# Framework and Strategies for Reducing Aircraft Lead Time

by

**John Andrew Marsh**

Bachelor of Science in Mechanical Engineering, Brigham Young University, 1997

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

Master of Business Administration
and
Master of Science in Mechanical Engineering

In conjunction with the Leaders for Global Operations Program at the Massachusetts Institute of Technology

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Signature of Author Signature redacted
MIT Sloan School of Management
MIT Department of Mechanical Engineering
May 9, 2014

Certified by Signature redacted
Bradley Morrison, Thesis Supervisor
Senior Lecturer, Sloan School of Management

Certified by Signature redacted
Bruce Cameron, Thesis Supervisor
Lecturer, Engineering Systems Division

Certified by Signature redacted
Stephen Graves, Thesis Reader
Abraham J. Siegel Professor of Management Science
Professor of Mechanical Engineering and Engineering Systems

Accepted by Signature redacted
Maura Herson, Director, MBA Program
MIT Sloan School of Management

Accepted by Signature redacted
David E. Hardt, Chair
Mechanical Engineering Committee on Graduate Students

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## Abstract

Aircraft are complex machines consisting of tens of thousands of parts and assemblies. Due to special engineering requirements, processes, and materials, the lead time for many of the parts can be several months resulting in a long aircraft lead time. During periods of high demand long aircraft lead time is less of a concern since manufacturers often have a large backlog, which is greater than the lead time, allowing them to build the aircraft to order. However, during periods of low demand, manufacturers may need to forecast demand and make the decision to start building aircraft before having a committed customer order. The longer the lead time of the aircraft, the further out into the future the manufacturer has to forecast, which leads to greater uncertainty and variability. In this environment it becomes essential to focus on lead time reduction to allow for better forecasting. Shorter aircraft lead times also have the added benefits of increasing flexibility in production and capacity planning, and lowering inventory holding costs and work in process.

Reducing aircraft lead time can often be a difficult task. However, a structured approach to lead time reduction can be very powerful. This paper presents a framework for lead time reduction that is composed of a lead time reduction chart, which provides the correct areas of focus; a strategy flowchart, which identifies the components, strategies, and actions that can be implemented to reduce aircraft lead time; and a summary of reduction strategies that are focused on low rate, complex parts. While the framework is detailed toward aircraft lead time reduction, it is general enough to apply to most supply chain and manufacturing situations.

This framework was used during a six month aircraft lead time reduction study at Sikorsky Aircraft Corporation, and analysis reveals that this structured approach was effective at reducing average aircraft lead time by 12.7%.

Thesis Supervisor: Bradley Morrison
Title: Senior Lecturer, Sloan School of Management

Thesis Supervisor: Bruce Cameron
Title: Lecturer, Engineering Systems Division

Thesis Reader: Stephen Graves
Title: Abraham J. Siegel Professor of Management Science, Professor of Mechanical Engineering and Engineering Systems

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First, I would like to express my gratitude to Sikorsky Aircraft Corporation for their continued support of the LGO program and for providing me with a great learning opportunity during my internship. I would like to thank my supervisor, Stephen Pawlowicz, for helping me gain a greater understanding of supply, inventory, and operations planning and for taking the time to discuss my observations. The support of his operations team, in particular Amit Shah and John Lundy, was essential in making my project successful. I'm also grateful for the insights and support from the various individuals that I interacted with in the manufacturing and procurement centers.

My extreme gratitude goes to the Leaders for Global Operations network for its support of this work and for providing me with an amazing learning experience these last two years at MIT. I would like to acknowledge my two thesis advisors, Brad Morrison and Bruce Cameron, for their support and insights. Both gave me direction in my research and helped me navigate my way through this thesis. Also, special thanks go to a fellow LGO classmate, Jerry Chiang, who also interned at Sikorsky and was a sounding board for my observations.

Most importantly, I would like to thank my family. Caleb, Jayden, and Madison, provided me much needed distractions from my schoolwork. I hope the three of you enjoyed the time we spent at MIT and will look back at it with fond memories. And finally, I would like to thank my wife Heidi. Words cannot express how grateful I am for your love and strength during this roller coaster ride. I am eternally grateful for your support and encouragement, and for making it possible for me to pursue this incredible opportunity at MIT.

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## Proprietary Information

Due to the proprietary nature of much of the information contained in this report, steps have been taken to disguise the data. For example, charts have been presented in terms of percentages only (normalized by base numbers), helicopter models are presented as A/C 1, A/C 2, etc., and terms have been changed for part name, description, and number. Publicly available figures have been included and appropriately cited.

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# 1 Introduction

This chapter provides an introduction and context for understanding the importance of reducing aircraft lead time. First, the aircraft industry and its associated long aircraft lead times are discussed in section 1.1. Next, focusing in on the helicopter manufacturing industry, section 1.2 provides background for this industry with an emphasis on Sikorsky Aircraft Corporation. Continuing to focus inward, the impact of long lead times for aircraft manufacturers is discussed in section 1.3 helping to emphasize why lead time is a critical manufacturing topic. Section 1.4 then presents the problem statement and research questions that this paper proposes to answer. Finally, definitions of types of lead times that will be discussed throughout this paper and limitations of the study that was performed are discussed in sections 1.5 and 1.6.

## 1.1 Introduction

Over the last few decades, economic growth, advances in technology, and increasingly demanding customers have created a fast moving environment for many manufacturing companies. To meet these challenges, manufacturers have embraced various continuous improvement strategies in order to reduce costs, reduce inventory, and improve quality and flexibility, all in an attempt to gain a competitive advantage. Some of these strategies include quick response manufacturing (QRM), just in time (JIT) manufacturing, total quality management (TQM), time based competition (TBC), and theory of constraints (TOC) (Tersine & Hummingbird, 1995). The success of these various methods has highlighted to manufacturers the value of reducing both build times and procurement lead times (McCutcheon, Raturi, & Meredith, 1994).

Aerospace manufacturers, in particular, face unique challenges when it comes to reducing the lead times of their products. Compared to other manufacturing products, aircraft are manufactured at a lower rate and a higher cost, and they are more complex. As an example of complexity, the A380, which is the largest commercial jet being manufactured today, has about 4 million parts, with 2.5 million part numbers produced by 1,500 companies from 30 countries around the world, including 800 companies from the United States (Wallace, 2007).

But the complexity of aircraft doesn't stop there. Aircraft are highly regulated products made up of highly specialized parts and materials; produced using explicit manufacturing processes; and required to meet strict engineering specifications. Under these conditions, part lead times can range from several months to a year or more. Consequently, the aircraft lead time (defined as the amount of time between the date when the first part is ordered for a given aircraft and the date when the manufacturing of that aircraft is complete) will be in the range of one to two years. Long aircraft lead times are a challenge for all aircraft manufacturers including helicopter manufacturers, which is the segment of aerospace manufacturers chosen for this study.

## 1.2 Helicopter Market

**Global Helicopter Market**

The global helicopter market has six major players: Russian Helicopters, Sikorsky, Airbus (formerly known as Eurocopter), Bell Helicopter, Boeing, and AgustaWestland. The market share is divided as follows in Figure 1 and segmentation by platform is shown in Figure 2 (Leboulanger, 2013).

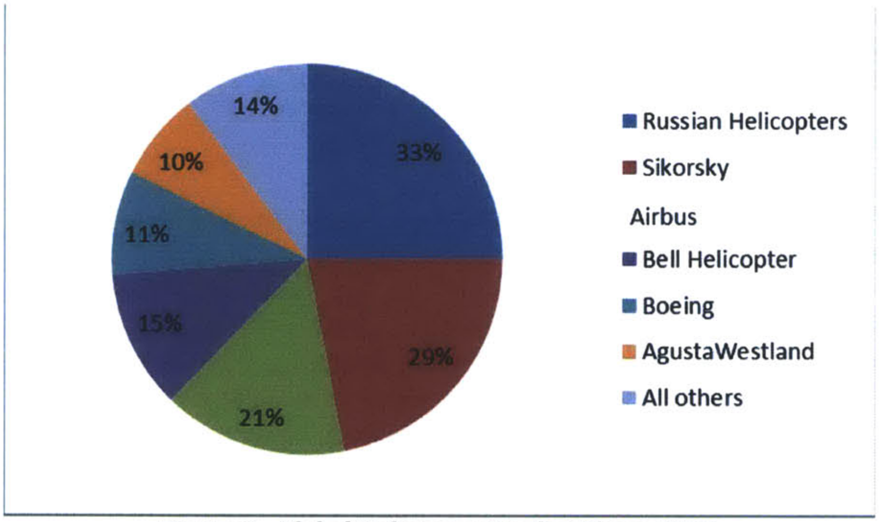


**Figure 1 - Global Helicopter Market Share 2012**

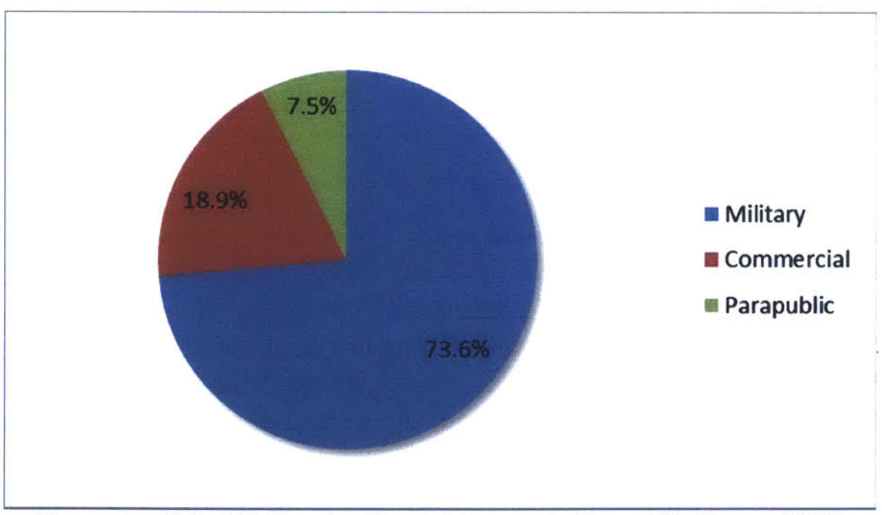


**Figure 2 - Global Helicopter Market Segmentation of Platforms 2012**

The revenues of the six major helicopter manufacturers are primarily from the large volume of military orders and/or upgrade programs. However, these manufacturers are also capitalizing on the needs of offshore oil and gas platforms, and business aviation sectors in emerging countries located in Eastern Latin America, West Africa, and Southeast Asia (Leboulanger, 2013).

**Sikorsky Aircraft Corporation**

Sikorsky Aircraft Corporation is a world leader in the design, manufacture, service, repair, and overhaul of military and commercial helicopters. The company was founded in 1925 by Igor Sikorsky and became a subsidiary of United Technologies Corporation in 1929. Sikorsky Aircraft is most widely known for manufacturing the BLACK HAWK family of helicopters (UH-60M, HH-60M, & S-70i™) and the SEAHAWK® family of helicopters (MH-60R, MH-60S, & S-70B™). In the commercial market they manufacture the S-92® helicopter, used for transport and search and rescue, and the S-76®[1] helicopter, used for executive transport, airline operations, offshore oil transport, and search and rescue. Their helicopters are used by all five branches of the United States armed forces, along with military services and commercial operators in 40 nations (About Sikorsky, 2014). In 2012 Sikorsky Aircraft employed 16,591 people, had $6.8 billion in net sales, and $712 million in operating profit (UTC, 2012). Their company headquarters are located in Stratford, Connecticut which is where the research for this thesis was conducted. To continually improve their operations and increase their competitive advantage in this global landscape, Sikorsky has chosen aircraft lead time reduction as one of their operational goals.

## 1.3 Impact of Long Lead Times

Backlogs are normally defined in monetary terms as the value of a company's sales orders that are waiting to be filled; however, in the context of this discussion backlog refers to the amount of time that it would take to complete the manufacture of all the sales orders that have been received. In essence the backlog represents the summation of the cycle time between completed aircraft. For example, if a manufacturer completes one aircraft each week and several customers together order a total of 100 aircraft, then the backlog would be 100 weeks long. Continuing with this example, a new customer wanting to purchase an aircraft would have to wait 101 weeks until that aircraft was completed, even if the aircraft lead time was only 50 weeks long.

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[1] BLACK HAWK, SEAHAWK®, S-92® and S-76® are registered trademarks of Sikorsky Aircraft Corporation. S-70i™ and S-70B™ are trademarks of Sikorsky Aircraft Corporation.


**Figure 3 - Aircraft Lead Time with a Large Backlog**

During periods of high demand, helicopter manufacturers generally have a large backlog of orders, which can be good and bad depending on the backlog length (see Figure 3). A large backlog that exceeds the lead time of the aircraft allows the helicopter manufacturer to build the aircraft to order without risk of over or under producing. If the backlog is long enough, then long part lead times and long aircraft lead times are not a big concern. After all, if a customer won't receive a helicopter for multiple years because they're waiting in a long line behind other customers in the backlog, then the manufacturer has plenty of time to order parts, start production, and complete the helicopter assembly. A long backlog provides a secure future for the aircraft manufacturer. Even in this given scenario, helicopter manufacturers should still focus on reducing manufacturing lead time because of the benefits that this can bring to their operations (lower WIP, Inventory holding cost, flexibility, etc).

This scenario is not as beneficial for the customers because it forces them to wait multiple years (depending on the length of the backlog) for delivery of their aircraft. Customers will be burdened with the task of forecasting their future needs further and further into the future with greater and greater uncertainty in their forecasts. They may even choose to walk away completely because they need the aircraft sooner than can be provided by the manufacturer. This can occur even if the manufacturer produces a better product. The customer will not necessarily purchase the best aircraft but rather the best aircraft that is available. In this environment shorter aircraft lead times become a competitive advantage for manufacturers.

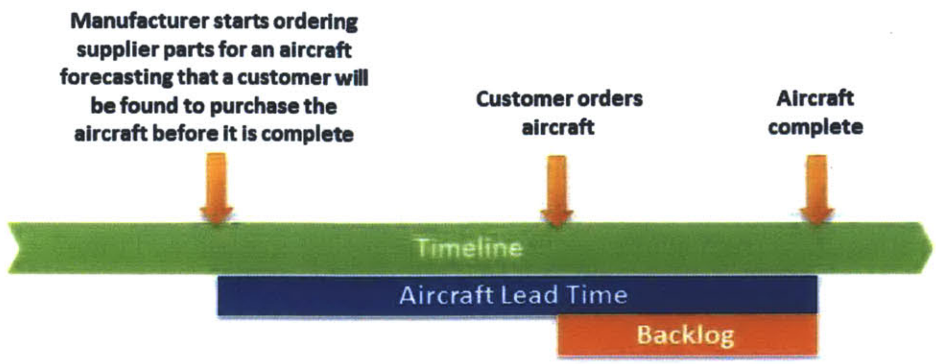


**Figure 4 - Aircraft Lead Time with a Small Backlog**

In contrast, during periods of low demand, due to economic or political conditions, some manufacturers may work through most of their backlog and then face a situation where they are forced to decide whether or not to start ordering parts to build an aircraft. This places the manufacturer at risk of making an aircraft that it can't sell and then dealing with high inventory holding costs of a finished product until the aircraft is sold (see Figure 4). The manufacturer may even decide to stage inventory of large assemblies that can be quickly brought together to provide a completed aircraft for a new customer, but this too would result in high inventory holding costs. Even worse than these two scenarios, the manufacturer may choose to not start building an aircraft and miss out on the revenue from an aircraft that it could have sold if it was available to meet the purchase timing of a customer. This places the manufacturer in a position where now it must forecast the demand for aircraft. Management must make the business decision to build or not to build taking into consideration risk of losing an aircraft sale to the competition; capacity utilization of their work force and machinery; and supply chain and inventory management. The longer the aircraft lead time, the further out that they have to forecast with greater uncertainty. Extending the company's planning horizon is one of the most significant consequences of long lead times (Weiters, 1979). On the other hand, if manufacturers can lower their aircraft lead time then they can decrease the uncertainty of their aircraft and provide aircraft to their customers in a shorter period of time providing the manufacturer with a sales advantage.

## 1.4 Problem Statement & Research Questions

As aircraft manufacturers search for strategies to help with their lead time goals they will find a large array of tools and strategies to reduce lead times. The bulk of the research, however, is focused on manufacturing of high rate, low cost products including everything from clothing to computers. Little research exists that focuses on the unique issues associated with low rate (less than 50 finished products per month), high cost (price of product valued in millions of dollars), and complex products like aircraft. Additionally, research on lead time reduction has mostly focused on strategies that a manufacturer can use to remove wasted time in its factory, and improve its operations, but places less emphasis on supplied parts that are often the longest component of the overall aircraft lead time and therefore pose the greatest opportunity for improvement.

This paper proposes to demonstrate that aircraft lead times can be significantly reduced by using a framework with a structured approach to applying lead time strategies that are focused on low rate, high cost, highly complex parts. Below are some of the questions that will be addressed with respect to reducing aircraft lead time:

- Where should the focus be in order to reduce aircraft lead time?
- Can a structured framework be effective at reducing aircraft lead time?
- What strategies are effective at reducing the lead time of low rate, high cost products?

## 1.5 Definitions

Throughout the course of this thesis the general term 'the manufacturer' is used to represent the company that produces the end product (e.g. Sikorsky, which produces helicopters). Additionally, the following definitions are used throughout the course of this paper and are provided as an easy reference. Figure 5 presents a visual representation of the lead time definitions.

1. **Aircraft Lead Time (a.k.a. Order to Delivery Lead Time)** - The amount of time between the date when the first part is ordered for a given aircraft and the date when the manufacturing of that aircraft is complete (i.e. If a manufacturer wants to finish an aircraft by a given date, when does it need to start ordering parts from suppliers?)
2. **Supplier Lead Time** - The total amount of time required, after receipt of purchase order, for a supplier to manufacture and deliver the parts to Sikorsky Aircraft. Transit time is included as part of the quoted supplier time.
3. **Buyer Administrative Time:** The total amount of time required by the original equipment manufacturer's buyer, after receipt of the production requirement, to perform solicitation, source selection and release of the purchase order.
4. **Procurement Lead Time** – The sum of the buyer administrative time and supplier lead time and (the amount of time from the point when a production requirement for a part is identified until the time that the part is delivered to Sikorsky Aircraft).
5. M**anufacturing Lead Time** - The amount of time between the date when the first internal work order is opened at the manufacturer (sufficient parts have been received in inventory to start the build process) and the date when the aircraft is complete.

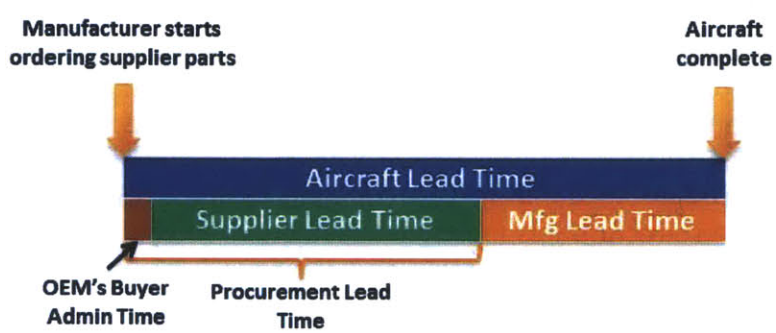


**Figure 5 - Components of Aircraft Lead Time**

## 1.6 Limitations

The scope of the study was limited to observations of operations at Sikorsky Aircraft Corporation during a six and a half month internship. As such, the small sample size and lack of a control group limits the confirmation of data that has been collected. However, existing literature has been cited, when possible, to support the conclusions of this paper. Additionally, the length of the study limited the ability to observe and measure the effectiveness of all lead time reduction strategies that are presented in chapter 3. A more comprehensive study would include observations of other aerospace manufacturing companies or companies that produce low rate, high cost products.

## 2 Literature Review of Lead Time Reduction

The competitive landscape of manufacturing has been the topic of many articles in literature over the last few decades, and much focus has been placed on ways to gain a competitive advantage. One way to attain a competitive advantage is through lead time reduction, which has been the subject of literature in manufacturing and supply chain management.

There were several papers related to lead time reduction that were studied, grouped by general topic, and explored in the sections of this literature review. Section 2.1 will address research related to Quick Response Manufacturing (QRM). Section 2.2 will focus on research studies about part supermarkets and safety stock inventories. Finally section 2.3 explores articles related to frameworks and strategies for lead time reduction.

### 2.1 Quick Response Manufacturing

Throughout the course of the literature review there was an abundance of papers that focused on, or referred to, Quick Response Manufacturing (QRM). QRM is an expansion of the concepts of time-based competition pioneered by Japanese enterprises in the 1980s. What is unique about QRM is that it promotes a relentless emphasis on lead time reduction that has a long-term impact on every aspect of a company, from manufacturing to engineering, to sales and beyond (Suri, 1998). The following analogy helps to illustrate the focus of QRM.

The Toyota Production System (TPS) (on which just-in-time (JIT) is based) has as its core the principle of elimination of waste throughout the manufacturing system. From this one principle stem several other supporting structures that are needed to implement JIT, such as continuous improvement, Total Productive Maintenance (TPM), quick changeover, zero defects, etc. Similarly, for QRM, from the single principle of minimizing lead time come implications for organizational structure, manufacturing systems, purchasing policies, office operation structures, capacity planning and lot sizing policies, and much more (Suri, 1998).

In his book, *Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times*, the author presents a list of ten QRM principles that counter ten traditional beliefs in order to provide a better understanding of QRM. As this comparison provides a quick understanding of the general philosophies of QRM it is quoted below.

- "*Traditional belief #1*: Everyone will have to work faster, harder and longer hours, in order to get jobs done in less time.
- *QRM principle #1*: Find whole new ways of completing a job, with the focus on lead time minimization.

- *Traditional belief #2*: To get jobs out fast we must keep our machines and people busy all the time.

- *QRM principle #2:* Plan to operate at 80 percent or even 70 percent capacity on critical resources.

- *Traditional belief #3:* To reduce our lead times, we have to improve our efficiencies.
- *QRM principle #3:* Measure the reduction of lead times and make this the main performance measure.

- *Traditional belief #4:* We must place great importance on "on-time" delivery performance by each of our departments and suppliers.
- *QRM principle #4:* Stick to measuring and rewarding reduction of lead times.

- *Traditional belief #5:* Installing a material requirements planning (MRP) system will help in reducing lead times.
- *QRM principle #5:* Use MRP to plan and coordinate materials. Restructure the manufacturing organization into simpler product-oriented cells. Complement this with a new material control method that combines the best of push and pull strategies.

- *Traditional belief #6*: Since long lead time items need to be ordered in large quantities, we should negotiate quantity discounts with suppliers.
- *QRM principle #6:* Motivate suppliers to implement QRM, resulting in small lots at lower cost, better quality, and short lead times.

- *Traditional belief #7:* We should encourage customers to buy our products in large quantities by offering price breaks and quantity discounts.
- *QRM principle #7:* Educate customers about your QRM program, and negotiate a schedule of moving to smaller lot sizes at reasonable prices.

- *Traditional belief #8:* We can implement QRM by forming teams in each department.
- *QRM principle #8:* Cut through functional boundaries by forming a quick response office cell, which is a "closed-loop," collocated, multifunctional, cross-trained team responsible for a family of products. Empower it to make necessary decisions.

- *Traditional belief #9*: The reason for implementing QRM is so that we can charge our customers more for rush jobs.
- QRM principle #9: The reason for embarking on the QRM journey is that it leads to a truly lean and mean company with a more secure future.

- *Traditional belief #10:* Implementing QRM will require large investments in technology.
- *QRM principle number 10:* The biggest obstacle to QRM is not technology, but "mindset." Combat this through training. Next, engage in low-cost or no-cost lead time reductions. Leave big-ticket technological solutions for a later stage. (Suri, 1998)"

Many of the articles that discuss lead time reduction as it relates to QRM are effective at presenting the principles but lack an adequate discussion of a structured approach that can be used, and challenges that are faced, when reducing lead time. A list of some of these articles is provided below.

- (Filho & Saes, 2013) – Presents a review of the literature, between the years of 1988 and 2011, regarding time-based competition and QRM. The paper uses a classification system to categorize the 67 studies by applying five criteria: approach, method, scope, principles/tools, and contributions. The classification system reveals that a strategy focused on reducing lead time is the principle that ranks first in 49 of the studies.
- (Ericksen, 2013) – Provides a case study of a division that focused on lead time reduction by following QRM principles with results that are described as the "holy trinity" of supply chains: better prices, better quality, and more on-time deliveries.
- (Tersine & Hummingbird, 1995) – Proposes that lead time can be used as a competitive advantage and demonstrates the benefits of time based competition.
- (de Treville, Shapiro, & Hameri, 2004) – Presents a framework for prioritizing lead time reduction in a demand chain improvement project and demonstrates that it is better for parties in a supply chain to focus first on lead time reduction and then turn to communication of demand up the chain.

## 2.2 Part Supermarkets / Safety Stock

Several of the papers reviewed pointed to part supermarkets or safety stock levels as a way to reduce product lead time. This was seen as a valuable tool to ensure that a manufacturer was responsive to customer demand.

One of these papers was a case study of a company's use of materials requirements planning (MRP) and kanban together to manage selected long lead time components that were included in a part supermarket (Krupp, 2002). The company that was studied was a major supplier of modular units used in the manufacture of industrial and agricultural machinery. The most troublesome component in the critical path of the module was the suppliers' precision mechanical assembly, and lead time of the mechanical assembly, was driven by two process intensive parts. A simple approach would be to use a pull system for the sub-assemblies, but this was not practical because of the number of variants of the sub-assemblies and the inconsistent demand which would require a large inventory investment.

Also, reducing the lead time for these sub-assemblies was difficult due to the way that they were dependent on MRP. To solve this problem, the supplier decided to convert part of the lead time of the sub-assemblies to a self-generating replenishment system that would use a part supermarket and kanban like cards to control the levels of work in process (WIP) in the system. The manual cards, in effect, created a continuous review system that limited inventory/WIP, but would allow sufficient levels in order to make the sub-assemblies readily available, effectively reducing lead time.

Another paper that was reviewed, (Yang & Geunes, 2007) discussed how some customers demand short lead times and are willing to pay additional costs if necessary while others are more price sensitive and willing to wait if it means that the price of the product will be lower. This presents a dilemma for the manufacturers as they attempt to find the best positioning for their products. The paper provides a solution to this problem by establishing a continuous review system where both cycle stock and safety stock levels are managed by both sales lead time and price.

Both of these papers demonstrate creative ways that inventory levels can be used to mitigate the effects of long lead products. Part supermarkets and inventory management systems can be effective tools to reduce part lead time for low cost, high rate products; however, they become impractical when dealing with very expensive, highly complex, low rate products like aircraft that can have part lead times in the range of months instead of weeks.

## 2.3 Frameworks & Strategies

Through the course of the literature survey, there were a few articles that stood out because they provide good insight in one or more areas of lead time reduction, and they provide some sort of framework for applying lead time reduction strategies. These papers provide useful strategies but fall short of providing a comprehensive discussion on their implementation.

David McCutcheon, Amitabh Raturi, and Jack Meredith (McCutcheon, Raturi, & Meredith, 1994) present a discussion on how firms can respond to a global market that demands flexibility and fast response for the products that they manufacture. In determining how to respond, the paper presents a framework for analyzing the problem as it relates to the company and provides a range of ways to respond to these challenges. The three steps of the framework are:

- Analyze customer expectations
- Assess the firm's capabilities
- Select and implement appropriate tactics

When analyzing customer expectations, the paper suggests a focus on the level of customization and responsiveness that is demanded and that "the success of just-in-time manufacturing methods and lean production systems has sensitized manufacturers to the value of reducing both build times and delivery times" (McCutcheon, et al., 1994). The paper provides several questions to help the firm understand what value customers place on customization and acknowledges that the responsiveness dimension can become somewhat difficult because it varies depending on the expected delivery time relative to the product's build time. These focal points are important because by understanding the expectations of customers, a firm can gain a greater understanding of where to focus its resources.

Next the paper turns the focus inward and provides different areas where a firm can evaluate its strengths and weaknesses, which allow it to understand the best way to respond to customer expectations and prepare to make appropriate strategic decisions.

Finally, the paper recommends a range of approaches to respond to customer expectations that can be organized into discrete areas: altering process design, altering product design, managing demand, managing supply, using slack resources, and building to forecast. When choosing the right response, it is suggested that a common theme through all successful efforts is functional integration. Some of the tactics that are presented are similar in approach to those in this thesis, which will be described in section 3.5. The high level concept of this paper is sound in that it acknowledges the importance of a structured approach and provides strategies that can be used to meet customer expectations but only superficially discusses how the strategies can be used to reduce product lead times that would allow firms to be more responsive to their customers. Other papers that provided a range of strategies for lead time reduction include:

- (Perry, 1990) – Focuses on ways that Department of Defense (DOD) can act more like the private sector to reduce their long lead times.
- (Weiters, 1979) – Compares lead times from various industries and highlights ways how they deal with long lead times.
- (Raturi, Meredith, McCutcheon, & Camm, 1990) – In order to lessen the impact of long lead times, firms used strategies to reduce complexity, reduce uncertainty, and provide slack provision.
- (Johnson, 2003) – Good framework and strategies but focused only on reduction of manufacturing lead time.

## 2.4 Summary

Current research on lead time reduction focuses on the following topics:

- Quick Response Manufacturing
- Part Supermarkets / Safety Stock
- Frameworks & Strategies

However, the existing literature on lead time reduction lacks a focus on supplier parts and falls short in providing strategies for reducing the lead time of complex, low rate products (airplanes, helicopters, ships, bulldozers, etc.). The purpose of this thesis is to provide a framework and strategies for lead time reduction that supports these areas in manufacturing.

# 3 Methods

The following research questions are addressed in this thesis:

- Where should the focus be in order to reduce aircraft lead time?
- Can a structured framework be effective at reducing aircraft lead time?
- What strategies are effective at reducing the lead time of low rate, high cost products?

The setting for the study was at Sikorsky Aircraft Company during a six and a half month internship associated with the Leaders for Global Operations (LGO) program[2]. Eight helicopter programs were included in the study (introduced in section 1.2) since they are the primary focus of the operations team and subsequently information about the helicopters was readily available when employing the methods discussed in this chapter. Additionally, some of the military helicopters shared common parts, which provided a useful comparison of the impact of the methods. The goal presented by the hosting company was to reduce aircraft lead time.

Section 3.1 summarizes the lead time reduction process that was used prior to commencing the study. Evaluation of the build plan critical path, and time periods within the critical path, is then conducted in section 3.2 which helps in the development of a structured approach to lead time reduction. The framework for reducing aircraft lead time includes a lead time reduction chart (discussed in section 3.3) to manage progress, detect trends, and measure the effectiveness of lead time reduction efforts; and a strategy flowchart (discussed in section 3.4) that identifies components, strategies, and actions to reduce aircraft lead time. The lead time reduction strategies associated with the strategy flowchart are then presented in section 3.5. Finally, a discussion of the study, and how these frameworks were used, is presented in section 3.6.

## 3.1 Observe Existing Processes

Prior to commencing the study at Sikorsky, the author observed the processes that the operations team had in place to reduce aircraft lead time. They had already determined that the supplier parts have the greatest impact on aircraft lead time and they were working to reduce the lead time of these parts. Their long lead part lists consisted of the first 25 or so parts that needed to be procured in order to complete a helicopter at a given date. This was done for all eight helicopters resulting in a list of 381 long lead parts. They arranged the parts by their 'calculated start date'/'order date' (need date from MRP[3] minus the days of lead time of the part) so that the first part that needed to be ordered was at the top of the list; and then focused their efforts each month on this list of parts. Their process consisted of the following steps which were repeated on a monthly basis.

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[2] For more information about the LGO program go to http://lgo.mit.edu/

[3] Suppliers are contractually expected to deliver their parts to the manufacturer per the material requirements plan (build plan) for the aircraft so the use of MRP data is considered an acceptable representation of actual delivery and assembly of supplier parts.

1. Pull lead time data for the long lead supplier parts from SAP[4] and arrange the parts by order date.
2. Identify incorrect part lead times.
3. Negotiate with suppliers to reach lead time targets.
4. Update the new negotiated part lead times in the SAP.
5. Discuss progress at the lead time reduction status meeting.
6. Identify further opportunities with engineering and necessity for a value stream mapping exercise at the supplier.

The author hypothesized that an improvement on the existing process would be to create tools and strategies that could be used for a more structured approach to lead time reduction (discussed in sections 3.3 through 3.5). After the framework and strategies for lead time reduction were created, a six month study was performed to test the author's hypothesis, using the existing process as a baseline.

### 3.2 Evaluate Critical Path & Lead Times

In order to reduce the aircraft lead time it is essential to evaluate ways to reduce the build plan critical path. The operations team at Sikorsky uses a supply chain and operations management program called Kinaxis RapidResponse which, among other capabilities, allows for detailed critical path analysis. RapidResponse is a powerful program that can be used by operations analysts to pull MRP data from the company's SAP database and create a copy of the aircraft build plan which can then be used to create hypothetical production plan scenarios. Each scenario appears as a separate instance of the entire dataset (does not impact the original SAP data) and allows manufacturers to perform what-if analysis by modifying the data to simulate changes to the bill of materials (BOM), the supply chain, plant capacity, or demand.

An indented BOM is a tool within RapidResponse that is used for critical path analysis. The indented BOM shows all of the parts and assemblies required for each aircraft and then illustrates their interdependencies and sequence of production by listing the very first part needed for the build on the left margin and then indenting the subsequent assemblies and installations to the right until reaching the final assemblies that creates a completed aircraft. This indented BOM is then used to identify the list of parts and assemblies that make up the critical path.

One effective way to visualize the critical path is to put this list of parts on a Gantt chart[5]. The order date and quoted lead time for each of these parts is used to create the bars on the Gantt chart. The beginning of the bar is the order date and the length (or duration) of the

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[4] SAP (Systeme, Anwendungen, Produkte, German for "Systems Applications and Products.") is a corporation that makes enterprise software to manage business operations. The software is used to centralize data storage which is used for material management and production planning.

[5] A *Gantt* chart is a type of bar chart that illustrates a project schedule.

bar is defined by adding the lead time days to the right[6]; the longer the bar, the longer the lead time between ordering and receiving the part (see Figure 6 for an example). It should be clarified that in this example, the first row of the Gantt chart represents the lead time duration of the first procured part for a given helicopter and subsequent rows represent the amount of time between assembly and installation steps in the build process until finally the aircraft is complete. So the duration of the green bar in the second row doesn't represent the longest lead time of all the parts that go into the assembly but it represents the amount of time it takes to assemble all the parts together before they are ready to proceed to the next step in the build process.

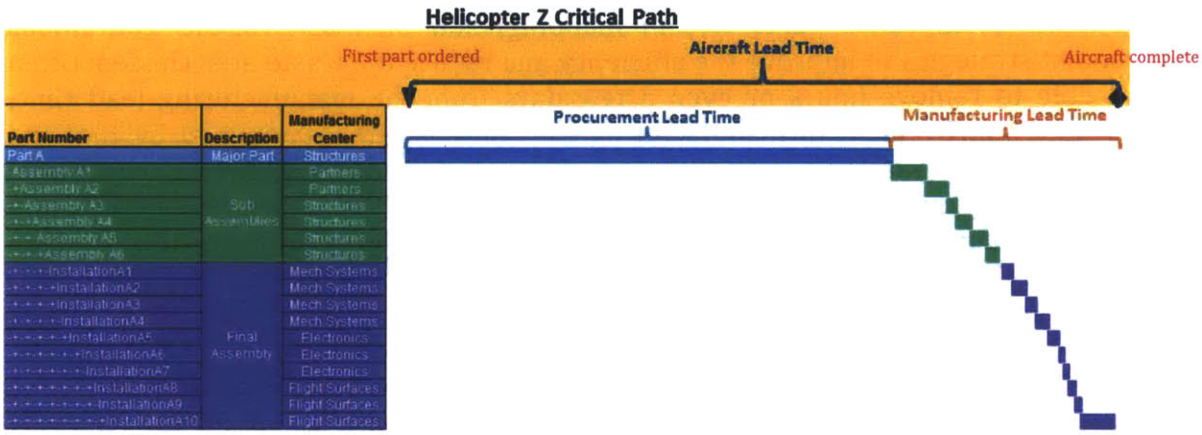


**Figure 6 - Helicopter Critical Path**

When looking at the critical path, there are two main lead times that are important to examine; procurement lead time and manufacturing lead. Procurement lead time is the amount of time from the point when a production requirement for a part is identified until the time that the part is delivered to Sikorsky Aircraft (i.e., buyer admin time + supplier part lead time + transit time). Manufacturing lead time is the amount of time between the date when the first internal work order is opened at the manufacturer (sufficient parts have arrived at the manufacturer to begin assembly) and the date when the aircraft is complete. In simple form, these represent the split of the aircraft lead time between the supplier and the original equipment manufacturer (OEM).

As can be seen in Figure 6, the duration of the procurement lead time represents the majority of the aircraft lead time. This is a common theme for all eight helicopters that were part of the study. Analysis of the critical paths for these helicopters showed that, on average, the supplier part lead time represented 47% of the aircraft lead time, the buyer admin time and transit time together represented 14% of the aircraft lead time, and the remaining steps in the manufacturing lead time represented 39% of the aircraft lead time. Since this data was pulled from SAP, the accuracy of this analysis depends on the accuracy

[6] The length (or duration) of the bar can also be illustrated by taking the MRP need date and adding lead time days to the left.

of the quoted lead times as compared to actual lead times. However, the illustrated point would remain the same; that procurement lead time represents a substantial amount of the aircraft lead time and therefore should be a focused area of aircraft lead time reduction.

In order to reduce the aircraft lead time, each step of the build process needs to be analyzed to see if there are opportunities to shrink the duration. Many manufacturers begin by focusing on manufacturing lead time since it's the work that is performed in their factory over which they have the most control. Manufacturers will analyze the flow of materials and information that is required to perform the assembly or installation in the build process (often called value stream mapping) and then use various continuous improvement strategies to improve the efficiency and reduce the waste at each step. Often they are able to remove hours or even a few days from the manufacturing lead time. However, any improvement in manufacturing lead time is often dampened by the lead times in the supply chain. The net result of reducing manufacturing lead time is only a local optimization and is not as effective or efficient as a global optimization which includes a focus on procurement lead time (Tersine & Hummingbird, 1995). Since procurement lead time represents the greatest opportunity for improvement it became the sole focus of this study.

The problem with working on critical path parts is that once you've been able to reduce the lead time for that part, the critical path shifts to a another part. Reducing the lead time for this second part might shift the critical path back to the original part or to an entirely new part. In order to avoid chasing the critical path from part to part, a lead time reduction goal should be chosen. The lead time reduction goal, in essence, creates a reduction zone. Any part that has its build path in the reduction zone will need to have its lead time reduced in order to meet the goal.

One analogy that can be used to describe this process is to think of critical paths of all the parts that go into building an aircraft as all the branches of a tree and think of the bottom of the tree trunk as the finished aircraft (see Figure 7 on the next page). Next, imagine that this tree is too tall for the area where it is planted (maybe it's growing into the power lines) and that the height of the tree needs to be reduced by 20%. You would need to measure the height of the tree and then multiply this height by 0.8 in order to get the new desired height of the tree. You could then begin this tree reduction process by cutting the longest branch down to the 20% reduction line but another long branch would still exist making the tree still too high. You could then cut the next largest branch and then chase and cut the next longest branch until eventually the height of the tree was reduced by 20%. Or as an alternative approach, you could use the 20% reduction line to create a reduction zone and take one big cut along this line. Any branch that extends above that line would be cut and the tree height would be reduced by 20%.

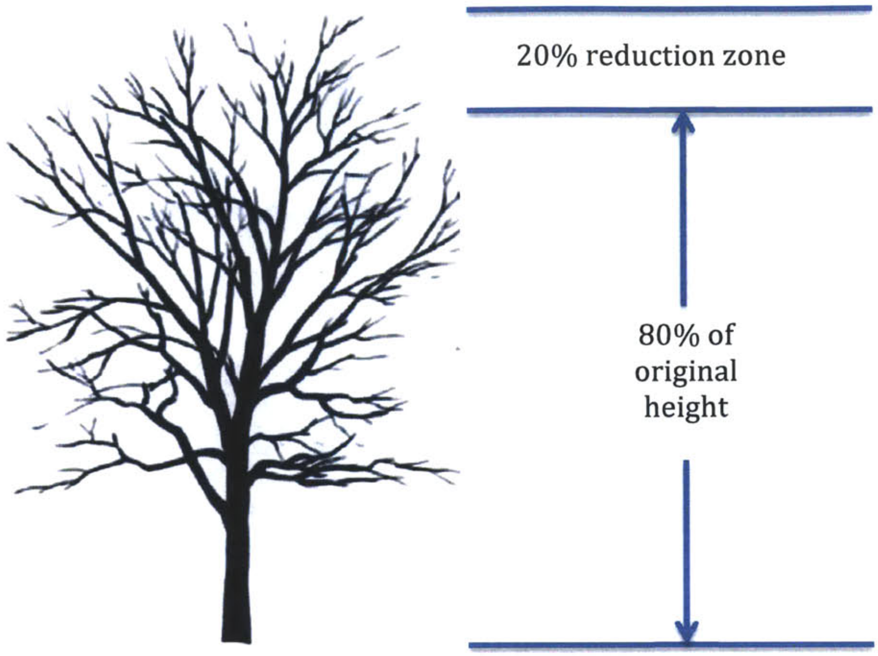


**Figure 7 - Tree Analogy**

## 3.3 Lead Time Reduction Chart[7]

The lead time reduction chart uses the reduction zone approach described in the tree analogy. A reduction zone is plotted on the reduction chart and is used to determine the list of long lead parts. MRP data (specifically, part need date and part lead time) is pulled from SAP to create the build plan timeline for all the parts that make up the aircraft. Any part whose duration bar (branch) extends into the reduction zone is considered a long lead part. Figure 8 is a generic example of this chart. Reducing the lead time of these parts is the best way to reduce aircraft lead time because they are all the critical path parts that can have a direct impact on aircraft lead time.

[7] The lead time reduction chart is comparable to a Gannt chart but only showing the first part for several potential critical paths.

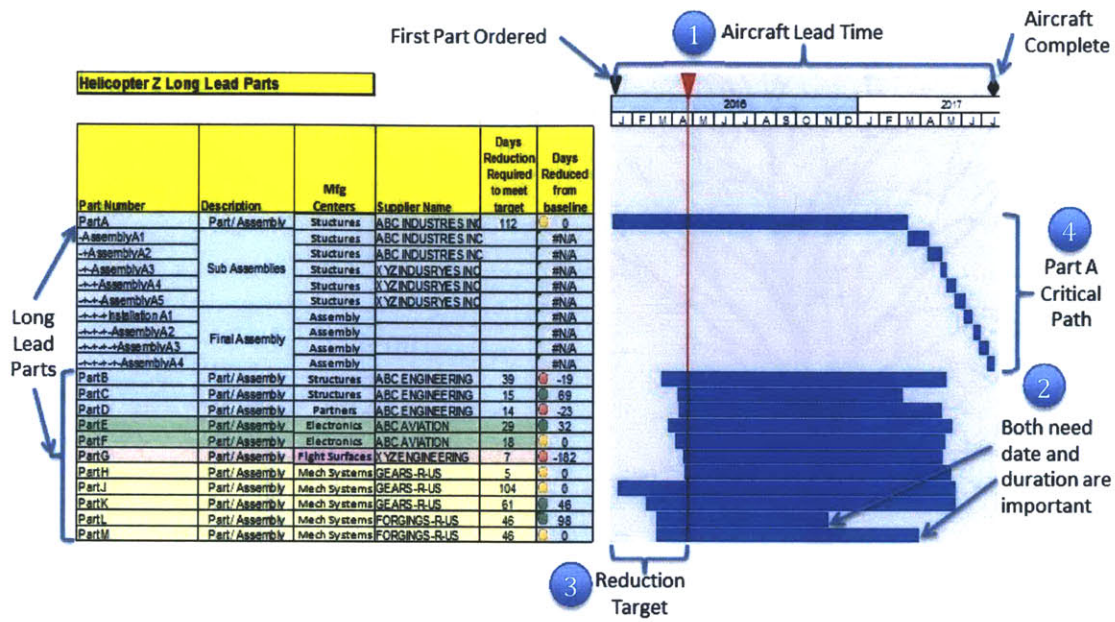


**Figure 8 - Lead Time Reduction Chart**

Important pieces of information that are the foundation of the lead time reduction chart are:

1. **Aircraft Lead Time** – The amount of time between the date when the *first part is ordered* for a given aircraft and the date when the manufacturing of that *aircraft is complete*. This establishes the timeline for the lead time reduction chart which is illustrated at the top right portion of the chart. The timeline is derived from a RapidResponse theoretical scenario where a completed aircraft is needed at some arbitrary point in the future. For example, if a completed aircraft is needed for a customer on May 9th 2016, then what date will the manufacturer need to start ordering parts so that the parts arrive at the right time in the aircraft build plan.
2. **Part duration** – The parts that populate this chart represent the range of parts that need to be ordered first, once the decision to build an aircraft has been made. Each part can potentially become the first part of the critical path if the lead times of other parts are reduced. The part number of the long lead part is on the left side of the chart. The colors associated with the long lead parts represent the functional group that is responsible for the part. The length of the blue bar represents the lead time duration of the part; which is the summation of the OEM's buyer admin time and the supplier quoted lead time from the MRP data in SAP[8]. The longer the bar, the longer the lead time of that part. The placement of the blue bar is based on when the part is needed for the build of the aircraft. If a part is needed at some point in the future (right end of the bar) then the part needs to be ordered on the date aligned with the left end of the bar.
3. **Reduction Target** – Instead of chasing the critical path from one long lead part to another as the lead time for the individual parts is reduced, apply a target which

[8] Supplier quoted lead time includes transit time.

defines a reduction target zone. If the left end of the blue bar falls inside the zone then its lead time needs to be reduced in order reach the lead time goal for the aircraft. This method brings attention to suppliers who provide multiple parts in the reduction zone (the supplier may need help with operational efficiency) or to the same part used on multiple aircraft.

4. **Part critical path** - The critical path of the longest lead time part (a.k.a. 'tent pole part') is denoted.

Visually representing the duration and need date of the long lead parts in this format reveals the following helpful insights that would not otherwise be readily apparent.

**Focused Part List**

Some organizations may try to reduce lead time by focusing on an arbitrary number of long lead parts (i.e. focus on the 50 parts with the longest lead time) but neglect to consider the need date of the part. For example, the rotor blades on a helicopter are complex parts that use a combination of high strength metals and low weight composite materials. The lead time for the rotor blades can be substantial but they will not have any impact on the aircraft lead time because the manufacturer chooses to install the rotor blades at the end of final assembly. This is done to prevent the rotor blades from getting in the way of other helicopters in the final assembly production line.

Furthermore, as seen in Figure 8 near the number 3 bubble, there are situations where a part will have a relatively short lead time, however, because it has an earlier need date (based on the MRP build plan data in SAP) its blue duration bar extends past the reduction target line and is therefore a part that should be on the long lead list. Also because the chart only captures those parts that extend past the reduction target line, the long lead part list will include the right number of parts instead of an arbitrary number. For example, one helicopter in the study only had one part[9] that needed to be reduced in order to meet the aircraft lead time reduction target.

**Focused Reduction**

Previous to this study the manufacturing centers were given a list of part numbers and then asked to reduce them all by the target percentage. However, as can be seen in Figure 8, not all parts need to be reduced by the same amount in order to meet the reduction target. In some cases the lead time for the part only has to be reduced by a few days. Moreover, when parts are common to multiple helicopters, the number of days necessary to remove the part from the long lead list can be slightly different for each helicopter model depending on when the part is needed in its build plan (i.e. the lead time for the part could be reduced enough to remove it from one helicopter's long lead part list but not enough for another). Because of this situation the lead time reduction target for a part should be based on the largest reduction necessary to remove it from all helicopter's long lead parts lists.

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[9] This may be an indication that the lead time for this part is excessive (since it has to be ordered much earlier than other parts) which may be an alert that help is needed by the supplier or than the build plan should be evaluated to determine if the need date for the part can be shifted to the right.

Knowing exactly how many days that the lead time needs to be reduced becomes particularly important when working with a supplier that provides several parts. Instead of asking the supplier to find ways to reduce their long lead parts by the same target percentage they can be asked to reduce the lead time of each part by the amount that is needed to get the part across the target line. This allows the supplier to focus their lead time reduction efforts where they are needed.

Since the lead time reduction need is specific to each part it also allows the manufacturer to focus their efforts. Most importantly the visual tool easily identifies the one part that needs to be reduced by the largest amount (a.k.a. the 'tent pole part'). If a manufacturer is able to reduce the lead time of several parts but can't reduce the lead time of the tent pole part, then the aircraft lead time will not change. Undoubtedly another part can become the tent pole part when the previous part is reduced and consequently the focus will shift. It is important to always keep an eye on the one part that can have the greatest impact on aircraft lead time while also remembering that all the parts in the reduction zone have to be reduced in order to meet the established goal.

**Reveals Unique Situations**

Returning again to Figure 8 and focusing on the second part from the bottom; it may seem strange that the need date for this part is significantly earlier than the other parts. This may indicate a unique situation which can be exploited to help reduce the lead time. During the study that was conducted a situation like this was identified and it was determined that the part was initially procured by Sikorsky and then sent off to another supplier to be used in an assembly that was subsequently returned to Sikorsky. Removing Sikorsky as the middle man moves the need date later and allows this part to be removed from the long lead time part list.

Visually representing the part data on the lead time reduction chart was an essential part of managing lead time reduction strategies used in this study at Sikorsky (more detail is discussed in section 3.6). This framework can easily be applied by other manufacturing companies to help them identify and focus on the right parts which will need to be scrutinized in order to reduce lead time.

## 3.4 Strategy Flowchart

The strategy flowchart[10] presented on the next page in Figure 9 is intended to provide a structured approach to identify components, strategies, and actions which can be implemented to reduce aircraft lead time.

[10] This flowchart has a similar framework as the one presented by Danny Johnson (Johnson, 2003) which emphasizes objectives, component changes, factors that will change component, and actions to alter factors.

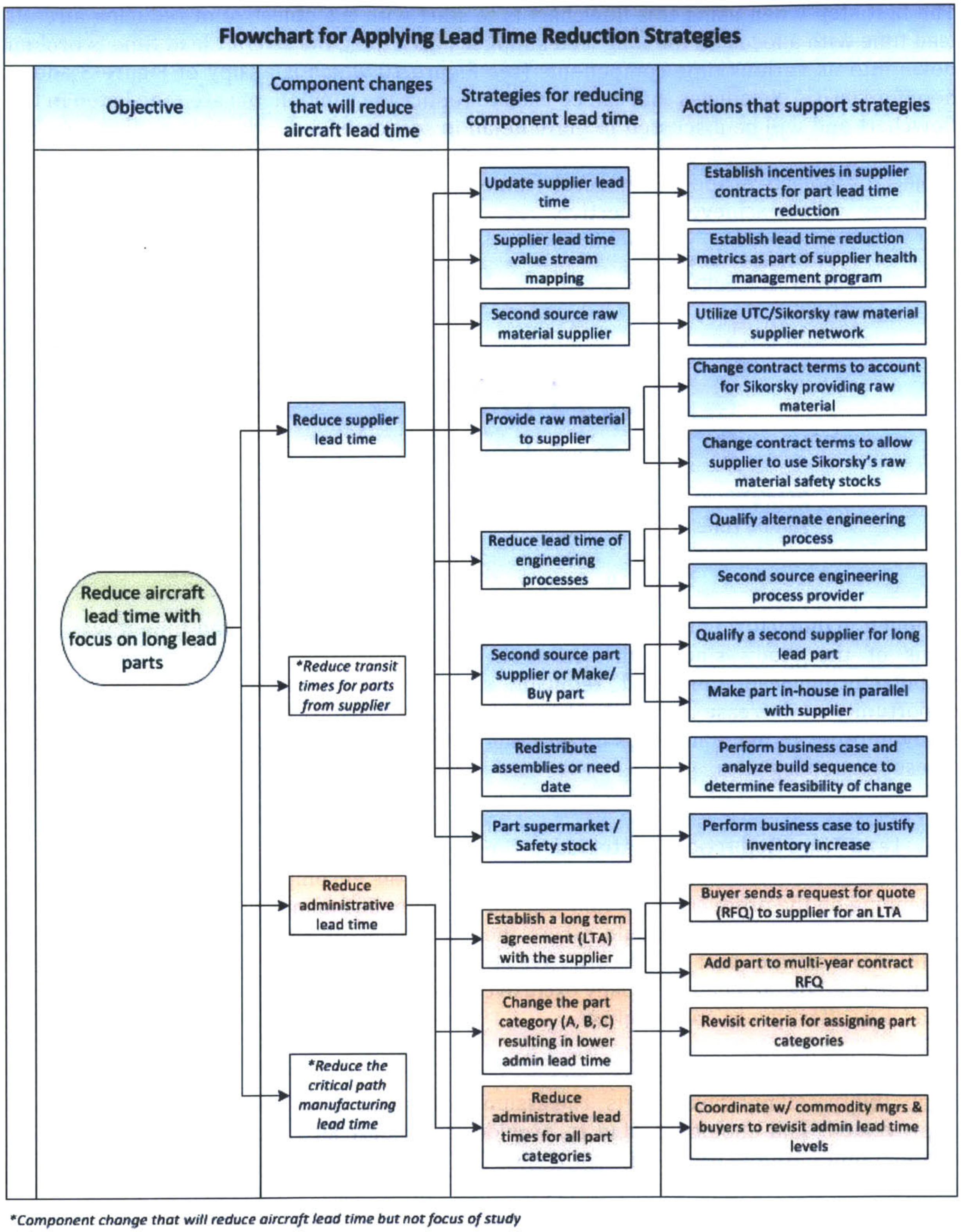



**Figure 9 – Flowchart for Applying Lead Time Reduction Strategies**

The first step when using this flowchart is to start with the objective of reducing aircraft lead time with a focus on the long lead supplier parts. Next, the aircraft lead time is broken down into its various time components (see Figure 10 which is a copy of Figure 5 added here for clarity). Strategies that can be used to reduce the components are then listed in the flowchart and will be discussed in more detail in section 3.55. Lastly, actions that support the strategies are listed. This flowchart is an effective way of breaking down the parts of a project or objective and the general framework can be used by manufacturers when exploring ways to achieve an objective.

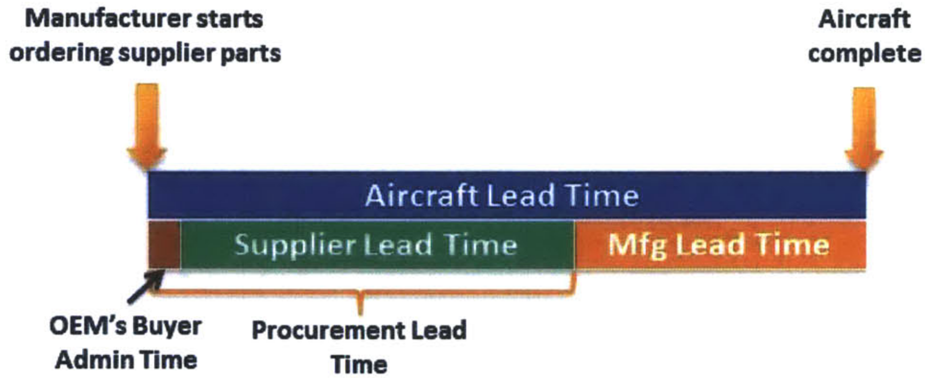



**Figure 10 - Components of Aircraft Lead Time**

Although manufacturing lead time is a large contribution to aircraft lead time it was not a focus of the study since much focus in literature is already placed on reducing manufacturing lead time and reducing supplier lead time presents that greatest opportunity to decrease aircraft lead time. Similarly, transit time was not included in the study in order to maintain focus on working with the supplier and not trying to optimize transportation logistics.

## 3.5 Lead Time Reduction Strategies

This list of lead time reduction strategies is not all encompassing since it will vary depending on the product and organizational structure of a manufacturer and its suppliers. Manufacturing companies should assess the capabilities of their suppliers and consider additional strategies that may be effective at reducing their product lead times. Also, these strategies are by no means mutually exclusive; combinations of approaches across different areas may offer synergistic benefits.

### Update Supplier Lead Time

Applicability - All purchased parts. The assumption is that all suppliers work on continuous improvement and should be able to provide lower part lead times over time (up to a certain point until the process is world class and can no longer be reduced). In many cases it may have been years since the supplier has updated their lead time especially if the supplier is in a multi-year contract.

Pros

- Low hanging fruit. Requires little effort from buyers with potentially a significant gain reduction in the lead time that was previously quoted. You never know until you ask.
- Signals to suppliers that they are expected to continually look for ways to improve their processes.

Cons

- Suppliers may not be willing to reduce their part lead time without some incentive.
- Places supplier at a greater risk of missing a part delivery (less buffer=more risk).
- Seems like a broken record if the manufacturer asks them time after time to reduce their lead time.

Things to consider – The manufacturer may want to consider providing better contract terms for suppliers that are willing to provide aggressive lead times. It is also important to understand that asking a supplier to reduce their lead time puts them in a position where they are eroding their buffer and taking on more risk of missing a committed delivery date. It would be helpful if metrics were established that not only tracked on-time delivery but also tracked whether or not a supplier is working to reduce their part lead times. For example, if a supplier misses on-time delivery a very short percentage of the time but has taken measures to reduce lead times significantly then they should not be penalized for the few times that they have missed delivery but should be rewarded for the aggressive posture they are taking in reducing their part lead times. The point is that they are operating closer to the point of maximizing on-time delivery and lead time reduction without a lot of extra fluff built into their schedules. This strategy yielded substantial results that are discussed in section 4 and the incentives discussed above will be further elaborated in section 5.

**Supplier Lead Time Value Stream Mapping**

Applicability - Best for suppliers who provide several long lead parts or suppliers who provide a tent pole part and other strategies have been ineffective in reducing the part lead time. Also, would be easier if the supplier is geographically located close to the manufacturer.

Pros

- Creates a better working relationship with the supplier.
- Value stream mapping can provide a better understanding of where the bottlenecks exist and reveals any buffer that may have been added to the part lead time estimate. Also, may reveal areas where other reduction strategies can be used (e.g. second sourcing material or process provider).
- If the manufacturer is already working with a supplier in other capacities they could work with the existing team to also emphasize lead time reduction as a focus area.
- If the supplier has not performed value stream mapping then they could apply what they've learned to other parts that they produce.

Cons

- Sending teams to a supplier is an investment of time and resources and it may be difficult to quantify the value of providing this help.
- Supplier may not be open to our 'help'.

Things to consider – This approach would most likely require submitting a business case for why teams should go and visit a certain supplier, and it may be difficult to quantify the anticipated value of helping the supplier. Working as a partner to suppliers can deliver a competitive advantage by increasing the effectiveness and efficiency of the supply chain. The greater the collaboration, at all levels, between supplier and customer, the greater the likelihood that an advantage can be gained. (Rich & Hine, 1997)

**Second Source Raw Material Supplier**

Applicability - Parts where raw material lead time is a large portion of total part lead time.

Pros

- Provides supplier with multiple raw material sources which can help to create competition between raw material suppliers (cost competition) and mitigate the risk of a supplier not being able to obtain raw materials.
- Can provide more leverage on raw material suppliers through association with the larger manufacturer (e.g., Sikorsky can use their influence as the manufacturer and as a subsidiary of UTC).
- Can utilize raw material suppliers that are used across all of the business units of the manufacturer.

Cons

- Possibility of inconsistency between raw material providers would make it more difficult to isolate quality problems attributed to raw materials.
- Suppliers may be reluctant to use an alternative raw material source that is recommended by the manufacturer.

Things to consider –In many cases, raw material is the major factor of the long lead time of a supplier, reaching in some cases up to several months. Castings, in particular, can impose technological constraints on the supplier part which can make reducing supplier lead time infeasible since a large majority of castings may be imported (McCutcheon, et al., 1994). The manufacturer will need to work closely with the supplier to understand their raw material strategy and how assistance can be provided.

**Provide Raw Material to the Part Supplier**

Applicability – Some manufacturers consider it a strategic advantage to maintain reserve inventories of raw materials for their own use. In special circumstances and under specific criteria they may allow select suppliers to have access to the raw material reserves to support urgent demand (e.g., when expediting a part from the supplier is necessary). Suppliers are allowed access to this material with the agreement that they will replenish the inventory with a raw material order that they would place. This strategy is best suited for parts where raw material lead time is a large portion of total part lead time.

Pros

- The manufacturer would have greater control over raw material lead times.
- Establishes a closer partnership with select suppliers.
- Manufacturers may be able to get better raw material terms than a first tier supplier could by leveraging their size as the product manufacturer.

Cons

- Would need to buy additional raw material reserves (more inventory and higher inventory holding costs).
- If too many suppliers have access to the reserves then there is a higher chance that the manufacturer could run out of their reserves.
- Would need to regulate access to the material so that not any one supplier could use all the reserves so raw material could still be available to another supplier.
- Risk of driving wrong behavior from suppliers where they become dependent on the manufacturer to provide raw material.

Things to consider – may want to make material available contingent on providing more aggressive lead times for the supplier parts (put the terms in the contract).

**Reduce Lead Time of Engineering Processes**

Applicability - Parts where multiple engineering processes (e.g., shot peening, heat treat, special coating or painting, etc.) are required during the production of the part and the first tier supplier doesn't have the capability to perform the required engineering process so they outsource the process to another shop adding anywhere from 2-4 weeks to their part lead time. Engineering process lead time can be reduced by:

1. Qualifying the first tier supplier to perform the engineering process.
2. Second source the engineering process to a faster provider.
3. Qualify an alternate engineering process that meets the same engineering functional requirements but can be completed in a shorter period of time.

Pros

- The manufacturer may be able to influence existing process providers to provide faster service.
- If a process provider is capacity constrained then the supplier can go to the alternate who can provide in a shorter period of time.
- Qualifying an alternative process may be helpful to lower lead time and costs.

Cons

- A process may be proprietary to a specific supplier requiring that they always perform the process.
- Will need to go through the qualification process to use an alternative process which can take a substantial amount of time and money.
- The process provider needs to be certified to do the process which can require a large amount of time and money.

Things to consider – Sometimes engineering requirements call out processes from a specific supplier or a process that is proprietary to a specific supplier. This creates a situation where the supplier has a monopoly on the process. Providing an alternative to the required process allows other suppliers to compete for the process which may drive down cost and lead time of the process.

**Second Source Part Supplier or Make/Buy Part**

Applicability - Best suited for parts that don't require special or proprietary processes. Second sourcing a part would be with the intent to purchase parts from both suppliers. Make/Buy a part would be choosing to also make the part entirely as the manufacturer or performing a portion of the production processes at the supplier and the remaining processes at the manufacturer.

Pros

- Provides the manufacturer with multiple suppliers which minimizes their risk should any issue occur at a single supplier (e.g., quality issues, process issues, union strikes, damage to a suppliers facilities, etc.)
- If a supplier is capacity constrained then a second supplier could add capacity allowing the manufacturer to increase their production rates or provide addition inventory to create a part supermarket.
- If the manufacturer chooses to make the part, or make/buy the part, then they will have greater control over the lead time.

Cons

- A second supplier may charge more to manufacture the part than the primary supplier.
- There may be some inconsistencies between suppliers that impact quality or longevity of the part.
- The manufacturer may be capacity constrained or tool constrained and may not be in a position to manufacture the part.
- In many instances it would cost more for the manufacturer to build the part (it may be why they outsourced the part in the first place).

Things to consider – There may be some parts whose engineering requirements are tied to a certain supplier (proprietary process). In this case the part could not be produced by a second source unless an alternative process is qualified.

**Redistribute Assemblies or Need Date**

Applicability - Best for parts that are less integrated into the systems of the aircraft or for jobs that can be done in parallel and do not depend on a predecessor. For example, Sikorsky chooses to install the tail rotor blades early in the build but could choose to install them at the end of the build if they were impacting aircraft lead time.

Pros

- Would not need to decrease the lead time of the part just move the need date.

Cons

- Could create an unbalanced daily or shift workload.
- Manufacturing engineers may be reluctant to change the build sequence to only support aircraft lead time reduction.
- It may be difficult to forecast the impact of the change to the build sequence.

Things to consider – Tooling needs at a given point in the build may impact the ability to redistribute the assemblies.

**Part Supermarket / Safety Stock**

Applicability - Best suited for low priced parts or smaller parts (less inventory holding costs). Also better suited for parts where suppliers have the capacity to reach the buffer stock and safety stock levels.

Pros

- Lead time essentially goes to zero if the service level is high for that part.

- Safety stock model can be applied to any part.

Cons

- Carrying more inventory and have to pay inventory holding costs.
- Parts may become obsolete while waiting in the part supermarket.
- Some parts have shelf life requirements (e.g. O-ring rubber that may degrade).
- Need to find a place to store the parts (may need to invest in warehouse space).
- Difficult to quantify value of reducing lead time compared to added inventory costs.

Things to consider - Many parts that go on an aircraft are subjected to long lead times because they are tied to flight safety and require special engineering processes and specialized materials that themselves are customer produced (e.g., large specialized castings, specialty steels, or regulated manufacturing processes) making it not possible to create a safety stock (e.g., Main Rotor Shaft on a helicopter). "When it is possible to implement safety stock inventories there are still risks of high inventory costs and losses through obsolescence" (McCutcheon, et al., 1994). The manufacturer may choose to set a price threshold for parts to be included in a supermarket (i.e. parts less than $10K/$50K/$100K). Similarly the manufacturer may want to stratify the risk level of a part becoming obsolete in a part supermarket (e.g. High/Medium/Low risk).

**Reduce Administrative Lead Time**

Applicability: Admin lead times range from weeks to months (depending on the part) and are in place to give the buyer sufficient time to send out a request for quote (RFQ) and choose the best supplier. Parts that are on a long term agreement (LTA) don't require admin time for each order, they only need this time at the end of the contract period, and so the manufacturer may choose to reduce or remove the admin lead time for these parts.

Pros

- Requires little effort for a significant gain.
- Removes the unnecessary admin time during the contract period.
- Depending on the reduction target that the manufacture has set, and their standard admin lead times, this strategy alone could be enough to remove a large portion of long lead parts from the reduction target zone.

Cons

- There may be no clear system to restore admin lead time at the end of the LTA making it more difficult to remove or reduce the lead time.
- Increased risk of placing buyer in a situation where they don't have sufficient time to rebid the part and result in missing delivery dates.
- Requires that admin lead time is switched back and forth.

Things to consider – This may require a policy change that would require approval from several purchasing centers. If the admin lead time is removed from parts that are on an LTA then the company would need to ensure that there is a full proof (automated) solution in place that restores the admin lead time at the end of the LTA contract or some other way of alerting the buyer that they need to perform a new RFQ.

### 3.6 Conduct the Study

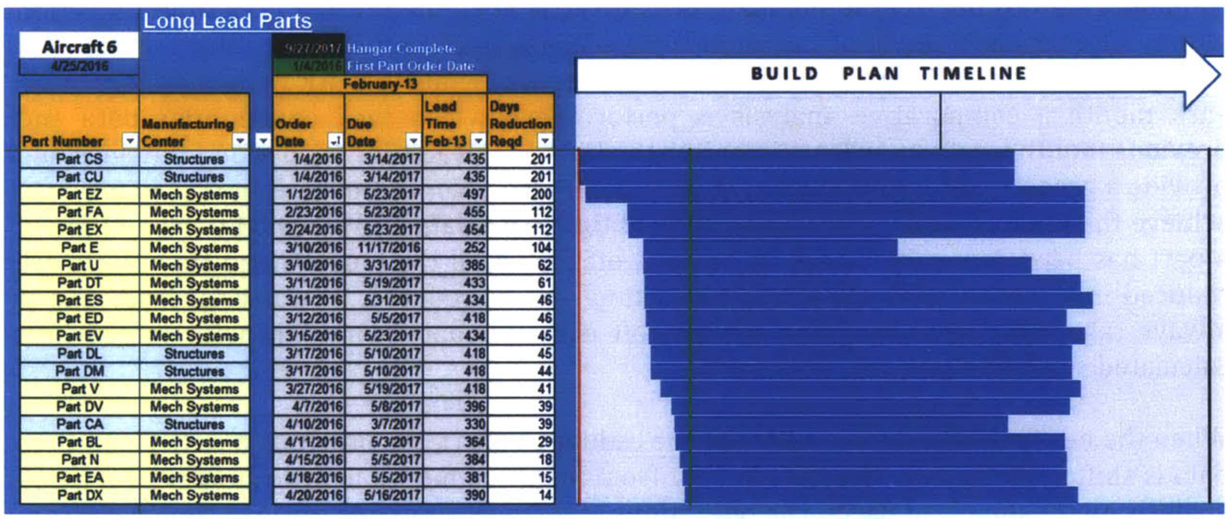
The framework for reducing aircraft lead time that was developed for this study consists of a lead time reduction chart, a strategy flowchart, and a summary of suggested lead time reduction strategies. The lead time reduction chart serves to visually represent key part information which helps to focus the manufacturer's efforts on the parts that can have the greatest impact on reducing aircraft lead time. The strategy flowchart provides an organized way of breaking down aircraft lead time into its various components, categorizing strategies for reducing component lead times, and identifying actions that support the strategies. Together these tools are used to provide a structured framework to investigate the right long lead parts and then provide strategies for reducing the lead time of the parts which in turn will reduce the lead time of the aircraft. This structured framework was used throughout the six month study. Results from the study are discussed in section 4.

The first step in the study is to establish a baseline of important elements. The first baseline used is the number of long lead parts that were being evaluated before the study was started. As discussed in section 3.1, the existing process was attempting to reduce the lead time of 381 parts in order to reach the reduction target which was a percent reduction of aircraft lead time of all eight helicopters. The second baseline used is the aircraft lead time at the beginning of the study. The actual lead time of the eight helicopters are not discussed in this thesis due to their proprietary nature, however, results for changes in lead time from month to month and from the beginning of the study to the end of the study are provided in section 4.

With the baseline values established, the next step is to populate the lead time reduction chart that was discussed in section 3.3 and develop the list of long lead time parts that need to be reduced in order to reach the percent reduction target. To populate the reduction chart, an analyst uses RapidResponse to create a hypothetical scenario of a completed aircraft requirement at some arbitrary date in the future. The analyst then pulls MRP data from the company's SAP database and creates a copy of the aircraft build plan based on the hypothetical aircraft complete date. This establishes the build plan timeline containing a list of all the parts needed to build the aircraft and the point in time when each part is needed. The analyst also calculates the aircraft lead time by subtracting the date when the first part is ordered from the date when the manufacturing of that aircraft is complete.

Next, the reduction zone for the aircraft is established by multiplying the aircraft lead time by one minus the reduction target percentage. For example, if the target is to reduce the lead time of the aircraft by 20%, then the aircraft lead time is multiplied by 0.8 resulting in the reduction target date that is the right-side boundary of the reduction zone. The order date of the first part in the critical path establishes the left side of the reduction zone. To establish the list of long lead parts, the analyst focuses on the order date of the parts starting with the very first part in the build plan and moving forward (to the right) along the build plan timeline. Any part whose order date lies within the reduction zone becomes part of the long lead part list. This process continues until the reduction target date (right side of the zone) is reached.

Once the long lead part list is established, more detailed part information (part number, description, supplier, lead time, admin lead time, responsible procurement center, etc.) is added to the reduction chart. The detailed part data is helpful when looking for the right strategies to reduce the lead time of the part. This process must be done separately for all eight helicopters since some parts may be common to several aircraft. Although the lead time for the part will be the same, the calculated start date and the due date may be different across the models based on when the part is needed for that model. An example of an aircraft reduction chart that was populated at the beginning of the study is provided in figure 11[11]. There are three vertical lines on the chart. The red line represents the left side of the reduction zone, the green line represents the right side of the zone (reduction target date), and the black line represents the date that the aircraft is complete.




| Part Number | Manufacturing Center | Order Date | Due Date | Lead Time Feb-13 | Days Reduction Reqd |
|---|---|---|---|---|---|
| Part CS | Structures | 1/4/2016 | 3/14/2017 | 435 | 201 |
| Part CU | Structures | 1/4/2016 | 3/14/2017 | 435 | 201 |
| Part EZ | Mech Systems | 1/12/2016 | 5/23/2017 | 497 | 200 |
| Part FA | Mech Systems | 2/23/2016 | 5/23/2017 | 455 | 112 |
| Part EX | Mech Systems | 2/24/2016 | 5/23/2017 | 454 | 112 |
| Part E | Mech Systems | 3/10/2016 | 11/17/2016 | 252 | 104 |
| Part U | Mech Systems | 3/10/2016 | 3/31/2017 | 385 | 62 |
| Part DT | Mech Systems | 3/11/2016 | 5/19/2017 | 433 | 61 |
| Part ES | Mech Systems | 3/11/2016 | 5/31/2017 | 434 | 46 |
| Part ED | Mech Systems | 3/12/2016 | 5/5/2017 | 418 | 46 |
| Part EV | Mech Systems | 3/15/2016 | 5/23/2017 | 434 | 45 |
| Part DL | Structures | 3/17/2016 | 5/10/2017 | 418 | 45 |
| Part DM | Structures | 3/17/2016 | 5/10/2017 | 418 | 44 |
| Part V | Mech Systems | 3/27/2016 | 5/19/2017 | 418 | 41 |
| Part DV | Mech Systems | 4/7/2016 | 5/8/2017 | 396 | 39 |
| Part CA | Structures | 4/10/2016 | 3/7/2017 | 330 | 39 |
| Part BL | Mech Systems | 4/11/2016 | 5/3/2017 | 364 | 29 |
| Part N | Mech Systems | 4/15/2016 | 5/5/2017 | 384 | 18 |
| Part EA | Mech Systems | 4/18/2016 | 5/5/2017 | 381 | 15 |
| Part DX | Mech Systems | 4/20/2016 | 5/16/2017 | 390 | 14 |

**Figure 11 - Lead Time Reduction Chart - Baseline**

With the focused list of long lead parts now established, the operations team then works with the functional procurement teams to identify the lead time reduction strategies that can be used with a specific part. The first strategy that is applies to all long lead parts is contacting the suppliers and asking for an updated lead time for the part. This strategy requires little effort but is very effective at several quick lead time reductions (see section 4.2 for results of reduction strategies). When faced with tens of thousands of parts that go into an aircraft, and the day to day problems that need to be fixed, it's easy to neglect updating the lead time of the part. As a matter of fact, it would be counterproductive to try to keep up with updated lead times for all the parts especially if they don't impact aircraft lead time. However, when the part is identified as one that does impact aircraft lead time, then updating the lead time of the part is essential. Additionally, once suppliers understand the impact that their part is having on aircraft lead time, they are more willing to look for

[11] There is much more information provided for each part in the actual lead time reduction charts that were used in the study. However, this information is hidden from this chart since it is considered proprietary.

ways that they can remove buffer in their production schedules and find ways to reduce the part lead time.

When procurement teams are successful at using one or more of the strategies to reduce the lead time of the long lead parts, they then enter the new part lead time into the SAP database where the original part data was pulled. Most of the time this change is communicated back to the operations team so they can update the reduction charts. But even if the change is not communicated 100% of the time, it will be discovered when the part data is pulled at the beginning of each month.

Each successive month of the study the data is pulled again to determine if any changes have been made to the SAP data regardless of whether or not that change has been communicated to the operations team or is directly attributed to the lead time reduction efforts. The repeat interval of one month was chosen to align with reporting processes in the operation team and to allow sufficient time for the teams to work with suppliers. Also, each month a comparative analysis is performed between the new month's data and previous month's data in order to monitor the impact of lead time reduction strategies and provide a greater understanding of where to apply the organization's resources in order to achieve the greatest reduction in aircraft lead time. This data also shows if the lead time of a part has been reduced enough to bump it off the list. If the longest lead time parts are reduced in a month, then the aircraft lead time will be reduced. The aircraft lead time is always calculated by subtracting the aircraft complete date from part with the earliest calculated start date (the tent pole part).

When the new month's data is added to the reduction chart, the previous months lead time data is shifted to the left. This data is kept from month to month in order to perform trend analysis on the long lead parts. The operations team then compares the lead time data from the previous month to the data from the current month noting any significant changes. Two comparisons should be performed to identify lead time changes that have occurred and whether the changes have an impact on the overall aircraft lead time.

1. Compare the lead time columns from the previous and current month for changes in lead time.
2. Compare the horizontal bar on the lead time reduction charts from last month's file to the current file.

When comparing the two months of data it is helpful to sort the parts from the earliest order date to the latest. This will align the parts showing the primary drivers on the top and the less significant parts on the bottom. This can be used to visually identify which parts have the most significant impact on overall aircraft lead time. Any changes in the long lead parts should be noted and the reason for the change should be investigated.

Since part data is only added to the reduction chart for those parts whose order date occurs after the reduction target date, there will be times when no current month data was noted for a part that was on the list in a previous month. This is an indication that the lead time for that part had been reduced enough that it is no longer a long lead part. Additional data may be needed for parts that are no longer long lead time parts. This information can be gathered by the operations analyst to determine the new lead time for these parts or if a change in build sequence has impacted the part.

There may also be instances when a new long lead part is added to the list. This may be due to changes in the parts lead time (it's now longer) or build sequence that has caused the part to cross the reduction target line. Any new long lead parts or parts that are no longer identified as long lead parts should be examined to understand why the change occurred and if they have an impact on overall aircraft lead time. During the study, a 'part changes' log was maintained from month to month to understand which strategies were most effective at reducing part lead times. Findings from the 'part changes' log are discussed next in chapter 4.

# 4 Results

This chapter provides the results of the six month lead time reduction study. Section 4.1 describes results from using the lead time reduction chart. Next the lead time reduction strategies are summarized in section 4.2 showing how often the strategies were used and which strategies made the best gains. The key metric that is used to confirm the hypothesis of this thesis is a reduction in aircraft lead time. Summary of the aircraft lead time reduction and data considerations associated with calculating the reduction is discussed in sections 4.3 and 4.4.

## 4.1 Use of the Reduction Chart

As discussed in section 3.6, one of the first steps in the study was to populate the lead time reduction chart and determine the list of long lead parts. This is a powerful first step because it provides a structured way to identify the right parts that should be the focus of the lead time reduction efforts. Figure 12 compares the difference between the number of parts that were in the baseline list (see section 3.1) and the reduced number of parts after using the reduction chart framework. By simply populating the reduction chart, the 381 parts that were previously being worked were narrowed down to 193 long lead parts resulting in approximately 50% less parts that need to be reduced in order to meet the aircraft lead time target. It is interesting to note that for most aircraft the number of long lead parts are reduced but for one aircraft the number of long lead parts is increased. Additionally, three of the aircraft have very few long lead parts. A single long lead part indicates that this part has to be ordered considerably sooner than any other part. This may be an indication of that the supplier is experiencing difficulty producing the part and may need help.

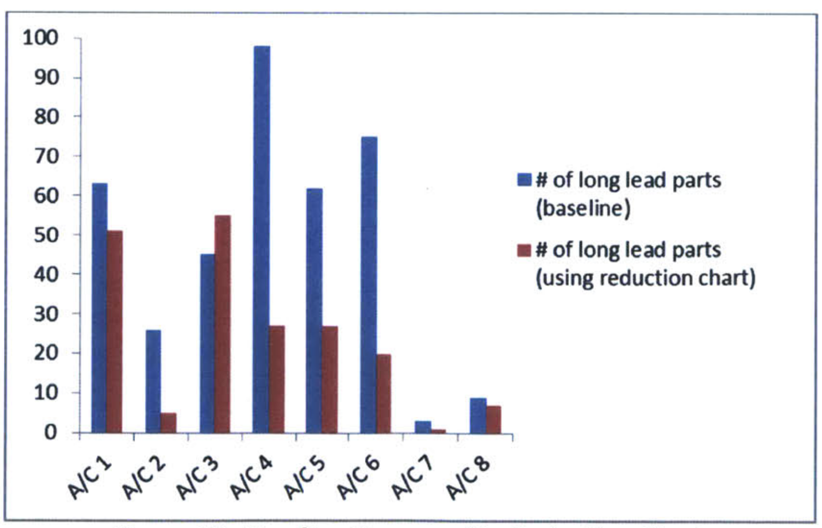



**Figure 12 - Baseline Compared to Reduction Chart**

## 4.2 Reduction Strategies

The lead time reduction team used multiple strategies to reduce the part lead time. The first approach for all parts was to ask the supplier for an updated lead time. This approach required little effort but provided the most substantial decreases in part lead time of any other strategy. If this strategy was unsuccessful in reducing the lead time of the part or removing the part from the long lead part list, then additional strategies were pursued. Table 1 summarizes the lead time reduction strategies that were used, how often each strategy was used, how effective the strategy was at removing a part from the long lead part list, and how many days were reduced by using the strategy.

| Lead Time Reduction Strategies | Number of parts where the strategy was used | Total number of parts bumped off long lead part list with this strategy | Total number of lead time days reduced using this strategy | Notes |
|---|---|---|---|---|
| Update supplier lead time | 67 | 51 | 3964 | Most successful lead time reduction strategy. |
| VSM w/ Supplier | 2 | 0 | 145 | Sikorsky provided full time support at supplier with highly engineered flight safety part. |
| source raw material supplier | 1 | 1 | 35 | In one instance a raw material supplier was willing to lower their lead time to the part supplier if the supplier was on an LTA. |
| Provide raw material to supplier | 0 | 0 | 0 | This option was vetted for one supplier but ultimately the strategy was not used during the course of the six month internship. |
| Second source part supplier or Make/Buy part | 18 | 18 | 1836 | It was determine that 18 of the parts on the long lead list were made by Sikorsky and a supplier. Since Sikorsky could promise a lower lead time these part were removed from the long lead part list. |
| Redistribute assemblies or need date | 1 | 1 | 210 | Part was initially procured by Sikorsky and then sent off to another supplier to be used in an assembly that was subsequently returned to Sikorsky. Removing Sikorsky as the middle man moves the need date later and allows this part to be removed from the long lead time part list. |
| Part supermarket / Safety stock | 0 | 0 | 0 | Sikorsky had previously determined the parts that they wanted to include in the part supermarket. |
| Reduce buyer admin lead time | 12 | 12 | 370 | Some buyers were willing to remove admin lead time from the procurement lead time because their parts were on a long term contract. |
| Other factors not related to reduction strategies | | 11 | 87 | There were multiple parts with the default lead time of 290 days. The buyer was asked to verify the lead time for these parts resulting in 11 dropping off the long lead part list. |

**Table 1 - Effectiveness of Lead Time Reduction Strategies**

One situation in particular showcased the effectiveness of using multiple lead time reduction strategies. The part in question was a critical flight safety part that was common to four of the helicopters. It also happened to be the 'tent pole part', so reducing the lead time of the part would have a direct impact on reducing the aircraft lead time for all four helicopters. As just described, the first approach was to ask for an updated lead time. In this instance, the supplier was in the process of re-negotiating a long term agreement (LTA) with Sikorsky so the supplier lead time had recently been updated and was accurate.

Learning more about the manufacturing of the part led to the realization that the raw material lead time was the majority of the lead time of the part. With this in mind, the team looked for ways to reduce the raw material lead time by providing the raw material through Sikorsky, second sourcing the raw material provider, or using Sikorsky's influence on the raw material provider to offer better lead time terms to the supplier. After a series of negotiations, the raw material provider said it was willing to reduce the raw material lead time for the part as long as it had a commitment from the supplier that it would be making this part for at least the next few years and that the raw material provider could count on this source of demand. This emphasized the importance of establishing an LTA with the supplier that would lock it into making the part for several years. Understanding this situation, the buyer put re-negotiating the LTA as its highest priority. In the end, coordination of work among operations, procurement, supplier, and raw material provider resulted in a reduced part lead time that was past the lead time reduction target, dropping the part off the long lead part list for all four helicopters.

## 4.3 Aircraft Lead Time Reduction

The primary indicator of effectiveness of the framework and strategies that were used during the course of the study is a reduction in aircraft lead time. Each month when the lead time reduction chart was populated, the aircraft lead time was also calculated for each of the eight helicopters included in the study. The data was combined into a common table and presented to Sikorsky management each month to track progress of the study. At the end of the study the aircraft lead time data was converted to a percent change in aircraft lead time from the baseline (aircraft lead time at the end of 2012). This conversion was done to prevent disclosure of actual aircraft lead times. Positive percent change is an indication that the aircraft lead time was reduced.

As can be seen from Table 2, there was an 8.2% average reduction of aircraft lead time over the course of the study, illustrating the effectiveness of a structured approach to aircraft lead time reduction. Some of this summary data shows irregularities that require further explanation in order to get a true sense for the impact of the lead time reduction that was performed through the study.

| Aircraft Lead Time Percent Change From Baseline | | | | | | | |
|---|---|---|---|---|---|---|---|
| A/C Model | Jan-13 | Feb-13 | Mar-13 | Apr-13 | May-13 | Jun-13 | Jul-13 |
| Aircraft 1 | 2.1% | 0.5% | 0.2% | 0.2% | 0.0% | 8.6% | 10.2% |
| Aircraft 2 | 12.3% | 10.4% | 10.4% | 10.4% | 11.5% | 15.6% | 15.6% |
| Aircraft 3 | 3.6% | -3.0% | -3.1% | -3.1% | -5.6% | -6.0% | 8.3% |
| Aircraft 4 | -2.0% | -2.6% | -2.7% | -2.4% | -2.3% | 5.7% | 5.7% |
| Aircraft 5 | 0.0% | 7.0% | 8.3% | 8.3% | 11.4% | 13.1% | 17.6% |
| Aircraft 6 | -2.8% | 2.8% | 2.9% | 4.1% | 7.8% | 7.8% | 11.7% |
| Aircraft 7 | -0.5% | -0.4% | -0.5% | -0.5% | -1.1% | 2.0% | -1.0% |
| Aircraft 8 | 13.5% | 31.0% | 31.0% | 31.0% | 31.0% | 0.3% | 0.0% |
| Average | 2.0% | 2.1% | 2.2% | 2.5% | 3.1% | 5.1% | **8.2%** |

**Table 2 - Aircraft Lead Time % Change from Baseline**

## 4.4 Data Considerations

**Aircraft 4**

Early on in the study a decision was made by management to slow down the production rate of this helicopter in response to changes in demand. The cycle time for the helicopter was kept at a value that was greater than the lead time at that point in time. For this reason, there was no direct work performed to attempt to reduce the lead time of this aircraft. Although there was no active work for the Aircraft 4, there were still reductions in aircraft lead time since Aircraft 4 has common parts with other helicopters that were reduced and impacted the aircraft lead time.

**Aircraft 8**

The long lead parts for this helicopter presented a particularly difficult situation. There were only seven parts that fell within the lead time reduction zone for this helicopter at the beginning of the study. However, the longest lead part was a highly engineered flight safety part that required several special manufacturing processes, each adding more days to the part lead time. A team from Sikorsky was already working closely with the supplier to help optimize the supplier's manufacturing processes, which falls nicely under the 'Supplier lead time value stream mapping' strategy. There were also opportunities identified where the 'Second source part supplier' and 'Reduce lead time of engineering processes' strategies would be useful since there were other suppliers that could make the part and the current supplier was not certified to perform some of the engineering processes required, so it had to outsource this work. The progress for reducing the lead time of this tent pole part was steady but slow going. Since the lead time for this part was not changed, the aircraft lead time did not change. This is a good example of why it's so important to focus on the tent pole part.

**Database Processing Issues for Aircraft 7**

After adding Aircraft 7 baseline data to the reduction chart there were only five long lead parts. The operations and procurement teams were able to quickly reduce the lead time of these parts past the reduction target. Since the target for this helicopter was reached, the lead time reduction focus was shifted to other helicopters. Even though the target for this helicopter was reached it remained on the reduction chart and its data was still pulled each month to monitor any changes that might occur. In June, the operations analyst altered the way that the simulated helicopter was created using RapidResponse, resulting in a long lead part surfacing and extending the aircraft lead time back to the point where the study began. After further investigation it was determined that the reason for this error was due to the choice of the theoretical aircraft complete date that was associated with the aircraft build scenario in RapidResponse. The aircraft complete date was chosen almost a decade into the future and it was speculated that SAP would not load MRP requirements that far into the future for some parts, so those parts were overlooked. It was determined that the new way of pulling the data was more accurate and that the part should have been accounted for throughout the entire study. Consequently, the aircraft lead time for this aircraft would not have changed without reducing the lead time of this part. The part in question was the equivalent part to the one just discussed for Aircraft 8, and was provided by the same supplier and therefore faced the same issues as discussed above.

**Default Part Lead Times**

When buyers create part contracts, they are required to enter part information in SAP with any changes in lead time. If the buyer doesn't add the lead time for the part (maybe the buyer was waiting to hear back from the supplier) then the SAP will assign the part a default value of 290 days. If the regular monthly retrieval of data occurs before the part has an updated lead time, then this may cause this new part to come on to the lead time reduction chart as a long part or even the longest lead time part for that aircraft. This error would continue until the correct lead time value is entered into SAP, which explains some of the instances in Table 2 and Table 3 where the lead time increased one month and then returned to its previous value the following month.

Removing the helicopter data for the issues that were discussed above increases the **average percent reduction to 12.7%** and reflects a more accurate picture of the results of the study and the effectiveness of the framework and strategies for reducing aircraft lead time (see Table 3).

| ***Revised* Aircraft Lead Time Percent Change From Baseline** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **A/C Model** | Jan-13 | Feb-13 | Mar-13 | Apr-13 | May-13 | Jun-13 | Jul-13 |
| **Aircraft 1** | 2.1% | 0.5% | 0.2% | 0.2% | 0.0% | 8.6% | 10.2% |
| **Aircraft 2** | 12.3% | 10.4% | 10.4% | 10.4% | 11.5% | 15.6% | 15.6% |
| **Aircraft 3** | 3.6% | -3.0% | -3.1% | -3.1% | -5.6% | -6.0% | 8.3% |
| **Aircraft 5** | 0.0% | 7.0% | 8.3% | 8.3% | 11.4% | 13.1% | 17.6% |
| **Aircraft 6** | -2.8% | 2.8% | 2.9% | 4.1% | 7.8% | 0.9% | 11.7% |
| **Average** | 3.0% | 3.5% | 3.7% | 4.0% | 5.0% | 6.5% | **12.7%** |

**Table 3 - Revised Aircraft Lead Time Percent Change from Baseline**

# 5 Conclusions & Recommendations

Chapter 5 discusses conclusions and recommendations from the lead time reduction study that was performed at Sikorsky. The results from the study indicate that a structured approach to lead time reduction can provide several benefits that are discussed in section 5.1. Human responses that impact lead time reduction efforts are discussed in section 5.2. And finally, recommendations for future research are presented in section 5.3.

## 5.1 Structure Makes a Difference

The framework and strategies for lead time reduction that have been presented in this thesis were instrumental in reducing the lead time of the helicopters at Sikorsky Aircraft Corporation by approximately 13% over a six month period. This framework provided focus and insights that made the efforts of the operation and procurement teams more effective.

Several of the strategies discussed in section 3.5 were used throughout the course of the study. The first approach for all parts was to ask the supplier for an updated lead time. This approach required little effort but provided the most substantial decreases in part lead time of any other strategy. This is either an indication that the suppliers focus on continuously improving their part lead times or they had some buffer in the part schedules that they were willing to remove, or a combination of both. Part of the reason that the suppliers may have been willing to reduce their part lead times was because they were made aware that their part was impacting aircraft lead time and that they were asked to reduce the part lead time a specific number of days instead of an across the board arbitrary amount. The lead time reduction chart helps to provide this level of clarity so the suppliers understand that they're helping to reduce aircraft lead time and not just receiving pressure from the manufacturer to deliver better results. Communicating this level of detail with suppliers is an essential part of the manufacturer-supplier partnership. David Weiters came to this same conclusion years ago. "A study that surveyed 244 companies and six different manufacturing companies concluded that the most effective technique to reduce supplier lead time was frequent communication. The next most effective technique was a visit to the supplier." (Weiters, 1979). What was true back then is still true today.

Not only is a structured approach effective at reducing aircraft lead time, but it's also very effective at revealing unique challenges (e.g., manufacturing of the highly engineered flight safety part on Aircraft 8) and inconsistencies that may exist in the data. Some of the other benefits and insights from using the lead time reduction tool (see section 3.3) are listed below.

- Focused reduction - Not all parts need to be reduced by the same percentage or days in order to meet the reduction goal.
- Focused part list – only focus on the parts whose lead time duration is in the reduction target window (reduced part list by approximately 50% from previous process).

- Reveals unique issues – importance of both, part need date and lead time duration, build plan insights, data trends, tent pole parts, etc.
- Can visually see the importance of working on the long tent pole.
- Can see that supplier lead time is greater than manufacturing lead time.

Creating and using this tool was an integral part of the success of reducing aircraft lead time. Before this tool was created, the same data was available and could have been used to come to some of the same conclusions if a person spent enough time analyzing the data. But by representing the data visually, important information naturally surfaces providing insights and focus. Presenting the 'big picture' can be very powerful.

## 5.2 Human Dynamics in Lead Time Reduction

Metrics are meant to be used to monitor and evaluate performance and drive desired behavior. However, sometimes metrics will drive performance in one area but reduce performance in another. For example, if a supplier is evaluated on its 'on-time performance' and then is asked to quote the part lead times that it can commit to, it will probably provide one of two responses:

1. Look at the value stream of the part and add up the time it takes to perform each step in the production process.
2. Do same as (1), but add a few weeks or more of buffer to ensure that the part can be delivered 100% on time.

With response (1), the supplier has done due diligence to determine how long it takes to procure raw material, forge the raw material, machine the forging, heat treat and stress relieve the machined part, coat/paint the part, etc. The quoted lead time should have little room for error if the process to make the part is in control. But inevitably unforeseen problems do occur and if the supplier happens to deliver the part late then it will probably be accused of poor performance. But was it really poor performance or was it just a 'pothole' in the road that interrupted production? Obviously it depends. Supplier management's reaction to a late delivery can make a big difference as to whether or not a supplier will continue to quote an accurate lead time or will add buffer to protect its performance rating.

With response (2), the supplier has put itself in a comfortable position with buffer that will protect its performance rating. Distorted procurement lead times are often a result of management decisions to either anticipate lead time changes or add buffer to avoid late delivery. Such management decisions generally are implemented by the mass overlay of procurement lead time data without respect for individual item characteristics (Perry, 1990). All things being equal, when a supplier responds this way it will have a greater probability of delivering parts on time and is more likely to receive a higher performance rating. But that's not all. When the manufacturer comes to the supplier in the future and asks if the supplier can reduce the lead time of its part, then it will easily have room to reduce the lead time. Result? More praise and increases in performance ratings for being a team player and helping out the manufacturer in a time of need. And if a supplier is particularly crafty, then it will still keep buffer in reserve to protect itself and be ready for the next time that a lead time reduction comes around. The point is, there are natural incentives to insert as much buffer as reasonable into a production schedule to receive a high supplier performance rating. But should a schedule full of buffer really be considered high performance? Clearly this doesn't happen all the time or with all suppliers, but imagine what would happen if many of the suppliers did follow this natural incentive. In this case, the aircraft lead time would be inflated and impact the competitive advantage of the manufacturer.

Unfortunately, this is not the only location where unnecessary buffer is inserted into the lead time of the part. This same pressure to deliver on time impacts the buyers in a manufacturers' organization. When buyers first send a part out to bid they need enough time to prepare the request, provide the suppliers with sufficient time to respond, and then evaluate the returned proposals to determine the 'best' supplier for the part. This can take several weeks to a few months depending on the complexity of the part and the supplier environment. This administrative time is needed to go through the procurement process and by default is added to the supplier quoted lead time of the part (procurement lead time of part = supplier quoted lead time + buyer administrative lead time).

For the majority of the parts, buyers will try to establish a contract with a long term agreement (LTA) in place for up to a five year period, which makes good business sense. With an LTA in place, buyers and suppliers don't need to go through the entire procurement process each time a part is needed for a helicopter. Instead the manufacturers' resource planning system will automatically generate a demand request based on the build plan of the helicopter. The problem in the resource planning system is that once the administrative lead time is attached to a part, it's there to stay. So each time the system sends out a request for a part it will tack on the admin lead time even though this extra time is not necessary. So why not remove this glitch from the system? The response from some buyers is that the admin lead time is needed for when the part contract comes to an end and another bid (or contract extension) is needed. The argument is that the admin lead time is there to keep uninterrupted delivery of aircraft parts. However, this time is only needed at the end of the contract. So the result of not removing the admin lead time is that unnecessary buffer is inserted each time an automatic part request is sent to the supplier, for the duration of the contract, which can be up to five years long. If this part happens to be the longest tent pole, then that means that for five years the operations team will be forecasting further out into the future than necessary, resulting in less accurate forecasts.

The solution to this problem is to not only measure on-time delivery performance but to also use lead time as a performance metric. Without a doubt, measuring good lead time performance or bad lead time performance is more difficult than simply calculating the percentage of the time that supplier parts are delivered according to schedule. One possible way to evaluate lead time performance would be to establish a requirement that in order to receive the highest overall supplier rating, a supplier must submit a value stream map or detailed production schedule for each of its supplied parts. Or if a manufacturer really wanted to emphasize the importance of aggressive supplier lead times, then it could make this part of the supplier selection process. Granted, if a supplier was required to submit this information it could still potentially hide buffer in the schedule but at least this would encourage suppliers to go through the process of writing down all the production steps and adding up the time spent at each step. Oftentimes when value stream mapping is done correctly, the supplier will be able to identify over-processing, transport, motion, waiting, or inventory waste that can be removed from the process.

Another possible way to measure performance of lead time could be to provide the suppliers with a lead time reduction goal for the year. By reducing the lead times for its parts, the supplier will drive the quoted lead time closer to actual lead time (with large buffers removed). The metric could be applied to the supplier in the same way that a manufacturer uses the metric in its own facility. In a true partnership environment, the manufacturers and the suppliers could share best practices, processes, and tools to help reduce lead times.

Regardless of how it's done, metrics for lead time need to exist before there will be significant reductions in procurement lead time. It is promising to note that, partially due to the lead time reduction study, the manufacturing centers at Sikorsky were meeting together to revisit lead time reduction and the best way to evaluate performance both at the manufacturer and at suppliers.

## 5.3 Recommendations for Future Research

Given the length of the study, it was not possible to apply all of the lead time reduction strategies and observe their effectiveness. A more comprehensive study could allow more time to observe all of the lead time reduction strategies including those that may result in an engineering process change or observing the challenges and benefits of qualifying a second supplier for a part.

Also, the study was performed mainly from the prospective of the manufacturer with some feedback from suppliers. Future research studies could be performed at a supplier's facility with industrial engineers and supplier management representatives from the manufacturer providing assistance to the suppliers. The study would allow direct observation of value stream mapping exercises and best practices that could be shared between the manufacturer and supplier as partners. The teams could also work to establish lead time reduction metrics and definitions of high performance.

Since the greatest opportunity for reducing aircraft lead time can be found in the procurement lead times, manufacturers should continue to look for ways to work with suppliers, reduce part lead times, and gain a competitive advantage.

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