Reducing Government Proposal Procurement Process Complexity

by

Jerry Kao Chiang

B.S. Electrical and Computer Engineering, Cornell University, 2005

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

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Master of Science in Engineering Systems

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Signature redacted

Signature of Author ____________________
Engineering Systems Division, MIT Sloan School of Management
May 9, 2014

Signature redacted

Certified by ____________________
Bruce Cameron, Thesis Supervisor
Lecturer, Engineering Systems Division

Signature redacted

Certified by ____________________
Roy Welsch, Thesis Supervisor
Professor of Statistics and Management Science, MIT Sloan School of Management

Accepted by Signature redacted ____________________
Richard C. Larson
Mitsui Professor of Engineering Systems
Chair, Engineering Systems Division Education Committee

Signature redacted

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

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Abstract

US Aerospace Defense Vehicle Manufacturer (UADVM) sells Assembled Complex Equipment to the US Government through multi-year contracts. According to the Truth in Negotiations Act (TINA), such government defense contracts require cost and pricing data as well as supporting documentation, known as material substantiation, to justify pricing and supplier selection. In order to comply with these government regulations, UADVM needed to estimate material costs provided by its supply chain, in a process known as multi-year procurement process. At UADVM, this process involved substantial time, effort, and rework. Through interviews and surveys, total administrative effort to manage the Multi-Year X (MYX) Procurement Process is estimated to be about 41 full-time equivalents (FTEs) per year for three years, translating to an estimated fully loaded cost of $17.3 million. In order to significantly improve the current process, a key area of opportunity is to reduce the complexity of the entire process through 1) reducing the number of inputs, including the number of parts and bids sent out as well as suppliers and price points solicited, and 2) improving the design of the bid strategy, the determination of which parts are bid out to which suppliers, how to group these suppliers and parts into bids, and who should manage these bids in the most efficient and effective manner. Through the analysis of UADVM's MYX data, input reduction can potentially reduce the number of price points solicited by 99.2% and the number of interactions, also known as the number of unique combinations between parts, bids, and suppliers, by approximately 94%. These efforts can be complemented by an improved bid strategy through the use of a data-driven mixed integer linear programming optimization model, which, in tests on a sub-portion of the data, reduces the number of packages by 43%. These methods and analyses for complexity reduction can be generalized beyond current applications at UADVM, aerospace companies, and government proposals; they may be applied to any procurement process where multiple parts, suppliers, and bids are involved.

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

Thesis Supervisor: Roy Welsch
Title: Professor of Statistics and Management Science

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Finally, I would like to thank my family and friends for all their support. I could not have made it this far without your encouragement, companionship, and guidance.

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Note from the Author

While preparing for my thesis, I realized that readers who may not have an appreciation of the multi-year government procurement processes for such a complex product may come away with a mistaken impression about the people who work at UADVM or for the US government. My opinion is that the individuals on both sides are intelligent, capable people who work exceptionally hard to abide by the regulatory requirements around defense contracting and protect the interests of the American taxpayer. There are no easy answers or silver bullets for creating a fair, effective, transparent, and simpler defense contracting process. In fact, the Multi-Year X contract is considered a model contract by the government. It was completed on-time, provided significant cost savings, and yielded unprecedented transparency, allowing the government to truly assess that the data is current, accurate, and complete. The systems in place at UADVM are considered the "best of breed," and the people on Multi-Year X were truly dedicated, working long hours, often late into the night or throughout weekends. If anything, the challenges UADVM faced with such a complex process and closely monitored environment are just reflections of their commitment to do the best it could on behalf of the government customer. My thesis will explore these challenges, and provide opportunities to reduce the complexity of the process, but that does not diminish the admiration I hold for them in undertaking this enormous task.

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Glossary

Ariba – The system used to solicit bids from suppliers and manage the RFQ process in the Multi-Year X Procurement Process

AWS – Adaptive Workspace – a database that contains copies of all the data in the RFQ process, accessible to government

Business Acquisition Team (BAT) – Team that manages the multi-year government proposal on behalf of UADVM. Team includes, but is not limited to, representatives from Proposal Operations, Government/Commercial Programs, Engineering, Worldwide Customer Service, Operations, Facilities, Government Property, Program Planning and Control, Finance and Contracts and Counsel.

Bid Package – The bid data and negotiation history around a collective set of parts which would be specified in a common contract

Bid Strategy – The process step where decisions are made regarding what parts or bid out to what suppliers, and who should be managing those bids and suppliers

Case File - Holds all the details around the RFQ process for a particular package (may contain multiple vendor / parts)

Competitive Solicitation – A bid where multiple suppliers are invited

DCAA Audit – The cost and pricing audit conducted by the Defense Contract Auditing Agency (DCAA) in the case where the supplier refuses a CPA audit from UADVM

Defective Pricing –The negotiated contract price is significantly higher because of failure by a contractor or subcontractor at any tier to provide current, accurate, and complete cost or pricing data where required by law

OneSource – UADVM's standard bidding tool that allows suppliers to provide quoted prices to Buyers for most proposals and production orders

Handshake – The point in time when UADVM and the government come to agreement on the pricing and terms for a government proposal

HUBZone Small Business (HZSB) – Business must be located within a designate HUBZone Area (historically underutilized business zones). Must be a small business that is owned and controlled by U.S. Citizens, and at least 35% of its employees are HUBZone residents.

Multi-Year X Database – UADVM's custom Oracle database that contains all the data for the Multi-Year X Procurement Process

Price Analysis – A standard required analysis that compares historical pricing with bid prices, taking into account the effect on price due to both quantity and time

Price Type – The type of pricing that is quoted or contracted; while there are a variety of possible Price Types, such as Firm Fixed, Variable, and Not-To-Exceed, for MYX, Price Types are expected to be Firm Fixed, implying prices should not change over the life of the contract

Service Disabled Veteran Owned Small Business (SDVOSB)– Business that is owned and operated by one or more U.S. citizens that were disabled during their military services as determined by the Veterans Administration.

Single Source Award – Bid awarded to supplier for reasons other than strict price competition, or without competition for various business reasons (e.g. no response from other competing suppliers). Under normal procurement circumstances, the bid would have more than one approved source of supply.

Small Business (SB) - A business that is independently owned and operated, not dominant in the field in which it is bidding, and which meets small business size standards as defined in FAR Part 19.

Small Business Plan (SBP) – A plan provided by large suppliers that outlines how much spend they will allocate to small businesses as they purchase materials from their suppliers

Small Disadvantaged Business (SDB) - A small disadvantaged business (including Black, Hispanic, Native and Asian Americans, or other groups) as defined in FAR Part 19.

Sole Source Award - Bid awarded to a supplier who is the only currently approved source of supply (i.e. item categorized as proprietary or patented with no license)

Sole Source Solicitation – A bid where only one supplier is invited

OneSourceSupplierTrakker - A tool that allows the government customer to see all the bid prices across all the suppliers by part number

Sweep Database – The data repository the collects all of the latest pricing from across negotiation teams before the Handshake

Veteran Owned Small Business (VOSB)- Business that is owned and operated by one or more U.S. citizens that serviced in the U. S. Military for a minimum of 180 days.

Women Owned Small Business (WOSB) - A small business that is at least 51% unconditionally owned and operated by one or more women as defined in FAR Part 19.

List of Acronyms

BAFO	-	Best and Final Offer
BAT	-	Business Acquisition Team
CID	-	Commercial Item Determination
CPA	-	Cost-price Analysis
DCAA	-	Defense Contract Auditing Agency
DFARS	-	Defense Federal Acquisition Regulation Supplement
FAR	-	Federal Acquisition Regulation
ITSR	-	Information Technology Service Request
LE	-	Latest Estimate
LSO	-	Last Supplier Offer
LTA	-	Long Term Agreement
MOA	-	Memorandum of Agreement
NAM	-	Negotiation Authority Meeting
OTLB	-	Other Than Low Bid
RFP	-	Request for Proposal
RFQ	-	Request for Quotation
SDB	-	Small and Disadvantaged Business
TINA	-	Truth In Negotiations Act

1 Introduction

In this thesis, I explore the challenges with a multi-year government procurement process at a major prime aerospace defense contractor, the drivers for those challenges, and an approach for process improvement. The approach involves: 1) recommendations in planning to reduce complexity of the inputs, and 2) an optimization tool that facilitates a data-driven approach to further reduce in-process complexity. Many of these approaches can be extended to reduce the complexity required in order to meet the needs of other companies conducting procurement processes in support of government proposals. Finally, this thesis will conclude with a treatment of the results and cover remaining questions open to further research.

Hence, the structure will be laid out as follows: Chapter 1 and 2 will provide a brief introduction of the background, scope, hypothesis, methodology, and relevant literature. Chapter 3 will provide the reader with some familiarity with the process before diving into the key areas for opportunity for further improvement, which are identified in Chapter 4-5. Chapters 6-7 will provide details on the approaches mentioned above, before concluding in Chapter 8 with overall findings and areas for further study.

1.1 The Company

US Aerospace Defense Vehicle Manufacturer (UADVM) is a subsidiary of Large Multinational Corporation and a world leader in the design, manufacture and service of military and commercial Assembled Complex Equipment. UADVM's largest customer is the United States government, and as a result, "defense industry-related work accounts for about 65 percent of the company's business" (Defense Industry Daily, 2013). The bulk of UADVM's business with the United States government comes from five-year term multi-year contracts that cover the sale of Assembled Complex Equipment. Due to the volume consolidation, multi-year contracts have been shown to yield considerable savings for the US government over annual contracts. At the same time, the multi-year contract is the bedrock of UADVM's business, providing a critical measure of stability for the company, allowing for steady cash-flow, stable operations, and longer term planning.

In 2010, UADVM started discussions with the US Government on the Multi-Year X (MYX) Proposal, which covers the terms and pricing for the production of the Army and Navy's Assembled Complex Equipment from 2013-2017. After a 3 year process, UADVM and the US government signed a multi-billion dollar contract.

1.2 Context and Motivation

In order to prepare for the next multi-year proposal, Multi-Year Y Proposal (MYY), covering government purchases for Assembled Complex Equipment from 2018-2022, UADVM is reviewing lessons learned from the MYX. This review may also serve to improve and streamline the process for future multi-year proposals in general. One of the major areas of review is the MYX Procurement Process, which is the process UADVM runs in order to estimate the costs of the parts sourced from its supply base in order to meet regulations around government contracting. The MYX Procurement Process runs in parallel with the MYX Proposal Process, and provides key inputs to help price the helicopter for the MYX Proposal.

MYX is one of the largest contracts in UADVM's history, and met all of the government's primary objectives, yielding cost savings through a compliant process that was completed on-time. Yet the contract also resulted in the most complex procurement processes, resulting in high workloads for UADVM staff, suppliers, and government auditors, complex bid packages (i.e. the bid data and negotiation history around a collective set of parts that would be specified in a common contract), long negotiations, potential issues with future estimating accuracy, and additional costs to UADVM. One factor that has influenced complexity is the tighter regulatory environment around defense contracting due to government pressures (Perez, 2010). As the result of government pressures, there is more pressure for cost savings and transparency, resulting in increased competition (Federal Register, 2010), more detailed reporting (Censer, 2011), and more conservative interpretation of key regulations (Freeman, 2013).

The MYX Procurement Process, the largest multi-year procurement process in UADVM's history, took approximately three years to complete and encompassed over 14,000 part numbers, 1,750 bid responses, 370 suppliers, 100 buyers, 60 negotiators, and 12 million price points. The purpose of such a large operation is to achieve better pricing for the government customer. However, since the savings are passed through to the government, who provides UADVM with a fixed percentage markup on the cost base, the majority of the benefit of savings is unable to be captured by UADVM. UADVM's motivation for obtaining better pricing includes 1) a desire to satisfy the government customer, 2) a chance to leverage savings on common parts on other products, and 3) an opportunity to reduce the cost base to win additional sales.

To manage the MYX Procurement Process, UADVM spent an estimated $17.3M on administration of the procurement process alone. Given the tight regulatory environment for the foreseeable future, requirements around future procurement processes likely will stay similarly stringent. Hence, there is a pressing need to streamline the Multi-Year Procurement Process itself so that UADVM can better serve the government customer while lowering the overall risks and costs in administering the process. Increased efficiency shrinks the cost, effort, and time required.

1.3 The Scope

The scope of this thesis includes examining the entire Multi-Year Procurement Process from initial RFQ strategy to Purchase Order (PO) approval and placement. The focus of the thesis will be improving the MYX Procurement Process from a Supply Management perspective, but will consider the perspectives of other stakeholders to mitigate the chance of producing myopically-focused recommendations that improve the Multi-Year Procurement Process at the expense of estimating workflows, compliance workflows, and other, non-multi-year proposal processes. However, the scope will neither include recommendations for improving the Multi-Year Proposal Process itself, nor improving the workflow used to gather and estimate costs, even though both processes rely on data from the Multi-Year Procurement Process, thus both may be indirect beneficiaries of a more efficient procurement process.

1.4 The Hypothesis

A major driver of process inefficiency in the MYX process is complexity. Complexity is driven by the number of inputs into MYX and the number of connections between these inputs. The inputs are described in more detail below:

Part Numbers – the number of unique part numbers bid out to external suppliers

Bid Responses – the number of bids received from suppliers in the process

Suppliers – the number of suppliers involved in the bid process

Negotiators – the number of UADVM personnel in charge of negotiations with suppliers

Buyers – the number of UADVM personnel responsible for day to day purchase of parts bid out

Price Points – the number of data points solicited from suppliers for a given part on a given bid

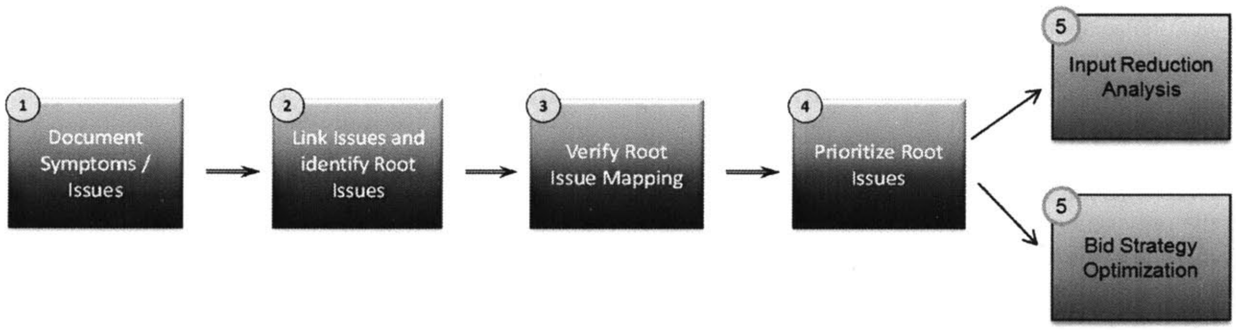
Connections between inputs is determined by what is known as the Bid Strategy, which specifies what parts are bid out to what suppliers, what parts and suppliers are grouped into which bids, and which bids or suppliers are managed by which negotiators. While Bid Strategy can include reassigning parts to Buyers as well, this assignment is assumed to be fixed for UADVM.

With the above definitions in mind, my hypothesis is that the MYX Procurement Process can be improved by reducing complexity by 1) the reducing the number of inputs to the process, and 2) improving the Bid Strategy using a data-driven approach embodied by an optimization tool coupled with a structured, well-defined Bid Strategy Review Process.

1.5 Research Methodology

The process improvement methodology used in the Multi-Year Procurement Process includes an Investigative Approach that led to two solutions, as illustrated below:

Figure 1: Methodology Process Flow



The steps in the diagram are described in more detail below:

Document: Issues were gathered through qualitative as well as quantitative sources. Qualitative information was surfaced through conducting interviews with 35 stakeholders across 11 departments, including managers in Proposals, Estimating, Compliance, CPA, Contracts, Commodity Management, and IT, Chief Procurement Officers, Buyers, and administrative staff. Interviewed subjects were asked to provide 1) a description of the issue, 2) the impact or potential impact (may be short-term and/or long-term) to their function and overall business, 3) the drivers of the issue, and 4) any potential ideas or solutions to mitigate the effects. Quantitative data on MYX was subsequently examined and used to confirm or shed further light on the issues documented.

Link: Based on the information gathered in the prior step, issues were linked together causally to identify potential root issues, symptoms at intermediate stages, and overall end effects. Due to the nature of the process, many of the documented issues were driven by issues identified upstream and that were leading to further issues downstream. A detailed treatment of root issues will be provided in Chapter 4.

Verify: Once a conceptual mapping of issues and their relationships was formed, the mapping was shown to key stakeholders for feedback. Stakeholders provided adjustments to the mapping and confirmation of hypothesized causal relationships.

Prioritize: The root issues are examined and prioritized based on their potential impact, urgency, and potential for mitigation. The focus is on identifying areas for process improvement, thus root issues due to factors beyond UADVM's control are not given great consideration.

Solutions: Input Reduction Analysis and Bid Strategy Optimization are the two hypothesized approaches, and will be covered in great detail in Chapters 6 and 7.

2 Background

In order to understand the MYX Procurement Process, it is important to first have a grasp of the aerospace defense industry as well as the regulations around defense contracting.

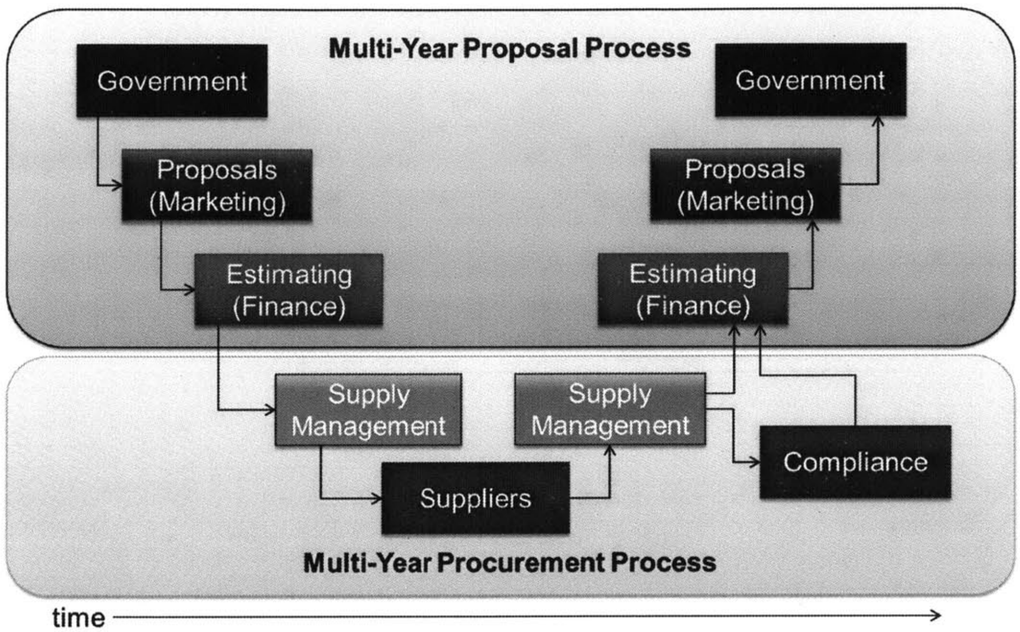
2.1 Aerospace Defense Industry

The aerospace defense industry employs approximately 3.53 million workers directly and indirectly and generated $324 billion in sales revenue in 2010 with $15.6 billion in profits (Deloitte, 2012). It is the largest net industry exporter and provides considerable benefit to the US economy. The industry is closely monitored, due to its ties to the government, sensitivities around defense-related businesses, and the importance of safety. Due to regulation, the industry is also prone to business cycles induced by changes in the US defense budget, and the current economic climate has resulted in a decline in defense spending since 2008 (Jesse Ellman, May 2011).

2.2 Links between the Multi-Year Proposal and Procurement Processes

The Multi-Year Proposal Process is the contract negotiation process between the government and UADVM. In MYX, the government solicited UADVM for a sole source proposal, meaning UADVM is the only one bidding for the MYX contract. As a result, government regulations stipulate that UADVM must provide certain supporting documentation, also known as material substantiation, in order to help the government negotiate a fair and reasonable price. In accordance with the Truth In Negotiations Act (TINA), UADVM "must submit cost or pricing data and certify that such data are current, accurate, and complete prior to award of any negotiated contract." (Guiseppe, 2011) In order to do so, UADVM must estimate its costs to build the product, which includes current and estimated future labor and material costs. Estimating material costs can be done using historical costing data or through soliciting suppliers for bids, though a sufficiently high percentage of the total spend with external suppliers (historically speaking, at least 80%) needs to be bid out. This gives the government confidence that the vast majority of the cost base has been validated by going to the market, reducing the risk of the government losing out on any savings UADVM might gain from further bidding part after the contract has been signed. Furthermore, in order to meet the government customer's expectations around data visibility, all supplier bid data collected by UADVM needs to be provided back to the government, along with an audit trail showing UADVM followed proper bid control and negotiation procedures as well as provided supplier selection rationale. The figure below shows the relationship between the two processes, the parties involved, and the flow of information required.

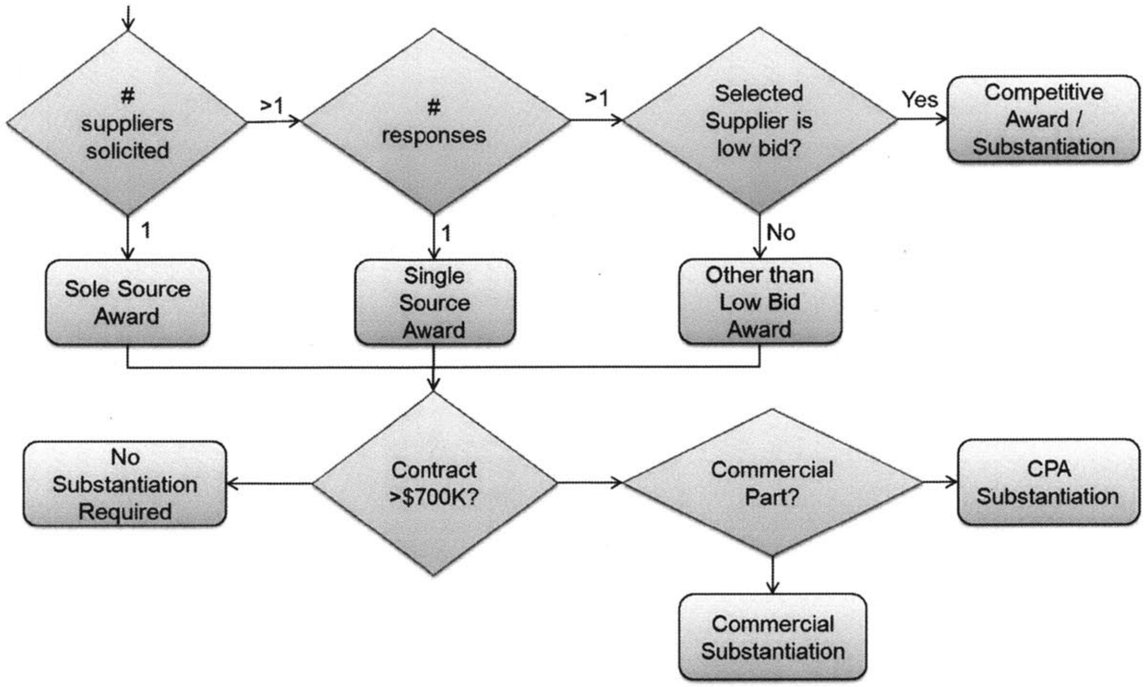
Figure 2 - Link between the MY Proposal and Procurement Processes



Substantiation Requirements

In addition to UADVM providing current, accurate, and complete data to the government customer on the bidding process, in accordance with the Truth In Negotiations Act (TINA), UADVM needs to substantiate all spend for parts sourced from suppliers, as material substantiation is a required for any part or product purchased directly or indirectly (i.e. a contractor, such as UADVM, purchases a part that goes into a product or subassembly that eventually ends up in a government purchase) by the government. The goal is to ensure the government and its agents, including sole source contractors like UADVM, have information to negotiate a fair and reasonable price on behalf of the government. The paths for substantiation are illustrated in the figure below:

Figure 3 - Bidding Situations and Substantiation Types



Material substantiation is waived for any supplier that contributes parts or products totaling less than $700,000 in spend on a government contract. For suppliers with an aggregate spend that exceeds $700,000, there are the following three ways to achieve substantiation (Freeman, 2013):

Competitive Substantiation

If the suppliers selected for a given part or product is the lowest bidder in a competitive bidding environment (i.e. more than one supplier solicited and more than one supplier response received), then the part can be awarded on a competitive basis. This is known as competitive substantiation, and supporting documentation showing the competitive bidding environment and the bid price responses is required. Competitive awards can be given out on a best value basis, which includes factors beyond unit cost, including fixed costs and switching costs such as tooling, non-recurring engineering, and qualification costs. Generally speaking, competitive substantiation is the easiest, most inexpensive, and least complex form of substantiation, while expected to provide the highest potential cost savings. Hence, there is a preference both by the government and by UADVM for competitive substantiation. In MYX, approximately 37% of the part numbers from external suppliers, which covers 28% of external spend, was substantiated competitively.

Commercial Substantiation

Material substantiation can also be accomplished if a part can be classified and approved as a commercial part, with the theory that prices for such parts are regulated by natural market mechanisms. This requires the supplier to provide evidence that the part has been sold in a commercial setting. In the past, this only meant suppliers needed to fill out a claim form and provide an invoice showing the sale to a commercial entity, but it did not need to show the price. In the current regulatory environment, commercial substantiation has become much stricter, and now requires invoices with pricing and customer information, an escalated price analysis, a list of part modifications and estimated costs, and end user information. (Freeman, 2013) Government oversight appears to be increasing for commerciality, and as a result, commercial substantiation has become more complex, expensive, and challenging for UADVM to manage.

Cost and Pricing Data Substantiation

In lieu of competitive or commercial substantiation, material substantiation can be accomplished by having the supplier provide cost and pricing data. This often occurs in situations with sole source suppliers who own the part designs and intellectual property, or when there are no other qualified or competent suppliers available to make the part. This may also occur when the selected supplier did not provide the lowest bid. Similar to the government's effort to obtain labor and material cost information from UADVM, UADVM would need to obtain labor and material cost information from its suppliers so that it can conduct a cost and pricing analysis (CPA). Suppliers often prefer not to reveal their cost data to UADVM, as it may undermine their negotiating position. Should suppliers decline to provide cost and pricing data to UADVM, the Defense Contract Auditing Agency (DCAA) can conduct such an audit, though historically, a DCAA audit requires a longer cycle time than a CPA. Substantiation through CPA or DCAA is significantly more time-consuming and costly than competitive substantiation. In either case, the results of the CPA or DCAA audit are meant to arrive at a price target that is meant to inform the negotiation and help UADVM arrive at a better price on behalf of the government.

<u>Uncertainties in Pursuing Competitive Substantiation</u>

As discussed, competitive substantiation is the preferred route by both UADVM and the government. However, competitive substantiation is often difficult to guarantee because its definition depends on two moving targets: 1) who is the selected supplier, and 2) what is their latest price, also known as the Latest Estimate (LE). NegLeads can decide to transition a part from an incumbent to a new supplier, and if so, the substantiation required for the incumbent versus the new supplier will be different – one may allow for competitive substantiation while the other may require cost and pricing substantiation. Furthermore, in a fluid negotiating situation, the Latest Estimate from both suppliers may change by the day or hour. Hence, a supplier who provided a lowest price yesterday may no longer be the lowest today.

<u>Bidding Situations and Effect on Substantiation Type</u>

Generally speaking, there are four possible bid award scenarios that could occur, with different implications for substantiation. They are summarized in Figure 3 from above and also detailed below:

Sole Source: Single Solicitation, Single Response and Single Source Award

In this scenario, UADVM solicits a single supplier for bid. The supplier is made aware it is a sole source supplier, and submits the requisite documentation around commercial or CPA substantiation with their bid.

Single Source: Competitive Solicitation, Single Response and Single Source Award

In this scenario, UADVM solicits multiple suppliers for bid, but only one supplier provides a response. Technically, under Federal Acquisition Regulations 15.403-1, UADVM can make the case that a competitive solicitation to two or more suppliers who are capable of providing a meaningful offer and where suppliers presume there will be other competitive offers means that competitive substantiation is reasonable. However, given the conservative regulatory environment and current government budgetary pressures, UADVM tends to treat such cases similar to sole source scenarios, requiring commercial or

CPA substantiation. However, because suppliers were solicited competitively, it may be difficult to obtain the requisite data. In those cases, UADVM can reissue a sole source RFQ to the supplier, or ask the DCAA to help with an audit.

Other than Low Bid (OTLB): Competitive Solicitation, Competitive Response, Single Source Award

This is the scenario where UADVM solicits multiple suppliers, receives multiple offers, but ends up selecting a supplier that is not the lowest bid or best value. Similar to Single Source, UADVM would then need to obtain commercial or CPA substantiation.

Competitive: Competitive Solicitation, Competitive Response and Competitive Award

This is the competitive award scenario where UADVM is able to obtain competitive substantiation as it solicited multiple suppliers, received multiple offers, and awarded the supplier with the lowest bid or best total value. Given the complexities of substantiation, coupled with the uncertainty around which suppliers would respond, what their prices will be, and who the selected supplier will be, ascertaining which substantiation path may be challenging at times.

3 Multi-Year Procurement Process Current State

The Multi-Year Procurement Process is designed to enable UADVM to 1) select supplier(s) for parts that go into the product on the multi-year contract, 2) substantiate the selected suppliers' prices, 3) sign Long Term Agreements (LTAs) with those suppliers at a negotiated price, and 4) provide pricing interim and final data to the Estimating function. MYX organizational structure, process details, and system tools and architecture are described below.

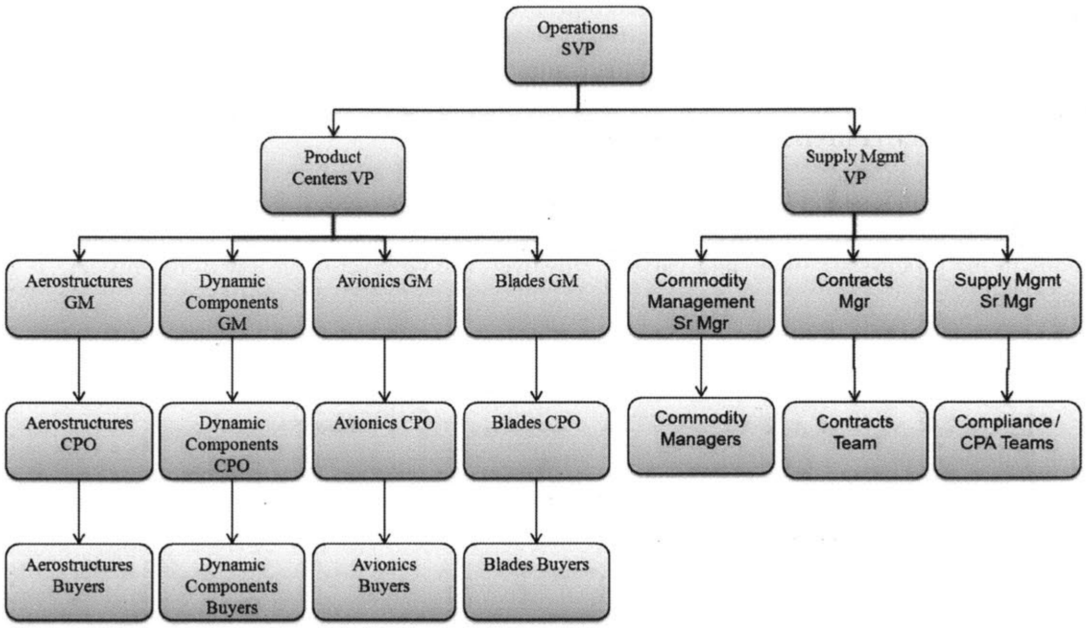
3.1 MYX Procurement Roles and Responsibilities

<u>Purchasing Roles at UADVM</u>

Procurement roles at UADVM consist of those at the business units, known as Product Centers, and those in Commodity Management. Buyers within each Product Center (Aerostructures, Avionics, Blades, and Dynamic Components) focus on the day-to-day transactional activities, such as purchasing the parts under their responsibility and ensuring the parts make it to the factory floor on time. All parts roll up to a specific buyer, who has the requisite domain knowledge and history around the purchase of that part and the relationships with the suppliers involved.

Commodity Managers, on the other hand, look at purchasing and the supply chain holistically across a longer time horizon. Each Commodity Manager is in charge of a material type (also known as a "commodity"), which includes avionics, forgings, castings, bearings, machining, composites, electrical components, fasteners, gears, hydraulics, equipment, raw materials, sheet metal, gearbox housings, and ground support equipment. The following figure is a representative organizational structure at UADVM for a snapshot in time:

Figure 4 - Representative Organizational Structure



For most proposals, Buyers take the lead on providing price estimates, including the bidding, negotiation, and associated information management. However, since MYX is a large, long-term proposal, Commodity Management ended taking the lead on managing the MYX Procurement Process.

Other MYX Roles

In addition to Commodity Management and Buyers, a number of other important functions are involved with the process. Besides the involvement with the Proposals and Estimating teams to manage the interface with the MYX Proposal Process, the MYX Procurement Process also involved the Compliance, CPA, Contracts, Engineering, Legal, and Supply Management IT. In addition, a number of contractors were staffed to support Commodity Management and a number of other functions, such as CPA. However, despite the large numbers of staff that are full-time or part-time dedicated to MYX, many departments ran short on staff.

Roles across Phases of MYX

At the start of MYX, Commodity Management managed the initial process, dividing the Bill of Materials (BOM) among different Commodity Managers, assigning each to manage parts for different Product Centers. Commodity Managers were tasked with figuring out the Bid Strategy, i.e. how to group parts together for RFQs and which suppliers to invite for bid. Product Centers were to approve the bid strategy, but were not as heavily involved in the supplier selection process. After the bid strategy was determined, Commodity Managers handed the management of the bid process and negotiations back to the Product Centers.

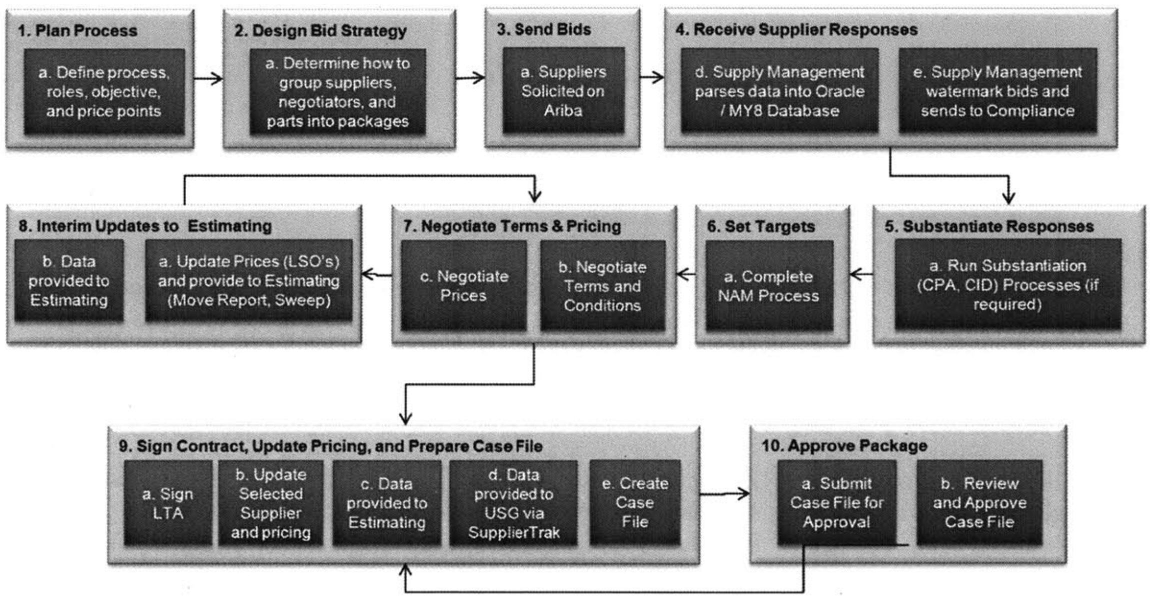
However, due to the fact that Buyers had day-to-day transactional activities to manage, it became difficult to make progress at the required pace. Hence, UADVM formed "Tiger Teams" of negotiators (NegLeads) that consisted of Commodity Managers and Buyers that were 100% dedicated to closing MYX.

After negotiations were completed, much of the work was turned over from the NegLeads back to the Buyers to put together PO Documentation (also known as case file), which provided all the information UADVM's Compliance Department needs in order to audit the process and approve the contract to allow for Buyers to purchase off the contract.

3.2 MYX Procurement Process Steps

In order to understand the hypothesis and approaches proposed, it is first important to understand the Multi-Year X Procurement Process in further detail. Given the scale and scope of MYX, the elements and steps in the process are many and varied. However, a high level overview of the process is given in the figure below:

Figure 5 - Multi-Year X Procurement Process Overview

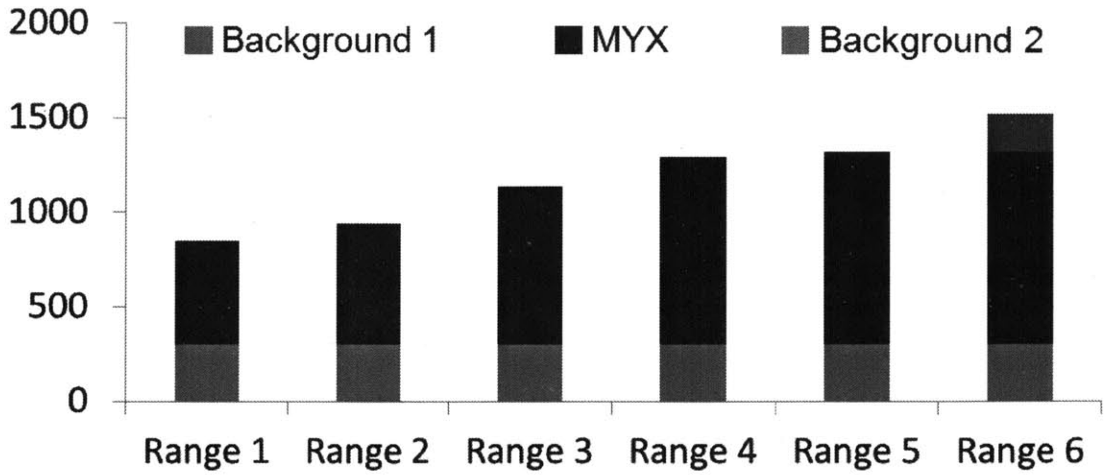


The steps from Figure 6 can be described in further detail:

1. Plan Process

The MYX Business Acquisition Team (BAT), which works with the government and manages the MYX Proposal Process, worked with Supply Management and the Product Centers to develop the process for the MYX Procurement Process. This ensures the process aligns with agreements made between UADVM and the government on timing, specifications, savings objectives, and data transparency. In particular, the scenarios, volume brackets (also known as "ranges") and years required for which pricing would be solicited from suppliers are initially defined. To clarify, "scenarios" in this context are different contracting scenarios (i.e. if suppliers are given a guaranteed one-year contract versus a two-year contract with options for annual renewal up to a total of five years, or a guaranteed five-year contract). Volume brackets or "ranges" are the various ordering quantities that UADVM and the government jointly agreed on for soliciting price points. These brackets took into account different government purchasing scenarios for Assembled Complex Equipment, as well as different assumptions for the background business, which is all the aggregated volume from spares and other programs added in. The figure below provides an illustration of how the quantities break down for each bracket:

Figure 6 - Representative View of Quantity per Range (Volume Bracket)



Background 1 = common business core, held constant across ranges
MYX volume changes based on range
Background 2 reflects additional potential background business in which orders have not been secured
Note: bars reflect a representative view of sum of quantities from 2012 thru 2017

In MYX, there were 3 contracting scenarios – single-year (1Y), two-year with options (2Y), and five-year (5Y) – and 6 ranges (denoted R1 through R6), as well as initially 8 years of pricing (2010 – 2017; the early years were an attempt to secure better pricing in the near term), resulting in 144 price points. Later, the number of years solicited was shortened to 6 (2012 – 2017; an extra year was provided to manage the fact that contract years tended to start midway through the year; thus a five-year contract needed to be covered by 6 calendar years). The team for leading the MYX Procurement Process is defined, and supporting resources in other departments are outlined. Finally, the Request for Proposal (RFP) document for suppliers is developed, including the cover letter and initial terms and conditions.

2. Design Bid Strategy

In this stage, decisions are made about what parts are to be quoted by which suppliers, and who should manage this process. First, the specifications from the government are translated into a Bill of Materials (BOM). The forecasted quantities for each part number are then determined by consolidating the spend volume across the rest of the enterprise (i.e. there may be requirements for part numbers common across other helicopter programs or in spares) with those required for MYX in order to leverage purchasing power and increase potential savings for the government and UADVM's other programs. The quantities required for MYX only are based on the BOM quantities for each helicopter type multiplied by the forecasted number for each of the six helicopter volume brackets (known as each "range") and year within that bracket. Next, the suppliers that would be solicited for bid are determined, primarily by looking at historical data as a starting point, and then soliciting input from the Buyers in the product centers. One of the goals of supplier selection is to maximize competition, as the belief is competition helps obtain lower prices and potentially helps reduce the number of CPA substantiations required.

Supplier selection should also fulfill other goals, such as meeting the government's goal of providing a minimum amount of spend to small businesses in six different socioeconomic categories (US Small Business Administration). These categories and their required percentages of spend are shown in the chart below:

Category	Minimum Required % of Spend
Small Business (SB)	23%
Small Disadvantaged Businesses (SDB)	5%
Women Owned Small Businesses (WOSB)	5%
Veteran Owned Small Businesses (VOSB)	3%
Service Disabled Veteran Owned Small Business (SDVOSB)	3%
Small Businesses in Historically Underutilized Business Zones (HUBZONE)	3%

Finally, a pricing matrix is then developed based upon the scenarios, ranges, and years specified for the parts, and the parts are grouped into bid packages. The figure below shows a simplified example of such a pricing matrix, with the part numbers on the left and 3 ranges (quantities) for 2 years in a single contracting scenario with room for the supplier to provide pricing.

Figure 7 - Sample Pricing Matrix

UADVM Part	QUOTATION PRICING STEPS MULTI-YEAR 2013			QUOTATION PRICING STEPS MULTI-YEAR 2014			SUPPLIER PRICING PROPOSAL MULTI-YEAR 2013			SUPPLIER PRICING PROPOSAL MULTI-YEAR 2014		
Part Number	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Part123	24	36	60	24	36	60						
Part124	24	36	60	24	36	60						

These packages are uploaded into Ariba, the bidding platform used to solicit and manage supplier bids. Finally, negotiators, also known as Negotiation Leads (NegLeads) are selected to manage certain supplier relationships and the packages for which they are involved. In the current state, the bid strategy design was accomplished manually without the use of optimization tools.

3. Send Bids

Suppliers are solicited to bid via Ariba, where they are able to see the full packet of RFP documents, which includes the details of the proposal, the specifications, logistics, as well as the Pricing Matrix in Excel. Suppliers download the Excel file and fill out the price points for each part, scenario, range, and year in the unprotected section of the spreadsheet. Suppliers also examine the terms and conditions and provide their revisions, as well as complete other required paperwork, including documentation for substantiation via Commerciality or Cost and Pricing Analysis (CPA) if applicable. Suppliers then upload their responses and must submit the bid before the deadline in order to be considered. The average amount of bidding time available to suppliers is about 63 days.

4. Review Supplier Responses

After the deadline for the bid, UADVM receives supplier bid responses via Ariba. Some suppliers may not have responded, and UADVM may choose to re-solicit suppliers if necessary (e.g. the incumbent failed to place a bid by the deadline), but since all suppliers need to respond to the same bid in order to achieve competitive substantiation, UADVM may need to re-solicit even the suppliers who have responded.

After receiving the bid, Supply Management watermarks the bids and sends them to UADVM's Compliance Department for review and approval. Watermarking is the process where the bid documents, including the bid data in Excel, are automatically converted to PDF and stamped with a watermark indicating the proposal (i.e. MYX) and the RFQ Close Date. This process provides a control mechanism and an audit trail to verify that a supplier bid was received. After approval, the watermarked documents are uploaded into case files in a system known as Adaptive Workspace (AWS), a repository of all the key documents generated from the procurement process and organized by bid package.

Next, the NegLeads review the supplier responses, noting the prices as well as other required documentation, including any required for substantiation. On pricing, NegLeads review which parts were bid on and what the bid price is. For each part, they conduct a price analysis against historical prices taking into account the effect of both time and quantity. NegLeads working on the same parts across different suppliers may compare prices and discuss next steps. One possibility is to follow up with another Request for Quotation (RFQ) to the suppliers, or in some cases, an RFQ labeled as a "Best And Final Offer" (BAFO) RFQ, which would override all prior bids made in MYX on the parts listed in the bid. In such cases, the BAFO or RFQ would follow steps 3 (Send and Receive Bids) and 4 (Review Supplier Responses) again.

In addition to pricing, NegLeads also review the terms and conditions, and are supported by a legal team known as the Contracts Team. The Contracts Team scores any revisions suppliers made to the standard terms and conditions (the SA-908 form) based on predefined criteria, known as the Negotiation Authorization Meeting (NAM) Scorecard.

5. Substantiate Responses

As mentioned earlier, material substantiation is waived for any supplier with less than $700,000 in aggregate spend on MYX. In order to determine applicability, spend by supplier needs to be aggregated and often estimated, because there is inherent uncertainty in who the selected supplier is and what its pricing will be midway through the process. The rest of the steps below apply only to suppliers once substantiation requirements are known or likely.

In certain cases, suppliers know or are instructed upfront how their bid will be substantiated, such as when they are a sole source supplier and requested to provide cost and pricing data upfront, or if it is known they will claim commerciality. In such cases, suppliers are expected to provide the requisite information for substantiation with their bid.

For commercial substantiation, the NegLead would update the commerciality tracker, review the documentation, and work with the supplier to obtain any missing documentation or manage changes. Since the requirements around commercial substantiation kept changing, oftentimes suppliers would need to resubmit or update their documentation. Once the documents have been verified, they need to be reviewed and approved by Engineering (or the relevant subject matter expert), the Chief Procurement Officer, and Legal. After approvals are in, the commerciality status tracker is updated, and an Approval Letter is drafted. This letter is reviewed by Legal, then reviewed and signed by the Chief Procurement Officer before it is sent to the government, stored in a shared drive, and printed out as hard copies for the

Chief Procurement Officer. On average, the internal approval process takes about 18 working days. (Freeman, 2013)

For cost and pricing substantiation, the NegLead again reviews the documentation and works with the supplier on any required changes. Afterward, the NegLead provides them to the Supply Management CPA Coordinator, who updates the CPA tracker and provides the documentation to the CPA team. The CPA analyst on the team then reviews the documentation. If there are issues, the documentation is sent back to the submitter. In the past, virtually every submission required a revision. After the review is complete, the CPA analyst schedules an audit with the supplier, and visits the supplier to examine their records and data. Afterward, the CPA analyst creates a report that provides an estimate for the optimal and max prices based on the findings and the rationale for them. These estimates are to be then used to inform the negotiators who are in discussions with these suppliers. The CPA tracker is then updated accordingly, and paperwork completed to document the cost and pricing substantiation. The CPA process may take up to 45 working days to complete.

6. Set Targets

After substantiation, the next step is to set a target price to for supplier negotiations. In the past, for most other proposals, NegLeads were not required to get authorization on a price target unless it was a single source bid situation with an estimated spend exceeding $700,000. However, for MYX, the guidelines for authorization shifted towards a more conservative approach, and most if not all negotiations required the NegLead to get authorization for a predetermined price target.

NegLeads, informed by historical price analysis and potentially PCA data, commercial sales data, or competing bid information, develop price targets for their suppliers, and create presentations and documentation to support their estimates. They arrange a Negotiation Authority Meeting (NAM) to get approval from key executives. If approval is provided, the NegLead can proceed to negotiations. If approval is withheld, the NegLead and executive withholding approval may discuss directly, often revising the negotiation target until there is agreement and approval.

7. Negotiate Terms and Pricing

Supplier negotiations include discussions on price as well as terms and conditions. The Contracts Team supports the negotiations for terms and conditions while the NegLead tends to focus on pricing. While certain terms have price implications (e.g. warranty, delivery terms, intellectual property, limitations and liabilities, net payment terms), most terms can be negotiated independently of price. As a result, most price negotiations and terms negotiations can occur in parallel.

8. Interim Updates to Estimating

Since the government requires current, accurate, and complete data, Supply Management needs to provide updates to Estimating on the bids as well as the current price, also known as the Last Supplier Offer (LSO). Given Ariba does not link to SAP, and no system at UADVM tracks LSOs / LEs, Supply Management IT created a few tools and systems to manage the reporting process:

Move Report – The move report provides a periodic update to estimating on the LEs. They require NegLeads to populate the MYX database with the most current LEs and the Selected Supplier. However, many times NegLeads are too busy with the tasks at hand to be able to provide truly real-time updates during the price negotiation.

Sweep / LSO Database – Toward the end of the proposal process, the government pushed for receiving a final update of the latest pricing before moving to closing on a price with UADVM. The LSO Database is the result of that effort, with data compiled from across NegLeads, asking for the LEs and the Selected Supplier.

9. Sign Contract, Update Pricing, and Prepare Case File

Price negotiations close when UADVM signs a Memorandum of Agreement (MOA) or a Long Term Agreement (LTA) with the supplier. The MOA / LTA would stipulate the agreed upon pricing for a set of parts, including unit pricing per year per part, and any fixed costs that UADVM would need to cover. Assuming the pricing hits the target set by NAM (or target is revised accordingly), UADVM and the supplier can sign an MOA while the terms and conditions are worked out, and finalize the LTA once both parties agree. Alternatively, if the terms and conditions are already in place, both parties can move directly to an LTA.

After the negotiations close, NegLeads should update the Multi-Year X Database with the selected supplier and the latest pricing, and upload the MOA / LTA to the system. The NegLead then hands the package off to the Buyers, who are charged with preparing the PO documentation (case file) for the package and get signoff by managers before a PO can be placed and released. This involves collecting and completing up to 17 different discrete forms / pieces of data, including, but not limited to, all the watermarked bids (RFQs) associated with all parts in that package, price comparison sheets, price analysis, negotiation plan, approvals and signatures, MOA / LTA, commercial or CPA substantiation, and other documentation for large suppliers, foreign suppliers, and large contract awards. In addition, Buyers may have to write the justifications for selecting the awarded supplier if NegLeads had not put together the documentation. In cases where Buyers had not worked closely with NegLeads during the negotiation process, this may be a challenging task.

Towards the end of the MYX Proposal Process, the government customer requested updates on the MYX Procurement Process. In order to comply with the request, Supply Management IT created an Access interface called SupplierTrakker, which contained all the latest bid and pricing information.

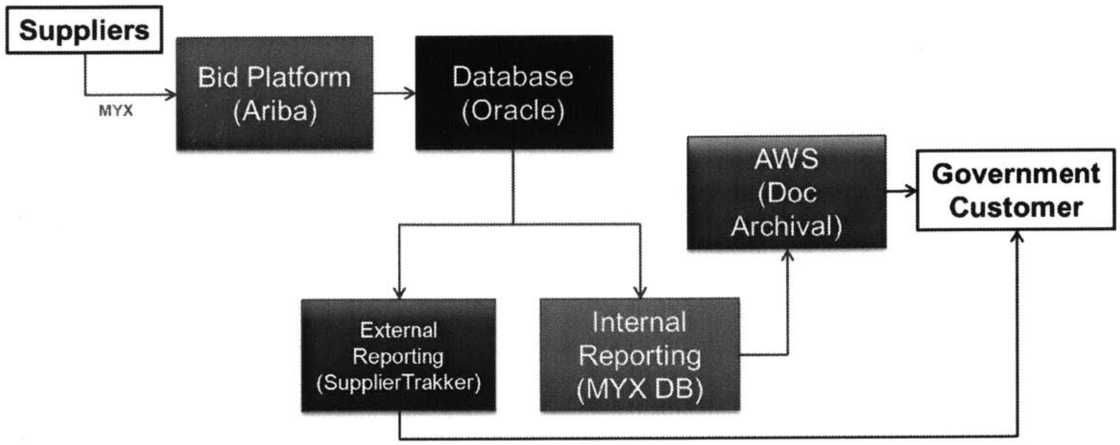
10. Approve Package

After signing the LTA and completing the PO documentation, packages are sent to anywhere from 2-6 stakeholders for approval. The number of stakeholders depends on the anticipated spend covered by the package. However, every package needs to go through UADVM's Compliance Department, which does a thorough check through the case file. This may involve examining the entire case file, including verifying the veracity of the RFQ watermarks, auditing how bids were evaluated, checking the price analysis, reading the justifications, scrutinizing the substantiation documentation, and confirming that the package is complete. If there are any issues, the package is returned to the Buyer with questions or instructions for modification. If approved, Buyers are notified and can start to purchase off the LTA.

3.3 MYX System Tools and Architecture

The systems UADVM uses to support MYX can be split into the bid platform, database, internal reporting and updating tools, external reporting tools, and document archival. A chart showing the relationships among the systems is shown below:

Figure 8 - MYX Systems and Data Flow



A discussion of the challenges around data management for MYX will be covered in Chapter 4.2.

<u>Bid Platform</u>

For most proposal processes, UADVM uses a homegrown bidding platform known as OneSource to solicit suppliers and manage their responses. However, for MYX, UADVM opted to use Ariba, a third party bidding platform that allows for the additional flexibility needed to manage MYX bidding. In addition, Supply Management IT built several tools to help support the use of Ariba. This included a scheduled task that checks for closed RFQs and downloads their bid information, an automatic parsing script to scrape the pricing data from Excel into Oracle tables, and a functionality to automate the watermarking of bid files.

<u>Database</u>

As in most proposal processes, the data from MYX resides in tables in an Oracle database, though in this case the MYX data is segregated from other bid data in a separate table that is unable to be accessed by SAP, UADVM's enterprise resource planning system, due to differences in data structure.

<u>Internal Reporting and Updating Tools</u>

Since the MYX data could not be accessed by SAP at the time, Supply Management IT created the MYX Database in order to provide more visibility across the organization into the data and to support additional functionality. MYX Database is an Access front-end user interface that reads off of the MYX data tables in Oracle created from Ariba and provides several reporting functionality as well as embeds the logic used to manage some of the complexity. Reporting tools and functions include the Bid Evaluation Price Analysis, which automatically calculates a reference price of a part escalated by time and adjusted for quantity, the Product Rollup Report, which provides a summary of the estimated total product cost, and the Supplier Rollup Report, which shows bids and spend at a supplier level. Supply Management IT also included tools to change the Scenario-Range selected as the price of record, as well as the Selected Supplier, a key input that determines substantiation type. In addition, logic is put in place to choose a default Selected Supplier if the NegLeads have yet to provide their input. Since there were often multiple RFQs for the same part, additional logic is put in place to help the system select the RFQ of record, known as the "Optimal RFQ," based on a hierarchy of criteria. Moreover, the MYX Database also includes additional update functionality such as the Move and Sweep Reports, which allow NegLeads to update their latest pricing and provide that information to Estimating. Finally, functionality was added to allow a user to auto-update the pricing for a list of parts from an MOA or LTA into the MYX Database.

External Reporting Tools

As mentioned, UADVM provided the data to the government via an Access program known as SupplierTrakker, which was sent to the government on a DVD and refreshed periodically.

Document Archival

UADVM uses software known as Adaptive Workspace (AWS) to manage the archival of case files for compliance purposes. AWS allows various users to upload documents into the various tabs of a predefined case file structure. To supplement and increase the efficiency of case file uploads, Supply Management IT created a feature to auto-upload key documents such as the Bid Evaluation Price Analysis spreadsheet created by the MYX Database (discussed below) into AWS.

4 Analysis of the Current Process

UADVM's objectives for the Multi-Year X Procurement Process were to 1) complete the process on-time, 2) meet the regulatory requirements for substantiation and transparency, and 3) find cost savings for both the government customer and UADVM. In these respects, UADVM's process performed exceptionally well. However, while reducing workload and increasing efficiency were not primary objectives, stakeholders recognize the importance of saving administrative costs, increasing standardization, reducing potential errors and associated rework, increasing clarity and transparency, and making the process sustainable for engaged employees to manage.

In order to understand where areas of opportunity exist, we first have to understand the issues that arise and their drivers before we can identify root causes. Through interviews with 35 stakeholders across a number of different departments, these issues were surfaced and the causal relationships between them were hypothesized and vetted. From this, a picture of the larger system can be drawn along with the key challenges that the organization faced and the interdependencies between them.

In the following sections, I will first identify and explain the distilled set of key challenges in the process and with the systems before identifying the drivers of these challenges. While a thorough explanation of the issues may not be necessary, a diagram has been included for purpose of illustration the major challenges and relationships among them. Each box outlines a different issue and is color coded based on the major grouping of issues to which it belongs:

Figure 9 - MYX Issues Map

4.1 Key MYX Process Challenges

In order to make sense of the challenges in the MYX Procurement Process, I will describe the key issues working backwards in the process, starting from the end of the process and working towards the beginning of the process. This will highlight the causal links between issues, allowing one to arrive at the root causes.

<u>PO Approval Issues</u>

As discussed, the last stage of the MYX process is to obtain approval from UADVM's Compliance Group and other stakeholders for approval. Buyers submit the case files electronically, and they are reviewed by UADVM's case file auditors. However, the review process for approval is long, and this has a few important consequences:

Bridge POs

Since all packages need to be reviewed and approved before Buyers can purchase off of the LTA, Buyers may resort to negotiating what is known as a Bridge PO with the supplier, a short-term contract that allows UADVM to buy a required part to ensure production continues. Given the short required turnaround time and smaller volume, pricing on Bridge POs is potentially unfavorable when compared with LTAs.

Longer Queues

Long approval times also result in increased backlog of case files, impacting the length of time required for both MYX packages as well as non-MYX packages. While a backlog of roughly 10 cases is standard, the backlog queue at times hovered around 70 cases during MYX.

More Time and Effort

Long approval time implies the auditors are spending more time and effort to inspect and release the packages. Assuming three full-time equivalents (FTEs) working three years to manage MYX, fully loaded costs for this project are estimated to approach $1.2 million dollars.

Long approval times bring potential risk to UADVM as well as higher administrative costs. However, the issue can be attributed to several causes:

Required Resubmission

Many packages needed to be returned for modification and resubmittal. This may be because:

- Buyers may not be well-versed with the details of the MYX negotiations, and their justifications need to be more rigorous.
- Requirements for approval could be better defined upfront. Due to uncertainties and changing expectations around the government's interpretation of defense contracting regulations, it became difficult for Compliance to pin down these requirements and provide them to Buyers in advance.
- Compliance may discover the negotiators failed to negotiate with all the suppliers in the competitive range, or that confusion on the award type resulted in single source packages being awarded on a competitive basis, for example. One reason for this is that the reports generated by the MYX process are often custom and potentially unfamiliar to some Buyers. Another may be that the complexity of the package may confuse some Buyers and NegLeads.

Package Complexity

Many packages are highly complex. Given that the same package of parts may not have been grouped together from start to finish, they may have been bid out to different suppliers on different RFQs, making the evolution of the pricing extremely difficult to unravel from a package standpoint. As alluded to earlier, this makes it difficult for both Buyers and NegLeads to understand whether the contract was ultimately awarded on a competitive basis, which may not require as much documentation, or on a single source basis, which would require CPA or commercial substantiation and further accompanying case file documentation. In addition, the complexity makes it difficult for auditors in Compliance to understand the packages. As a result, packages may take anywhere from a few hours to more than a week to review. In the meantime, packages sit in the queue, and tools to automate or help manage the process are limited.

Late Packages

Packages arrived later in the process than expected and in large waves. This was due to bottlenecks farther upstream in the process, such as the length of time it takes to bid, substantiate, and negotiate terms and pricing, as well as the time it takes to prepare case files.

Challenges in Operations

Only 2-3 auditors were staffed to manage the influx of packages, and there was little support available to help ameliorate the situation. Furthermore, although the case files were electronic, inspection and auditing is a highly manual process that requires auditors to make sense of each tab in the case file. Manual management and tracking of case files is also required and adds additional burden to the Compliance staff.

Case File Preparation Issues

Many of the PO Approval issues stem from how the case files were prepared and how long some case files took to prepare. Case file preparation took a substantial amount of time for Buyers to manage, and the causes for the long preparation time in this step include:

Handovers

After the negotiations and contract signing, NegLeads handed the package off to the Buyer(s) responsible for the parts in the package to put together the case file for compliance approval. However, some Buyers may not have been actively involved in the negotiation and lacked the proper context. Due to these difficulties, some Buyers may procrastinate and delay the process of compiling the case file. Others may put together case files with justifications that lack the rigor necessary to pass through Compliance.

Complex Packages

Some Buyers become confused by the complex packages while trying to make sense of the parts on different bids that were bid out to different suppliers. This confusion may lead Buyers to fail to recognize the required type of substantiation needed, and verify that the supporting documentation is available. Complexity in the packages is compounded by the amount of work involved in compiling case files; as mentioned, the case file contains 17 discrete tabs that request supporting documentation, further annotation, and/ or form completion.

Training and Tool Proficiency

Since some Buyers were not involved in the negotiations, they may not be trained or even aware of the tools available to help them with preparing the case file. Some Buyers did not attend trainings or were not even aware of their existence. Another driver is that since Supply Management IT was developing many of the tools on the fly, there were frequent changes to the available toolset. This adds further confusion to the process, and for many tools, there is little available documentation to help guide Buyers. Finally, many of the tools were developed without enough feedback from users, resulting in functionality that could have better met user needs.

Negotiation Issues

Another driver of packages arriving late into Compliance is the long lead time required for negotiations. In addition to causing a bottleneck for processes downstream, long negotiations also mean more required effort for NegLeads, Buyers, and the Contracts Team. Long negotiations may also frustrate suppliers involved in the process. The items below outline the drivers of long negotiations:

Long Terms and Conditions Negotiations

In MYX, suppliers provided more revisions to the standard UADVM terms and conditions than had been anticipated. One reason may be that the terms from MYW may have changed measurably in MYX due to the effort to standardize terms and conditions across UADVM. As a result, suppliers are faced with new and unfamiliar terms, resulting in substantial revisions. Another challenge, due to the trend of outsourcing more and more parts to suppliers, is that UADVM's leverage over suppliers may be lower than in the past, resulting in longer and more protracted negotiations. Moreover, UADVM's internal standard terms and conditions may change over time even while negotiations are ongoing, sometimes resulting in UADVM altering terms for items where there may be prior consensus. These changes consume a lot of time for both the Contract Team and NegLeads, requiring further explanation to suppliers on what the new terms were and why they needed to be changed. Finally, the Contracts Team and NegLeads were overwhelmed by the amount of negotiation and pushback by suppliers, and required additional staffing and support in order to move the process along at the desired rate.

Long Pricing Negotiations

Price negotiations were conducted by NegLeads, who were paired to suppliers in order to ensure that UADVM's entire spend with a supplier could be leveraged in the negotiation. However, because the same part may be bid out to many suppliers, this required negotiators who were paired to different suppliers to work with one another to piece together the complete picture of which supplier was the low bid, what the competitive price range was, and thus who should still be seriously considered in a negotiation. Since prices, known as latest estimates (LEs), are fluid in a negotiating situation, this information is often only available locally to a single negotiator. No tool currently exists to share the LE's. Given some packages have hundreds or thousands of parts, there may be considerable effort required to coordinate, and as a result, it is often difficult to ascertain the type of substantiation required.

Another issue with negotiations is the changes to the project scope and the team. Throughout MYX, the scope of the negotiations increased incrementally, as spend from other programs such as Spares and Developmental Product being added into the forecast. This increased the workload of the NegLeads, forcing them to revisit the volumes and, potentially, the parts in the negotiations with suppliers. Furthermore, there were changes in the team composition. As mentioned earlier, Tiger Team NegLeads stepped in for the original negotiators midway through the process, resulting in some loss of information in those handoffs. This further increased the workload required, and increased turnover with the NegLeads, because of the difficulty of fulfilling the expectations of the role. New NegLeads with less experience and training would be added, which often meant they would take on even more of a workload as they ramped up the learning curve.

Besides issues with the negotiation team and increases in scope, price negotiations were complicated by the number of price points received. UADVM collected prices across 3 scenarios and 6 ranges for each scenario, resulting in difficulties in tracking the scenario and range of record, especially if that changed midway through the MYX Proposal Process due to discussions with the government customer. Suppliers may also be equally confused, as some may assume the wrong price during negotiations, or they may not have provided prices for the scenario and range of record. Adding to the confusion is the repetitive bidding for the same part out to the same supplier, with some bids, such as Best and Final Offer (BAFO) bids, taking precedent over others.

Making an award decision is further complicated by the fact that competitively substantiated awards can be made on a market basket basis – i.e. a supplier can be awarded a contract for a group of parts on a competitive basis if the total price of those parts is less than the total price of competing suppliers, even if they are not the low bid on any single part. Another factor is that competitive awards can be made on a best value basis, meaning that fixed costs such as tooling, non-recurring engineering, and qualification need to be considered. Given they are fixed costs, this presumes a volume or quantity is required to spread those costs across to each unit, something that is difficult to pin down initially given the number of different quantity ranges suppliers were solicited to bid for.

In addition, long price negotiations are also affected by the two key inputs into the process, the substantiation process and the Negotiation Authority Meeting (NAM) Process.

Negotiation Authority Meeting (NAM) Issues:

A number of challenges surfaced during the NAM process, resulting in longer cycle times and more effort:

Ambiguity, Changes, and Complexity in the Process

Given that spend for MYX is much higher than normal contracts, the approval guidelines are different than in the normal process. Furthermore, the approval criteria may not have been completely clear upfront, and they tended to change with time. Also, the required number of signoffs also increased, and the specific executives that need to sign off also changed with time. This added additional complexity in managing the process and acquiring the signatures.

Lack of Automation

The NAM signoff many times does not take place in the meeting, and since executives are often busy individuals, a manual process was put in place to manage signoffs. The NAM process coordinator would manually send an email reminder to the busy executives after five days. After 10 days, if there was still no response, the proposed target price is considered auto-approved by the executive. An Excel spreadsheet is used to manage NAM approvals, as are frequent emails between the NAM process coordinator and the various stakeholders, including the NegLeads and Approvers.

Substantiation Issues

As described earlier, CPA and commercial substantiation are both long processes with substantial complexity and cycle times. Furthermore, there often is a high degree of uncertainty around the required substantiation path. These two separate issues are described in detail below:

Inherent Complexity and Workload

Both Commercial and CPA substantiation are highly manual processes that require someone to manage and organize the documents received from the supplier, check for compliance, coordinate across stakeholders in different departments to obtain signatures, and assemble, store, and send the documentation to the government. CPA substantiation also requires scheduling time with suppliers and preparing the analysis and report to arrive at a CPA price. In both cases tracking substantiation progress is manual and time consuming, as there currently is no system to manage substantiation workflow.

In addition, staff allocation for managing CPAs and commerciality may need to be revisited. Given the goal was to aim for competitive substantiation, the number of CPA and commercial substantiations required may have exceeded expectations, and created bottlenecks in the process.

Uncertainty

There is a high degree of uncertainty in determining the substantiation type. For commercial substantiation, part of the uncertainty comes from ambiguity in the interpretation of the definition of a commercial item. In claiming commerciality, suppliers are allowed to claim items with minor modifications that do not alter the function, purpose, or essential physical characteristics of a product (Freeman, 2013). However, the interpretation of "minor" may vary based on the individual reviewing and approving a commercial substantiation claim.

Even more troublesome is the degree of uncertainty due to competition. In MYX, since most of the parts were bid out competitively, in most cases, suppliers will not be asked to provide documentation for commercial or cost and pricing substantiation upfront. When aiming for competitive substantiation, the substantiation step is often skipped over temporarily and returned to after negotiations, when the documentation and justification for competitive substantiation becomes available. In fact, when suppliers bid competitively, UADVM is prohibited by the Federal Acquisition Regulation 15.403-1 from asking for cost and pricing data upfront. However, due to the fact that there are inherent uncertainties in the bidding process, many times the result of competition is a single response or an award to an Other Than Low Bid (OTLB) supplier. In fact, in certain cases, due to the complexity of the package, it may not be clear to NegLeads or Buyers that CPA substantiation is required until the package reaches Compliance. In any case, it may be difficult to obtain cost and pricing data after a competitive bid, as some suppliers may see it as undermining their own interests. Suppliers may claim commerciality to avoid providing cost and pricing data. Alternatively, UADVM may need to re-solicit the selected supplier on a single source basis, though suppliers may not respond, or they may still refuse a CPA audit or even a DCAA audit after responding.

Should UADVM select a single source or OTLB supplier in the case above, UADVM will attempt to run the commercial substantiation process or the CPA substantiation process. Interestingly enough, the output of the CPA substantiation process for an OTLB supplier is meant to inform the negotiation with that supplier, which is often already well under way.

Another possible scenario is that some CPAs are performed on suppliers that did not require one, potentially wasting time and effort for both UADVM and the supplier. In certain cases, UADVM may have asked and received cost and pricing data upfront, but the supplier may end up as the low bidder.

Supplier Bidding

Further upstream, the supplier bidding process also has many challenges, which exacerbate the processes downstream. Of particular importance is the issue of repetitive bidding, where the same part is bid out on another RFQ, potentially to the same suppliers, to different suppliers, or some mix of the two. On average, parts are bid out 1.7 times, or 70% more than the ideal case of one bid per part. Extra bidding is partially responsible for the complexity of the packages.

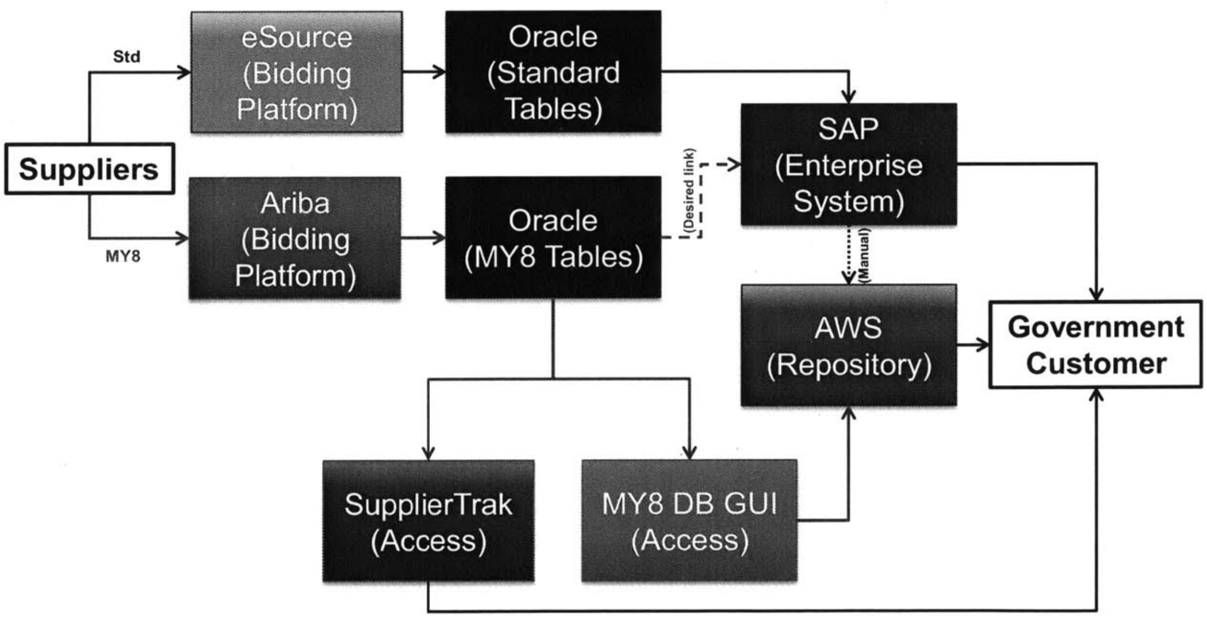
Rebidding has many causes, but most of them have to do with unsatisfactory bid results or issues with original bid setup. One example of an unsatisfactory result may be a bid that comes back without a response from the incumbent. Another may be receiving zero or only one response, thus failing to achieve competitive substantiation. There may be also issues with the bid set up – for example, the incumbent supplier may not have been included or may have changed since the bid went out; parts may have been bid out to suppliers that may not yet be qualified; some suppliers may have bid unrealistically low prices indicating a misunderstanding of the specifications; certain suppliers may not have been added to or excluded from the bid; certain parts may need to be added or subtracted from a package; the BOM may have been updated; certain parts may have undergone engineering changes while out on bid; relational parts that should be included on the same bid may have been separated.

Unfortunately, rebidding also causes a downward spiral: when the same part is bid out, suppliers (especially those who have already responded) may be more reluctant to respond again. In addition, the use of a Best and Final Offer (BAFO) bid, which wipes out all preceding bids, complicates matters should key suppliers fail to respond.

4.2 Challenges with the MYX System Tools and Architecture

Normally, a number of standard systems at UADVM are used to support procurement and proposal processes. However, many of the existing tools were not equipped to handle MYX's scale and complexity, making them unsuitable. The figure below diagrams the various systems and data flows in a standard proposal-related procurement process (the blue path) and in the MYX Procurement Process (the red path).

Figure 10 - Systems and Data Flow for Proposal-Related Procurement Processes



<u>Challenges with the Bid Platform</u>

As mentioned, UADVM uses OneSource for most proposal procurement processes. OneSource was developed a few years ago to support both production procurement as well as supplier solicitation for proposal cost estimation. However, OneSource has a number of limitations that make it unsuitable for MYX:

1. Inability to handle multiple ranges and scenarios

OneSource only allows buyers to create relatively straightforward templates for suppliers to provide just one price per part number per year (up to a total of six years). This means if UADVM were to solicit suppliers for 3 scenarios and 6 ranges (quantities) via OneSource, suppliers would receive 18 copies of the same pricing matrix, resulting in a lot of confusion. Furthermore, while the OneSource interface enforces this limitation, the true limiting factor is in the structure of tables that are used by SAP, which requires considerable forethought before modification.

2. *Inflexibility around years*

Buyers are only able to solicit pricing for the current year plus up to five years out. However, the multi-year cycle often start far later than the current year, and so pricing needs to be solicited for more than five years beyond the current year.

3. *Limitations on Spreadsheet Uploading*

OneSource only allows suppliers to input pricing into its Web interface and does not support the uploading, downloading, and auto-extraction of Excel templates with pricing matrices. If suppliers are to input pricing for hundreds or thousands of parts across a number of scenarios, ranges, and years, this creates a tedious and error prone process.

4. *Fixed Buyer Queues*

OneSource sets permissions that allow only the Buyers that are associated with a part number to be able to manage that part. Given the MYX Procurement Process touched on thousands of parts and over a hundred Buyers, it would be difficult to manage so many buyers. Instead, MYX requires the creation of custom buyer queues to allow a negotiator to manage a specific set of parts as dictated by the bid strategy.

As a result of these shortcomings, UADVM opted to use Ariba, a third party bidding platform that allows for the flexibility needed in order to manage MYX bidding. However, using Ariba instead of OneSource resulted in the following challenges:

1. *Ariba not automatically linked to SAP*

SAP is UADVM's enterprise software system, and in order for Estimating to use supplier quotes for estimating prices for MYX or for any future proposal, the data needs to be available in SAP. However, the tables SAP feeds off of cannot take in the complexity of the data from Ariba without manipulation, resulting in a disconnection between the two systems.

2. *Limited access to Ariba across the enterprise*

Unlike OneSource, which is available to all Buyers, Ariba is only available to a few people in Supply Management. Hence, Supply Management becomes the bottleneck to access MYX data, as well as the responsible stakeholder for managing that data.

3. *Suppliers Lack Familiarity with Ariba*

Suppliers are used to bidding on OneSource, and may not be as familiar with the interface on Ariba. As a result, some suppliers failed to bid by the deadline, uploaded multiple or blank pricing spreadsheets into the system, or provided erroneous information.

Challenges with the MYX Database

Since the MYX data in Ariba and even Oracle was not easily accessible to the rest of the organization, Supply Management IT developed the MYX Database. However, the downside of the MYX Database is that given the system is not maintained by UADVM IT, releases come sporadically. Moreover, little training is available for potential users, providing them with opportunities to become well-versed in the tools developed. Finally, functionality is developed on an as-needed basis, at times without a thorough understanding of user needs and requirements.

Challenges with External Reporting

Normally, the government customer has access to proposal data via SAP; however, due to the complexity of MYX, the data cannot conform to the standard data structure for proposals. Hence, SAP cannot read the data without significantly altering the Oracle table structure, developing rules on how to map and select those fields into SAP, and figuring out what additional options, toggles, views, and data need to be shown. Given the short timeframe, SupplierTrakker was developed to provide the government with a static view of the data at a point in time. Originally, SupplierTrakker extracted all the MYX bid data in tables residing in Oracle. However, the data overwhelmed the government customer, and so SupplierTrakker was scaled back to show just the most relevant bids and price points.

Challenges with the Document Repository

Storing documents into AWS is a highly manual process, requiring users to click on certain folders and tabs and upload the required documents. If there are multiple bids and parts for the same package, the documentation requirements are quite high. Every part requires a price analysis, and parts that require commercial or CPA substantiation require further documentation. To mitigate these issues, Supply Management IT developed tools to auto-create the price analysis and auto-upload them into the right tabs. However, some Buyers do not use the auto-upload tools, as they feel in certain situations it uploads items that are not necessary into AWS. Another issue is the limitations on AWS in terms of upload capacity, due to network speeds; at times AWS is unable to take in so much data at once, resulting in long upload cycle times.

4.3 Investigative Approach Findings

In examining the challenges within the MYX Procurement Process, the key issues can be separated into internal and external factors.

External Factors:

While external factors may be difficult to change, it is important to acknowledge them and recognize the effect they have on the entire process. These external factors, all beyond the scope for change in this study, can be summarized into the following areas:

Government Pressure

As mentioned earlier, governmental budgetary pressures and a more conservative contracting environment resulted in stricter interpretations of regulation, changing expectations and uncertainties in approval requirements, a push for more competition, and a desire for increased transparency and reporting. All of this adds additional overhead and complexity to the processes described.

Desire to Increase Competition

As a result of government pressure as well as UADVM's internal desire to test the market to achieve cost reductions, UADVM increased the scope of the procurement process when compared with past multiyear procurement processes. In MYW, most parts were estimated from historical data; yet in MYX, the number of parts bid out to suppliers went from 1,000 parts in MYW to about 14,000 parts. The average number of suppliers solicited is 4.4, and 94% of all parts had two or more different supplier responses. More data points across more scenarios, ranges, and years were solicited than ever before.

Dependencies between Parallel Processes

MYX Procurement and Proposal Processes run in parallel, resulting in dependencies between the processes. For example, the terms and conditions flow down from the government proposal negotiations into supplier negotiations. The key parameters – the number of scenarios, ranges, years, the BOM specs, the price negotiation targets, approvals regulations for packages – all of that hinges on discussions with the government customer that runs in parallel with the procurement process.

Product Center Model

In the past, UADVM had a centralized procurement function, but since moving to a Product Center model, the buyers have been scattered across the business units. This decentralization creates challenges for managing a proposal that affects the entire company, as some suppliers have relationships with buyers in multiple product centers. Commodity Management is responsible for managing procurement for the longer term and for the company as a whole, but the effort still requires coordination between Commodity Managers and Buyers in order to invite the right suppliers to bid on the right parts, develop a full picture of the supplier relationship in preparation for negotiations, and transfer the relationship back to the Product Centers to manage the day-to-day transactions in the future.

<u>Internal Factors:</u>

Besides the external factors, many internal drivers were also responsible for the issues faced in MYX. To improve future multi-year procurement processes, stakeholders within the process can consider making adjustments to the following internal factors:

Planning

Due to the short lead time available before MYX started, planning – including resource allocation, support functionality, and process planning – appears to have room for further improvement. Planning has a role in determining the scope and complexity of the procurement process, what staffing levels are required, what training and communication is required, what are the roles, responsibilities, and connections among groups, and what timelines are to be expected.

Systems

UADVM's existing systems were unable to handle MYX given that the requisite bids required a much more complex data structure than past proposals. As a result, data had to go through offline systems (Ariba, MYX DB), resulting in low transparency across UADVM, ad-hoc upgrades given changing requirements, additional training requirements, and confusion by suppliers.

Package Complexity

Much of the difficulties with MYX stem from the fact that so many parts, suppliers, bids, NegLeads, Buyers, and price points were involved in the process. This created very complicated packages resulting in many of the challenges cited above. Package definition could have been improved by having a data driven bid strategy coupled with a rigorous and fully engaged bid strategy review process.

Process Definition

Bottlenecks appeared in the Negotiation Authority Meeting (NAM) process, substantiation processes, and PO approval processes in MYX due to uncertainties in the process and low level of workflow automation. In NAM, NegLeads had uncertainties about which packages required NAM as well as who and how many sign offs were required. Substantiation had uncertainties stemming from the fluid nature of negotiations, but was exacerbated by the complexity of the packages and the number of NegLeads involved in each one. Finally, PO approval guidelines could be better defined upfront, reducing the number of packages that would need to be sent back to the Buyer. Furthermore, NAM, CPA, CID, and PO Approval all required manual workflows, tracking, and inspection.

5 Primary Root Cause

Within the internal factors, my hypothesis is that package complexity is one of the primary root causes and the area of biggest opportunity. While having better planning, more sophisticated systems, and better defined processes will all improve the process if complexity is kept constant, reducing package complexity reduces the range of variation required to manage during the planning process, may reduce the minimum system requirements, and mitigates the process-level uncertainties such as substantiation.

However, the reasons for higher complexity are partially driven by outside factors, including government pressure and the desire to increase competition, both of which are driven by overall objective of finding additional cost savings. Yet simultaneously, complexity increases a lot of hidden costs, including bridge POs, higher workloads, demoralized employees, strains on supplier relations, and increased risks around defective pricing. Furthermore, even if the cost savings are greater than hidden costs of complexity, there is still ample room for improvement, as complexity is also driven by internal factors, such as how the bid packages were constructed and reviewed, and how negotiation teams were structured. Hence, there are two approaches that can be taken to reduce package complexity – one is to reduce the inputs (parts, bids, suppliers, price points, etc.) required during the planning process, and the other is to improve the bid strategy, or the way parts and suppliers are grouped into packages and NegLeads are assigned.

In the following section, I will describe key metrics used to measure complexity in the current state. Then in the following two chapters, I will describe the two approaches to reduce complexity while maintaining cost savings, the analysis behind them, and the results expected.

5.1 Key Metrics

One of the key challenges then is to develop a metric to measure complexity. Since the analysis is done post-mortem after the MYX has completed, measuring complexity is nontrivial. Nevertheless, it is still essential to developing an understanding of the system.

Number of Interactions

One measure of complexity is to look at the number of interactions between the discrete elements in the process that arise. In the MYX Procurement Process, I defined each interaction to be a unique part number, RFQ, supplier, NegLead, buyer combination. That is, each interaction identifies every part that goes on a different bid (RFQ), which goes out to a different supplier, for a negotiation managed by a different NegLead, and will be eventually managed by a different buyer. Since every supplier is assigned to only one NegLead, and every part is assigned to only one Buyer, this essentially boils down to the number of distinct Part x Supplier x RFQ combinations there are. The rationale behind the measure is that every increase in part, supplier, or RFQ adds an additional amount of work, and that increase in work required is proportional to the number of other elements that are affected by it. A chart that shows which of the key steps in the process are affected by an incremental increase in what dimension (marked with an 'X') is shown below:

Figure 11 - Steps Affected by Incremental Increases in Key Dimensions

			Dimension				
#	Step	Party	RFQ	Supplier	PartNumber	NegLead	Buyer
1	Bid Preparation	Neg Lead	x				
2	Supplier Response	Supplier	x	x			
3	Watermarking	Compliance	x	x			
4	Bid Evaluation	Neg Lead	x	x	x	x	
5	CID / CPA	CPA / CID	potentially	potentially	increases threshold		
6	NAM Process	Neg Lead, Approvers		x	increases threshold		
7	Price Negotiation	Neg Lead		x	x		x
8	T's & C's Negotiation	Contracts		x			x
9	LE Sweep & LSO Updates	Neg Lead			x	x	x
10	Package Write-up	Buyer			x	x	x
11	Package Evaluation	Compliance	x	x	x	x	
12	Supplier Trak Review	Government	x	x	x		
13	Data Analysis & Mgmt	Supply Mgmt IT	x	x	x		

Note that the interactions measure takes into account the multiplication in the workload for a given step when two or more dimensions increase simultaneously. For example, rebidding (i.e. increasing the number of bids by 1) the same part for the same supplier increases the interaction metric by 1, but rebidding the same part to five suppliers will increase the interaction metric by 5. This reflects the fact that negotiators have to manage five more supplier responses rather than simply one more response. Similarly, adding two extra parts on 1 RFQ going to 1 supplier may increase the number of interactions by 2, but if it goes out to 8 suppliers, then the metrics will have increased by 16, reflecting the fact that you will have two extra parts to consider in the pricing analysis for each supplier.

The advantage of the interaction metric is that it is fairly easy to measure. Given the data requirements around government contracting, it is required to track what parts are bid out on what RFQs to which suppliers, and it is known what NegLeads are responsible for which suppliers, and which buyers are responsible for which parts. The measure is also intuitive and directionally correct, as every additional interaction increases the number of case file items that needs to be audited by compliance, the number of comparisons required across suppliers, potentially the number of suppliers, NegLeads, and buyers that need to work with one another, the number of potential substantiation cases, and the number of items that need to be managed by the system.

The drawback is that the measure is rather rough – the amount of extra complexity, effort, and time that arises from adding an extra part is different than adding an extra supplier. It is also different to add an interaction with a completely new supplier versus a supplier that has bid on other parts in MYX, as there is extra effort involved in setting up the supplier for bid, explaining the bid process to the supplier, etc. Furthermore, the complexity and effort in certain steps will scale non-linearly. For example, the amount of additional effort it takes to analyze an additional part added to a bid and sent to one supplier is likely small, but if that part pushes the supplier over the $700,000 threshold that requires substantiation, then the work increases dramatically. Similarly, if the chance that a CPA is required when you receive two supplier bids is only 25% and jumps to 60% when you receive three supplier bids, the effort and costs required increase disproportionately in ways that are not captured by the metric.

However, since the objective is to merely obtain a baseline benchmark, interactions are used as a proxy for level of effort required and the complexity in the system. In MYX, UADVM had 85,000+ unique Part-Supplier-RFQ-NegLead-Buyer interactions.

Price Points

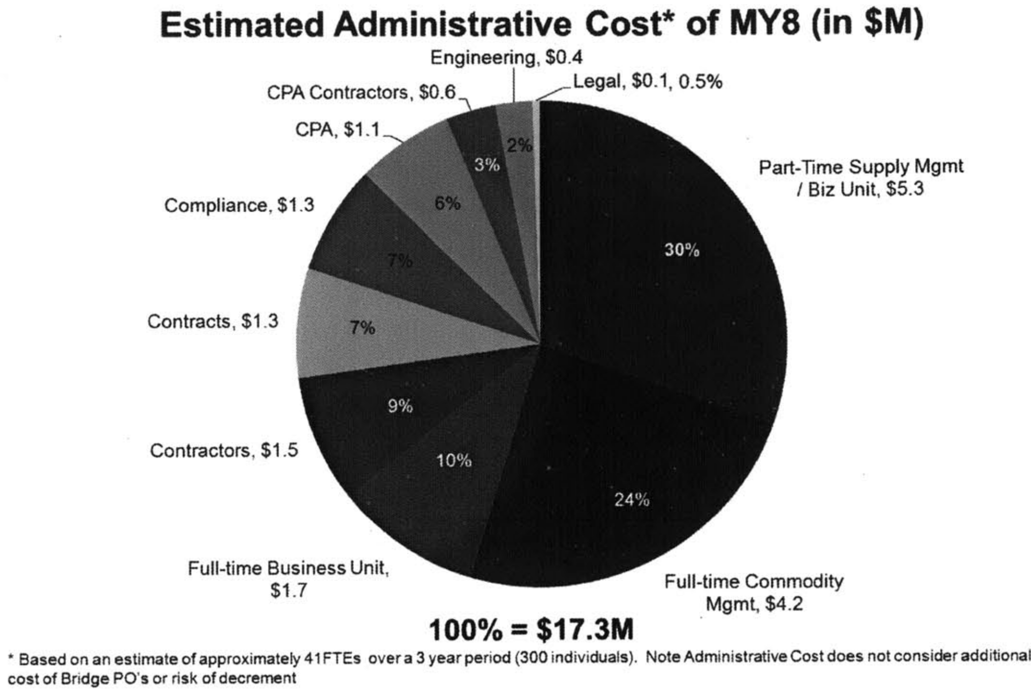
Another measure of complexity is the number of price points requested from the supplier and captured in the MYX Database. The number of price points can be calculated by starting with the number of Part-Supplier-RFQ interactions and multiplying that by the number of price points per interaction, which would be the number of Scenarios x Ranges x Years requested. Above and beyond interactions, the number of price points captures additional complexity in having to manage IT systems to meet requirements around scenarios, ranges, and years, along with the confusion and complexity that comes with that. For example, more price points may make it easier for the incorrect scenario-ranges to be picked during analysis. It may also increase the overhead it takes to find the right data, teach someone how to obtain data, and train someone to decipher the bids. More price points also mean more work and errors in building systems to manage transparency of prices to the customer. Finally, it may also result in more supplier input errors – sometimes suppliers may not fill out all the price points, including the critical prices required for the scenario-range of record. While the number of price points solicited per line in a bid may have changed over time, generally the MYX Database shows fields available for 8 years of data, 3 scenarios, and 6 quantities, reflecting 144 price points per bid. With more than 85,000 interactions, this means the MYX Procurement Process collected approximately 12.75 million price points.

Administrative Costs

Another measure of complexity is to find a way to measure the administrative costs associated with running the entire process. Generally speaking, costs may be thought of as sum of the costs associated with the man-hours of effort for the process, the licensing or purchasing costs for systems, and additional costs, such as exposure to risks, errors, and variation. In the analysis, the majority of the visible costs can be attributed to the labor in the process, as the system costs are relatively low in comparison, and it is difficult to quantify the cost of risks, errors, and variation. For example, it is assumed that Bridge POs due to inability to complete the MYX process on time would be costly to UADVM, but it is a nontrivial task to associate POs back to the MYX LTAs and find the difference in price. Hence, my analysis focuses on estimating costs primarily from hours of effort.

From interviews and surveys, the total effort involved in MYX is estimated to be about 41 full-time equivalents (FTEs) per year for three years, or approximately 123 annual FTEs for the entire effort. This translates to an estimated fully loaded cost of approximately $17.3 million. The chart below details the breakdown on MYX administrative costs:

Figure 12 - MYX Administrative Cost Estimate



Of those costs, it is estimated that $2.1 million can be attributed to actual contractor expenses, all paid by UADVM, while the rest are attributed to salaried employees, who are fixed overhead. Nevertheless, the hours expended by salaried employees cannot simply be discounted as part of a constant overhead; time may have been taken away from other areas, deprioritizing other important assignments, and resulting in the hiring of contractors to support other areas of the business. Alternatively, salaried employees may be asked to work above and beyond their standard work hours for a sustained period of time, lowering employee morale, increasing job dissatisfaction, and risking potential burnout. These long term costs are not as easily measurable and could well exceed the estimated administrative costs outlined above.

Other Complexity Measures

Besides complexity across the entire MYX Procurement Process, it is important to understand complexity at steps in the process, particularly when there are pain points involved. However, for some steps, it is difficult to attribute interactions, price points, and costs; hence, other proxies of complexity will be considered as well. For example, the complexity of having multiple negotiators in the same negotiation can be assessed by some measure of the number of negotiators across the number of parts in the negotiation.

Cost Savings

The other measure to be cognizant of is the cost savings from the process. At UADVM, cost savings are measured against a baseline known as the transfer price, which is the last price paid for a given part number. However, transfer prices may fail to capture important factors such as the type of contract the last part was purchased off of, how many units were purchased, and how long ago the part was purchased. Prices may also fluctuate with market conditions, and so there are drawbacks to such a measure.

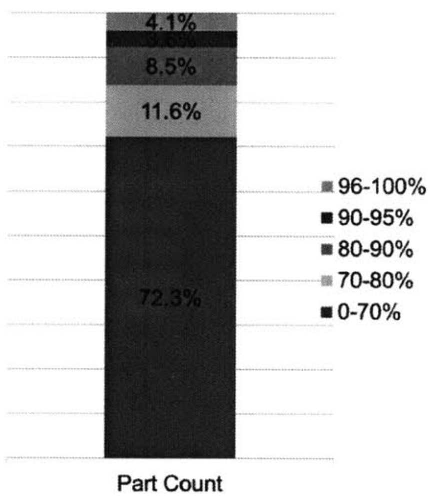
6 Package Input Rationalization

Reducing the number of inputs that go into the process is key to reducing overall process complexity in the MYX process. Doing so requires considering the case and effectiveness for each of the following input dimensions: parts (synonymous with part numbers), suppliers, bids, and price points.

6.1 Part Rationalization

In MYX, UADVM bid out 100% of all parts numbers from external suppliers for all four Assembled Complex Equipment models in question (i.e. 100% of the external BOM), which was approximately 14,000 part numbers. In comparison, for the previous multi-year contract, Multi-Year W (MYW), UADVM only bid out the top 80% of the external BOM, meaning that if parts were ordered by spend in descending order, UADVM only bid out the parts that added up to 80% of the total spend, starting from the most expensive parts. Only about 1,000 parts make up the top 80% of spend; the rest of the part estimates came from historical data. The figure below shows the percentage of parts covered by as a percentage of external BOM Spend:

Figure 13 - Part Number Count Coverage by % of BOM Spend

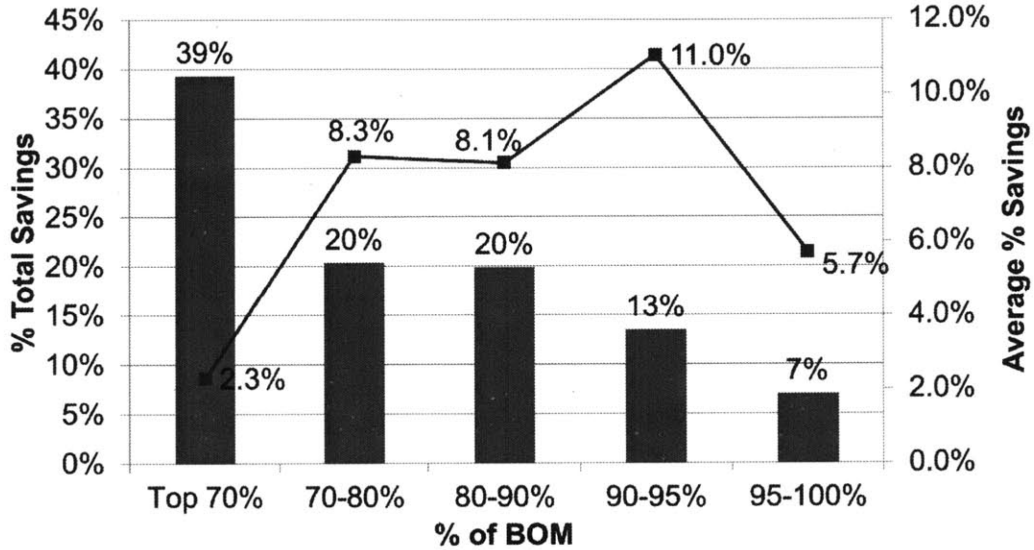


While all parts eventually need to be substantiated, the government does not require UADVM to bid out 100% of the external BOM. Yet a high enough percentage (historically at least 80% of the external BOM by spend) of the total product spend needs to be bid out for the government to have confidence that the cost base they are assuming for negotiations aligns with reality.

The 14x increase in parts is one of the biggest drivers of complexity. The rationale for bidding out the bottom 20% of the external BOM is primarily a drive for increased competition in order to achieve more cost savings. By bidding out more parts, especially in competitive bids, prices are expected to come back lower. In addition, bidding out more part numbers also allows for more volume consolidation across the same supplier, providing UADVM with additional leverage in negotiations.

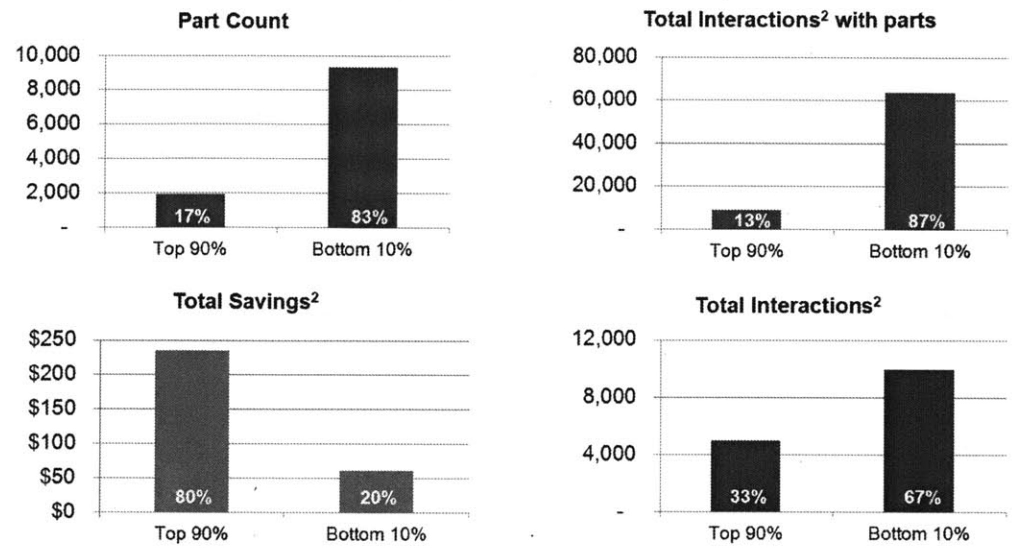
There are two countervailing effects to bidding out each incremental percentage of the external BOM. By definition, less expensive parts have a smaller spend base and thus a smaller impact. However, the data also shows that in general, the percentage cost savings achieved increases as the less expensive parts are bid out, up to a certain point. When these two effects are multiplied together, we can see where most of the savings come from. The figure below illustrates the increase in percentage savings and its effect on total dollar savings:

Figure 14 - Savings across % of External BOM



If we look across total savings, we note that there are diminishing returns to targeting the lower percentages of the external BOM, especially in the last 5% of the external BOM. Hence, there is a case for reducing complexity by not bidding out the bottom of the external BOM while capturing most of the savings. The figure below shows one scenario comparing the top 90% of the external BOM (17% of the part count) with the bottom 10% of the external BOM (83% of part count):

Figure 15 - Top 90% versus Bottom 10% of BOM by Spend



1 Compares Option 2 Year Range 6 Scenario vs. 2010 Transfer Prices; in millions of dollars
2 Interactions defined to be between RFQs, suppliers, negotiation leads, and buyers

The top 17% of parts captures 80% of savings, but only accounts for 13% of the interactions between RFQs, suppliers, NegLeads, buyers, and parts, and 33% of the interactions when normalized without parts. Hence, there appears to be an opportunity to capture the majority of the savings by bidding out just a small portion of the total part count.

For MYY, in examining the part list, less than 400 parts make up the top 80% of the external BOM. However, purely targeting these parts may reduce the leverage UADVM is able to get. Hence, an alternative way to proceed is to focus on sourcing all the parts associated with top suppliers. Analysis shows that the approximate same level of spend (76%) could be reached by targeting all the parts associated with the incumbents associated with the parts that form the top 60% of the external BOM. There are approximately 1,600 parts in that case, approximately 11% of the MYX parts count. The chart below compares these two alternative paths to reaching 80% of the external BOM spend:

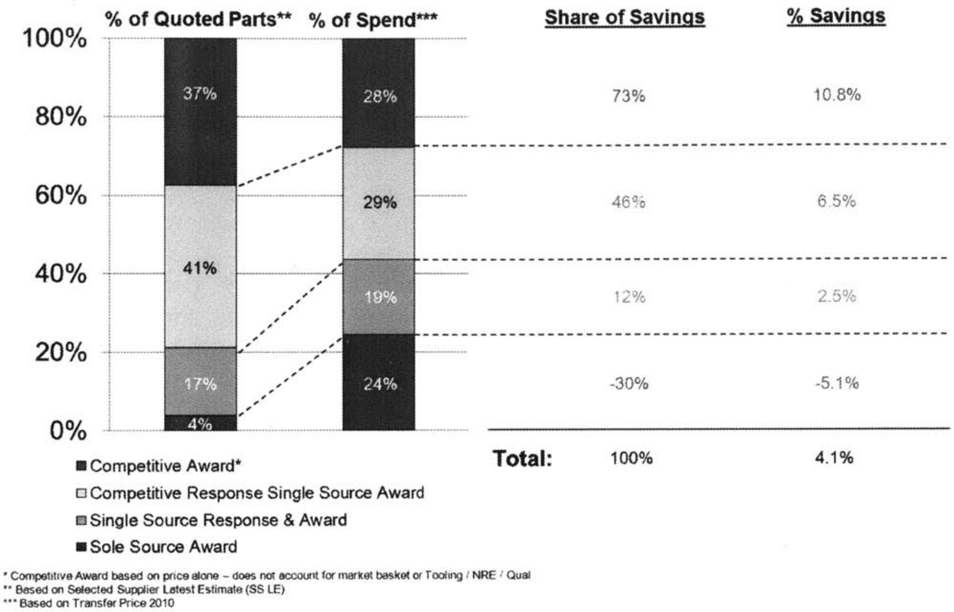
Figure 16 - Two Methods of Covering External BOM Spend

Description	Incumbent Suppliers	Parts	% Spend Covered
Top 80% of Exernal BOM	130	378	80%
Top 60% of External BOM + All Parts associated with top incumbents	58	1660	76%

6.2 Supplier Rationalization

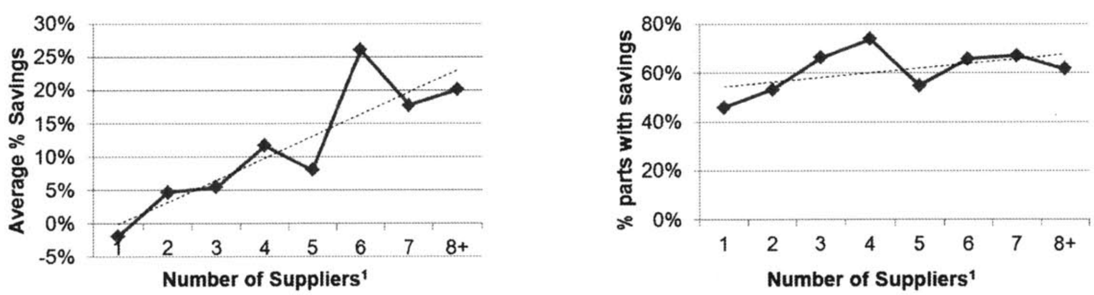
Another area of consideration is the number of suppliers that were solicited for bid in MYX. In MYX, 96% of parts were bid out competitively and 37% were awarded on a competitive basis, whereas only roughly 8% of parts were awarded on a competitive basis in MYW. However, competition appears to yield higher cost savings against transfer price, even when the lowest bid was not selected or when only one bidder responded. The figure below shows the progression from sole source award to single source award (competitive solicitation but only one response), to OTLB (competitive response, but awarded on a single source basis), to a competitive award:

Figure 17 - Award type and Savings



With every step toward competition, the % savings increases from a -5.1% loss in sole source awards (where awarded prices were higher compared to transfer price) to an average of a 10.8% savings on true competitive awards. In addition, more supplier responses also correlates with increased savings, as shown in the figure below:

Figure 18 – Average Savings as a function of Supplier Responses



In aggregate, it appears that % savings grows steadily with the number of responding suppliers, and even though increasing the number of suppliers also increase the complexity of the process, the increased savings achieved should more than offset the cost of that complexity given the size of the spend base. A simple linear regression indicates a 3.4% in additional savings for every supplier added, and with the external spend base a generous portion of the total proposal value of $8.5 billion, the savings should be an much larger than any the cost of administration.

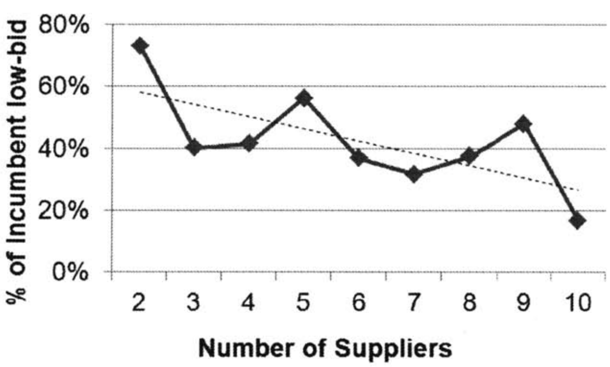
However, a number of caveats apply. First, spend in the higher buckets is increasingly small. For example, at the greatest extreme, the category with 8 or more suppliers only covers 1.6% of total spend. The level of savings achieved may not translate to the larger spend base.

Second, increasing supplier responses in certain material types ("commodities") may not work. For example, in avionics, nine of the 16 parts bid out competitively to two or more suppliers resulted in two parts that were moved from an incumbent to a new supplier, seven incumbent non-low bid awarded parts, and zero incumbent low bid awards. Moreover, the material types where it is beneficial to increase the number of responding suppliers are often more commoditized and may benefit from increased competition. For example, 1,194 out of 1,242 machining parts in competitive bids had two or more responses, resulting in 135 (11%) parts moved from an incumbent to a new supplier, 624 (52%) incumbent non-low bid awards, and 435 (36%) incumbent low bid awards. Hence, further study is required before the effectiveness of more supplier responses can be extrapolated across all material types.

Third, savings are highly dependent on the baseline, and a large savings percentage may indicate that the quoted prices are closer to actual costs. Hence, on may not expect the same percentage savings for future sourcing events, although suppliers certainly have the potential to improve their cost base over time.

Fourth, with the increase of every supplier, the chance for a complex substantiation path increases for incumbents, who often are the logical choice in many material types ("commodity") that have high switching costs such as tooling, non-recurring engineering expenses, and qualification costs. More competition decreases the chance that the incumbent will be the low bid, resulting in longer substantiation paths if the incumbent is kept, and increasing transition risks and timelines if the part is moved to a new supplier. The figure below illustrates this phenomenon:

Figure 19 - Incumbent Low-Bids as a function of Supplier Responses



In cases where the incumbent is no longer the low bid and UADVM decides not to transition the part to a competitor, this means UADVM may have to go back to the incumbent and conduct a CPA or ask for CID documentation even though they have already gone through and bid the part out competitively. Since such substantiation costs are significant and increases nonlinearly with the number of suppliers, in many cases, it may make sense to solicit pre-identified sole source suppliers upfront on a sole source basis.

Finally, UADVM does not retain the vast majority of savings – they are passed through to the government customer. While UADVM does directly benefit from savings on any parts that are also used in their commercial programs, the commercial business is a small part of UADVM's business and difficult to quantify. UADVM also would benefit from reducing its total cost base and increasing its competitiveness to win other proposals, but the benefit is also difficult to measure. Further study would be needed in order to quantify these benefits.

Since competition does work to some extent, our ability to constrain the inputs for this dimension is limited. However, some improvement can be made if sole source suppliers are bid out on a sole source basis rather than on a competitive basis. We note that well over half of MYW parts were bid out to sole source suppliers. If we assume 45% of MYX parts can be bid out to one supplier and 55% stays as is, then that may lead to a modest decrease in the average number of suppliers per bid, with an estimated decrease from 2.8 to 2.0.

6.3 Bid Rationalization

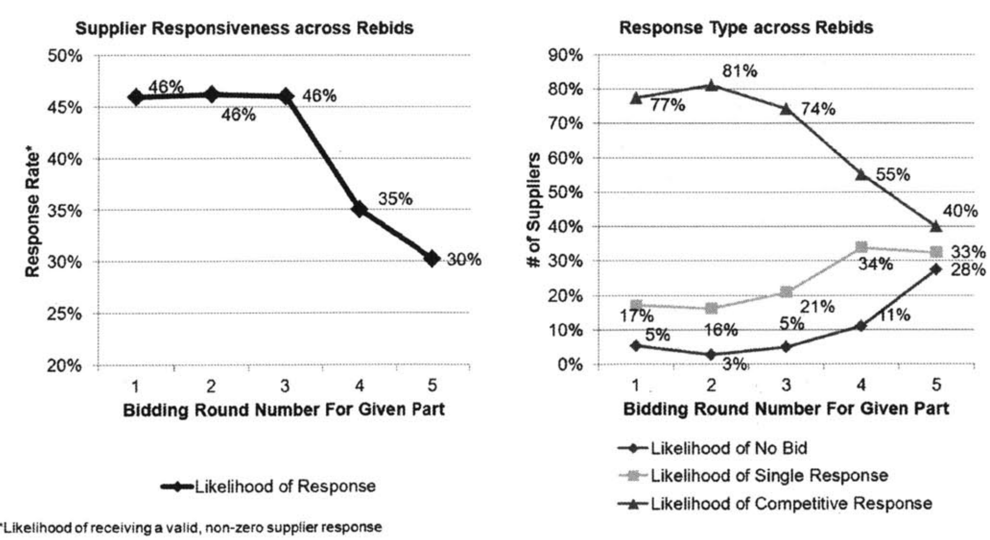
In MYX, there were approximately 1,750 bids with responses from suppliers. As we will see in Chapter 7, the number of bids is related to the design of the bid strategy that groups parts together for bid to a set of common suppliers. However, in addition to initial bidding, there was a fair amount of rebidding that occurred in MYX. On average, 1.7 bids were sent out for every part, indicating a significant number of parts were rebid.

Due to permutations that may occur as packages of parts are bid out, rebidding is difficult to track. After a bid is received, the same package of parts may be bid out to the same suppliers, a subset of the same suppliers, completely new suppliers, or a mix of new and old suppliers. Furthermore, bid packages may add new parts or drop parts. Hence, for simplicity, the analysis on rebidding is done on a part-supplier level, and is defined as when the same part is bid out to the same supplier.

Rebidding occurs for a number of reasons, but most of them have to do with UADVM's dissatisfaction with bid results. Certain suppliers may not have responded, or the bid did not generate a competitive result. This may occur because of lack of interest or expertise to bid on the supplier's side, bidding fatigue, or lack of supplier knowledge, such as when suppliers fail to understand how to bid, how to use the bid platform, or when bids are due. In some cases, non-low bid incumbents may not provide CPAs unless they are rebid via a sole source bid.

Regardless, rebidding not only increases downstream complexity, but also loses effectiveness with each attempt. Analysis shows that the average supplier response rates do not increase when the same part is bid out to the same supplier. The following graphs illustrate the effect of rebidding the same part to the same supplier:

Figure 20 - Results of Rebids



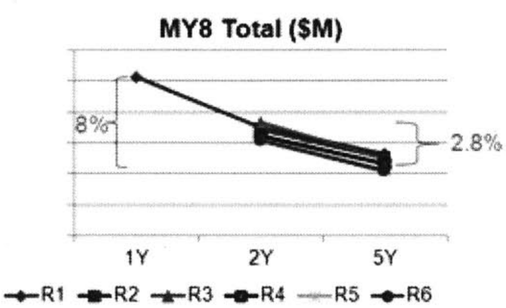
With each rebid, suppliers grow less likely to respond, dropping the average response rate from 46% to 30%. Furthermore, rebidding increases the likelihood of no bids and single responses. Since the government considers each bid a separate scenario, bids for the same part cannot be combined into one competitive pool, making the chances for competitive substantiation even slimmer. This may be exacerbated by Best and Final Offer (BAFO) bids, which effectively wipe out all past bids and do not allow UADVM to even consider using an old bid as the basis for evaluation.

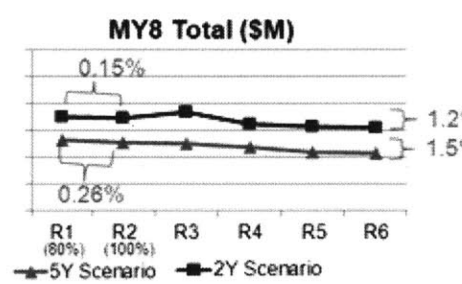
The root of rebidding is also from bid strategy, in particular the supplier selection and part-supplier grouping processes. However, NegLeads can also improve responsiveness by working closely with suppliers, ensuring they are aware of deadlines, how the bid platform works, and what must be done to submit a bid. Furthermore, NegLeads can reduce rebids by committing to sending out just one RFQ, then negotiating with the suppliers and updating their LE's rather than sending out another bid. Finally, NegLeads can avoid BAFOs wherever possible. All of these efforts should reduce the number of rebids. If UADVM approaches the ideal case, the number of rebids can be reduced from 1.7 to ~1.0 bids per part, though 1.2 bids per part would be a more realistic milestone.

6.4 Price Point Rationalization

In MYX, UADVM solicited suppliers for 3 contract scenarios, 6 volume brackets (ranges), and 8 years of pricing. At least two scenarios are required for a multiyear contract in order to demonstrate the advantages of contracting for multiple years as opposed to a single year to the government customer, and analysis shows that there is a significant price differential (3~8%) across scenarios. However, the number of volume brackets solicited can be reconsidered. The analysis conducted on the total spread of prices in different volume brackets, which correspond to Range 1 ~ 6 in Figure 8, shows a relatively small spread (1.2~1.5%) across the most extreme cases and even smaller differences between most volume brackets. The hypothesis is that since background business is added into every volume bracket, the quantities across different brackets are already relatively high, and so price differences are not as large as would be expected. Furthermore, anecdotal evidence points to the possibility that given the volume of data requested, many suppliers simply copied and pasted prices across one range to the other ranges. The figures below illustrate the findings:

Figure 21 - Total Cost compared across Scenarios and Volume Brackets



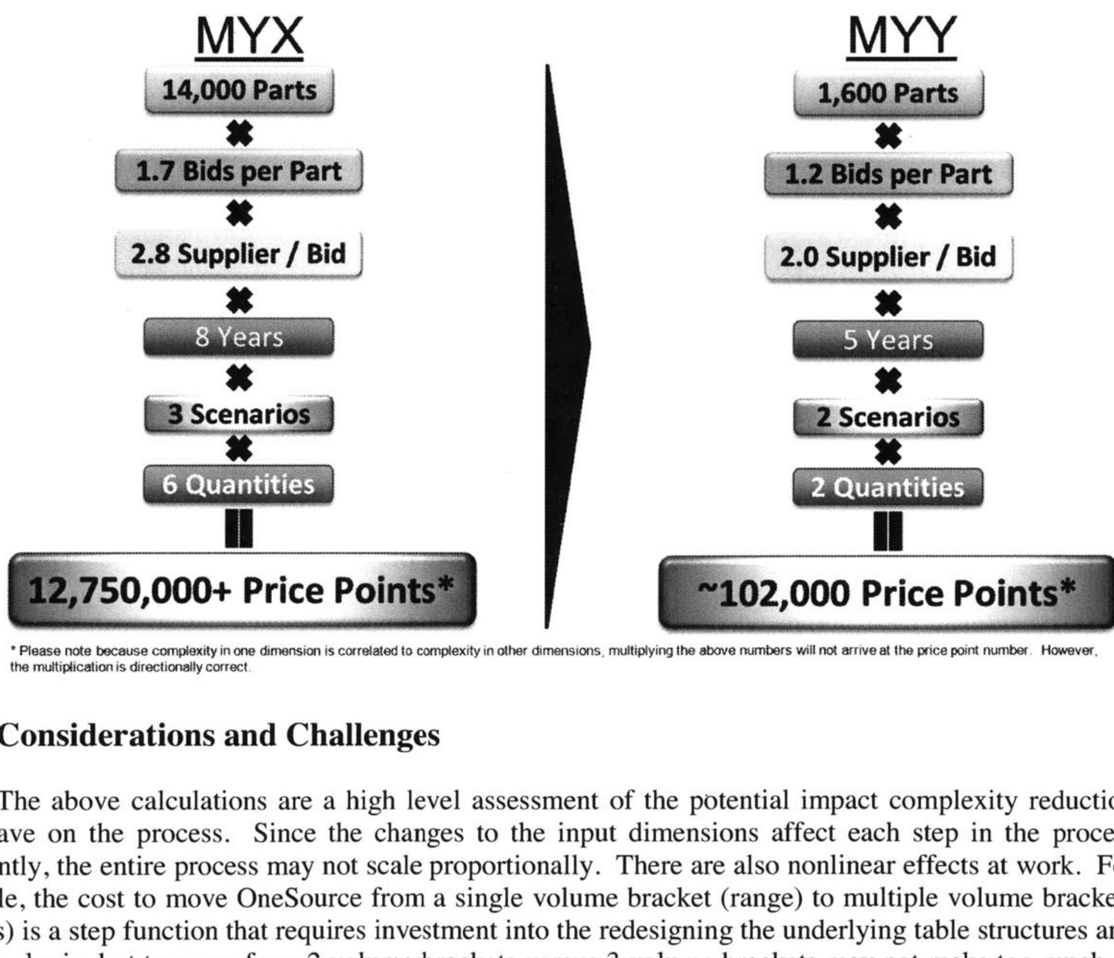


Hence, perhaps only one or two volume brackets are needed. In addition to reducing the scenarios and volume brackets, the number of years can be reduced as well. Ideally, only a single year needs to be quoted – one that is a weighted average of the annual price across the life of the multi-year contract. However, if this is not possible, at minimum, the number of years should be reduced to five in order to match the term of the multi-year contract. Hence, the number of price points may be reduced significantly – if the reduction can fall to the minimum of 2 scenarios, 2 volume brackets, and 5 years of data, then only 20 price points are needed per part as opposed to 144 price points.

6.5 Results and Recommendations

The MY Process can be improved by limiting the number of parts numbers, suppliers, bid solicitations, and price points per part, bid, and supplier. As discussed, the number of part numbers can be reduced from 14,000 to about 1,600 while still capturing 80% of the external spend. If we assume, the number of bids per part can be reduced to 1.2, while the number suppliers that respond to each bid can be dropped to 2.0 if single source solicitations were used more strategically. Finally, if the number of price points drops to 20 per part per supplier per bid (2 scenarios x 2 volume brackets x 5 years), then the number of interactions can be decreased significantly. Using the conservative assumption that the number of price points scales linearly, then these recommendations should reduce complexity to be 1/125th of MYX, or roughly 102,000 price points. If we consider only interactions between parts, bids, and suppliers, the number of interactions drops from roughly 88,000 to around 5,070, a 94% reduction. The figure below shows this transformation:

Figure 22 - Estimate of Complexity Reduction from Input Rationalization



6.6 Considerations and Challenges

The above calculations are a high level assessment of the potential impact complexity reduction may have on the process. Since the changes to the input dimensions affect each step in the process differently, the entire process may not scale proportionally. There are also nonlinear effects at work. For example, the cost to move OneSource from a single volume bracket (range) to multiple volume brackets (ranges) is a step function that requires investment into the redesigning the underlying table structures and business logic, but to move from 2 volume brackets versus 3 volume brackets may not make too much of a difference.

In addition, competitive pressures may erode the case for package simplification. Due to the size of the contract, even small percentage cost savings can be significant for the government customer, even if most of it is pass-through for UADVM. Hence, it is possible that government pressure may push for more competition in hopes of capturing additional savings even though increasing input creates more opportunities for errors as well as reduces clarity and transparency. However, many of these reductions (such as reducing the volume brackets and scenarios) can be done without significant loss of cost savings.

Hence, despite the simplifications taken in the impact assessment and push for competition, reducing the number of inputs for each of the dimensions analyzed above still indicates potential for significant complexity reduction in the MYX process.

7 Bid Strategy Optimization

7.1 Motivation

Another approach to reducing package complexity is to address the package construction process in the initial bid strategy design, which is defined to be how parts are grouped into packages for bid, what suppliers should be invited to bid on what packages, and who should manage the process. In MYX, there was no tool that suggested a bid strategy, and the data on supplier capabilities and part requirements was not systematically available. However, the bid strategy was guided by a supplier selection tool, which organized PO history to indicate which suppliers UADVM purchased what parts from, but it was still primarily a process that relied on human effort to sift through the data and manually group parts together and figure out to which suppliers to bid out these parts. Commodity Management put together an initial draft and then had each Product Center review the suppliers selected to bid. However, during this process, individual Product Centers often added more suppliers to a package. The additions were due to a bias for more competition as well as the familiarity each Product Center had with certain sets of suppliers. In addition, since there was no systematic way to ensure the required spend would be allocated to small businesses, occasionally small business suppliers would be added in with the hope that they would potentially be able to win some additional business. As a result, there was a bias for adding more suppliers into the bid packages and no mechanisms to measure and curb the increasing complexity. Hence, packages that went out for bid became much more complex than any single product center had anticipated.

Paradoxically, many Product Centers were surprised at the suppliers to whom bid invitations were sent, and felt they had not been completely included in the decision making process. Part of the reason may be certain Product Centers may not have signed off on the final bid package. This may be understandable given that Product Centers provided comments asynchronously to Commodity Management, and these comments included additions that may not have been shared with other Product Centers. Furthermore, Commodity Managers realized that oftentimes the more Product Centers vetted the bid packages, the more suppliers were added. As the administrator and gatekeeper of the process, Commodity Management had to keep the supplier list manageable, and bring the review process to an end.

The result of such a supplier selection process resulted in several issues during the bid process. Some bids went to suppliers who were not yet qualified to bid, or did not understand the specifications to the level that would allow them to provide a realistic bid. As a result, unqualified suppliers may put in an unrealistically low bid, potentially resulting in questions from the government or a need to conduct a rebid. In other cases, sole sourced parts may have been competitively bid out. That may have been by design, due to the emphasis on competition, but this oftentimes delayed the CPA or commerciality substantiation route and resulted in complications afterward when suppliers refused to provide cost and pricing data given the understanding they were bidding on a competitive basis.

There were also cases where bids missed out on including key suppliers, such as incumbents or other key competitors. Some of this may be attributed to timing issues between where the data was when captured by the supplier tool compared to where the data was when the bids went out. For example, when the data was collected, supplier A may have been the incumbent, but by the time the bids went out, the incumbent became supplier B, who may not have been invited to the bid. Data in the supplier selection tool was captured as a moment in time, but not updated and did not account for source transitions that may have happened in the coming months. As a result, the new incumbent in some cases was not included in the bid.

The manual process to structure a bid strategy also resulted in overlooking key part level inputs. For example, some bids included parts undergoing engineering changes, meaning that the part specifications would be changing and the new bids for that part would need to be sent out again. Some relational parts – parts that are related in some way and should be bid out on the same RFQ – were not put on the same bid. Changes to the external BOM, though unknown the time, also resulted in rebidding packages that were updated with certain parts to be added or dropped.

Certain key metrics are available to highlight the issue of suboptimal package groupings. In MYX, on average, each supplier responded to 13.6 different bids, with one supplier having to respond to as many as 264 bids. The problem is compounded when considering how NegLeads are assigned to suppliers, who are often in so many different bids against different suppliers: 59% of all RFQs have two or more NegLeads involved in determining the package award, and 30% have three or more. The figure below provides additional details:

Figure 23 - Number of NegLeads per Package

# of NegLeads	RFQs	% of RFQs	Cumulative % of RFQs
10	1	0%	0%
9	2	0%	0%
8	5	0%	0%
7	11	1%	1%
6	40	2%	3%
5	74	4%	7%
4	148	8%	15%
3	269	15%	30%
2	536	29%	59%
1	755	41%	100%
Grand Total	**1,841**	**100%**	**100%**

Furthermore, 40% of all bids only had 1 part number, and 74% of bids had fewer than 5 part numbers. The figure below provides further details:

Figure 24 - RFQ by Size

# Parts in RFQ	# RFQs	% RFQs
>1000	12	1%
100~1000	64	3%
20~100	109	6%
10~20	123	7%
5~10	174	9%
<=5	1,359	74%
Total	**1,841**	**100%**

To relieve these issues and create a more optimal grouping of parts, suppliers, and NegLeads, one approach is to use a mathematical optimization model, known as a mixed integer linear programming (MILP), that would account for all the necessary constraints (e.g. supplier qualifications, incumbents, number of NegLeads per bid, etc.) to ensure the bid contains the most capable and necessary bidders while minimizing complexity. MILPs and other linear programming models allow users to leverage existing algorithms to solve large optimization problems quickly once the decision variables, objective function, and business / logical constraints have been defined for a particular problem. The MILP for the bid strategy problem was initially developed in Excel and then coded in Python using the Gurobi linear optimization engine.

A mathematical optimization model has several advantages over other methods. First, it systematically standardizes the bid strategy – the criteria for supplier selection, part groupings, and NegLead assignment. The model can provide a starting point using preset criteria, and the output can be adjusted if necessary during the course of a review process between Commodity Management and the Product Centers. Second, such a model can provide an inherent bias for simplicity, allowing requirements to be put in as constraints, but then minimizing the number of packages required, the complexity of each package, and the number of interactions necessary. Third, such a model can potentially quantify the impact of business constraints. For example, if a constraint, such as the number of parts one NegLead can manage is modified, the model can quantify the impact that has on complexity by showing the impact it has on the number of interactions required in one case versus the other. Fourth, given that the model requires clean inputs, having a model may enforce the discipline of maintaining those inputs, which may be important pieces of data for other systems. And finally, the model can be built in a way that provides flexibility and extendibility to other proposal procurement processes.

7.2 Optimization Formulation

The ultimate goal of such a model is to pick the "right" number of suppliers that are the best and most qualified for each part in a way that satisfies existing business constraints, such as including incumbents and ensuring the proposal meets the criteria for the six socioeconomic categories, while minimizing the number and complexity of packages these parts and suppliers are grouped into before assigning NegLeads in a way that minimizes the number of NegLeads, interactions between NegLeads and suppliers, and the "distance" between NegLeads and parts.

Given the complexity of such an optimization, an initial attempt will try to simplify the problem in many ways. First, it may be difficult to determine the "right' number of suppliers to bid at this point, and that is a further research question in of itself. Hence, the model will take an input for the minimum and maximum number of suppliers desired instead. Second, it is difficult to minimize complexity and simultaneously maximize quality of suppliers without weighting the two factors, which may also be a further research question. Third, although the two are closely tied, it is a more complex problem to simultaneously minimize package-level complexity and NegLead related complexity. Hence, this initial attempt will aim to break the formulation down into three distinct and sequential stages. Stage 1 answers the question, "Which suppliers should I invite to bid on what part?" and is primarily concerned with supplier selection. Stage 2 addresses the question, "How should we group parts and suppliers into packages?" and answers the question of package generation. Stage 3 handles the question, "Who should be assigned to manage each package?" and assigns the packages that each NegLead should take on. I will describe the formulation for each stage of the model in further detail:

Stage 1: Which suppliers should I invite to bid on what part?

Decision Variables

The decision variables consist of a matrix of parts by suppliers, indicating which part-supplier combinations are selected. This matrix shows which suppliers to solicit for what part.

f = A part index, part 1, part 2, ..., F, where F represents the total number of parts

s = A supplier index, supplier 1, supplier 2, ..., S, where S represents the number of suppliers

A_{fs} = The binary decision to solicit supplier s to bid on part f

Objective Function

Given that the range of the possible number of suppliers is already provided as an input, the objective function in the first stage is to maximize supplier quality. Supplier quality scores are inverted so that Supplier Gold scores is the smallest number and Underperforming Suppliers have the highest number. The model attempts to minimize the supplier quality scores, thus taking the fewest number of high performing suppliers possible. One additional benefit of optimizing supplier selection based on quality is that there is now a clear link between supplier quality and supplier selection, allowing UADVM to reward high quality suppliers.

The objective function also weights the supplier quality scores by spend, as the desire is to minimize supplier scores on a global basis. The mathematical formulation is as follows:

Minimize:

$$\sum_{f=1}^{F}\sum_{s=1}^{S} K_0 * Quality_s * PctSpend_f * A_{fs}$$

Where *K0* is a quality coefficient, *Quality[s]* indicates the quality of Supplier s, *PctSpend* indicates the percent of total spend Part f represents, and A[f][s] is the decision variable that determines whether or not that part-supplier combination is counted.

Constraints

1. Minimum Supplier Constraint – Pick no less than the minimum number of suppliers per part specified
For each Part f
$$\sum_{s=1}^{S} A_{fs} \geq MinSupplierCount_s$$
where $MinSupplierCount$ is an input vector of the minimum number of suppliers for each part

2. Minimum Supplier Constraint – Pick no more than the maximum number of suppliers per part specified
For each Part f
$$\sum_{s=1}^{S} A_{fs} \geq MaxSupplierCount_s$$
where $MaxSupplierCount$ is an input vector of the maximum number of suppliers for each part

3. Eligible Suppliers – Eliminate any ineligible suppliers for each part
$$\sum_{f=1}^{F} \sum_{s=1}^{S} A_{fs} \leq EligibilityMatrix_{fs}$$
where is a binary matrix consisting of f Parts and s Suppliers

4. Incumbents – Ensure all incumbents and must-have suppliers are selected
$$\sum_{f=1}^{F} \sum_{s=1}^{S} A_{fs} \geq IncumbentForcingMatrix_{fs}$$
where is a binary matrix consisting of f Parts and s Suppliers

5. Socioeconomic Categories – Select suppliers such that they meet the minimum spend criteria for each of the six socioeconomic categories. Since parts may be bid out competitively, the model does not count spend into one of the socioeconomic categories unless every supplier bidding for that part fulfills the criteria of having that same socioeconomic indicator. Since this is not a straightforward constraint, it requires linearization in order to implement.
Step 1: Take in an input SDB[s][i], which determines whether or not a supplier qualifies for the i^{th} socioeconomic (out of 6) criteria

Step 2: Define SDBXSPSUM[f][i] as the sum of the number of suppliers allocated to Part f that fulfill the i^{th} socioeconomic (out of 6) criteria:
$$SDBXSPSUM_{fi} = \sum_{s=1}^{S} A_{fs} * SDB_{si}$$
Step 3: Define SCount as the number of suppliers allocated to Part f:
$$SCount_f = \sum_{s=1}^{S} A_{fs}$$
Step 4: Check to see if SCount[f] = SDBXSPSUM[f][i], or in other words, that every supplier bidding for the part fulfill the i^{th} socioeconomic criteria. If so, consider Part f as one that fulfills the i^{th} socioeconomic (out of 6) criteria by marking a newly created

dummy binary variable SDBPartInd[f][i] to equal 1. In other words, set the following constraint:

$$SCount_f * SDBPart_{fi} \leq SDBXSPSUM_{fi}$$

For each Part f and each socioeconomic category i

Step 5: However, since SCount and SDBPart are both decision variables, in order to linearize the equation, we create a dummy variable ZSDBPartInd[f][i] and set it equal to SCount[f] * SDBPart[f][i] through the following series of constraints:

$$\sum_{f=1}^{F}\sum_{i=1}^{6} ZSDBPartInd_{fi} \geq SCount_f - \left(1 - SDBPartInd_{fi}\right) * M$$

$$\sum_{f=1}^{F}\sum_{i=1}^{6} ZSDBPartInd_{fi} \leq SCount_f$$

$$\sum_{f=1}^{F}\sum_{i=1}^{6} ZSDBPartInd_{fi} \leq SDBPartInd_{fi} * M$$

$$\sum_{f=1}^{F}\sum_{i=1}^{6} ZSDBPartInd_{fi} \leq SDBXSPSUM_{fi}$$

$$\sum_{f=1}^{F}\sum_{i=1}^{6} ZSDBPartInd_{fi} \geq 0$$

where M is defined to be a large integer.

Step 6: Set constraints to ensure spend for each socioeconomic category is met:

$$\sum_{f=1}^{F} SDBPartInd_{fi} * PartSpend_f \geq TotalSpend * SDBMinPct_i$$

for each socioeconomic indicator i, and where PartSpend[f] indicates the estimated value of the part, TotalSpend is the sum of all the parts in the proposal, and SDBMinPct[i] is the minimum percentage of spend required to be spent in the socioeconomic group i.

Stage 2: How should we group parts and suppliers into packages?

Decision Variables

p = A package index, package 1, package 2, …, P, where P represents the number of packages

f = A part index, part 1, part 2, …, F, where F represents the number of parts

s = A supplier index, supplier 1, supplier 2, …, S, where S represents the number of suppliers

X_{fp} = The binary decision to include part f in package p

Y_{sp} = The binary decision to include supplier s in package p

Objective Function

The goal here is to minimize the total number of packages as well as the complexity of each package. Hence, we want:

Minimize:

$$\sum_{f=1}^{F}\sum_{s=1}^{S}\sum_{p=1}^{P} K_1 * C_{fsp} + \sum_{p=1}^{P} K_2 * IsPckg_p$$

Where K_1 and K_2 are the coefficients, and C_{fsp} and $IsPckg_p$ are two dummy variables required for linearization. $IsPckg_p$ is a dummy binary variable that is high for every package that is used.

C_{fsp} is binary dummy variable related .to the complexity matrix that represents the multiplication between the number of suppliers in each package and the number of parts in each package:

$$Complexity_p = \sum_{f=1}^{F} X_{fp} * \sum_{s=1}^{S} Y_{sp}$$

Ideally, the complexity measurement portion of our objective function is the sum of complexities across all the packages:

Minimize:

$$\sum_{p=1}^{P} K_1 * Complexity_p$$

This implies our complexity measurement portion of the objective function should be:

Minimize:

$$\sum_{p=1}^{P} K_1 (\sum_{f=1}^{F} X_{fp} * \sum_{s=1}^{S} Y_{sp})$$

However, a multiplication of the sum of suppliers and the sum of parts in each package is a nonlinear operation. Yet we note that for each package p:

$$Complexity_p = (X_{1,1} + X_{2,1} + \cdots + X_{F,1}) * (Y_{1,1} + Y_{2,1} + \cdots + Y_{S,1})$$

This implies if we create a dummy variable C_{fsp} defined as follows:

$$C_{fsp} = X_{fp} * Y_{sp}$$

Then we should be able to represent the complexity function with standard linearization formulations.

Constraints

1. One package per part – Ensure every part will only be assigned to one package:

$$\sum_{p=1}^{P} X_{fp} = 1$$

   For each Part f

2. Respect supplier to part assignments from Stage 1:

$$\sum_{p=1}^{P} C_{fsp} = A_{fs}$$

   Where A[f][s] is the output from Stage 1

3. IsPckg Dummy Variable definition – if there any part is assigned to package p, then p is considered to be an active package and IsPckg[p] should be set to 1.

$$\sum_{f=1}^{F} X_{fp} - M * IsPckg_p \leq 0$$

   For each package p, and where M is defined to be a large integer

4. C_{fsp} Dummy Variable definition – we use the following standard linearization technique in order to express $C_{fsp} = X_{fp} * Y_{sp}$ linearly:

   $C_{fsp} \leq X_{fp}$, for each Part f, Supplier s, and Package p

   $C_{fsp} \leq Y_{sp}$, for each Part f, Supplier s, and Package p

   $C_{fsp} \geq X_{fp} + Y_{sp} - 1$, for each Part f, Supplier s, and Package p

Stage 3: Who should be assigned to manage each package?

Decision Variables

p = A package index, package 1, package 2, ..., P, where P represents the number of packages

n = A NegLead index, NegLead 1, NegLead 2, ..., N, where N represents the number of NegLeads

Z_{np} = The binary decision to assign NegLead n to package p

Objective Function

The goal here is to minimize three terms: 1) the number of "unfamiliar" parts a NegLead has to manage in the packages he or she is covering, 2) the number of overall NegLeads used, and 3) the number of "extra" NegLead-Supplier interactions required. Each of these three terms may require some additional explanation:

"Unfamiliar" parts – Since many NegLeads are buyers who already are in charge of certain parts, we can define those parts as "familiar parts." Hence, unfamiliar parts are parts assigned to a NegLead who is not in charge of those parts on a day-to-day basis. As much as possible, we would want to have NegLeads negotiate the parts with which they are most familiar.

NegLeads used – Because of the costs of training and managing additional NegLeads, it is most efficient to use as few NegLeads as possible. This may also help reduce the number of potential handoffs. The minimization of NegLeads needs to be balanced by the workload one NegLead can handle.

"Extra" NegLead–Supplier interactions – Ideally, each supplier would only need to interact with one NegLead. Since in this model, we have assigned NegLeads to packages and not to Suppliers, it may not always be the case that such an arrangement is possible. Nevertheless, the model attempts to do that by defining "extra" NegLead-Supplier interactions as the number of NegLeads a supplier interacts with minus one. The model attempts to minimize this number and penalizes extra interactions.

Keeping those three terms in mind, the objective function can be defined as follows:

Minimize:

$$\sum_{n=1}^{N}(K_3\sum_{f=1}^{F} X_{fp} * NN_{fn} * Z_{np}) + \sum_{p=1}^{P}(K_4 * IsNegLead_n) + \sum_{s=1}^{S} K_5 * OverlapCount_s$$

where K_3, K_4, and K_5 are the coefficients, X_{fp} is the Part-Package output from Stage 2, NN_{fn} is a matrix that describes the associations between NegLeads and Parts, $Z_{np}$is the binary decision variable that determines the assignments of packages to NegLeads, and $IsNegLead_n$ and $OverlapCount_s$ are two dummy variables required to help track the number of NegLeads used and the number of extra Supplier-NegLead interactions required.

Constraints

1. One NegLead per part – Ensure every package will only be assigned to one NegLead:

$$\sum_{n=1}^{N} Z_{np} = 1$$

   For each package p

2. NegLead Package Workload Constraint – Ensures NegLeads don't manage more packages than the maximum desired

$$\sum_{p=1}^{P} Z_{np} \leq MaxNegLeadPackageWorkload$$

For each NegLead n

3. NegLead Part Workload Constraint – Ensures NegLeads don't cover more parts than the maximum desired

$$\sum_{p=1}^{P} Z_{np} * FSum_p \leq MaxNegLeadPartWorkload$$

For each NegLead n, where *FSum[p]* is the number of parts in each package

4. NegLead Supplier Workload Constraint – Ensures NegLeads don't cover more suppliers than the maximum desired

$$\sum_{p=1}^{P} SNLMbin_{ns} \leq MaxNegLeadSupplierWorkload$$

For each NegLead n, where SNLM_bin[n][s] is a dummy variable that is high if a particular supplier interacts with a particular NegLead in any package

5. IsNegLead Dummy Variable Definition – if a NegLead is assigned to any of the packages, then we want the IsNegLead variable to be high:

$$\sum_{p=1}^{P} Z_{np} - M * IsNegLead_n \leq 0$$

For each NegLead N, and where M is defined to be a large integer.

5. Overlap Count Dummy Variable Definition – if there is more than one supplier-NegLead interaction, we want to count that extra interaction using this dummy variable. In order to do so, we first have to define a couple other dummy variables.
Step 1: Define SNLMInt[n][s] as the number of times NegLead n interacts with Supplier s:

$$SNLMInt_{ns} = \sum_{p=1}^{P} Z_{np} * Y_{sp}$$

Note that since Y[s][p] is passed in as a fixed input, it is treated as a constant rather than a variable in this stage of the model, thus avoiding issues with linearization.

Step 2: Define SNLMBin[n][s] as a binary dummy variable that indicates whether or not NegLead n interacts with a Supplier s:

$$\sum_{p=1}^{P} SNLMInt_{ns} - M * SNLMBin_{ns} \leq 0$$

Step 3: Set OverlapCount[s] as the number of extra NegLeads each supplier interacts with, in other words, OverlapCount[s] is one less than the sum of SNLMBin across NegLeads:

$$OverlapCount_s \geq \sum_{n=1}^{N} SNLMBin_{ns} - 1$$

Since our objective function will attempt to minimize the terms, OverlapCount[s] should equal SNLMBin[n][s] -1.

Key Considerations on Team Structure

Note that implicit in the Stage 3 model is a change in the team structure – NegLeads are assigned to packages, not suppliers. The model will, as much as possible, try to group all the packages that a single supplier is on with the same NegLead, but in many cases that is not possible. Hence, to go along with this sort of team structure, a different role, known as an Account Rep, can be assigned so that every supplier only has one Account Rep. This Account Rep may participate in every negotiation that his/her supplier is in, look across all the negotiations across different packages, and negotiate separately with the supplier to understand the terms the supplier is willing to set in the case they win multiple packages. The Account Rep can then provide those terms as input to the NegLead as considerations in the decision process. One Account Rep should be assigned to every supplier.

Team structure can be further improved by assigning a NegLead and a secondary NegLead (known as a "Second") to every package, and ensuring there is one buyer for every NegLead-Second pair. It will also help to keep the same team together throughout the process from bid solicitation to PO approval.

7.3 Results

One way to compare the impact such a model might have is to consider running it on the MYX data and comparing it the manual process of determining a bid strategy. Since UADVM may not readily have the inputs necessary for Stage 1, we can assume the output of Stage 1 by taking in the supplier-part combinations in MYX and running them through Stage 2 to see if there is a reduction in the number of RFQs used. Using the output from Stage 2, Stage 3 can be tested as well, though additional assumptions need to be made around a negotiator's workload constraints and the relative coefficient weightings that balance between the three different types of complexity.

Initial efforts to run the model for the entire MYX effort have required more computational power than is easily available, and so the recommendation would be to run the model for each material type (castings, forgings, avionics, etc.) separately. As an illustration, the forgings commodity was run through Stages 2 and 3 of the optimization model using the MYX data as a starting point. The MYX data showed there were 49 forging parts and 13 suppliers involved, which were grouped into 21 RFQs (including rebids). After running the Stage 2 model using the existing relationships between the 49 parts and 13 suppliers, the model grouped the parts and suppliers into 12 RFQs, a 43% decrease from the baseline. While a good portion of those extra RFQs may be due to rebids, the model still shows the potential for significant reduction in grouping parts and suppliers into packages as well as reducing and standardizing the preparation stages for RFQs.

Stage 3 was run with fairly relaxed constraints, and assumed each negotiator could manage up to 30 parts, 6 suppliers, and 14 packages. The penalty coefficient for each unfamiliar part managed by the negotiator was set to 1.0, the penalty for each negotiator involved was set to 3.0, and the penalty for suppliers having to work with more than one negotiator was set to 10.0. The solution assigns each part to only one package and only one negotiator while keeping the number of negotiators each supplier has to deal with relatively low. Four suppliers only had to deal with a single negotiator, seven had to deal with two negotiators, and only one had to deal with three negotiators. Results could be further improved if the workload constraints were increased to allow one negotiator to deal with more suppliers and parts.

7.4 Implementation Challenges

The code for the bid strategy optimization model has been specified in the appendix. However, the model still faces a number of challenges for implementation, including the following:

Data availability and accuracy

One of the requirements for the model is to be able to provide accurate inputs on supplier eligibility for parts and part families. While currently there are efforts under way to gather supplier capabilities for each part family, there is no systematic way to ensure that all capabilities are gathered for every potential supplier. Furthermore, some parts within part families may have unique requirements that need to be considered. Finally, certain parts, such as those that are flight safety or flight critical, require qualifications and other upfront steps. These qualification requirements by part and the qualification status of suppliers for these requirements need to be made transparent to the model.

The model also needs clean, complete, and accurate inputs for additional data such as supplier quality, incumbents for each part, the negotiator's familiarity for each part, and estimated part spend.

Run-time for large data sets

Since the number of decision variables required scales quickly with the number of parts and suppliers, Run-time performance for production may get unwieldy as the model expands to other material types. In fact, when the Stage 2 optimization was run for forgings, the model failed to complete in a reasonable period of time. Examination of the logs indicated that while a reasonable though suboptimal solution was reached after a few minutes, the model continues to explore the vast search space for small incremental gains. Hence, to ensure Stage 2 completes in a reasonable amount of time, the model was cut off after 210 seconds of computation.

Specification of Key Inputs

The model requires important inputs such as the number of suppliers to solicit for each part, penalty coefficients to weigh between different options in optimization, and limits such as a reasonable workload for NegLeads in terms of packages, parts, and suppliers. To define these inputs may require additional analysis.

Outside Considerations

The model does not take into account other factors that may be important in bid strategy, such as relationships NegLeads may already have with certain suppliers, relational parts, parts undergoing engineering changes, potential timing considerations that would require splitting out the bids, and offset spend considerations.

8 Conclusion

Due to the size of the Multi-Year Proposal, Multi-Year Procurement Processes have always been the most complex procurement processes at UADVM, resulting in higher workloads, more waste, and challenges around providing transparency. However, the complexity of MYX in particular had increased dramatically over MYW. To tackle this increase in complexity, UADVM can consider reducing the number of parts, bids, suppliers, and price points as well as employ a data-driven, standardized approach toward developing the bid strategy. Reducing the number of inputs can potentially cut the complexity of future multi-year procurement processes down to 1/300th of MYX in terms of data points to manage, and approximately 5% of the number of total interactions. Creating a data-driven approach for bid strategy via an optimization model can streamline package groupings by 43%, and provide more standardization and clarity. These approaches can counter increases in complexity due to an increase in the number of product centers, more conservative substantiation rules, and a desire to increase competition among suppliers.

8.1 Applications

Beyond the Multi-Year Procurement Process, these methods and analyses can be used to reduce complexity for procurement processes with multiple parts, suppliers, and bids, though its greatest applications may still be in the government contracting space, where complexity will likely continue to be an important consideration in the near future. Note that the potential impact of these approaches depends heavily on the complexity of the process in question and the results found in MYX may not be predictive of results for other processes.

The analyses described in Chapter 6 to reduce the process inputs can only be employed for cyclical procurement processes, where there is data available that allows one to make a case for part, supplier, bid, and price point rationalization. Furthermore, since the analysis may only reveal areas where complexity can be reduced, and provide no insight on where complexity can be increased in order to potentially gain greater savings, the analysis should be applied on a process that clearly requires greater simplification rather than sophistication.

The mixed integer linear programming methodology illustrated in Chapter 7 can be applied more widely to a number of procurement situations, though depending on the scenario, the constraints, parameters, and inputs would have to be modified accordingly. For other government proposals at UADVM, only the inputs would need to be changed – i.e. the parts, suppliers, and negotiators involved, as well as the relationships between them. For non-government proposals, certain constraints, such as the socioeconomic constraints can be removed. However, most of the other constraints still apply – e.g. parts should still only be bid out to eligible suppliers, each part should only be placed in one bid, negotiator workloads should be respected, etc.

8.2 Remaining Questions and Areas of Study

There are a number of areas that can benefit from further study, including those on how supplier behavior affects complexity and opportunities to improve the optimization model. In addition, there are a number of other key issues that resulted in the challenges on MYX, including planning, systems, and process definition, each of which can be explored in more detail. Finally, there are a couple of external factors that may merit research, such as the impact of the product center model on purchasing and an analysis on the defense contracting as well as solutions for increased alignment of incentives in order to reduce the need for inspection and its associated waste. I will describe these areas in more detail below:

Supplier Behavior

Supplier behavior has a very large impact on planning the number of suppliers to solicit in the multi-year process, which impacts bid strategy, substantiation strategy, and procurement strategy. Knowing whether certain suppliers will respond and what price range they are likely to respond in helps you narrow down how many and which suppliers you need to solicit. Additionally, quantifying the probability for competitive substantiation can help make tradeoffs in substantiation paths. Finally, more accurate predictive modeling can help UADVM understand in what situations it is economical to add one more competitive supplier in order to improve negotiation results. Next steps to better understand supplier behavior in bidding situations are further study into the factors that affect supplier response rate, variables that may be predictive of potential pricing (e.g. past prices, knowledge of part, competitiveness of bid, size of relationship), and the effect on price negotiations through adding an additional competitive supplier.

Savings Benefit

As discussed, increasing competition does increase savings, and for MYX. However, most of the savings is passed onto the government customer. Yet there are still some direct benefits to UADVM, such as improving its cost base, which increases its ability to win more proposals, and lowering costs for parts common to commercial programs. Additional research is required in order to estimate these benefits and weigh against increasing costs due to complexity.

Bid Strategy Optimization Enhancement

Further research can also be conducted to enhance the bid strategy optimization model. As alluded to earlier, there are a number of possible improvements, including the following:

Optimize across complexity, quality, and cost savings in Stage 1

Currently, Stage 1 of the model only optimizes for quality; however, a more robust model may translate cost of quality into financial terms, estimate potential cost savings from bidding certain suppliers or a number of suppliers, and estimate cost of complexity to add another supplier to a part. This would allow the model to minimize across total costs and account for cost savings as well as complexity; in addition, this would allow the model to output the number of suppliers to lower overall costs rather than take such a parameter in as input. In order to estimate costs, further research is required to accurately estimate cost of quality, cost of complexity, and potential savings.

Optimize across stages

In order to simplify the problem, the optimization model breaks it into three stages; however, finding a way to combine two or more stages would yield an even more optimal solution. With a combined approach, the model can make tradeoffs, for example, between the potential loss in savings in not adding another supplier in Stage 1 in order to improve the grouping possibilities in Stages 2 and 3.

Set coefficients

Further research is also required to set the coefficients involved in the objective function at various stages, especially in Stage 3, where the tradeoff between the number of NegLeads per supplier, the number of NegLeads, and the number of unfamiliar parts is unclear.

Runtime Performance

Most of the looping in the optimization code occurs across sparse matrices. While the code already limits looping to go through eligible suppliers, further improvements can be made to improve the runtime performance of the code, allowing it to scale up for larger datasets.

Planning

Many of the issues go beyond just complexity reduction through reducing and simplifying packages. Issues like resource planning, scope and input definition, communication protocols, training, policies and procedures, and overall strategy all need to be examined in depth to improve the multi-year process further. While a checklist of the sub-items within each of the above categories has been defined to help with the planning, further research is required to expand upon each sub-item in the checklist.

Systems

A number of systems can be upgraded to ensure data transparency, improved linkages between systems, and improved efficiency. While UADVM's IT team has taken on a number of initiatives to improve existing systems, further research can be conducted to detail the specifications around user needs, estimate the cost of development, and quantify the risk of system limitations.

Process Definition

A number of opportunities exist to define specific pieces of the process better, including the Negotiation Authority Meeting (NAM) process, substantiation processes, and PO approval process. Specifically in substantiation, further research can be done to calculate the cost of additional complexity required for competitive substantiation, the cost of CPA and CID substantiation, and the potential savings that may be gained from competitive substantiation for different part families.

Product Center Model

Further research can be done to examine the advantages and drawbacks of having a product center model for purchasing as opposed to a centralized purchasing model.

Defense Contracting Model

Additional research can be done to understand how incentives between the government customer and its contractors affect motivation and regulations. There may be an opportunity to explore different incentive models that may better align government and contractor interests so contractors are incentivized to find savings and pass a portion of it on to the government.

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10 Appendix

10.1 Bid Strategy Optimization Code

The bid strategy optimization code is written in python and calls on the Gurobi Optimizer. Gurobi Optimizer (http://www.gurobi.com/products/gurobi-optimizer/gurobi-overview) is a solver for mathematical programming and is required in order to run the bid strategy optimization code.

The code 3 functions: `Stage1Model.py`, `Stage2Model.py`, and `Stage3Model.py`. A demo driver file, called `MYOpt.py`, is included below to show how to structure inputs, call each of the three stages sequentially, and pass the outputs from one stage as the inputs of another.

Master File: MYOpt.py

```
Filename: MYOpt.py
Description: Sample file to run 3 stage model
----------------------------------------------------------------------
# Data for Optimization Model

from gurobipy import *

# Input Data
# Part, SMin, SMax, Spend
Parts, SMin, SMax, Spend = multidict({
'204-35': [1,4,50.0],
'3258-29': [2,4,480.0],
'1583-455': [1,4,320.0],
'2811-803': [3,4,150.0]
})
Parts = tuplelist(Parts)

# Supplier, SDB[s][6], Quality
Suppliers, SDB1, SDB2, SDB3, SDB4, SDB5, SDB6, Quality = multidict({
5047: [1,0,1,0,0,1,4],
2385: [0,1,0,1,1,0,7],
3920: [1,0,1,0,0,0,2]
})
Suppliers = tuplelist(Suppliers)

# NegLeads
NegLeads = ('NegotiatorA', 'NegotiatorB')
NegLeads = tuplelist(NegLeads)

# Packages
L = 4 # Number of Packages
Packages = [x+1 for x in range(L)]
Packages = tuplelist(Packages)

# EM[f][s] - Eligibility Matrix
EM_Ind, EM = multidict({
('204-35', 5047): 1,
('1583-455',5047): 1,
('2811-803',5047): 1,
```

```
('204-35', 2385): 1,
('3258-29',2385): 1,
('2811-803',2385): 1,

('204-35', 3920): 1,
('3258-29',3920): 1,
('1583-455',3920): 1,
('2811-803',3920): 1
})
EM_Ind = tuplelist(EM_Ind)


# IFM[f][s] - Incumbent Forcing Matrix
IFM_Ind, IFM = multidict({
('2811-803',5047): 1,

('204-35', 2385): 1,

('3258-29',3920): 1
})
IFM_Ind = tuplelist(IFM_Ind)

# Part x NegLead Relationship Matrix
NNegPart = {
('204-35', 'NegotiatorA'): 1,
('3258-29','NegotiatorA'): 0,
('1583-455','NegotiatorA'): 0,
('2811-803','NegotiatorA'): 1,
('204-35', 'NegotiatorB'): 0,
('3258-29','NegotiatorB'): 1,
('1583-455','NegotiatorB'): 1,
('2811-803','NegotiatorB'): 0
}

# SDB % Constraints:
SDBMinPct = {1: 0.23,
                 2: 0.05,
                 3: 0.05,
                 4: 0.03,
                 5: 0.03,
                 6: 0.03}

# Stage 1 Constant
QualityCoeff = 1.0

# Stage 2 Constants
ComplexityCoeff = 1.0
nPckgCoeff = 1.0

# Stage 3 Constants
MaxNegLeadPartWorkload = 3.0
```

```
MaxNegLeadSupplierWorkload = 3.0
MaxNegLeadPackageWorkload = 2.0
PenaltyCoeff = 1.0
NegLeadCoeff = 3.0
OverlapCoeff = 10.0


# Run Models
# Commented out areas where we would create Indices for the output -
not sure yet if we need to run across them with a select statement
import Stage1Model
PartSupplier = Stage1Model.solve(Parts, SMin, SMax, Spend, Suppliers,
SDB1, SDB2, SDB3, SDB4, SDB5, SDB6, Quality, EM, EM_Ind, IFM, IFM_Ind,
QualityCoeff, SDBMinPct)

import Stage2Model
PackagePart, PackageSupplier, FSum, NewPackages  =
Stage2Model.solve(Parts, Suppliers, Packages, PartSupplier,
ComplexityCoeff, nPckgCoeff, EM_Ind)

import Stage3Model
PackageNegLead = Stage3Model.solve(Parts, Suppliers, NegLeads,
NewPackages, MaxNegLeadPartWorkload, MaxNegLeadSupplierWorkload,
MaxNegLeadPackageWorkload,
      PenaltyCoeff, NegLeadCoeff, OverlapCoeff, NNegPart, PackagePart,
PackageSupplier, FSum)

-----------------------------------------------------------------------
```

Stage 1: Selecting Suppliers for each part

Inputs Variables

The input variables for Stage 1 are as follows:

- Parts – list of part numbers to be considered
- Suppliers – list of supplier codes to be considered
- Eligibility Matrix (EM, EM_Ind) – informs the model of what parts (or part families, depending on what level the model is run at) each supplier is capable of and qualified to supply
- Incumbent Forcing Matrix (IFM, IFM_Ind) – informs the model of which suppliers are the incumbents for which parts (or part families)
- Minimum (SMin) and Maximum (SMax) Number of suppliers – sets the number of suppliers desired for each part or part family. The minimum and maximum is set to 1 (sole source) if: A) the part is sole source or single source in MYX, or B) the part went to an OTLB supplier and the price is greater than some threshold above the lowest price, or C) the part is sole source in MYW. Beyond that, individual supplier minimums and maximums can be set by part. Any parts not individually set can be determined by the setting for part family, and any part families not yet set can take on a default minimum number of suppliers.

- Socioeconomic Indicators (SDB1, SDB2, SDB3, SDB4, SDB5, SDB6) – informs the model of which of the six socioeconomic indicators does each supplier qualify for
- Spend – informs the model of the estimated spend per part in order to estimate whether or not quotas set aside for the six socioeconomic categories have been fulfilled
- Socioeconomic Minimum Spend Percentages (SDBMinPct) – dictates the minimum spend percentages needed to be fulfilled for each socioeconomic category
- Quality – informs the model of the level of quality for each supplier – Supplier Gold, Performing, Progressing, or Underperforming.
- QualityCoeff – Coefficient for the quality term in the objective function

Notes on Model Inputs:

1. The following rules around inputs are to be taken into account to ensure a solvent solution:
2. Incumbent Forcing Matrix and the Eligibility Matrix should be sparse (only provide 1's)
3. Min Suppliers <= Max Suppliers <= 10
4. Eligibility Matrix >= Incumbent Forcing Matrix
5. # of Eligible Suppliers in the Eligibility Matrix >= Min Suppliers for each part
6. Feasibility given Socioeconomic Indicators – check to see if it is feasible to fulfill the minimum spend criteria given the Incumbent Forcing Matrix (i.e. if you force a supplier without any socioeconomic indicators to be on a certain % of parts, there may not be a way to ensure socioeconomic constraints will be satisfied)

Finally, it is recommended to try to keep the minimum number of suppliers as uniform as possible across a part family or material type ("commodity"), as having parts with the same number of minimum suppliers will make it easier to group them into like packages. As seen in Stage 2, in the current formulation, a part that requires 2 suppliers can never be grouped together with a part that requires 3 suppliers.

Stage 1 Code:

```
Filename: Stage1Model.py
Description:  First Stage of Bid Strategy Optimization Model, which
figures out what parts to bid to what suppliers, optimizing for
supplier quality
-------------------------------------------------------------------

# Stage 1 Model

from gurobipy import *

def solve(Parts, SMin, SMax, Spend, Suppliers, SDB1, SDB2, SDB3, SDB4,
SDB5, SDB6, Quality, EM, EM_Ind, IFM, IFM_Ind, QualityCoeff,
SDBMinPct):
      #try:
      M = 999999999 # Big MP
      SDBCount = [x+1 for x in range(6)] # index for 6 SDB categories

      # Calculate Total Spend
      TotalSpend = sum(Spend[f] for f in Parts)

      # Calculate Percentage of Total Spend
```

```
	Pct_Spend = {}
	for f in Parts:
		Pct_Spend[f] = Spend[f] / TotalSpend

	# Create optimization model
	m = Model('MY_Stage1')

	# Create variables
	# PartNumber x Supplier Matrix A[f][s]
	A = {}
	for f1 in Parts:
		for s1 in Suppliers:
			for f,s in EM_Ind.select(f1,s1): # Only run through
and create DV's where there is even a possibility of a 1
				A[f,s] = m.addVar(vtype=GRB.BINARY,
obj=QualityCoeff*Quality[s]*Pct_Spend[f], name='A_%s_%s' % (f, s))
#				print 'A[f,s]: f = ', f, ', s = ', s

	#SDBPartInd[6][f] - dummy DV
	# Desired Result: Z_SDBPartInd[6][f] = Scount*SDBPartInd [int]
	Z_SDBPartInd = {}
	for sdb in SDBCount:
		for f in Parts:
			Z_SDBPartInd[sdb,f] = m.addVar(lb=0,
vtype=GRB.INTEGER, obj=0, name='Z_%s_%s' % (sdb,f))

	#Z_SDBPartInd[6][f] -  dummy DV: Indicates number of SDB-only
parts by 6 SDB characteristics
	# Desired Result: SDBPartInd[6][f] = SDB Part Indicator: Whether
or not part has SDB characteristic (IF STMT) [binary]
	SDBPartInd = {}
	for sdb in SDBCount:
		for f in Parts:
			SDBPartInd[sdb,f] = m.addVar(vtype=GRB.BINARY, obj=0,
name='SDBPartInd_%s_%s' % (sdb,f))


	m.update()

	# Add Constraints
	# Number of Suppliers assigned to each part (SCount) must be at
least SMin and at most SMax
	for f in Parts:
		m.addConstr(quicksum(A[f,s] for f1,s in
EM_Ind.select(f,'*')) >= SMin[f],'Smin_%s' % (f)) # Only sum the
possible DV's
		m.addConstr(quicksum(A[f,s] for f1,s in
EM_Ind.select(f,'*')) <= SMax[f],'Smax_%s' % (f)) # Only sum the
possible DV's

	# Eligibility Matrix and Incumbent Forcing Matrix Constraints
	for f1 in Parts:
```

```
            for s1 in Suppliers:
                  #for f,s,k in EM_Ind.select(f,s): # No need for this
loop any more - see below
                  #     m.addConstr(A[f,s] <= EM[f,s],'EM_%s_%s' % (f,s))
# No need for this constraint anymore because you've eliminated those
DV's altogether.
                  for f,s in IFM_Ind.select(f1,s1): # Only run through
the IFM's necessary
#                       print 'IFM: f = ', f, ', s = ', s
                        m.addConstr(A[f,s] >= IFM[f,s],'EM_%s_%s' %
(f,s)) # ** Note: Create an intermediate step to set IFM = max(IFM,
EM).  You can use max fxn since it's just a constant going in. **

      # Dummy DV Constraints:
      # Note: SDBXSPSUM[f] = quicksum(A[f,s]*SDBX[s] for s in
Suppliers)
      # Note: Scount = quicksum(A[f,s] for s in Suppliers)
      # 4 Constraints:
      # Constraint: Z_SDBPartInd[f][6] >= Scount[f] - (1 -
SDBPartInd[f][6] ) *M
      # Constraint: Z_SDBPartInd[f][6] <= Scount[f]
      # Constraint: Z_SDBPartInd[f][6] <= SDBPartInd[f][6] *M
      # Constraint: Z_SDBPartInd[f][6] <= SDBXSPSUM[f][6]
      # Constraint: Z_SDBPartInd[f][6] >=0 (handled via the lower bound
in the variable definition)
      for sdb in SDBCount:
            for f in Parts:
            # Note: All the quicksums have been fixed to sum across
only the possible DV's
                  m.addConstr(Z_SDBPartInd[sdb,f] >= quicksum(A[f,s] for
f1,s in EM_Ind.select(f,'*')) - (1 - SDBPartInd[sdb,f]) *M,'ZHi_%s_%s'
% (sdb,f)) # Z_SDBPartInd[6,f] >= Scount[f]-(1-SDBPartInd[6,f])*M
                  m.addConstr(Z_SDBPartInd[sdb,f] <= quicksum(A[f,s] for
f1,s in EM_Ind.select(f,'*')),'ZSCLo_%s_%s' % (sdb,f)) #
Z_SDBPartInd[6,f] <= Scount[f]
                  m.addConstr(Z_SDBPartInd[sdb,f] <= SDBPartInd[sdb,f]
*M,'ZSLo_%s_%s' % (sdb,f)) # Z_SDBPartInd[f][6] <= SDBPartInd[6,f] *M

      # ****Can be combined with eval function later        ****
      for f in Parts:
      # Note: All the quicksums have been fixed to sum across only the
possible DV's
            m.addConstr(Z_SDBPartInd[1,f] <= quicksum(A[f,s]*SDB1[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_1_%s' % (f))    #
Z_SDBPartInd[1][f] <= SDB1SPSUM[f]
            m.addConstr(Z_SDBPartInd[2,f] <= quicksum(A[f,s]*SDB2[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_2_%s' % (f))    #
Z_SDBPartInd[2][f] <= SDB2SPSUM[f]
            m.addConstr(Z_SDBPartInd[3,f] <= quicksum(A[f,s]*SDB3[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_3_%s' % (f))    #
Z_SDBPartInd[3][f] <= SDB3SPSUM[f]
```

```
            m.addConstr(Z_SDBPartInd[4,f] <= quicksum(A[f,s]*SDB4[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_4_%s' % (f))    #
Z_SDBPartInd[4][f] <= SDB4SPSUM[f]
            m.addConstr(Z_SDBPartInd[5,f] <= quicksum(A[f,s]*SDB5[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_5_%s' % (f))    #
Z_SDBPartInd[5][f] <= SDB5SPSUM[f]
            m.addConstr(Z_SDBPartInd[6,f] <= quicksum(A[f,s]*SDB6[s]
for f1,s in EM_Ind.select(f,'*')),'ZSDBSumLo_6_%s' % (f))    #
Z_SDBPartInd[6][f] <= SDB6SPSUM[f]

        # SDB Constraints
        for sdb in SDBCount:
            m.addConstr(quicksum(SDBPartInd[sdb,f]*Spend[f] for f in
Parts) >= TotalSpend*SDBMinPct[sdb],'SDB_%s_%s' % (sdb,f))  #
SDBPartIndicator * Spend >= TotalSpend * MinSDB%



        # Compute optimal solution
        m.optimize()


        # Print solution
        if m.status == GRB.status.OPTIMAL:
            for f1 in Parts:
                    for s1 in Suppliers:
                            for f,s in EM_Ind.select(f1,s1): # Note: Only
loop through the possible DV's
                                if A[f,s].x > 0:
                                    print s, '->', f

        PartSupplier = {}
        for f1 in Parts:
            for s1 in Suppliers:
                for f,s in EM_Ind.select(f1,s1): # Note: Only pass out
the possible DV's
                    PartSupplier[f,s] = A[f,s].getAttr("x")
        return PartSupplier

        #except GurobiError:
            #print 'Error reported'

------------------------------------------------------------------------
```

Stage 2: Grouping suppliers and parts into packages

Inputs Variables

The input variables for Stage 2 are as follows:

- Parts – list of part numbers to be considered
- Suppliers – list of supplier codes to be considered
- Packages – maximum number of packages to be used. Ensure that this number is high enough to for feasible operation, though the more packages included, the longer the runtime required
- PartSupplier (A_{fs}) – Output of Stage 1 indicating the supplier-part solicitation pairs
- ComplexityCoeff – Coefficient for complexity term in the objective function
- nPckgCoeff – Coefficient for the term counting the number of packages in the objective function
- EM_Ind – Index from the Eligibility Matrix indicating eligible suppliers (used to reduce runtime)

Stage 2 Code:

```
Filename: Stage2Model.py

Description:  Second Stage of Bid Strategy Optimization Model, which
groups parts and suppliers into packages, minimizing the number of
packages and the complexity within each package

---------------------------------------------------------------------

# Stage 2 Model

from gurobipy import *

def solve(Parts, Suppliers, Packages, PartSupplier, ComplexityCoeff,
nPckgCoeff, EM_Ind):

      M = 999999999 # Big M

      #try:
      # Create optimization model
      m = Model('MY_Stage2')

      # Create variables
      # PartNumber x Package Matrix
      X = {}
      for f in Parts:
            for p in Packages:
                  X[f,p] = m.addVar(vtype=GRB.BINARY, obj=0,
name='X_%s_%s' % (f, p))

      # Supplier x Package Matrix
      Y = {}
      for s in Suppliers:
            for p in Packages:
                  Y[s,p] = m.addVar(vtype=GRB.BINARY, obj=0,
name='Y_%s_%s' % (s, p))

      # Complexity Dummy DV
```

```
      # May only need this or something like this to ensure that the
unchecked part-package & supplier-package matrices (non-existent in
part-supplier) are set to 0.
      C = {}
      for f in Parts:
            for s in Suppliers:
                  for p in Packages:
                        C[f,s,p] = m.addVar(vtype=GRB.BINARY,
obj=ComplexityCoeff, name='C_%s_%s_%s' % (f, s, p))

      # IsPckg Dummy DV
      IsPckg = {}
      for p in Packages:
            IsPckg[p] = m.addVar(vtype=GRB.BINARY, obj=nPckgCoeff,
name='IsPckg_%s' % (p))

      m.update()

      # Add Constraints
      # Only 1 Package Per Part Constraint
      for f in Parts:
            m.addConstr(quicksum(X[f,p] for p in Packages) ==
1,'SinglePckgPerPart_%s' % (f))


      # SF[f,s] == PartSupplier[f,s]
      # SF[f,s] = quicksum(X[f,p]*Y[s,p] for p in Packages) =
quicksum(C[f,s,p] for p in Packages]
      for f1 in Parts:
            for s1 in Suppliers:
                  for f,s in EM_Ind.select(f1,s1): # Only run through
the list of part-suppliers that are eligible (because there are no
values for those that aren't)
                        m.addConstr(quicksum(C[f,s,p] for p in Packages)
== PartSupplier[f,s],'Stage1Link_%s_%s' % (f,s))

      # Complexity Dummy DV Constraints
      # C[f,s,p] = X[f,p]*Y[s,p]
      # C[f,s,p] <= X[f,p]
      # C[f,s,p] <= Y[s,p]
      # C[f,s,p] >= X[f,p]+Y[s,p]-1
      for f in Parts:
            for s in Suppliers:
                  for p in Packages:
                        m.addConstr(C[f,s,p] <= X[f,p],'CXLo_%s_%s_%s' %
(f,s,p))
                        m.addConstr(C[f,s,p] <= Y[s,p],'CYLo_%s_%s_%s' %
(f,s,p))
                        m.addConstr(C[f,s,p] >= X[f,p] + Y[s,p] -
1,'CHi_%s_%s_%s' % (f,s,p))

      # IsPckg Dummy DV Constraints
```

```
    # X - M*Y <= 0 , where X is FSum[p] = quicksum(X[f,p] for f in
Parts), and Y is the IsPckg[p]
    # quicksum(X[f,p] for f in Parts) - M*IsPckg[p]  <= 0
    for p in Packages:
        m.addConstr(quicksum(X[f,p] for f in Parts) - M*IsPckg[p]
<= 0,'IsPckg_Def_%s' % (p))


    # Compute optimal solution
    m.optimize()

    PackagePart = {}
    for f in Parts:
        for p in Packages:
            PackagePart[p,f] = X[f,p].getAttr("x")


    PackageSupplier = {}
    for s in Suppliers:
        for p in Packages:
            PackageSupplier[p,s] = Y[s,p].getAttr("x")

    FSum = {}
    for p in Packages:
        FSum[p] = quicksum(X[f,p].getAttr("x") for f in Parts)

    # Create a shorter list of packages   via list comprehension
    NewPackages = [Packages[p-1] for p in Packages if
IsPckg[p].getAttr("x") > 0]

    # Print solution
    if m.status == GRB.status.OPTIMAL:
        for f in Parts:
            for p in Packages:
                if X[f,p].x > 0:
                    print f, '->', p

    if m.status == GRB.status.OPTIMAL:
        for s in Suppliers:
            for p in Packages:
                if Y[s,p].x > 0:
                    print s, '->', p

    return PackagePart, PackageSupplier, FSum, NewPackages

    #except GurobiError:
        #print 'Error reported'
```

Stage 3: Assigning negotiators to packages

Inputs Variables

The input variables for Stage 3 are as follows:

- Parts – list of part numbers to be considered
- Suppliers – list of supplier codes to be considered
- NegLeads – list of negotiators to be considered
- Packages – maximum number of packages to be used. Ensure that this number is high enough to for a feasible model solution, though the more packages included, the longer the runtime required
- Max Parts Workload – maximum number of parts one NegLead can handle. Ensure this number is high enough for a feasible model solution.
- Max Supplier Workload – maximum number of suppliers one NegLead can handle. Ensure this number is high enough for a feasible model solution.
- Max Package Workload – maximum number of packages one NegLead can handle. Ensure this number is high enough for a feasible model solution.
- PenaltyCoeff – Coefficient in the objective function to weigh the cost of every unfamiliar part a NegLead has to work with
- NegLeadCoeff – Coefficient in the objective function to weigh the cost of every additional NegLead required in the process
- OverlapCoeff – Coefficient in the objective function to weigh the cost of every additional NegLead a supplier has to work with
- NNegParts – Matrix that indicates what parts NegLeads are familiar with or associated with. Note that the matrix is inversed, so that a 0 indicates there is familiarity or association between the NegLead and the part, and a 1 indicates there is no association or familiarity. The entire matrix should be filled with binary values (all 0's and 1's).
- Part by Package Matrix (PackagePart) – The output from Stage 2 that groups parts into packages
- Supplier by Package Matrix (PackageSupplier) – The output from Stage 2 that groups suppliers into packages
- FSum – The number of parts in the package

Stage 3 Code:

```
Filename: Stage3Model.py

Description:  Third Stage of Bid Strategy Optimization Model, which
assigns negotiators to each package in a way that minimizes the number
of negotiators a single supplier has to interface with and maximizes
the number of parts most familiar to the negotiator

----------------------------------------------------------------------

# Stage 3 Model

from gurobipy import *

def solve(Parts, Suppliers, NegLeads, Packages,
MaxNegLeadPartWorkload, MaxNegLeadSupplierWorkload,
MaxNegLeadPackageWorkload,
```

```
      PenaltyCoeff, NegLeadCoeff, OverlapCoeff, NNegPart, PackagePart,
PackageSupplier, FSum):
# inputs:
# Parts = distinct tuplelist of parts from BOM [list]
# Suppliers = distinct tuplelist of all suppliers to be considered
[list]
# NegLeads = distinct tuplelist of all NegLeads [list]
# Packages = tuplelist of Packages
# MaxNegLeadPartWorkload, MaxNegLeadSupplierWorkload,
MaxNegLeadPackageWorkload = constants that specify the max Parts,
Suppliers, and Packages one NegLead should take on, respectively
# PenaltyCoeff, NegLeadCoeff, OverlapCoeff = Coefficients for NegLeads
take on unfamiliar parts, each additional Neg Lead, and more than one
NegLead per supplier, respectively
# NNegPart = NegLead to Part Matrix where 0's indicate a familiar
relationship and 1's indicate no relationship.
# PackagePartInd, PackagePart = Stage 2 Matrix that assigns parts to
packages
# PackageSupplierInd, PackageSupplier = Stage 2 Matrix that assigns
Suppliers to packages
# FSum = Count of Parts per package

      M = 999999999 # Big M

#     try:
      # Create optimization model
      m = Model('MY_Stage3')

      # Create variables
      # DV for whether or not to assign NegLead n to package p
      # NegPartCoeff[n,p] =
PenaltyCoeff*SUM(PackagePart[f,p]*NNegPart[f,n]) for all f
      Z = {}
      for n in NegLeads:
          for p in Packages:
              Z[n,p] = m.addVar(vtype=GRB.BINARY,
obj=PenaltyCoeff*sum(PackagePart[p,f]*NNegPart[f,n] for f in Parts),
name='Z_%s_%s' % (n, p))

      # Dummy DV to Count Number of NegLeads
      IsNegLead = {}
      for n in NegLeads:
            IsNegLead[n] = m.addVar(vtype=GRB.BINARY, obj=NegLeadCoeff,
name='IsNegLead_%s' % (n))

      # Dummy DV SNLM_int
      SNLM_int = {}
      for n in NegLeads:
            for s in Suppliers:
                  SNLM_int[n,s] = m.addVar(lb=0, vtype=GRB.INTEGER,
obj=0, name='SNLM_int_%s_%s' % (n,s))
```

```
    # Dummy DV SNLM_bin
    SNLM_bin = {}
    for n in NegLeads:
        for s in Suppliers:
            SNLM_bin[n,s] = m.addVar(vtype=GRB.BINARY, obj=0,
name='SNLM_bin_%s_%s' % (n,s))

    # Dummy DV to feed Overlap
    OverlapCount = {}
    for s in Suppliers:
        OverlapCount[s] = m.addVar(lb=0, vtype=GRB.INTEGER,
obj=OverlapCoeff, name='OverlapCount_%s' % (s))

    m.update()


    # Neg Lead Count Dummy DV Definition Constraint
    # X - M*Y <= 0 , where X is the number of Packages for given
NegLead, and Y is the IsNegLead flag
    # SUM(Z[n][] - M*IsNegLead[n]  <= 0
    for n in NegLeads:
        m.addConstr(quicksum(Z[n,p] for p in Packages) -
M*IsNegLead[n] <= 0,'IsNegLead_Def_%s' % (n))

    # Only 1 NegLead Per Package Constraint
    for p in Packages:
        m.addConstr(quicksum(Z[n,p] for n in NegLeads) ==
1,'SingleNegLeadPerPckg_%s' % (p))


    # NegLead Package Workload Constraint
    for n in NegLeads:
        m.addConstr(quicksum(Z[n,p] for p in Packages) <=
MaxNegLeadPackageWorkload,'MaxNegLeadPckgWorkConst_%s' % (n))

    # NegLead Part Workload Constraint
    for n in NegLeads:
        m.addConstr(quicksum(Z[n,p] * FSum[p] for p in Packages) <=
MaxNegLeadPartWorkload,'MaxNegLeadPartWorkConst_%s' % (n))

    # NegLead Supplier Workload Constraint
    for n in NegLeads:
        m.addConstr(quicksum(SNLM_bin[n,s] for s in Suppliers) <=
MaxNegLeadSupplierWorkload, 'MaxNegLeadSupplierWorkConst_%s' % (n))


    # SNLM_int Dummy DV Definition Constraint
    for n in NegLeads:
        for s in Suppliers:
            m.addConstr(SNLM_int[n,s] ==
quicksum(Z[n,p]*PackageSupplier[p,s] for p in Packages),
'SNLM_int_Def_%s_%s' % (n,s))
```

```
	# SNLM_bin Dummy DV Definition Constraint
	# X - M*Y <= 0 , where X is SNLM_int, and Y is the SNLM_bin
	# SNLM_int[n,s] - M*SNLM_bin[n,s]  <= 0
	for n in NegLeads:
		for s in Suppliers:
			m.addConstr(SNLM_int[n,s] - M*SNLM_bin[n,s] <=
0,'SNLM_bin_Def_%s_%s' % (n,s))

	# OverlapCount Dummy DV Definition Constraint (no need for
additional constraint for 0 given lower bound)
	for s in Suppliers:
		m.addConstr(OverlapCount[s] >= quicksum(SNLM_bin[n,s] for n
in NegLeads)-1,'OverlapCount_Def_%s' % (s))

	# Set Model to Minimize
	m.setAttr('ModelSense',1)

	# Compute optimal solution
	m.optimize()

	# Print solution
	if m.status == GRB.status.OPTIMAL:
	    for n in NegLeads:
		for p in Packages:
			if Z[n,p].x > 0:
		       print p, '->', n

	PackageNegLead = {}
	for n in NegLeads:
		for p in Packages:
			PackageSupplier[p,n] = Z[n,p].getAttr("x")

	return PackageNegLead
```