LOOKING BACK AT PORTOPT: AN ACQUISITION PORTFOLIO OPTIMIZATION TOOL

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The Problem

Can DoD afford to buy everything it is currently planning to buy? If not, what are the alternatives?

In 1998, the Acquisition Resources and Analysis (AR&A) directorate within the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)) had reviewed the recent long-term investment plans of Major Defense Acquisition Programs (MDAPs), and had added up the proposed spending by all of the programs year by year. The result showed both sharply rising investment costs within the five-year Future Years Defense Plan (FYDP) and continued growth beyond that horizon.[1]

AR&A asked IDA to address three questions:

1. Given plausible levels of defense funding, can we afford to execute all of the current programs?
2. If not, what are the cost implications of having to rearrange and stretch programs to fit under the budget?
3. How much money are we wasting by managing each program individually, rather than trying to coordinate acquisition across the entire portfolio of MDAPs?

Thus was born PortOpt, the Acquisition Portfolio Optimization project, which has provided analytical decision support to AR&A for the past fifteen years.

PortOpt was designed to answer this optimization question: "Given this much money to work with in each year, which set of simultaneous production schedules buys everything at lowest cost?"

DESIGNING A TOOL

IDA identified three critical challenges in answering the AR&A questions. First, we would need to be able to predict how the year-by-year procurement costs of a weapon system would change if its procurement schedule were changed. Second, we would need an optimization model that could find the lowest-cost combination of procurement schedules that could fit under a given top-line budget. Third, we would need to be able to refresh these models when new programs were started and as cost estimates and requirements changed within existing programs. For the tool to be useful, this refresh would need to happen in days or weeks.

[1] Defense analysts refer to rising planned costs in the years just beyond the FYDP as the "bow wave" of acquisition.

COST AS A FUNCTION OF SCHEDULE

The unit cost of a weapon system depends in part on how many you buy and how quickly you buy them. There are several different mechanisms at work, with many underlying complexities. In the next article, “Predicting the Effect of Schedule on Cost,” we talk about these complexities, both in terms of what they are and how we can figure them out from the available data. Here, we focus only on the three cost components that were included in the original PortOpt model: direct manufacturing costs, program management costs, and overhead costs.

MANUFACTURING

The most obvious costs of making a military system are the touch labor and materials costs. It takes a certain amount of metal to make a ship or helicopter, and it takes a certain number of labor hours to turn that metal into a hull or airframe. History has shown, however, that it doesn’t take the same number of hours for every ship or helicopter of a given design. Production of complex hardware exhibits learning—the direct labor hours for the second unit you make are less than for the first unit, and the third takes fewer hours than the second, and so forth. In general, the more systems of a given design you have already built, the lower the direct labor costs of the next one will be. Perhaps surprisingly, this is still true even in these days of highly automated manufacturing. Ongoing process improvements, more efficient uses of raw materials, better subcontractor arrangements—these all contribute to a general reduction of unit manufacturing cost as the cumulative quantity increases.

Learning has consequences that are not immediately obvious. One is that if you reduce the total number of units you plan to buy, the average unit cost will go up: the units you have canceled would have been the least expensive units built, having benefitted from all of the prior learning in making the earlier units. A second consequence is that the costs of production are not evenly distributed over the buy. If you were to make thirty helicopters per year for ten years, the annual costs would be much higher in the first year than in the last year—creating a tension between the desire for stable production rates and the desire for stable annual funding levels. It also makes it more complicated to predict exactly what will happen to funding requirements if you shift a few units of production from one year to another. PortOpt uses learning curves to capture these subtle nonlinear effects of changing production plans.

PROGRAM MANAGEMENT

Manufacturing costs are not the only procurement costs associated with acquiring weapon systems. Most programs also spend significant amounts on systems engineering, program management, quality assurance, training, documentation, support, and contract management. These and similar activities are direct costs of the program, but they are not associated with specific production units, and are essentially independent of whether the program is producing ten units or 1,000 units per year.

These costs are not subject to learning, and cannot be reduced in a given year by shifting production into the future. To be able to predict how annual and total costs will change as a result of a change in production schedule, one needs to understand what portion of the original planned cost is due to program management costs.

PLANT OVERHEAD

Finally, in addition to the direct costs of production (including both manufacturing and management costs), certain indirect costs must be paid. These are the overhead costs of the project; they pay for the salaries of employees who do not charge directly to individual programs, and also create the profit for the contractors. We tend to think of these as "fixed" costs, but they actually do vary somewhat as a function of how much business the contractor is doing.

For PortOpt, we collected historical direct and indirect cost data for the largest defense contractor facilities. Using those data, we estimated the total overhead costs per year for various prime contractors as a function of the total amount of business being done by the contractor in a given year. To estimate the overhead cost impact of a schedule change, we first estimated the direct costs in every year for every program (using the learning curves and program management costs), then allocated overhead costs to all of the programs at each plant, in proportion to the direct costs incurred by those programs in each year. If a contractor also had non-defense business at a plant, some of the plant's overhead was apportioned to that as well.

Putting the pieces together, PortOpt estimates the annual costs per program under a proposed production schedule by taking the following steps:

1. Estimating direct manufacturing costs in each year, taking into account how far down the learning curve the program will be at the beginning of each year and how many units are to be produced in that year;
2. Adding program management costs to each program that is still in production in each year;
3. Combining these to get total direct costs at each contractor facility in each year;
4. Using these total direct costs to estimate total overhead at each facility in each year;
5. Apportioning these overhead costs to individual programs at each facility in each year;
6. Adding direct costs to overhead costs for each program to get total program costs in each year.

PORTFOLIO OPTIMIZATION

PortOpt was designed to answer this optimization question: "Given this much money to work with in each year, which set of simultaneous production schedules buys everything at lowest cost?" Of course, not just any production schedule is practical. Because manufacturers have limited capacity, there is an upper limit on how many units they can produce per year. Conversely, there are economic and industrial base reasons never to let production drop below a certain "minimum sustaining rate" once it has begun. Finally, there are operational concerns—we need to buy all of the units of a given system while it is still operationally useful to do so.

This leads to an optimization formulation that can be summarized as:

Objective: buy all units of all systems at minimum total cost… subject to these constraints:

- *Stay within budget every year;*
- *Deliver all units on time;*
- *Don't produce too many per year; and*
- *Once you're in production, don't produce too few per year.*

That sounds pretty straightforward, but the result is a Mixed Integer Linear Program (MILP) with thousands of variables and tens of thousands of constraints. Even using the most powerful available commercial optimization software of the day, it took some clever formulation tricks for us to be able to optimize the entire MDAP portfolio in minutes or hours on a desktop computer.

DATA REFRESH

The goal of PortOpt was to be able to continue to update the model over time without having to conduct detailed assessments of plant overhead at defense contractors, which would be time consuming and costly. For that reason, we restricted the basic inputs to the data found in the annual Selected Acquisition Report (SAR) filed by each MDAP.

The SAR gives a description of past production quantities and costs, and a forecast of future quantities and costs by year. It is often not directly comparable to the previous year's SAR, due to changes in program requirements, cost growth, changes in planned total quantities, and so on. Every year, when the new SARs were published, we imported the new forecasts into PortOpt, estimated learning curves and annual program management costs from the new data, set delivery deadlines for each system, and set minimum and maximum production rates.

USES

Over the years, PortOpt has been used for different kinds of analysis. In this section, we discuss five of these.

ANALYZING AFFORDABILITY

The first of our original motivating questions was "Can we afford to execute all of the current programs?" This became an annual exercise for PortOpt—enter a plausible future top-line procurement budget, optimize all programs within that budget, and look to see how much money would be left to use on future programs that are not yet MDAPs. This gave the most optimistic picture of *affordability*, since it assumed no cost growth, no major development delays, and a stable future budget. From that baseline, we would then run sensitivity analyses and excursions reflecting different budget levels, different amounts of cost growth, "untouchable" programs, and changes in demand for various systems. Not uncommonly, the optimization would fail to find a feasible solution, indicating that not even the most efficient possible set of production schedules could buy all of those systems under the specified restrictions.

MEASURING THE COST OF THE "BOW WAVE"

The second of our original motivating questions was "What would it cost to knock down the bow wave?"—that is, how much more will systems cost, per unit, if we have to stretch out production in order to be able to afford them? For this analysis, we would fix the procurement schedules within the FYDP to be as planned in the SARs, but allow the optimization free rein to rearrange schedules in the outyears to make them fit under a projected budget. We would then use the PortOpt costing module to compare the projected costs of the SAR schedules and the optimized schedules for all programs. The difference in cost would be directly attributable to the budget constraint.

MEASURING THE COST OF STARTING TOO EARLY

Our third motivating question was "How much money are we wasting by managing programs one by one, rather than as a single optimized portfolio?" One special case of this question arises when deciding whether to start a new program in the current year, or to wait and start it at some future time. In general, it is more efficient to have fewer programs producing at higher rates at any given time. As those programs finish, new programs can be started. However, there are many incentives in the defense world to want to start programs as soon as funding is available, and to continue them for as long as possible.

Using PortOpt, we could compare the overall and unit cost difference between the "ideal" schedule, which finishes programs as quickly as possible by delaying the start of other programs, and the "typical" schedule, which funds all programs as soon as they are ready to start, but at lower production rates than in the optimal schedule. As above, the cost difference between the optimal schedule and the "typical" schedule gives a measure of how much could be saved through more efficient scheduling, in the absense of other constraints on acquisition plans.

REPROGRAMMING AFTER UNEXPECTED EVENTS

Occasionally, unexpected events cause a sudden change in the Services' expectations about budgets, program needs, or both. In those cases, PortOpt can be used to offer suggestions about the best way to reprogram everything in response to the disruption.

One example of this occurred when the Air Force, which had been planning to lease tanker aircraft using Operations and Support funds, was required by the Congress to purchase those aircraft instead. This led to a temporary (but large) shortfall in procurement funds available for other programs in certain years. Using PortOpt, AR&A was able to understand the magnitude of the problem, and to recognize that it would be impossible to remedy without significant changes to the then "untouchable" F-22 program.

A second example occurred when the Army identified an urgent need for mine-resistant ambush-protected (MRAP) vehicles in Iraq and Afghanistan. While some of the funds used to purchase MRAPs came from supplemental budgets, others had to be offset by reductions in Army procurement spending in other areas. PortOpt offered a way to estimate the opportunity cost of buying MRAPs, in addition to the monetary cost.

FINDING EFFICIENCIES

Finally, PortOpt can be used to find short-term efficiencies in how we procure military systems. In 2007, then-Under Secretary for Acquisition, Technology, and Logistics, John Young, challenged his staff to find $10 billion in procurement savings in the FY10 through FY15 budgets, without increasing acquisition budgets in any year or delaying full fielding of any system. Using PortOpt, AR&A identified the most effective set of current programs to accelerate and complete in the near term, in order to free up funds in the designated time window. While few of these programs were in fact accelerated, the PortOpt analysis framed the discussion for OUSD(AT&L) and contributed to initiatives that nearly met the $10 billion goal.

WHAT WE'VE LEARNED

In fifteen years of working with PortOpt, we have learned quite a bit about the opportunity costs of the way we do business, some of which confirm common sense (like the first two items below) while other insights are more nuanced:

- When every program is running near its minimum sustaining rate, there is no flexibility to cope with the unexpected.
- Finishing programs saves money. Everything else increases costs.
- Starting programs as early as possible often increases unit costs and delays fielding of systems—including the systems that were started as early as possible.
- Even if our current cost estimates are accurate, they don't account for the added costs of making everything fit under the budget we will actually have.
- Optimization is nice, but its real value is in showing the mechanisms that lead to savings. In real life, no single decision maker has the authority to optimize all procurement, even within a Service.

New tools using new methods are in development to take advantage of some of these lessons and to leverage new data sources and techniques that were not available in 1998. The timing is right for a change; as budgets turn down and the emphasis on affordability increases, PortOpt-like tools can help DoD acquire as many systems as possible within available budgets.

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