Projecting Program Spare Parts Sustainment with Incomplete Data

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Abstract

Analyzing a government acquisition, the team discovered that the existing agency supply chain system lacked transparency, and historical failure data was unavailable due to implementation of a new supply chain system. The team examined how to accurately project parts demand using incomplete data by conducting a comparative analysis between data sources, using subject matter experts to estimate upper and lower bounds, and applying statistical analysis fit curves to project spare parts needs.

1 Introduction

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2 Civil Agency Government Acquisitions/Capital Investments

The Federal Aviation Agency (FAA) has developed a detailed policies and guidance for lifecycle acquisition projects called the Acquisition Management System (AMS). AMS defines how the FAA manages its resources – money / people / assets to fulfill its mission. AMS also shows how to quantify and approve capital investments and acquisitions.

2.1 Required Cost Analysis

2.2 Shortfall Definition / Quantification

2.3 System Obsolescence & Legacy Sustainment

3 FAA Business Case – The Legacy Case

3.1 Need to Replace System that is Aging in the NAS

3.1.1 Past Its Usable Life

3.1.2 Need to Estimate Sustainment Cost

3.1.3 Cost Estimation Needs

3.1.3.1 Failures of Current Parts

3.1.3.2 Forecast of Lifetime Buy for Each Part by Year to Determine Legacy System Sustainment Costs for 15 Year Lifecycle

4 Business Case Problem

The problem faced by the FOOBAR team was to ascertain a reliable estimate of parts needed to sustain the system with a limited data set and biased SME input. A reliable estimate is needed for a quality cost estimate on the price of the proposed solution.

4.1 Data Is Not Completely Accurate

Unlike most supply chain systems, the legacy FAA supply system and integrated supply chain cannot calculate Mean Time Between Failure (MTBF). As a result, analysts are only capable of estimating demand based on parts orders from the field. Since field inventory is distributed using a budget-based inventory system with limited headquarter transparency, parts demand does not always reflect annual failure rates, and demand projections are often erratic. Where observed parts demand might include a large demand quantity in year 1, the same part might observe very few parts demanded in year two and another large demand in year 3. This inconsistency introduces challenges in applying statistical trend analyses using historical data.

4.2 Data Is Limited

The sample size of the data is limited, potentially impairing the ability to project future parts demand based on historical data.

4.3 SME Forecast May or May Not Be Accurate

The subject matter expert (SME) forecast for parts failure and failure growth rates is likely too simplified and not part-specific. The failure growth rate is a subjective and applied growth rate based on observed parts demand.

5 Proposed Approach for the Business Case

5.1 Extrapolate Historical Data & Develop Trend Analyses

The first logical approach toward estimating system sustainability includes collecting historical failure data and extrapolating that data in a forecast to replicate the same failure trends of the sample. However, if the sample size is too small to capture observable or repeatable trends, the accuracy of the forecast could suffer. There are many advantages to using historical data to forecast parts failures including the following:

(1) Assuming the sample size is adequate and replicates an observable failure growth trend during the parts lifecycles, historical data can be a good indicator of future performance and sustainability.
(2) Actual data is objective and removes the subjective human interpretation. Not only do projections based on historical data remove any self-serving bias, but they also reinforce confidence of decision-makers by providing an objective measure and alleviating accountability associated with subjective interpretation.
(3) In most supply chain systems, mean-time-between-failure calculations can be captured based on historical data, and despite some anomalies, these projections are usually accurate over a program's lifecycle.

Our team was careful not to rely solely on historical trend analysis to project future failure trends as rarely does past failure data accurately forecast future performance alone. Fundamental changes in system conditions or parts' end-of-life factors could modify historical trends and shift failure growth rate curves significantly.

5.2 Introduce Statistical Analyses & Fit Curves

In addition to an extrapolation of historical failure growth rate trends based on statistically significant historical data sample projected by part type or NSN, the business case team added a more quantitative statistical component in forecasting failure growth trends. Most annual failure rates (or in this case demand) do not follow a consistent year-over-year pattern (like straight line) that is observable without additional calculations. While analysts can add a fit curve and estimate the accuracy of that trend line with a correlation factor and r-squared metric, a more comprehensive approach is to correlate the data using a statistical trend equation that predominantly follows one of several popular fit curve options, i.e., straight-line, logarithmic, and exponential. While no fit curve is a perfect indicator of future failure rates, a calculated and customized statistical equation based on historical data can more accurately project future failure patterns.

Just like historical failure data using a trend line, statistical fit curves have disadvantages as well. Historical data sample size may not accurately represent lifecycle parts failure trends. If we have a limited number of historical years' data, we may not be able to accurately project sustainability. Without any context of expected parts' lifecycles, inventory turnover, and potential parts-specific anomalies, statistical analysis has limitations.

5.3 Leverage Subject-Matter-Expert (SME) Assumptions

One approach for evaluating system sustainment and conducting the failure analysis of legacy system parts is to leverage the knowledge of logistics subject-matter-experts (SMEs) who are knowledgeable about the system and parts in question and who can provide reasonable assumptions about the failure trends, lifecycle, and inventory turnover for system parts. There are specific advantages to using SMEs to project parts failures and sustainability including the following:

(1) Unlike using historical data in a vacuum to project failure trends, SMEs can provide information that simply cannot be discovered in a limited sample size. For example, if specific parts experience mass catastrophic failures at year 10 of a lifecycle do to some internal design or system wear, SMEs who have sustained these systems for years and are knowledgeable about specific parts' failure timelines could provide this upward bound failures and sustainment.

(2) When evaluating historical trends and extrapolating those trends over time, SMEs can offer up the expectation of inventory turnover and provide another upward bound for failure growth. If projected inventory turnover exceeds lifecycle expectations of parts as observed by SMEs for the same systems or similar systems, the analyst can impose an upward bound or a maximum annual failure rate once a growth rate reaches that annual failure quantity.

(3) Unlike limited sample historical failure trends, SMEs can offer context and expectations for early parts failures for new systems or for replacement parts. When systems are first installed, they often experience *infant mortality* in some of their parts, where the failure rates of new parts exceed that of the lifecycle average for a short duration. Infant mortality is difficult to recognize, and with a limited data set or sample size of historical failures, projections about new parts failures can be lost within the overall parts failure trends. SMEs can provide statistical inference and guidance about infant mortality which could impact parts failure projections and system sustainability.

While there are many benefits to the SME approach for projecting parts failures, there are an equal number of disadvantages in relying solely on SME input to estimate sustainability. SME input can be subjective, and estimates may differ from one expert to another. These data variations are mostly a consequence of the absence of objective data; however, user bias can also impact SME subjectivity. Relying on SME input only for parts failure forecasts increases the probability of an inaccurate sustainability forecast.

5.4 Identify and Qualify Risk Factors

5.5 Find the Right Combination of All Approaches

6 Our Failure Analysis Approach for This System

6.1 Historical Data Collection

6.2 Forecasting Failure Growth Rate Trends

6.2.1 Challenges Extrapolating Historical Data

6.2.2 Utilization of SME Input

6.2.3 Introduction of Statistical Analysis Based on Historical Data

The solution was to focus on the top ZZZ % of parts that had a enough data to make a reliable prediction.

NSN	Mean	SD	Bin
6130-01-596-5636			yearly
7025-01-567-4461			yearly
5895-01-574-2109			yearly
6685-01-567-2854			yearly
6140-01-596-5636			yearly

6.2.4 A Comparison of SME Failure Growth Rate Trends vs. Statistical Fit Curves

6.2.5 Setting Upper and Lower Failure Growth Rate Bounds

6.2.5.1 SME Upper and Lower Bounds

6.2.5.2 Inventory Turnover

6.3 Reconciling Statistical Trend Analysis and SME Constraints