Evaluating Screening and Care of Diabetic Retinopathy in Veterans Using Mixed-Integer Programming and Simulation

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Background

• Diabetes and diabetic retinopathy (DR)
  – Diabetes $\rightarrow$ blood sugar $\rightarrow$ retinal eye vessels weakened /weak new vessels $\rightarrow$ damage to vision
• DR diagnosed by an eye care specialist
  – Early retinopathy = monitoring, diabetes management
  – Advanced retinopathy = photocoagulation, vitrectomy, medical injection
  • Even after treatment, DR can reemerge
Veteran Eye Care

• Veterans face barriers accessing eye care
  – Access big challenge for rural veterans
  – Veterans report greater delays in seeking care than non-veterans
  – Eye care is 3rd most utilized service in VA (after primary care and mental health)
• Diabetes prevalence: VA patients (11.4%) > general US population (7.2%)
• Why VA research?
  – VA is cost-incentivized to reduce barriers to accessing care
  – Patient utilization of care is relatively consistent
  – Care coordination in VA: primary care/ophthalmology/endocrinology
Veteran Eye Care in Georgia

[Map of Georgia with eye icons and a blue house labeled 'VA Eye Care']
Add Screening Options
What kind of problem is this?

• Combinatorial matching problem  
  – Deciding locations to offer eye care and how to staff those locations
• Constrained resources
• Multi-criteria decision  
  – Consider cost, distance traveled, number of patients seen, etc.
Problem Statement

- Goal: Evaluate **which locations** to offer eye care screenings and **what provider type(s)** to staff each eye care location

- Assumptions:
  - Patients go to “assigned” clinic for eye care screening
  - One-year time frame
  - Patients have homogeneous screening need (one screening every other year)

- Limitations:
  - Considering eye care screening only (follow-up care not included)
  - No consideration for patients’ provider preferences
Possible eye care locations

• 28 VA locations in Georgia

Decide

• At which locations do we offer eye care?
• What kind(s) of provider(s) should staff each location?

“Assign” patients

• Patients from a given zip code assigned to clinic location(s)
Model Overview: Feasibility Constraints

- **Patient Capacity**

\[
\sum_{z \in Z} x_{zc}^t \leq v_t^c * y_c^t \quad \forall \ c \in C, \ \forall t \in T
\]

- **Demand**

\[
\sum_{t \in T} \sum_{c \in C} x_{zc}^t \geq n_l * p_z \quad \forall \ z \in Z
\]

\[
\sum_{t \in T} \sum_{c \in C} x_{zc}^t \leq n_u * p_z \quad \forall \ z \in Z
\]

- **Provider Capacity**

\[
y_c^t \leq g_c^t \quad \forall t \in T, \forall c \in C
\]

\[
\sum_{t \in T} y_c^t \leq g_c \quad \forall c \in C
\]
Model Overview: Two objective functions

I. Maximize patients assigned

\[ \text{Maximize } \sum_{z \in Z} \sum_{c \in C} \sum_{t \in T} x^t_{zc} \]

+ constraints: budget, distance

II. Minimize overall costs

\[ \text{Minimize } \sum_{c \in C} \sum_{z \in Z} \sum_{t \in T} \left( a^t_c \times x^t_{zc} + (d_{tc} \times x^t_{zc}) \times r + f^t_c \times y^t_c \right) + h \times \sum_{z \in Z} (n^u_z \times p^z - \sum_{t \in T} \sum_{c \in C} x^t_{zc}) \]

+ constraints: patients, distance
Data Overview

- Patients accessing Georgia VA for (any) care in 2017
  - Approx. 200,000 patients, grouped by zip code
- Clinic locations: 28 VA clinics in Georgia
- Driving distance from center of each zip code to each clinic location calculated via Google API
- Budget/costs, provider capacities, and other clinic-specific values obtained from VA
- Model implemented in CPLEX
## Results

<table>
<thead>
<tr>
<th>Metric</th>
<th>Model A: Maximize Patients Assigned</th>
<th>Model B: Minimize Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline Providers</td>
<td>Start from Scratch</td>
</tr>
<tr>
<td>Patients Screened</td>
<td>86,340</td>
<td>91,577</td>
</tr>
<tr>
<td>Average driving distance (miles)</td>
<td>15.8</td>
<td>27.6</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$24.0 M</td>
<td>$25.0 M</td>
</tr>
<tr>
<td>Per Patient Cost</td>
<td>$277</td>
<td>$273</td>
</tr>
</tbody>
</table>
Follow-up care for diabetic retinopathy

- We have considered DR screening, but what about longer term treatment?
- Use simulation to “follow” DR patients through treatment
  - Consider downstream effects of technician screenings
  - Determine best mix of MDs/ODs/technicians
Conclusions & next steps

• Each objective function inherently considers trade-offs, but access to diabetic retinopathy screening can be strategically implemented.

• Tool can be used by VA when evaluating community care integration.

• Next…
  – Further consider implications for follow-up care
  – Generalize beyond Georgia
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Implementation Challenges

• We solve using CPLEX, not available for provider organizations like the VA
• Implement in Microsoft Excel OpenSolver