Optimizing Supply Blocks for Expeditionary Units

Jefferson Huang, PhD
Assistant Professor
Operations Research Department
Naval Postgraduate School

Joint Work With:
Capt Nikolas Anthony (Marine Corps Logistics Command)
LTC Peter Nesbitt (US Military Entrance Processing Command)

This work is sponsored by the Office of Naval Research.

The XVI International Conference on Stochastic Programming
UC Davis, Davis, CA
28 July, 2023

Marine Expeditionary Units (MEUs)

Marines from the 13th MEU disembarking from a landing craft. (Image Source)

Marine Expeditionary Units (MEUs)

View of the amphibious assault ship *USS Iwo Jima* from a deployed landing craft. (Image Source)

Marine Expeditionary Units (MEUs)

Marines from the 15th MEU aboard the amphibious assault ship *USS Boxer*. (Image Source)

Building Supply Blocks

Question

What should a MEU take with them when they deploy?

- Frequent periods of days – weeks when **re-supply is infeasible**.
- Limited **budget and storage capacity**.
- Many **NIINs (National Item Identification Numbers)** (i.e., item types) to consider.

Marine Corps Logistics Command (LOGCOM) currently provides guidance on what to bring.

- Use **heuristics** and subject-matter expertise.
- Constraints such as weight and volume often handled in an **ad-hoc** way.
- **Time**-consuming.

Optimization Model

Nonlinear Knapsack Problem:

$$\text{minimize} \quad \sum_{i \in \mathcal{I}} \left[\ell_i \sum_{d \leqslant s_i} (s_i - d) p_i(d) + b_i \sum_{d > s_i} (d - s_i) p_i(d) \right]$$

$$\text{subject to} \quad \sum_{i \in \mathcal{I}} r_{i,k} s_i \leqslant R_k \quad \forall k \in \mathcal{K}$$

$$s_i \in \mathbb{N} \quad \forall i \in \mathcal{I}$$

Demand Data

- $p_i(d)$ = probability that exactly d units of NIIN $i \in \mathcal{I}$ will be demanded

Costs

- ℓ_i = per-unit leftover cost for NIIN $i \in \mathcal{I}$
- b_i = per-unit shortage cost for NIIN $i \in \mathcal{I}$

Constraints

- $r_{i,k}$ = per-unit amount of resource type $k \in \mathcal{K}$ consumed for NIIN $i \in \mathcal{I}$
- R_k = amount of resource type $k \in \mathcal{K}$ available

Linearized Model

Equivalent 0-1 Linear Program:

$$\begin{aligned} \text{minimize} \quad & \sum_{i \in \mathcal{I}} \ell_i \left(\sum_{d \geqslant 1} x_{i,d} - \mu_i \right) + (\ell_i + b_i) \left(\mu_i - \sum_{d \geqslant 1} \bar{F}_i(d) x_{i,d} \right) \\ \text{subject to} \quad & \sum_{i \in \mathcal{I}} r_{i,k} \sum_{d \geqslant 1} x_{i,d} \leqslant R_k \quad \forall k \in \mathcal{K} \\ & x_{i,d} \in \{0,1\} \quad \forall i \in \mathcal{I}, d \in \mathbb{N}_+ \end{aligned}$$

Demand Data

- μ_i = mean demand for NIIN $i \in \mathcal{I}$
- $\bar{F}_i(d)$ = probability that more than d units of NIIN $i \in \mathcal{I}$ will be demanded

Costs

- ℓ_i = per-unit leftover cost for NIIN $i \in \mathcal{I}$
- b_i = per-unit shortage cost for NIIN $i \in \mathcal{I}$

Constraints

- $r_{i,k}$ = per-unit amount of resource type $k \in \mathcal{K}$ consumed for NIIN $i \in \mathcal{I}$
- R_k = amount of resource type $k \in \mathcal{K}$ available

Implementation

- Currently implemented in Pyomo.
- Reasonable solution times using `glpk`.
  - **Example:** Roughly 28 seconds on an Apple M1 Pro, for randomly generated realistically-sized instances. (roughly 860,000 columns)

- For **Class IX (Repair) parts**, the recommended stock levels from the optimization model **outperform those recommended by existing methods**, while only using about half the amount of weight and volume.
  - Evaluated performance using historical part usage data from a past MEU deployment.
  - Demand occurrences modeled as Poisson processes with NIIN-specific rates.
  - Currently working with LOGCOM to obtain a publicly releasable item usage dataset.

Conclusions & Future Work

Summary

- We formulated an integer linear program modeling a **multi-item newsvendor** problem with **knapsack** constraints.
- **Tractable** for instance sizes of interest.
- Provides an alternative **quantitative perspective** for LOGCOM planners.

Research Questions

- How does the performance of the recommended supply blocks depend on parameter **estimation errors** (e.g., errors in demand distribution estimation)?
- Current formulation is risk-neutral; what about criteria based on **risk measures**?
- Other applications?