15.777 Healthcare Lab: Introduction to Healthcare Delivery in the United States
Professor Jónas Jónasson | Fall 2020

Optimization Modeling for Allergy Testing

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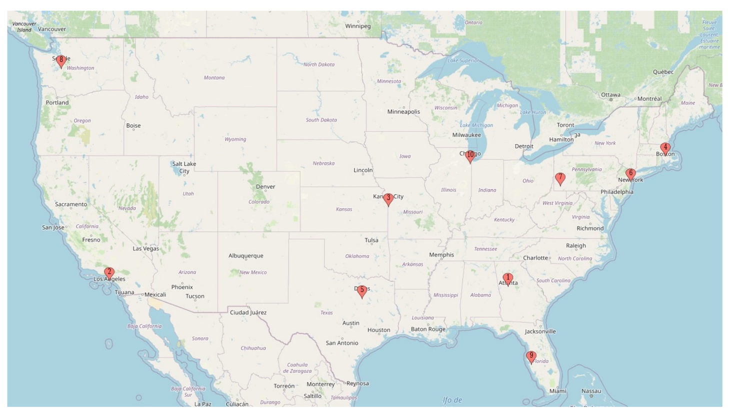
Background and Project Motivation

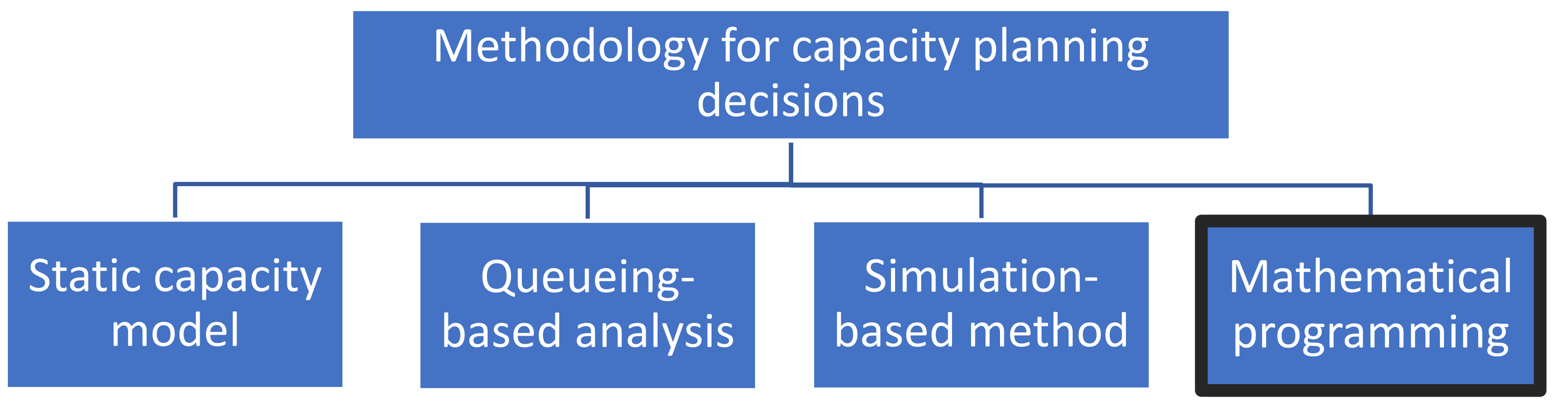
- Quest Diagnostics has 22 labs across the US and processes ~25 million allergy tests per year
  - 400+ unique allergens
- Existing equipment is approaching end of useful life, and Quest needs to purchase new testing equipment for all sites
  - Operational costs such as reagent costs play a significant role over the lifespan of the machines



Objective

- Develop and implement an optimization model to determine the number of testing machines to purchase at each lab
- Build operational strategy and menu offering to address infrequently tested allergens

Literature Review



Methodology

1. **Descriptive Analytics**: Quest provided several data sets, which included (i) historical daily testing volume by allergen type, (ii) cost data for each lab (labor, transportation, etc.), and (iii) instrument throughput. Through analysis of testing volume data, we discovered that roughly 60% of site-test combinations were responsible for 99% of the volume which satisfied minimum 3-month site-level volume thresholds to avoid reagent waste. This observation significantly lowered the complexity of our optimization model design

2. **Optimization Model – High Volume Tests:** Our model, shown on the right, sought to answer two questions: (i) how many and where testing machines should be purchased, and (ii) which origin labs should process all their own test volume, and which should divert to another lab. With the mathematical model built, we then used the Gurobi modeling program to code and solve our optimization problem

3. **Heuristic Design – Low Volume Tests:** The mathematical model served as a useful instrument to design operations for most of the allergen testing volume, but it fails to optimally allocate for low volume tests, where pooling at centers of excellence becomes part of design considerations. For each of these test types, we calculated the requisite volumes needed at each lab such that the cost of wasted reagents remained below the shipping cost to other labs and built decision rules based on projected volume

Definitions & Decision Variables

$$M_j = \text{number of Machines Purchased at Lab } j$$
$$X_{ijk} = \text{number of tests that travel from lab } i \text{ to lab } j \text{ during month } k$$
$$T_{ij} = \text{Travel cost from lab } i \text{ to lab } j \text{ where } T_{ij} = 0 \ \forall\, i = j$$
$$L_j = \text{Aggregate variable labor cost per test at lab } j$$
$$D_{ik} = \text{Demand at lab } i \text{ during month } k$$
$$\beta = 1 \text{ Month ImmunoCap throughput}$$
$$\alpha_j = \text{slack capacity at lab } j \text{ needed for given service level (ex: 90\%)}$$
$$\forall\, i,j \in \{1,\ldots 10\} \text{ and } k \in \{1,\ldots 120\}$$

Objective Function

$$Min \sum_{k}^{120}\sum_{j}^{10}\sum_{i}^{10} X_{ijk} * T_{ij} + \sum_{j}^{10}\left(\left(\sum_{k}^{120}\sum_{i}^{10} X_{ijk}\right) * L_j\right) + \$250{,}000 * \sum_{j}^{10} M_j$$

Subject To

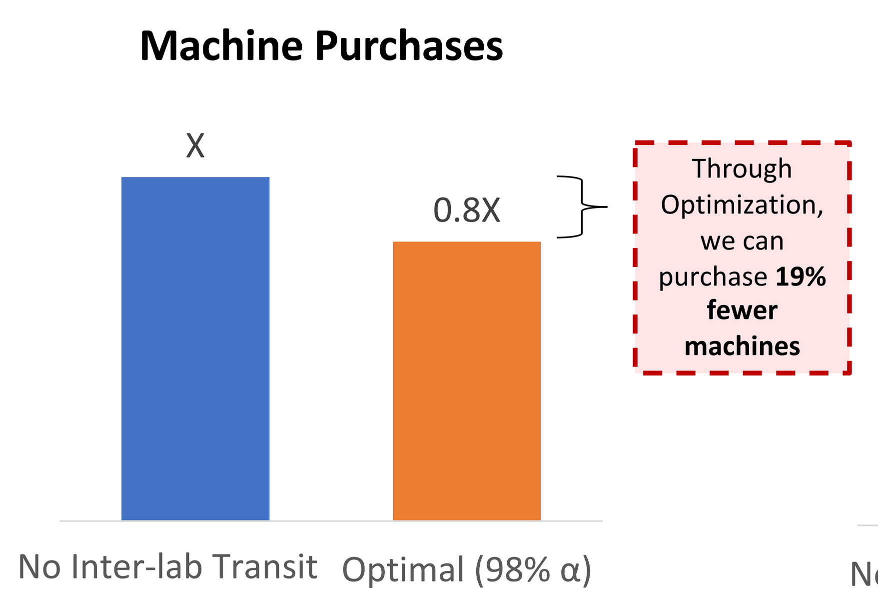
$$\sum_{j}^{10} X_{ijk} = D_{ik} \ \forall\, i,k \quad (\text{Forces all demand at Lab } i \text{ to be sent to a lab } j \text{ for testing})$$

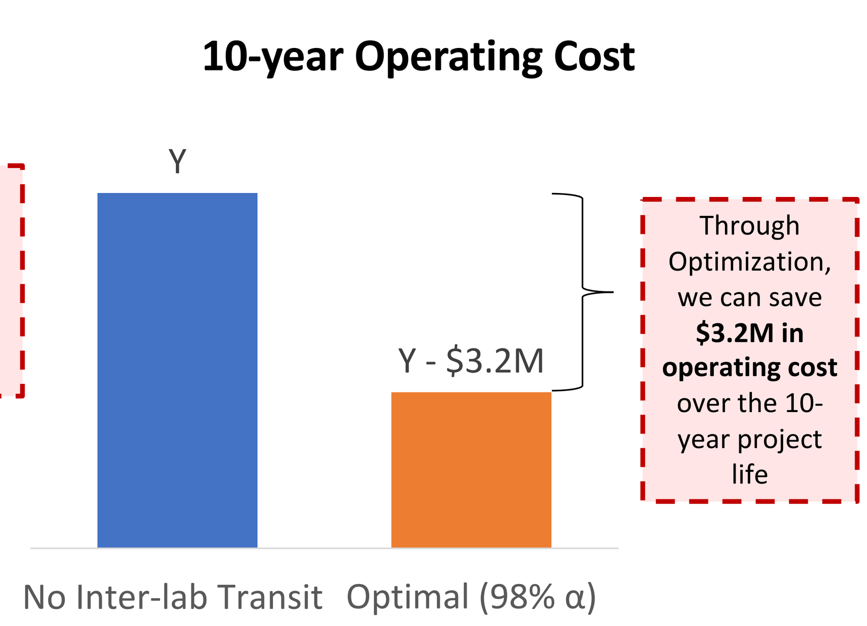
$$\beta * M_j \geq \sum_{i}^{10} \alpha_j X_{ijk} \ \forall\, j,k \quad \left(\begin{array}{c}\text{Throughput must meet testing needs at lab } j \text{ in month } k,\\ \text{with slack capacity of alpha}\end{array}\right)$$

$$\text{Where, } \alpha_j = \frac{\mu_j + 1.282 * \sigma_j}{\mu_j} \ (\text{capture 90th percentile demand variability})$$

$$M_j, X_{ijk,} \geq 0;\ M_j, X_{ijk,} \in Int \ (\text{Non} - \text{negativity and integer constraints})$$

Optimization Results

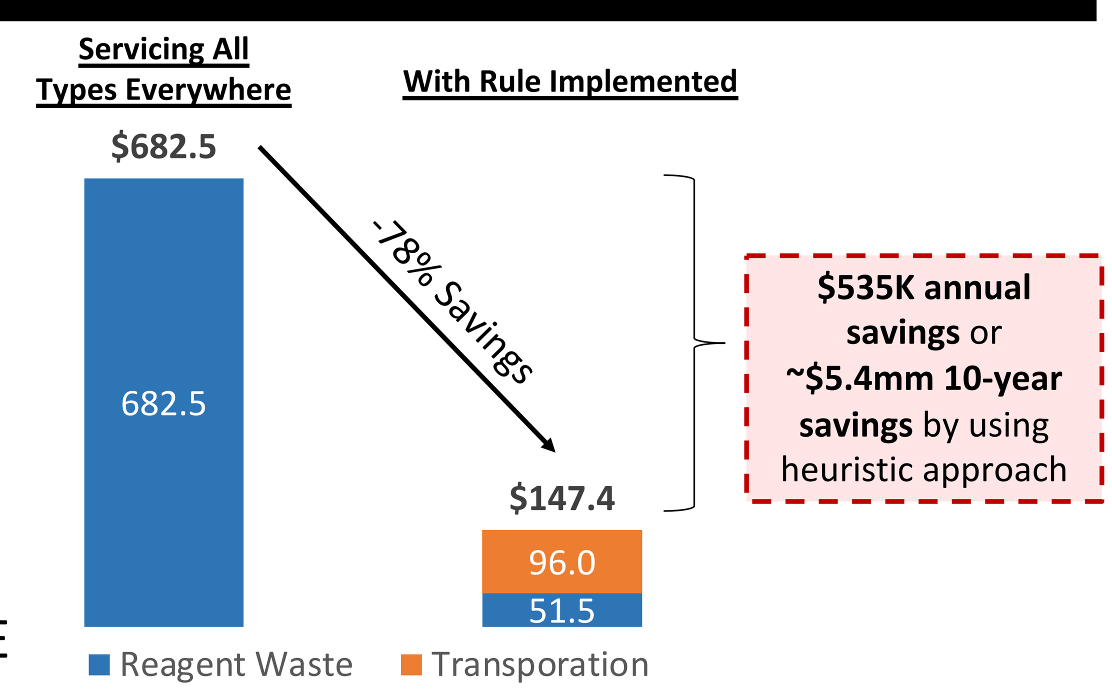




Heuristic Results for Low-Volume Tests

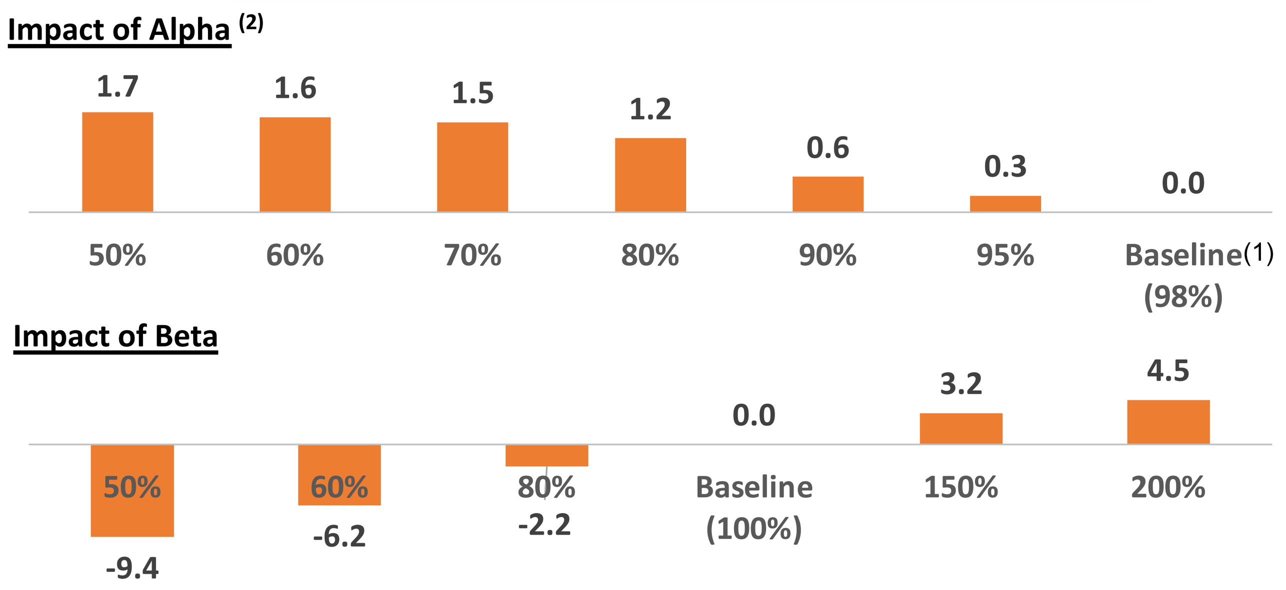
Rule Overview:

- Transportation threshold developed for each site
- If test doesn't meet site threshold, all specific allergen volume is sent to COE



Recommendations for Quest

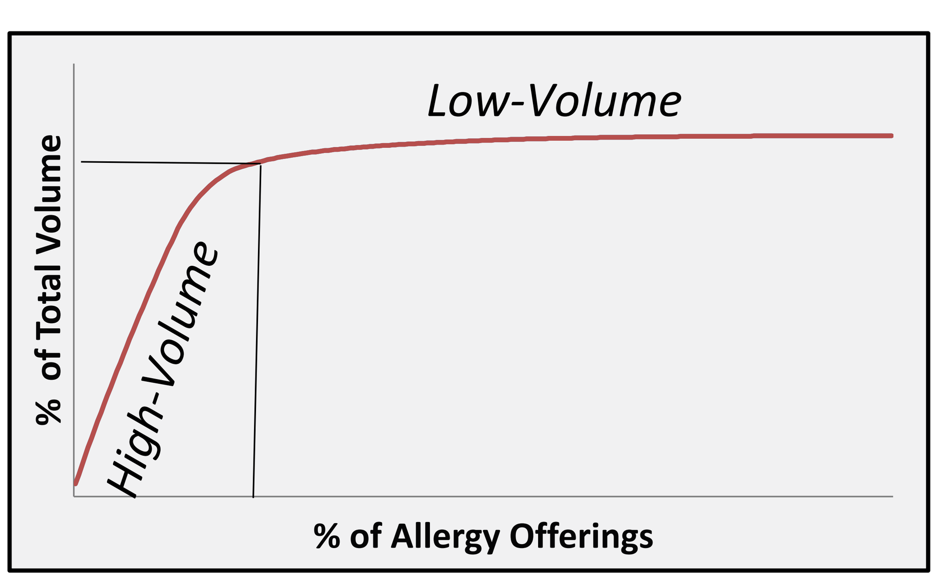
Total Cost Savings Sensitivity Analysis



(1) Baseline case is defined as the scenario where alpha is 98%, beta (throughput) assumes instruments running 12 hours/day, 30 days/month; (2) Alpha represents service level, determined by historical distributions of demand

High-Volume Menu

Logistics cost is rarely recoverable for high-volume tests.
Process tests locally.



Low-Volume Menu

Build a center of excellence in lowest cost lab. Simple heuristic can lower scrap cost by 78%

Key Findings

Asset Allocation		Menu Design		Total Savings
$3.2MM	+	$5.4MM	=	$8.6MM

The Team

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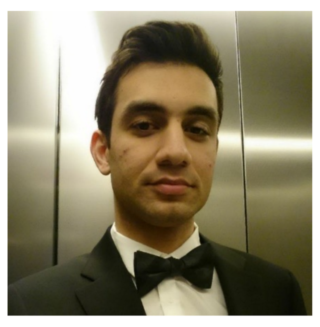

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