Advanced Analytics for Your Special Inventory Challenges

PSMC
April 29, 2015
Overview

• What are your special inventory challenges?
• Risk hedging strategies for dealing with demand uncertainty
• Readiness-based sparing (RBS) methods for optimizing system availability
• System-of-system modeling for complex operations and objectives
• Assessing your organization’s requirements
What is Inventory Optimization?

- Balancing inventory investment and performance objectives
- Accounting for variability and uncertainty
- What it’s not…but these can have an impact
  - Reliability and maintainability
  - Warehousing
  - Distribution
  - Etc…
Why Inventory Optimization?

- Inventory exists for a business purpose
  - What are your organization’s strategies and priorities
  - Who are you…there are often competing interests even within an organization
- Because of diverse objectives, having a range of inventory strategies to choose from is better than a point solution
- Quality solutions are ones that efficiently deliver your desired business outcomes
Assessment Framework

Operational Complexity

Item-Level Difficulty

Low

High
Assessment Framework

Operational Complexity

Item-Level Difficulty

Lead Time
- Short
- Long

Price/Complexity
- Inexpensive commodities
- Expensive items with indentured parts

Demand Stability
- High volume, low variability
- Highly variable demand

Supplier Base
- Multiple viable suppliers
- Sole source, DMSMS

Operational Complexity
Assessment Framework

Operational Complexity

Locations
- Single Location
- Multi-echelon network

Uncertainty
- High
- Independent Items
- System-of-Systems

Item-Level Difficulty
- Low
- Manufacturing (Deterministic)
- Remanufacturing (Stochastic)

Interactions
- Single Location
- Multi-echelon network

Type of Activity
- Low
- Retail
- Wholesale

High
## Assessment Framework

<table>
<thead>
<tr>
<th>Item-Level Difficulty</th>
<th>Operational Complexity</th>
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<tr>
<td><strong>Low</strong></td>
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<tr>
<td><strong>High</strong></td>
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### Operational Complexity
- **Low**
  - Risk hedging strategies
  - Economic Order Quantity (EOQ)
  - Days of Supply
  - Newsboy Problem
- **High**
  - Seasonality
  - System-of-systems optimization
  - Multi-Indenture, Multi-Echelon (MIME)
What Are Your Inventory Challenges?
Overview

• What are your special inventory challenges?
• **Risk hedging strategies for dealing with demand uncertainty**
• Readiness-based sparing (RBS) methods for optimizing system availability
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The Problems of Demand Uncertainty

- Replenishment lead-times are months to years
- Many unique, hard-to-buy items
- High uncertainty in demand over the replenishment lead-time
Segmenting DLA’s Inventory

Unforecastable Items

- Infrequent demand
  - ~1.1 million items (76%)

Forecastable Items

- Frequent demand
  - High variability
    - ~285,000 items (20%)
  - Low variability
    - ~65,000 items (4%)

Unforecastable Items

Frequency threshold

Variability threshold
Zero demand is the best forecast
Not economical to maintain the capacity to manufacture on demand
Can’t afford to not stock mission critical items
When to order and how much?
The Challenge of Variable Demand

- We lose information at each step
- Bad decisions lead to bad business outcomes

Steps:
1. Demand Plan or Forecast
2. Variance
3. Theoretical Distribution
4. Order Quantity

Optimized on incomplete data
- Stock levels
  - Forecasted demand
  - Safety stock
  - Order quantity

Bad business outcomes
A New Paradigm—Stop Forecasting

• Portfolio management
  – Target population outcomes (costs and risks)
  – Accept that individual outcomes cannot be predicted ("unforecastable")
  – Aim for more “winners” than “losers”

• Actual demand transactions
  – No forecasting
  – No distribution fitting
  – No fixed empirical distributions

• Single integrated decision with simultaneous 3-way tradeoff
  – Customer service
  – Inventory
  – Buyer workload
Infrequent Demand

• Order when inventory gets down to some % of Peak demand
• Order a quantity based on unit price

\[
\text{Min} = (\text{Price-based mult.}) \times (\text{Peak demand}) \\
\text{Max} = \text{Min} + (\text{Price-based order qty.})
\]

How to get good values for multipliers & order quantity
Developed an objective function \( \sum c(s,S) \) that captures real-world messiness.

How do we solve the objective function for min/max?

- Compute objective function based on inventory investment, wait time, and procurement workload
- Solve the objective function for the best min/max values

Real world does not conform to traditional distributions.
Key Elements of Risk Hedging

• Use an empirical rather than a theoretical distribution
• Use simulations to test the robustness of solutions—don’t assess with the same model you used to generate your solutions
• Select best parameter set to meet your business goals
Inventory Decisions with Options

- Pre-PNG Baseline:
  - $435 M Inventory
  - 14 Days Wait Time
  - 54K PR/Year

- Buyer workload:
  - 21k PR/yr (-60%)
  - 24k PR/yr (-56%)
  - 28k PR/yr (-48%)
  - 37k PR/yr (-32%)
  - 54k PR/yr (1%)

5% inventory $ reduction
22% wait time reduction
48% workload reduction
Results for DLA

2 years after implementation at DLA, the items in PNG have produced significant results.

- **$600 million**
  - Excess on-hand inventory value

- **35 percent**
  - Recommended annual buys

- **70 percent**
  - Cancelled buys

- **$127 million**
  - Estimated labor savings from unnecessary buys and cancellations over five years

- **$2 billion**
  - Estimated savings in working capital over five years

↑ 4 points
Material availability
An Exercise in Forecasting
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What’s the right balance between cost and availability for your organization?
System Availability Approach

• Item-level objective functions such as fill rate, profit, inventory turns, ... don’t capture the impact on the overall system
  – Average of item performance is not always consistent with your organization’s goals
  – Example: Fill rate concentrates on low-cost, high-demand items, accepts infrequent, but long-lasting backorders on expensive, low-demand items
Tell me how I’m going to be measured and I’ll tell you how I’m going to behave…just don’t blame me for my dysfunctional behavior.
Expected Backorders

• Calculating EBOs for a given stock level is an important foundation for RBS theory
  – Backorders have a duration
  – Not a “lost sales” case
• EBO computation algorithms come in varying degrees of complexity
  – Multi-indenture
  – Multi-echelon
  – Cannibalization/partial cannibalization
Expected Backorders

\[ EBO = \sum_{n=s+1}^{\infty} (n-s)p(n) \]

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<th>Dmds</th>
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<th>Prob</th>
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<tr>
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<td></td>
<td>0.9637</td>
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Readiness-Based Sparing in Practice

- Embed EBO calculations in a marginal analysis routine
  - Iteratively add items to the shopping list based upon “bang-per-buck”
- Graphical representation of this marginal analysis process is a “cost-availability curve”
  - As we add items, both the cost and availability increase…but exhibit diminishing marginal return
  - Each point on the curve has an associated shopping list
Range of Alternative Strategies

Cost ($M)

Availability

Impossible Solutions
Un-Dominated Solutions
Inefficient Solutions
Picking the Right Solution for You

Cost ($M) vs Availability

- Availability on the y-axis
- Cost ($M) on the x-axis

Example points:
- Cost: 200, Availability: 50
- Cost: 300, Availability: 90

Arrows indicating cost to achieve specific availability levels.
Air Force
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Challenges of a System of Systems

- Interactions between subsystems are too complex for analytical optimization tools
- Traditional Markovian approaches not scalable, suffer from the “curse of dimensionality”
- Static frameworks don’t handle dynamic environments such as aging and other types of time-dependent behavior
- Meaningful measures of performance are difficult to use as objective functions
Meaningful Measures of Performance

- Traditional measures of performance often fail to align with your organization’s actual goals
- **Case:** Military uses $A_o$ but it’s not necessarily appropriate for all weapon systems
  - Low-observable aircraft only fly at night
  - Training scenarios only require certain subsystems
- **Case:** NWS metrics for NEXRAD weather radar penalizes preventive maintenance and training
- What real-world outcomes are most relevant to your organization? Which ones are you using?
Are you looking under the streetlight just because the light’s better there?
Simulation Optimization Methodology

• Stochastic Petri net tool models mission scenario
  – Monte Carlo simulation allows us to relax Markovian assumptions, delivers richer results

• Analytical solution performs inventory optimization for individual subsystems
  – Produces rapid solutions with broad range of capabilities

• Parametric process iteratively converges on macrosystem solutions
  – Optimizes your inventory solutions against your true mission accomplishment targets
Benefits of Optimizing with Simulation

• Simulation gives insights
• Visualization helps with model validation
• Visualization helps leaders/decision makers understand complex interactions
• Monte Carlo tests the robustness of inventory decisions under conditions of operational and logistical variability
• Comprehensive approach addresses multiple resources—aircraft, facilities, manpower, equipment, etc.
Remotely Piloted Aircraft System

System Simulation

Mission Area

Preflight

Post Flight

Returning

Sparing Optimization

Sat Link (1/1)

GCS (1/2)

RPA (1/4)

D

E

F

G

H

I

J
Remotely Piloted Aircraft System
Optimizing Coverage vs. Availability

![Graph showing the relationship between inventory investment (in $M) and coverage and availability percentages. The graph indicates that as inventory investment increases, coverage also increases, reaching a peak and then plateaus, while availability remains relatively constant. The lines are labeled as 'Average Coverage' and 'RPA Availability.'](image-url)
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Some Supply Chain Questions

- What are my organization’s true objectives for its inventory?
- What objectives are we currently using to manage our inventory?
- Do the characteristics of our items pose special management challenges?
- Does our operating environment require advanced analytical tools and techniques?
- How can we make our inventory work for us?
Questions and Discussion