Optimizing Safe Routes to School
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Safe Routes to School Across the United States

Locations above represent more than 10,411 schools for which SRTS funds have been announced, according to information reported to the National Center for Safe Routes to School as of December 31, 2010. To see details on SRTS projects, please go to www.saferoutesinfo.org/project_list.
**Research Focus:** Engineering approaches to reduce the risk of cars crashing into pedestrians at high speeds

**Research Goal:** prioritize SRTS infrastructure improvements that minimize crash risk while accounting for funding constraints
Graph Theory

- specialized branch of mathematics that includes analyses of networks
- A network is a graph where nodes and arcs have attributes
  - Node: discrete object or phenomenon
  - Arc: connection between objects or phenomena
Network Optimization

Optimize: Find the best possible numeric solution to a problem

• examples:
  • max flow: given road capacities, what is the maximum number of vehicles that can move through the network
  • shortest path: what is the minimum distance from an origin to a destination
Network Flow Model

- **Nodes**
  - Origin: houses & apartments
  - Destination: School
  - Transshipment: Intersections

- **Arcs**
  - all pedestrian routes: sidewalks, crosswalks, informal paths and streets
Safe Routes to School
Infrastructure Improvement Model

Yes, there will be a math quiz after this…
\( i, j \) index of network nodes

\( \mu_{ij} \) upper capacity for flow from \( i \) to \( j \)

\( d_{ij} \) distance from \( i \) to \( j \)

\( A \) \( \{(i, j) | \text{arc connects } i, j \text{ where } i < j\} \)

\( K \) \( \{(i, j) \in A | A \text{ is a candidate for improvement}\} \)

\( R_{ij} \) risk factor before improvement

\( R'_{ij} \) risk factor after improvement

\( c_{ij} \) cost of improvement from \( i \) to \( j \)

\( C \) total budget available for improvements

\( s \) node representing a school

\( b_i \) number of students entering the network at node \( i \) for all \( i \neq s \)

\( x_{ij} \) potential pedestrian flow from \( i \) to \( j \) when arc is not improved

\( z_{ij} \) potential pedestrian flow from \( i \) to \( j \) when arc is improved

\( y_{ij} = \begin{cases} 1, & \text{if } (i, j) \in K \text{ is improved} \\ 0, & \text{otherwise} \end{cases} \)
Safe Routes to School Infrastructure Improvement Model (SRTSIIM):

Minimize \[ Z = \sum_{(i,j)\in A} \left( d_{ij} + R_{ij}\right)(x_{ij} + x_{ji}) + \sum_{(i,j)\in K} \left( d_{ij} + R'_{ij} \right)(z_{ij} + z_{ji}) \]  

Subject to:

\[ \sum_{(i,j)\in A} x_{ij} + \sum_{(j,i)\in A} x_{ji} + \sum_{(i,j)\in K} z_{ij} + \sum_{(j,i)\in K} z_{ji} \]

\[ - \sum_{(i,j)\in A} x_{ji} - \sum_{(j,i)\in A} x_{ij} - \sum_{(i,j)\in K} z_{ji} - \sum_{(j,i)\in K} z_{ji} = b_i \text{ for all } i \neq s \]

\[ z_{ij} + z_{ji} \leq \mu_{ij} y_{ij} \text{ for all } (i,j) \in K \]

\[ \sum_{(i,j)\in K} c_{ij} y_{ij} \leq C \]

\[ z_{ij} \text{ and } z_{ji} \geq 0 \text{ for all } (i,j) \in K \]

\[ x_{ij} \text{ and } x_{ji} \geq 0 \text{ for all } (i,j) \in A \]

\[ y_{ij} \text{ and } z_{ji} \geq 0 \text{ for all } (i,j) \in K \]
SRTSIIM overview

- Optimize SRTS infrastructure improvements
- pedestrian network flow model
  - generates walking routes to a given school
  - determines where sidewalk and crosswalk should be added along these routes
  - Minimizes pedestrian crash risk while accounting for funding constraints
SRTSIIIM application: Santa Barbara, CA

- California SR2S Program
- To obtain SR2S funding, cities and counties must submit a plan
  - mitigates safety hazards around schools
  - stays within a budget of $450,000
- Sidewalk construction is the most requested SR2S infrastructure improvement
<table>
<thead>
<tr>
<th>Instance</th>
<th>SRTSIIM 1</th>
<th>SRTSIIM 2</th>
<th>SRTSIIM 3</th>
<th>SRTSIIM 4</th>
<th>SRTSIIM 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Budget</td>
<td>$50,000</td>
<td>$150,000</td>
<td>$250,000</td>
<td>$350,000</td>
<td>$450,000</td>
</tr>
<tr>
<td>Solution Time (seconds)</td>
<td>251.82</td>
<td>21.75</td>
<td>10.92</td>
<td>4.57</td>
<td>4.23</td>
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<tr>
<td>Budget Spent</td>
<td>$49,856</td>
<td>$149,616</td>
<td>$249,496</td>
<td>$349,992</td>
<td>$450,000</td>
</tr>
<tr>
<td>Improved Sidewalk Arcs</td>
<td>14</td>
<td>55</td>
<td>88</td>
<td>130</td>
<td>170</td>
</tr>
<tr>
<td>Improved Crosswalk Arcs</td>
<td>16</td>
<td>30</td>
<td>38</td>
<td>48</td>
<td>54</td>
</tr>
</tbody>
</table>
What about Montgomery County?

...can’t we just stay in California?
Next Steps

• Apply this model to a study area in Montgomery County
  • Looking for collaborators
  • Need good GIS data
  • Funding would be nice
• Extend the model for other types of safety improvements: curb extensions, median refuge islands, biking infrastructure, etc..
• Develop a complete Decision Support System
Thank You!

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