wivDM: covid vaccine allocation modeling for Wisconsin

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Rector’s Guild, Madison, March 9, 2021
A Wisconsin exercise

- 72 counties, 72,000 doses, who gets what?

1000 doses to each county.
Build a (mathematical) model

- 1,000 doses to Milwaukee, 1,000 doses to Iron county “not fair”
- Generate survey to elicit demand requests from providers
- Simply (!) allocate supply to satisfy demand
- Issues to consider: population, social vulnerability, over 65’s, teachers, historical allocation
- What is the policy regarding “fair allocation”?  
- Model does not decide policy, only implements policy directives
- But that’s not all...
- Logistics (transport and storage)
  - Grace connection: Maj. Lyon
- Boxes, vials and boosters
- Fairness: county targets, provider targets, big changes in supply amounts and gaming
- Specials and minimums (for directives)
The data and weekly cadence

- $d_{v,g,t}$: request of doses by provider/vaccinator $v$
- $S_t$: number of vaccines (of type $m$) delivered to WI at $t$
- $b_{v,t}$: number of boxes of vaccines delivered to $v$ at $t$

- CDC: Centers for Disease Control and Prevention
- WIR: Wisconsin Immunization Registry
Exercise: providers send requests

100

2

5000

10,000

"proportional fairness"

county | targets | population

1000

6

900

12

90

100

1170

vials = 6 boxes

= 100
Vaccine allocation: more details

- Covid-19 Vaccines for Wisconsin: Pfizer (P), Moderna (M), Johnson & Johnson (J)
- All vaccines delivered at spokes (providers)
- (P) vaccines are stored at hubs (large freezer capacity)
- Delivery of (P) is via Hub and Spoke Model, (M/J) directly to Spokes
- Model values (P), (J) and (M) equally
- P and M require boosters
Optimization Process

1. Receive requests from providers from surveys, supply from CDC
2. Two phase optimization: first step - determine target allocation using fairness metrics, second step - get close to target while satisfying logistic constraints
3. Cap requests based on population served (at county level) - limit overly large requests
4. Generate weight $w_v$ for each vaccinator $v$ that incorporates SDMAC (State Disaster Medical Advisory Committee) recommendations
5. Additional emphasis on socially vulnerable counties (via Social Vulnerability Index (SVI))
6. Generate a target amount for each $v$ as a fraction of given supply with proportional fairness, and manufacturer for new vaccinators
7. Possible to add long term proportion information, and enforce other high level objectives
Timeframe results (is it working)

- Week 1-4: full demand satisfaction, building model and data streams, adding M
- Week 5-7: adding boosters (P and M), and pharmacy (M) allocation, (supply > demand), incorporating SVI and vaccinator preference, new fairness model, distribution for M
- Week 8 - 10: reduction in Pfizer allocation, caps on requests, enhanced output
- Week 11 - 14: P changed to vials of 6, school allocation, addition of J, increased supply, new fairness metrics and model
- Models help decision makers, not necessarily make the decisions themselves
- Model suggests allocation, policy group approves, Engle and Arndt adjust due to data changes
Objective: fair allocation of $j_{v,m,t}$ based on SVI

Request for vaccines $d_{v,t}$ determined from weekly surveys

Variables:

- $j_{v,m,t}$: jabs of $m$ done by $v$ at $t$
- $i_{h,m,t}$: inventory at $h$ of $m$ at $t$
- $b_{v,m,t}$: boxes of $m$ delivered to $v$ at $t$
- $\text{dev}_{v,t}$: deviation from request by $v$ at $t$

Constraints:

- Full boxes delivered to hubs (and split there), freezer capacity
- Jabs delivered to spokes in vial amounts, with a required minimum number of vials to a spoke
- Capacity constraints at hubs and spokes
- Limit vaccines inventory at hubs
- Model is written in the GAMS modeling system and can provide results to other software
Logistic model

\[ \min f(\text{dev}_{v,g,t}) \]

\[
\text{s.t. } \text{dev}_{v,g,t} = d_{v,g,t} - \sum_{m} j_{v,g,m,t} \\
\sum_{v,g} j_{v,g,m,t} + i_{h,m,t} = N_{m,t} b_{h,m,t} + i_{h,m,t-1} \\
\sum_{h} b_{h,m,t} \leq S_{m,t} \\
i_{h,m,t}, j_{v,g,m,t} \leq \alpha_{h} U_{h,m,t}, j_{v,g,m,t} \leq d_{v,g,t} \\
(b_{h,m,t}, j_{v,g,m,t}) \in \mathbb{Z}_+, \\
i_{h,m,t}, \text{dev}_{v,g,t}, b_{h,m,t}, j_{v,g,m,t} \in X
\]

- Model is a mixed integer linear program
- \( f \) encodes fairness and risk