 provides a view of what a dashboard for a theoretical Mod Center might look like.


*Figure 4-4: Module Center monthly management dashboard example (data represented here is fictitious, for illustrative purposes only)*

In addition to monthly management reviews, we recommended a bi-annual review of all TVAs. This would ensure that continuing to outsource a process is a conscious, strategic decision rather than inertial. The bi-annual review must be a comparative analysis of what it takes to perform the process internally vs. externally. To accurately represent the impact, it requires estimation of transaction costs. The relevant transaction costs which must be considered are:

- The cost of additional quality inspections
- The cost of shipping and handling
- The cost of packaging
- The cost of carrying excess inventory

## 4.3 Cost of Additional Quality Inspections

While testing and inspection is a routinely outsourced process, each part must undergo an inspection upon receipt at Pratt & Whitney. Quality inspectors at Pratt & Whitney will check to ensure that the part meets design requirements, is appropriately labeled, and comes with all required documentation, before routing to the appropriate subsequent work area. These additional inspections have a cost associated with them. This cost element is not explicitly captured and is difficult to measure. Receiving inspectors perform these operations on all parts received, not just for Vendor Assist parts. Isolating the portion of their effort dedicated to Vendor Assist would be extremely challenging. Rather, we establish an estimate for how long it takes to complete this inspection for the average Vendor Assist part. Parts received in batch may take much less time and large, complex parts could take much longer. By estimating the fully burdened salary of a quality analyst, we arrive at a $1.20 per unit cost estimate for additional quality inspections (see Table 4.2 for calculation details).

*Table 4.2: Calculation for cost of additional quality inspections*

**Cost of Additional Quality Inspections**

| | | |
|---|---|---|
| [A] Estimated Avg Annual Salary for Quality Inspector | *Figures withheld to obscure proprietary information* | $ / year |
| [B] Estimated Labor Burden Rate | | % of base salary |
| [C] Hours per Work Year | | hours / year |
| [D] Estimated Fully Burdened Hourly Rate [A * (1+B) / C] | | $ / hour |
| [E] Estimated Avg Inspection Time | | min / part |
| [F] Estimated Cost of Addt'l Quality Inspections [(E / 60) * D] | **$1.20** | **$ / part** |

This may seem insignificant, however, when evaluating volumes in the thousands of parts per year, the cost of additional quality inspections becomes a significant opportunity. More significant, however are the costs of shipping and handling.

## 4.4 Cost of Shipping and Handling

Most of Pratt & Whitney's Vendor Assist suppliers are located in the US or Canada. As a part travels through its value chain, it might cross the United States multiple times. Figure 4-5 depicts the theoretical routing for a part from initiation to finished part.

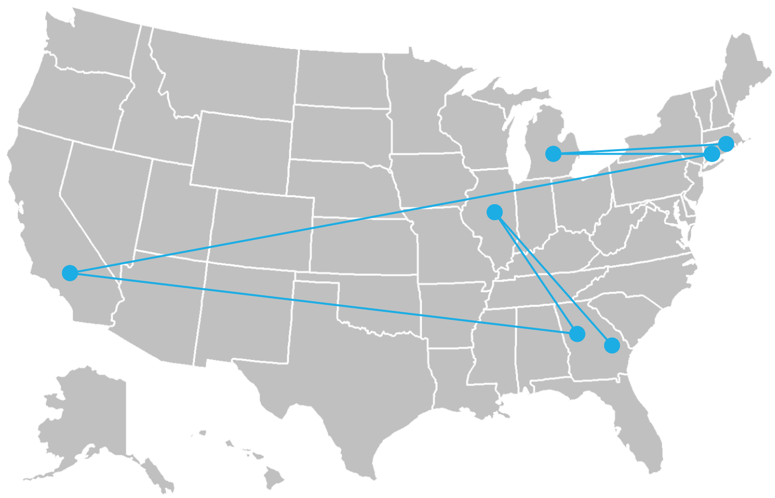


*Figure 4-5: Theoretical routing of a Vendor Assist part throughout its life-cycle*

Pratt & Whitney maintains contracts with logistics providers for shipping and handling between facilities or suppliers. Again, it is difficult to isolate the portion of shipping cost attributed to an individual part due to batch shipments. Additionally, parts vary in size from shafts and fan blades which can be almost as tall as a person, to airfoils which fit in the palm of your hand.

Most carriers use dimensional weight pricing to calculate shipping costs. This method of pricing balances the impact of weight and volume by establishing a density factor and an associated minimum weight [31]. UPS and FedEx currently use a density factor of 12lbs per cubic foot. Therefore, a 1-cubic-foot box will have a minimum weight of 12lbs. If the package weighs less than 12lbs, the minimum weight will drive the cost; if it weighs more, the actual weight will drive the cost. For high density materials, such as the metals used in jet engine parts, it is likely that the actual weight will determine shipping costs. Without getting into part-specific geometry, we can make a simplifying assumption that the average Vendor Assist part (including packaging) weights about 10lbs. There are some that weigh much more (such as disks which can weigh up to 50lbs) but many other metallic details which weigh less. For the purposes of aggregate estimation, using this average weight is sufficient to illustrate the point.

Shipping distance is the other major determinant of cost. While distance is not included in purchase orders, we do know the origin and destination locations. We first built a key, which identified the latitude and longitude of all cities which contain Pratt & Whitney's US factories and all Vendor Assist supplier factories. Then using the Haversine, or Great-Circle Formula, we can estimate the distance between origin and destination cities using Equation 4.1.

$$\mathrm{d} = 2\mathrm{r} * \arcsin\left(\sqrt{sin^2\left(\frac{\phi_2 - \phi_1}{2}\right) + \cos(\phi_1) * \cos(\phi_2) * sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$
$$r = radius\ of\ the\ Earth = 3958.8\ mi$$
$$\phi_i = latitude\ at\ location\ i\ (radians)$$
$$\lambda_i = longitude\ at\ location\ i\ (radians) \tag{4.1}$$

However, due to circuity of logistics in the United States, it is necessary to apply a circuity factor. A circuity factor of 1.2 is associated with the Eastern US, based on research from R.H. Ballou et al [32]. Table 4.3 summarizes this calculation for a Vendor Assist coming out of East Hartford, CT for an arbitrary vendor in Dallas, TX.

*Table 4.3: Calculation of shipping distance for a theoretical part routing*

| | Origin | Destination |
|---|---|---|
| Description | Pratt & Whitney | Vendor A |
| City | East Hartford, CT | Dallas, Tx |
| Longitude, λ (radians) | 0.7289 | 0.5721 |
| Latitude, ϕ (radians) | 1.2673 | 1.6894 |
| Radius of Earth, r (mi) | 3958.8 | |
| Haversine Distance, Hd (mi)<br>Hd=2r*arcsin(√ (sin^2 ((ϕ2-ϕ1)/2) + cos(ϕ1 )*cos(ϕ2 )*sin^2 ((λ2 - λ_)/2))) | 1667 | |
| Circuity Factor, Cf (US East) | 1.2 | |
| Estimated One-way Distance, D<br>D = Cf * Hd | 2000 | |

Combining weight and distance, we can estimate the associated shipping cost. To be conservative, we used rates from the United States Postal Office's (USPS) slowest and least expensive ground shipping service, Parcel Select. The fee structure is based on zones which correspond to distance thresholds. The rates for each zone for various package weights are provided in Table 4.4.

*Table 4.4: USPS Parcel Select Fee Structure for packages of various weights [11] and [12]*

| Zone | 1 & 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Radial Distance from origin (miles) | 150 | 151 - 300 | 301 - 600 | 601 - 1000 | 1001 - 1400 | 1401 - 1800 | 1801 + |
| Fee for 2lb DIM weight | $ 7.54 | $ 7.74 | $ 8.02 | $ 8.61 | $ 9.79 | $ 10.29 | $ 10.89 |
| Fee for 5lb DIM weight | $ 7.94 | $ 8.40 | $ 9.29 | $ 10.44 | $ 15.89 | $ 18.16 | $ 20.66 |
| Fee for 10lb DIM weight | $ 9.66 | $ 11.00 | $ 12.06 | $ 20.10 | $ 26.42 | $ 31.73 | $ 37.43 |
| Fee for 15lb DIM weight | $ 13.69 | $ 16.80 | $ 19.43 | $ 28.14 | $ 37.20 | $ 42.69 | $ 49.53 |

Figure 4-6 provides a breakdown of the volume of Vendor Assist parts according to their shipping zone. The average round-trip distance that a Vendor Assist order travels is 1,165 miles. In addition to the cost of shipping, there is a negative externality associated with carbon emissions from shipping and waste from packaging. Although it is not explicitly captured as a transaction cost, it negatively impacts progress toward Raytheon's sustainability commitments.

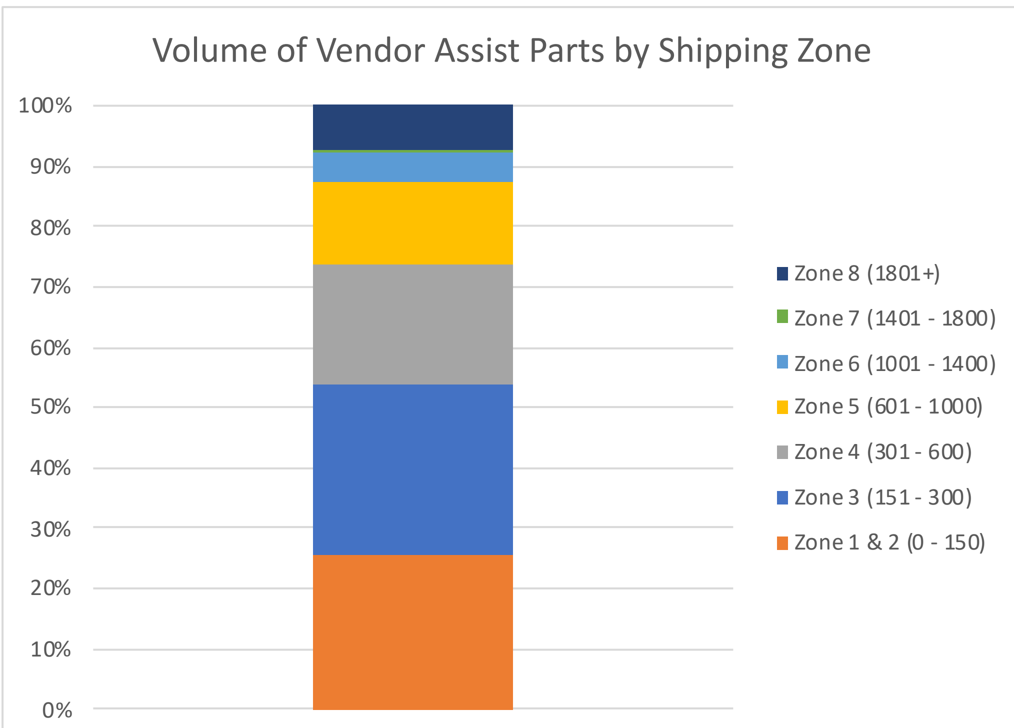



*Figure 4-6: Volume of Vendor Assist parts by shipping zone*

Finally, because most Vendor Assist shipments are round-trip (a part is sent to a supplier to perform a process, then they return ship it once their work statement is complete), it is necessary to calculate the round-trip shipping distance. Some contracts include drop shipments where one supplier will ship to another. In that scenario, we calculate only one leg of the shipment because the other will be captured in the transaction costs of the subsequent Vendor Assist estimation. The resulting average shipping cost per part is over $22 and it represents a significant contribution to the total cost metric.

## 4.5 Special Charges

The shipping fee we just introduced, corresponds to a slow method of ground transportation. When parts are needed quickly, expedite fees apply. Looking at historical data, it is easy to identify special charges, such as fees for expedite, overtime, and non-recurring engineering (as a result of a design change for an existing part, or introduction of a new part). Historically, less than 1% of the volume of Vendor Assist orders contain expedite fees. It's a useful backward-looking metric, but should not be included in our baseline total cost estimation.

## 4.6 Cost of Preparation and Packaging

Shipping fees do not include the cost of packaging or internal handling. Since our objective is to identify incremental transaction costs associated with outsourcing, we can omit the internal handling estimate. This is based on the assumption that if Pratt & Whitney were to perform the process internally, they would still have to move parts from one part of their factory to another. However, internal movements would likely use bins or rotatable containers for transportation. Therefore, we must include an estimate for packaging. Packaging costs are assumed to be $1/part. This corresponds to bulk pricing for cardboard boxes and assumes some batch shipping. However, this is likely a conservative estimate.

## 4.7 Cost of Carrying Excess Inventory

There is a cost associated with carrying additional inventory. Often, this cost is attributed to managing, warehousing, financing, and insuring finished goods inventory, and may even include the opportunity cost of capital. The Vendor Assist decision impacts the amount of Work-In-Process (WIP) inventory needed, rather than finished goods waiting to be sold. Therefore, our estimation of holding rate will focus more on financing and insuring additional inventory, and not include warehousing infrastructure costs such as those related to inventory storage and movement equipment. In order to arrive at an estimate for the cost associated with carrying additional inventory, we will first estimate the lead time impact, then the holding rate.

The difference in lead time between performing a process internally and outsourcing it, comes from required transit time and additional processing, both internally and at the supplier. The time required to perform the actual statement of work is not relevant because that time would be required for either sourcing decision. This, of course, assumes that both Pratt & Whitney and their supplier have the capability to perform the work at the same rate. Again, using the shipping zones described previously (Table 4.4), we estimate the total lead time impact ($LT$) associated with processing and shipping, depending on the distance traveled. Table 4.5 provides our calculation for lead time impact, using assumptions about average duration. Once again, if the contract includes drop-shipping, the return shipment would have no impact on lead time, as this effect would be captured in the subsequent Vendor Assist order.

*Table 4.5: Calculation for lead time*

| Zone | 1 & 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Days Required for Shipping | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Days Required for Supplier Processing | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Days Required for Return Shipping (if no drop ship) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Days Required for Internal Processing | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Est. Total Lead Time Impact (days)** | **5** | **7** | **9** | **11** | **13** | **15** | **17** |
| **Est. Total Lead Time Impact (months)** | **0.17** | **0.23** | **0.30** | **0.37** | **0.43** | **0.50** | **0.57** |

To arrive at an estimate for excess carrying quantity ($Q_{EC}$), we need a measure of monthly demand ($D$), or at Pratt & Whitney, monthly production commitments. This forecast is known and managed by operations leaders. It includes parts required for production of original equipment, as well as a forecast of aftermarket part demand (spares), and any production recovery or build-ahead requirements. Using production commitment data is certainly the most accurate way to estimate quantity, but we can make some simplifying assumptions and omit this data source.

Recall, that we are trying to build our tool using only data available in the purchase order. Almost all Vendor Assist orders operate on an all or nothing basis. That is, either all of the monthly demand for a part is outsourced, or none of it. Therefore, demand is equal to the outsourced quantity. There are some exceptions, one Mod Center in particular manages their Vendor Assist by outsourcing pre-determined percentages of monthly demand. In that scenario, it would be possible to build a key which identifies which parts are only partially outsourced; this is the approach we took to estimating monthly demand. Then we arrive at the excess carrying quantity ($Q_{EC}$), using the Equation 4.2.

$$Q_{EC} = LT * D \tag{4.2}$$

$Q_{EC}$ represents the additional units that are in process at any given time, due to the decision to outsource a specified process. At Pratt & Whitney, this results in about a 2% increase in WIP inventory (quantity) for Vendor Assist parts. These parts are spread throughout the value chain. As mentioned previously, some parts have multiple processes outsourced throughout their life cycle. A *Total* $Q_{EC}$ would require summing the effect from each individual Vendor Assist.

We will define excess carrying cost ($C_{EC}$) in terms of excess carrying quantity ($Q_{EC}$), the cost of the part ($C$), and the holding rate ($h$) in Equation 4.3.

$$C_{EC} = Q_{EC} * C * h \tag{4.3}$$

In serial production processes, each subsequent process adds value to the part. $C$ ideally represents the value of the part at the relevant stage in the process. Because the impact of the sourcing decision results in increased levels of WIP inventory spread throughout the value chain, we will use the Vendor Assist unit cost as a proxy for part value. This results in an underestimation of $C_{EC}$.

In order to estimate the holding rate, we first calculated Pratt & Whitney's former parent company, United Technology Corporation's annual interest rate to be about 4.26%, based on 2019 financial statements [18], reference Equation 4.4. This represents a lower bound for our holding rate estimate.

$$Approx. Cost\ of\ Capital = \frac{2019\ Interest\ Expense}{2019\ Long\ Term\ Debt\ Balance} = \frac{1{,}611}{37{,}788} = 4.26\% \tag{4.4}$$

In addition to the cost of capital, the holding rate should include some measure of insurance and risk. Risk of obsolescence is certainly non-trivial in the aerospace industry, as designs and industry standards are ever in flux. To account for these factors, we increase our estimate for the holding rate to 7% for carrying additional WIP associated with Vendor Assist. For comparison, the typical holding rate is about 20 - 30% for warehousing and holding finished goods inventory across industries [33]. Our parameter is significantly below this range due to the difference in scope that it captures.

Based on this estimation, the average cost of carrying excess inventory is $0.58 per unit. This is far less than 1% the unit cost. While this may seem trivial, it is a relevant cost factor which may tip the scales of a business case, especially when considering high volumes. Furthermore, the cost of carrying excess inventory scales linearly with holding rate, so if we feel that 7% is too conservative, it is possible to parametrically adjust this estimation. For example, if we feel this holding rate should be doubled to 14%, it has the effect of doubling the cost of carrying excess inventory to $1.15.

## 4.8 Summary of Total Cost Elements

Table 4.6 and Figure 4-7 summarize the various the cost elements we just estimated. The contribution from shipping is the most significant, making up almost 90% of the transaction cost. Average transaction costs, based on our assumptions, totaled $25 for the average part, or 10% of the unit cost. Therefore, when conducting a business case analysis based on unit cost alone, these hidden transaction costs cause an underestimation of actual costs to enterprise by approximately 10%.

*Table 4.6: Summary of Vendor Assist transaction costs*

| Cost Element | Avg per Part | |
|---|---|---|
| Theoretical Unit Cost | $ | 250.00 |
| Cost of Shipping | $ | 22.23 |
| Cost of Additional Quality Inspections | $ | 1.20 |
| Cost of Preparation and Packaging | $ | 1.00 |
| Cost of Carrying Excess Inventory | $ | 0.40 |
| **Total Relevant Transaction Costs** | **$** | **24.83** |
| **% of Unit Cost** | | **9.9%** |

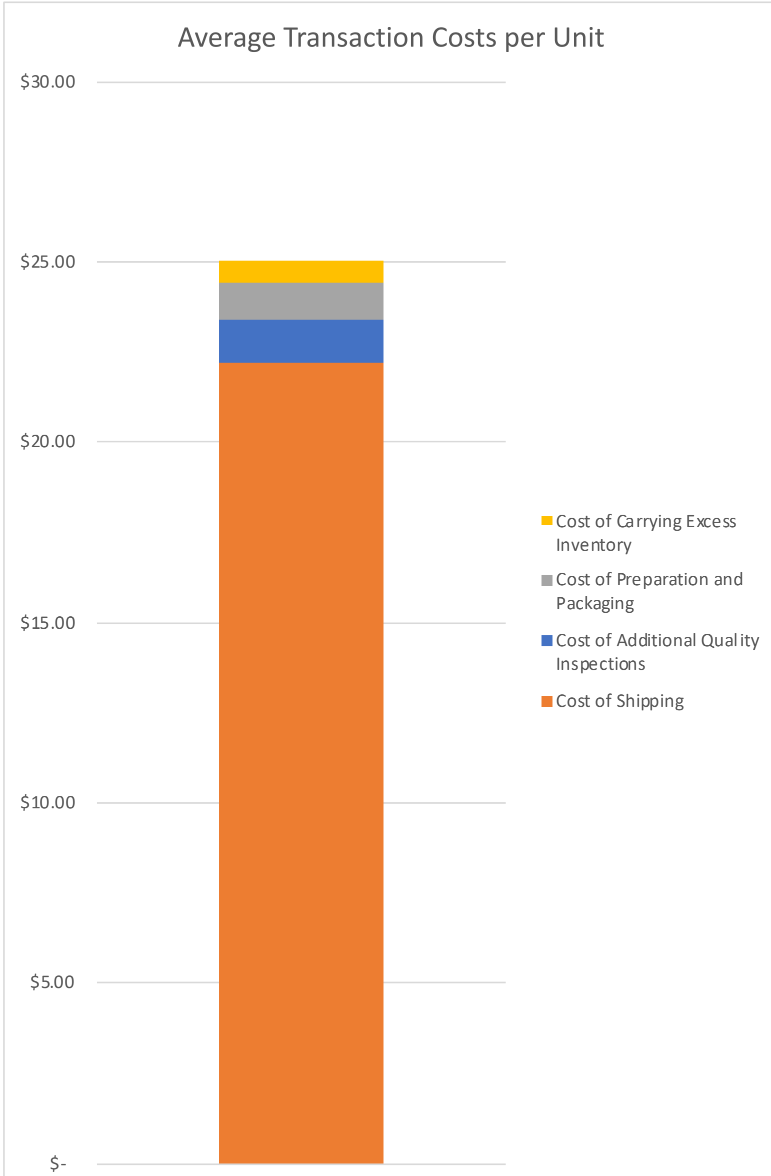



*Figure 4-7: Vendor Assist average transaction costs*

## 4.9 Comparison to Internal Processes

The value of TCE comes in the form of a comparative metric between two different modes of governance [30]. Therefore, it is still necessary to compare the cost of outsourcing to the cost of performing the work internally. Obtaining this internal cost estimate typically involves evaluating actual internal costs for similar part-processes. If the capability to perform the process internally does not exist, this becomes more complicated, requiring a more extensive business case analysis for procurement of new equipment as well as non-recurring and recurring engineering, labor, and overhead requirements. This is the primary reason for focusing on Temporary Vendor Assist (TVA) orders; for TVA orders, internal capabilities exist.

Indeed, often the part-process was performed internally at one point or another. Despite our objective of using only purchase order data, this input requires analysis from Mod Center personnel. Luckily, as part of our on-site research, we were able to obtain some of these internal equivalent process cost estimates.

In response to the COVID-19 business environment, Pratt & Whitney reduced production commitments and pursued immediate cost containment measures. One of these measures included insourcing of Vendor Assist work to enable better asset utilization in light of reduced production output. Mod Center leaders performed a comparative unit cost analysis to identify the best candidate part-processes for insourcing.

Figure 4-8 summarizes the cost comparison of outsourcing and insourcing for an individual Mod Center. Based on the unit cost analysis and newly available capacity, 61% of TVA part-processes were more cost effective to perform internally. When including transaction costs in this analysis, that increases to 69%.

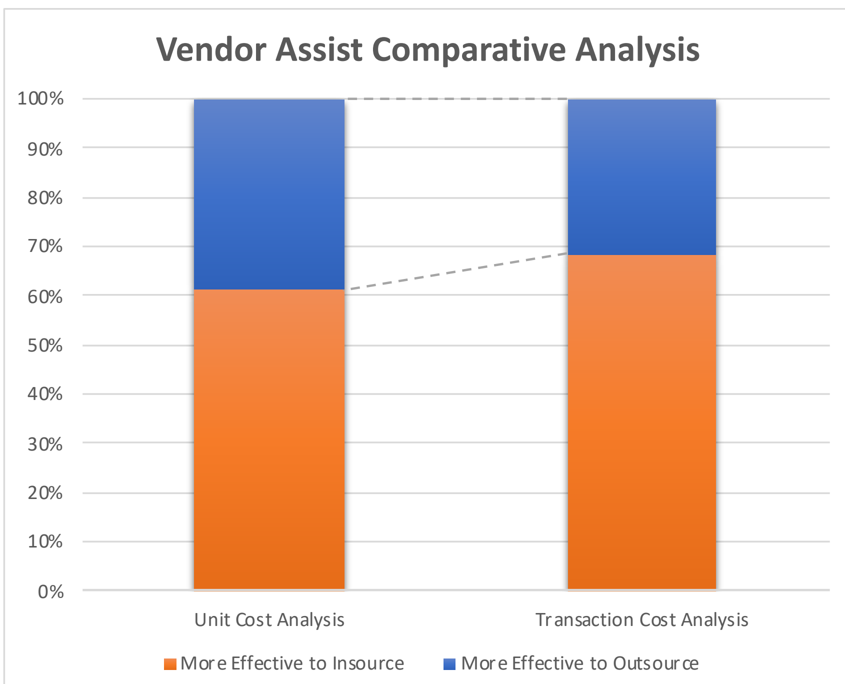



*Figure 4-8: Comparison of sourcing analyses: unit-cost only analysis compared with an analysis that includes transaction costs*

Additionally, in the spirit of continuous improvement (another lean manufacturing core tenet), Mod Centers have an opportunity to learn from vendors who are able to perform processes at a lower cost. This is recommended to be part of the TVA bi-annual review.

# Chapter 5: Analysis and Results

## 5.1 Sensitivity Analysis

The results of our analysis are highly dependent on the assumptions we made. Increasing or decreasing assumed values for key parameters has significant impact on magnitude of transaction costs. Table 5.1 explores the impact of relaxing or augmenting some of these key parameters.

*Table 5.1: Sensitivity analysis of transaction costs to key parameters*

| *Theoretical Unit Cost* | *$ 250.00* | **More Conservative** | | **Conservative Baseline** | | **Less Conservative** | |
|---|---|---|---|---|---|---|---|
| **Cost Element** | **Key Parameters** | Parameter Value | Avg Cost per Part | Parameter Value | Avg Cost per Part | Parameter Value | Avg Cost per Part |
| Cost of Shipping | DIM Weight | 2lbs | $ 11.88 | 10lbs | $ 22.23 | 15lbs | $ 32.08 |
| Cost of Additional Quality Inspections | Inspection Time | -50% | $ 0.60 | *Obscured* | $ 1.20 | +50% | $ 1.80 |
| Cost of Preparation and Packaging | Dollar Amount | $ 0.50 | $ 0.50 | $ 1.00 | $ 1.00 | $ 2.00 | $ 2.00 |
| Cost of Carrying Excess Inventory | Holding Rate | 4.26% | $ 0.35 | 7% | $ 0.58 | 20% | $ 1.64 |
| **Total Relevant Transaction Costs** | | | **$ 13.33** | | **$ 25.01** | | **$ 37.52** |
| **% of Unit Cost** | | | **5.3%** | | **10.0%** | | **15.0%** |

Without more detailed estimates, we feel it is more appropriate to provide a range of transaction costs. Therefore, transaction costs can conservatively account for anywhere between 5% and 15% of unit cost.

## 5.2 Limitations

At an aggregate level, our analysis is likely to provide a meaningful approximation of transaction costs, but there are limitations when analyzing a business case for an individual part. In this scenario, part-specific data should be used instead of our aggregate assumptions. These features include batch size, weight, routing, and monthly demand. This will provide a more accurate assessment of transaction costs.

In the literature, TCE focuses heavily on costs associated with contract administration [30]. Our analysis focused primarily on different operational costs. While these are certainly relevant transaction costs, our analysis neglects some costs of governance, such as negotiating contracts, management oversight, and even legal ramifications in the event of a breach of contract. It would be necessary to estimate these factors for both insourcing and outsourcing scenarios. This is beyond the scope of this study and was intentionally omitted, but the omission bears mentioning.

### 5.3 Business Process Deployment

The Operational Excellence (OpX) organization at Pratt & Whitney is aligned to the COO and plays an integration role between Mod Centers. It is their mandate to identify best practices, define new processes and deploy them across the enterprise. The Vendor Assist standard work and business process we developed is perfectly aligned with OpX's mission and resources. Indeed, deployment of the metrics dashboard and monthly reviews began in March 2020, focaled by OpX leaders. However, bi-annual TVA reviews using the transaction cost analysis we developed have not occurred. Our strategy of creating an Excel-based analysis tool which scrapes data from an existing report should promote adoption and facilitate ease of use. Alternatively, and honestly more likely, Mod Center leaders can identify the parameters which are most appropriate for their business and then arrive at a per unit percentage estimate that can be used as a proxy for aggregate transaction cost analysis. However, this percentage should be regularly revisited as factors change and businesses become more efficient.

# Chapter 6: Recommendations and Conclusions

We have demonstrated that our business process and analysis tools can be used to operationalize strategic sourcing decisions. Thus, our hypothesis has been validated. Instituting regular reviews of Vendor Assist activity will create accountability for the Mod Centers to understand and actively manage the work that they are outsourcing. Development of metrics and monthly reviews are the necessary first steps to strategic sourcing. Analysis of transaction costs provides a more holistic picture of the true cost to the enterprise. We have developed a method of extracting key data from purchase orders to facilitate this analysis in conjunction with estimates of internal equivalent processes. A bi-annual review of all temporary sourcing arrangements using transaction cost economics can improve resource efficiency and reduce cost. Figure 6-1 captures the additional strategic management step to the Vendor Assist process. This step was added to the end of the process rather than as an intermediate gate-keeping step to prevent impeding the flexibility of the Vendor Assist process. We recommend updating the Vendor Assist standard work to include these tools and requirements.

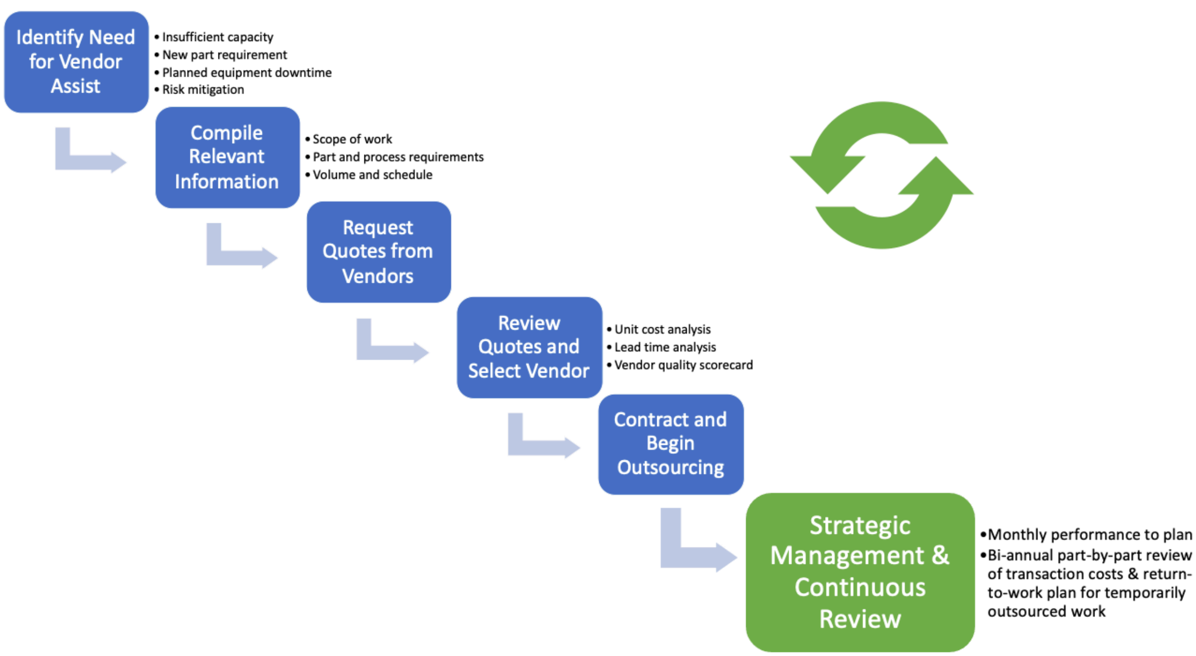



*Figure 6-1: Vendor Assist process updated to include strategic management*

## 6.1 Improvements to Transaction Cost Estimates

To more accurately capture detailed and part-specific transaction costs, we recommend combining purchase order data with part attribute data. This increases the complexity of the analysis, but provides part-specific and actionable insights.

Additionally, obtaining greater granularity in manufacturing process category (such as plasma thermal spray rather than coatings or surface treatment) across all Vendor Assists would highlight opportunities to invest new capabilities and capacity. This requires capturing new data which is not currently available.

## 6.2 Reducing Transaction Costs

Beyond improving the transaction cost analysis, there are actions that we recommend to reduce transaction costs overall. According to Han, Portfield and Li, investing in IT reduces the costs of coordinating transactions with suppliers and leads to higher levels of outsourcing. Therefore, investing in IT solutions can reduce transaction costs [34].

Blockchain is one such IT application with potential to reduce transaction costs. Blockchain is often used synonymously with Bitcoin, but blockchain technology is the framework upon which Bitcoin and most other cryptocurrencies are founded. Beyond currency, blockchain has remarkable potential as an alternative to traditional database structures. A blockchain is essentially an immutable, time-stamped, and distributed ledger [35]. Recording Vendor Assist transactions on a blockchain could improve transparency and traceability, resulting in lower network and verification costs [36]. However, this technology is nascent and a successful enterprise application has yet to emerge. Being a first mover in this space may create a significant competitive advantage.

## 6.3 Total Value Analysis

As an alternative to focusing on transaction costs, Gray, Helper, and Osborn suggest utilizing a Total Value Contribution (TVC) analysis which focuses on maximizing value rather than minimizing cost [10]. This is generally better aligned with the objectives of a firm – to deliver value to customers. They argue that using TVC for business case analyses creates a mindset shift in the organization, bringing about a focus on the firm's overall value proposition [10]. A TVC analysis would include the same cost elements we've identified in this project, but would also expand to include additional dimensions which counteract common biases, such as simply choosing the lowest cost option.

## 6.4 Conclusion

Regardless of the approach, providing visibility and awareness of transaction costs is the first step to reducing them and operating more efficiently. We have shown at Pratt & Whitney that these are non-trivial costs, accounting for between 5 and 15% of the unit cost of an outsourced process. Maintaining oversight of these sourcing decisions is key to strategic management and accountability. Furthermore, the visibility we have provided may help identify opportunities to invest in new capabilities or capacity.

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