



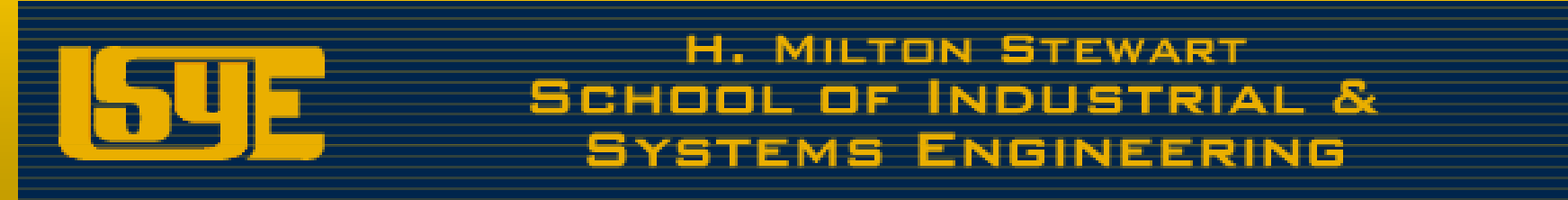
# Improving the Pan American Health Organization's Vaccine Supply Chain

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## PROJECT SUMMARY

### Pan American Health Organization (PAHO)

- Regional office for the Americas for WHO, serving countries in Latin America and Caribbean
- Manages Revolving Fund for Vaccine Procurement
- Supply chain challenges
  - Maintain high coverage of basic vaccines
  - Lead campaigns to eradicate disease
  - Introduce new, more costly vaccines



### Project Objective

- Improve PAHO's Vaccine Procurement Process

### Contributions

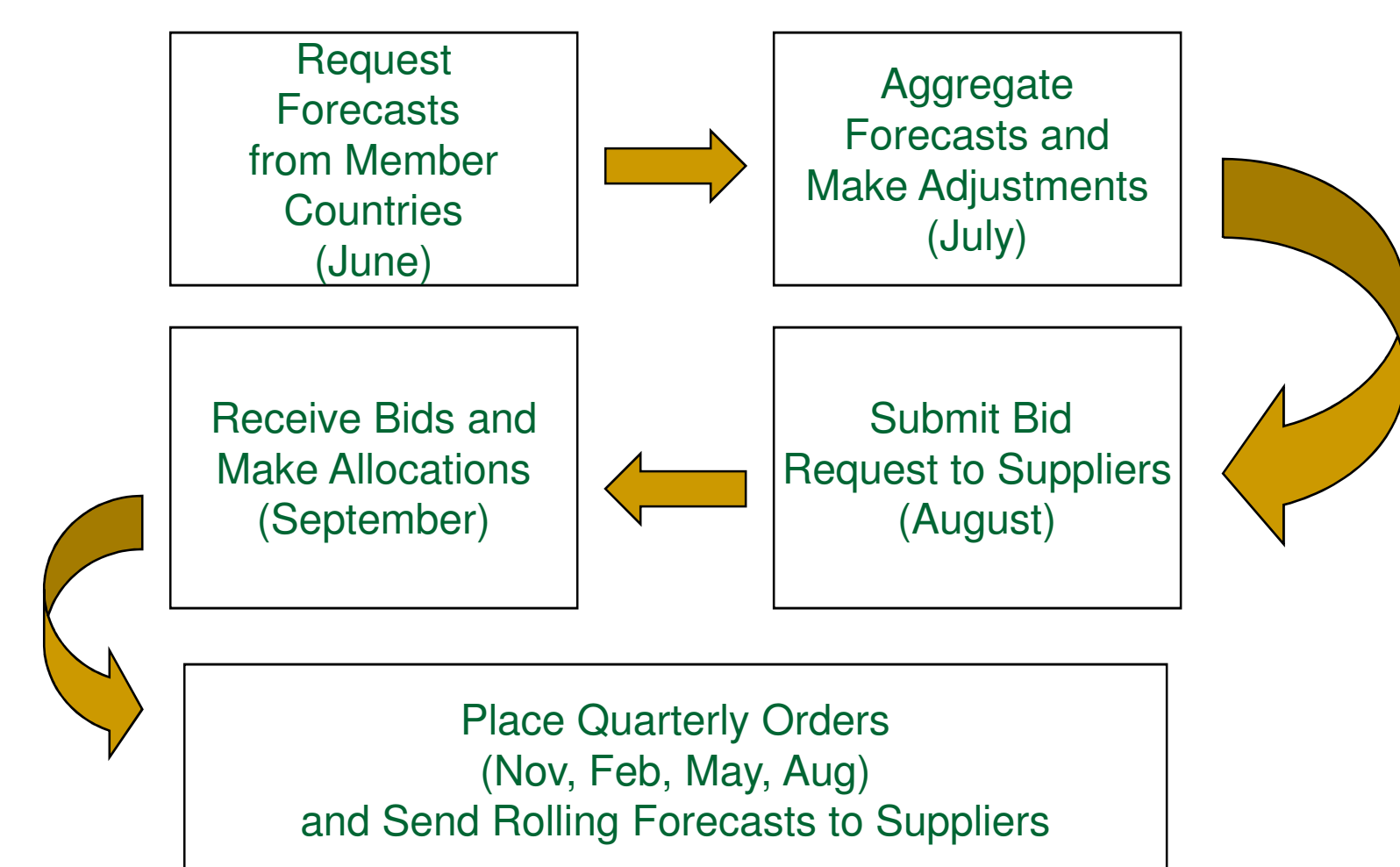
- Forecast quality analysis
- Improved transportation cost estimates
- Optimization models for bundle bidding
- Study of impact of bundle bidding on PAHO's procurement objectives

## CURRENT PROCESS

### Vaccination in PAHO Member Countries

- Approximately 20 different antigens
- 30+ different vaccines
- 16 WHO pre-approved suppliers
  - Between 1 and 13 approved vaccines per supplier; average is 3
- 37 countries, each with a unique immunization schedule

### PAHO's Current Procurement Process



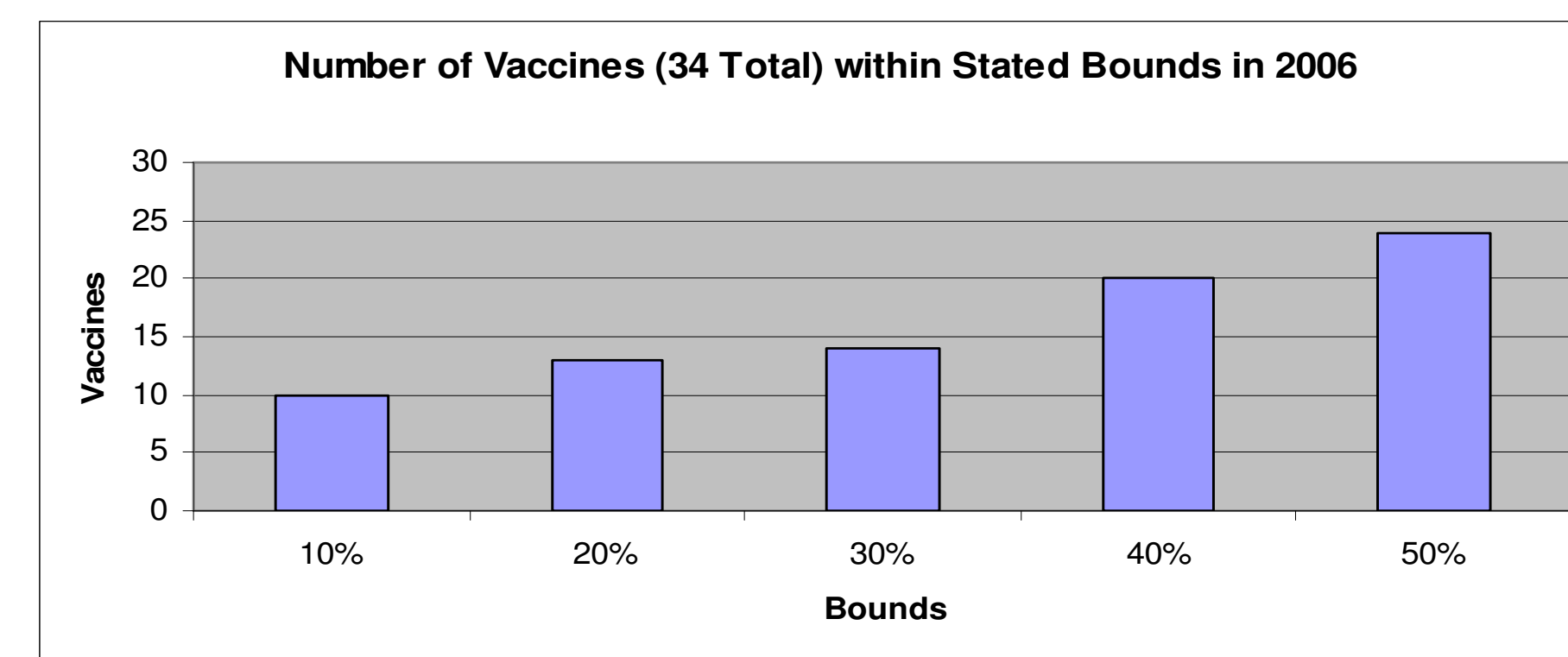
### Challenges

- Forecasting
  - Forecast quality impacts the whole process
- Transportation Cost
  - Bids do not include shipping costs; these must be estimated
- Bid Award Allocation Modeling (Auction)
  - Current award process is manual, making consideration of more complex options difficult

## FORECASTING

### How Good Is the Forecasting?

- PAHO's internal goal: Actual orders should be within 10% above or below forecasted quantities
- Actual performance falls short of this goal



### Forecasting Conclusions

- Analysis suggests there are very few countries who do a consistently bad job in forecasting
- Forecasting accuracy is more closely tied to the vaccine type

### What Affects Forecasting?

- Total quantity ordered?
- Number of countries ordering?
- Quality of country forecasts?
  - Classified countries based on PMAD of actual from forecast for each of 5 vaccines
    - 'Good': PMAD 2 [0, 0.5]
    - 'Fair': PMAD 2 (0.5, 0.8]
    - 'Bad': PMAD 2 (0.8, 1.0]
    - 'Very Bad': PMAD ≥ 1.0
  - Countries' classifications differ across vaccines
- Type of vaccine?
  - Poorly-forecasted vaccines (e.g. tetanus) tend to be so for most countries, and likewise for well-forecasted vaccines (e.g. BCG, MMR)

### Forecasting Recommendations

- Development of causal models
- PAHO-led training on forecasting at the country level
- Penalties for those countries with grossly miscalculated forecasts

## TRANSPORTATION COST ESTIMATION

### Factors Affecting Transportation Cost

- Data show supplier, vaccine, and destination country all impact shipping cost
- Current method of estimating transportation cost considers only supplier-vaccine pairs
- Developed shipping cost scalars for each country for use in bid award allocation model

### Shipping Cost Scalars

- Current approach for supplier-vaccine pairs:
  - Landed cost of vaccine  $j$  from supplier  $i = c_{ij} + t_{ij}$
- Proposed approach for supplier-vaccine-country triples using country scalars:
  - Landed cost of vaccine  $j$  from supplier  $i$  to country  $k = c_{ij} + \theta_k t_{ij}$
  - Tested several estimators and evaluated using four measures of error

### Transportation Cost Estimate Recommendations

- Using an estimator that captures supplier, vaccine, and country, effects can substantially improve transportation cost estimates

## NEW BUNDLE BIDDING PROCESS

### Why Investigate Bundle Bidding?

- Suppliers may experience production or transportation synergies between products
- Allowing bids on bundles in addition to single items may achieve cost savings for PAHO
- Bundle bidding may affect supplier diversity, so additional controls may be necessary
- Bundle bidding requires the use of optimization models rather than manual allocations



### New Bidding Process

- As in current process, each supplier for each single vaccine in his portfolio submits
  - A price
  - A quantity
- In addition, suppliers can create *bundles* of vaccines
  - A discounted price
  - A lower bound on acceptable quantity

## BID ALLOCATION MODELS

### Winner Determination Model for Bundle Bidding

- Basic model selects suppliers for each vaccine based on bundle bids
- Extensions:
  - Include transportation costs in supplier selections
  - Require multiple suppliers for each vaccine, a priority for PAHO's long-term supply security

$$\begin{aligned}
 & \text{Minimize } \sum_{ijk} c_{ij}^k x_{ij}^k \quad \text{Quantity of } j \text{ supplied by } i \text{ within bundle } k \\
 & \sum_{ik} x_{ij}^k \geq D_j \quad \forall j \quad \text{Demand} \\
 & \sum_k x_{ij}^k \leq S_{ij} \quad \forall ij \quad \text{Bid quantity} \\
 & l_{ij}^k y_j^k \leq x_{ij}^k \leq S_{ij} y_j^k \quad \forall ijk \quad \text{Bundle limits} \\
 & y_j^k \in \{0,1\} \quad \forall jk \quad \begin{array}{l} 1 \text{ if bundle } k \text{ of supplier } \\ i \text{ is selected, } 0 \text{ otherwise} \end{array}
 \end{aligned}$$

## COMPUTATIONAL RESULTS

### Insights from Test Scenarios

- Explicit supplier diversification is more costly when bundling is not allowed
- If discount depends on bundle size:
  - Fewer suppliers are represented
  - More vaccines have multiple suppliers
  - Greater savings is realized
- The greater the number of vaccines that belong to some bundle, the more PAHO saves
- Suppliers with large portfolios are expected to offer large bundles, which may lead to large discounts
  - If large bundles are allowed, these suppliers will be awarded more
- Limiting the *number* of bundles offered by a supplier:
  - Increases percentage of suppliers represented
  - Increases percentage of vaccines supplied by multiple suppliers
  - Slightly increases savings (over baseline) compared to limiting the *size* of the bundles

## PROJECT IMPACT

### Contributions to Theory and Practice

- New insight into benefits, challenges of bundle bidding in vaccine procurement
  - Importance of forecasting
  - Transportation cost estimation
  - Supplier diversification
- Increased focus on quantitative supply chain analysis at PAHO
  - Two Georgia Tech ISyE student interns in Summer 2007
- Improved understanding of challenges, opportunities for OR/MS in public health arena