wivDM: covid vaccine allocation modeling for Wisconsin

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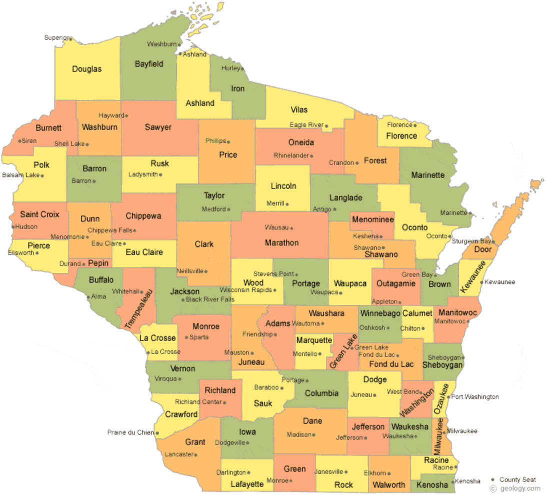
A Wisconsin exercise

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



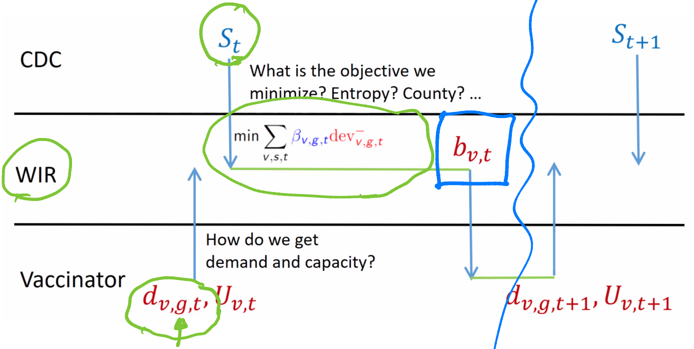
1000 doses to each county.

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 ~~1~~ 2000 10,000

~~10~~ 6 12 ~~90~~ 100 900

1000

"proportional fairness"

county targets population

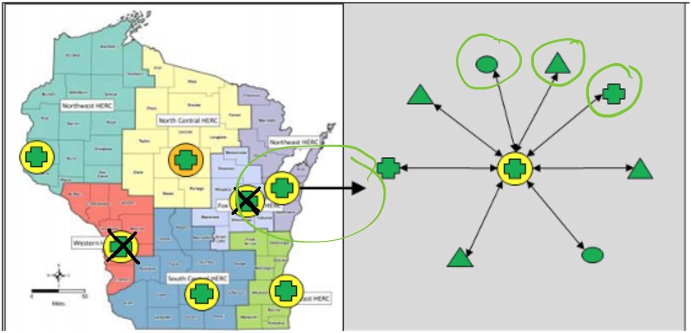
vials 6

boxes 100

1170

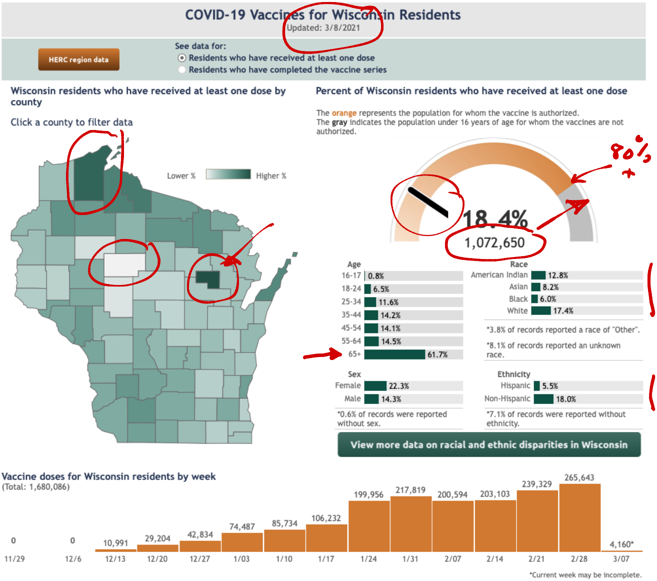
Vaccine allocation: more details

- 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



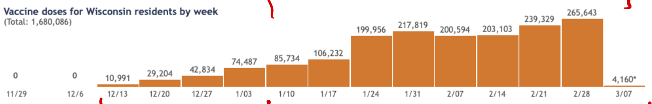
Optimization Process

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



- https://www.dhs.wisconsin.gov/covid-19/vaccine-data.htm

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

wiVDM: second phase logistic model

- 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
- $\mathrm{dev}^{-}_{v,t}$: 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

$$
\begin{aligned}
\min\ & f(\mathrm{dev}^-_{v,g,t}) \\
\text{s.t.}\ & \mathrm{dev}^-_{v,g,t} = d_{v,g,t} - \sum_m j_{v,g,m,t} \\
& \sum_{v,g} j_{v,g,m,t} + i_{h,m,t} = N_{m,t} b_{h,m,t} + i_{h,m,t-1} \\
& \sum_h b_{h,m,t} \leq S_{m,t} \\
& i_{h,m,t}, j_{v,g,m,t} \leq \alpha_h U_{h,m,t},\ j_{v,g,m,t} \leq d_{v,g,t} \\
& (b_{h,m,t}, j_{v,g,m,t}) \in \mathbb{Z}_+, \\
& (i_{h,m,t}, \mathrm{dev}^-_{v,g,t}, b_{h,m,t}, j_{v,g,m,t}) \in X
\end{aligned}
$$

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