Pedestrian Demand Modeling: Evaluating Pedestrian Risk Exposures

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Study Team

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Presentation Outline

• Review Purpose & Objectives
• Project Description
• Application Results
• Challenges and Limitations
• Implementation
Purpose and Objectives
Pedestrian risk exposure is an important measure of safety but often difficult to evaluate.

\[
\text{Risk Exposure} = \frac{\# \text{ of collisions}}{\text{measures of demand}}
\]
Pedestrian risk exposure is an important measure of safety but often difficult to evaluate.

Risk Exposure = \( \frac{\text{# of collisions}}{\text{measures of demand}} \)

We tend to have these data from police records.
Pedestrian risk exposure is an important measure of safety but often difficult to evaluate.

\[
\text{Risk Exposure} = \frac{\text{# of collisions}}{\text{measures of demand (counts)}}
\]

Pedestrian demand data (counts) are less common
We aim to develop a method to estimate pedestrian demand or volumes at intersections (numbers of pedestrians).

These estimates can be used to analyze pedestrian risk exposure.
Guiding Principles

• Employ data available for all Maryland communities
• Use a Geographic Information Systems framework
• Develop a user-friendly methodology for practitioners
• Apply the model in a MD community
Project Description
Background

- Previous project used transportation modeling software (2004)
- Estimated models using walking data from New York City metropolitan area
- Applied model in Baltimore City and Langley Park
- Validation revealed areas for improvement
Evaluation Of Prior Effort (Strengths)

+ Developed based upon traditional regional travel demand models
+ Applied at pedestrian scale
+ Successful in predicting pedestrian counts
+ Relied on readily available data
+ Permitted evaluation relative risk exposures in two communities
Evaluation Of Prior Effort (Limitations)

- Calibration data (actual pedestrian counts) limited
- Boundary effects
- Models estimated using NYC data
- Utilized several software programs
- Complicated interface
Project Description

- Builds on previous effort
- Retain general framework from previous model
- (Re) Specification of the pedestrian travel model using Maryland pedestrian data
- Data assembly
- Pedestrian travel model improvement & development in GIS platform
- Develop detailed user protocol
- Apply in Maryland community
- Combine with crash data to evaluate pedestrian exposures
Pedestrian Volume Model Components

- Pedestrian Network, Land Use and Zonal System
- Trip Generation – How many trips?
  - Sensitive to land use and demographics
  - Estimated from 2001 NHTS for Baltimore region
- Trip Distribution – Where are they going?
  - Based upon gravity model
- Network Assignment – By what path?
  - Minimum travel time
Data Needs

• Use archived data available for Maryland communities
  – US Census of Population and Housing
  – US Census TIGER files
  – MD Property View
  – National Household Travel Survey for Baltimore metro area
  – Aerial photos
  – Pedestrian-Vehicular collisions

• Pedestrian counts (model calibration)
Pedestrian Network

Census TIGER line file provides topology and basic characteristics

Expands single street link to pedestrian links (sidewalks & crosswalks)

Use aerial photos to make corrections and add links (paths, trails, facilities not adjacent to road network)
Land Use System

• Maryland Property View
  – Residential units, commercial, retail, service, and other uses

• US Census
  – Area vehicle ownership

• TIGER Files (street centerline)
  – Pedestrian Connectivity
Pedestrian Analysis Zones

Representation of activities/land uses

Similar to TAZ concept

Create centroid of block face that represents an aggregation of activities, land use and urban form
Trip Generation

• Estimates the number of walk trips produced and attracted to a PAZ

• Productions and Attractions for:
  – Home Based Walk Trips
  – Non-Home Based Walk Trips
Trip Generation – HB Walk

• Equations for Attractions and Productions for HB Walk Trips
  – Estimated using NHTS – Baltimore Add On data
Trip Generation – HB Walk

Attractions and Productions for HB Walk Trips

HB Walk (Walk trips/hh) = \exp(-1.034232 -0.9455401 \times \text{vehicle ownership} + 2.371351 \times \text{street connectivity} + 0.0070639 \times \text{percent commercial} + 0.0001527 \times \text{residential dwelling units})

Note: All of the land use variables are calculated at the ¼ mile buffer of PAZ; Vehicle ownership is calculated from the census tract.

Converted the walk trips/hh to walk trips/ PAZ with the equation:

\[
\text{HBWalk/PAZ (walk trips/PAZ)} = \text{HBWalk (walk trips/hh)} \times \text{total dwelling units in the PAZ}
\]
Trip Generation – NHB Walk

• Equations for Attractions and Productions for NHB Walk Trips

• Not enough NHB trips in NHTS to estimate directly:
  – Employed NHB Trip Generation Models for the San Francisco Bay Area (BAYCAST-90) for all modes
  – Estimated an Equation to “skim” walk trips using 2001 NHTS for Baltimore Area
Trip Generation – NHB Walk

• Equations for Productions for NHB Walk Trips

NHB Productions (Total trips/PAZ) =
  0.798*Other Employment
  +2.984*Retail Employment
  +0.916*Service Employment
  +0.707*Total Households

Note: all of the variables are calculated the PAZ level

• Convert All Trips to Walk Trips

Prob (Walk trip) = exp (UWalk) / (1+ exp(UWalk))

Where, UWalk = -4.286918
  + 3.041807*Connectivity
  + 0.0051575*percent commercial

Note: variables in this model are calculated at the ¼ mile buffer of the trip end.
Trip Generation – NHB Walk

• Equations for Attractions for NHB Walk Trips

  NHB Productions (Total trips/PAZ) = 
  0.636*Other Employment 
  +3.194*Retail Employment 
  +0.730*Service Employment 
  +0.803*Total Households

  Note: all of the variables are calculated at the PAZ level

• Convert All Trips to Walk Trips

  Prob (Walk trip) = \frac{\exp(U_{Walk})}{1 + \exp(U_{Walk})}

  Where, \quad U_{Walk} = -4.286918 
  + 3.041807*Connectivity 
  + 0.0051575*percent commercial

  Note: variables in this model are calculated at the ¼ mile buffer of the trip end.
Trip Generation – NHB Walk

- Equations for Productions and Attractions for NHB Walk Trips must be also converted from walk trips/hh to walk trips/PAZ

\[
\text{HBWalk/PAZ (walk trips/PAZ)} = \\
\text{HBWalk (walk trips/hh)} * \text{total dwelling units in the PAZ}
\]
1. Trip Generation

Frequency of Walk Trip Productions & Attractions by Trip Purpose in the Baltimore Study Area

Walk Trips per PAZ per Day

- HBWP/PAZ
- HBWA/PAZ
- NHBWP/PAZ
- NHBWA/PAZ
Trip Distribution

- Estimates the flows between origins and destinations
- Results in a trip table or OD matrix
- Use traditional approach – gravity model
- Distributes trips based upon the number of attractions and the distance separating PAZs.
Trip Distribution

- Apply Gravity Model for Pedestrian Trip Distribution

\[
T_{ij} = P_i \left[ \frac{A_j F_{ij} K_{ij}}{\sum_j A_j F_{ij} K_{ij}} \right]
\]
Trip Distribution - Distance

Walk Trip Distance Distribution

\[ F_{ij} = 0.00622 \times \left( \frac{1}{d_{ij}} \right)^{0.18445} \times \exp\left( -0.00233 \times d_{ij} \right) \]

Where, \( F_{ij} \) = Friction factor
\( d_{ij} \) = walk trip distance (meter)

Data source: 2001 NHTS
Trip Distribution: Home Based Walk Trips

Origin has 1 church, 1 apartment complex and 9 single family units.
1 inch equals .048525 miles
Trip Distribution: Non-Home Based Walk Trips

[Diagram of trip distribution]
Route Assignment

• Estimates the path taken by each trip and assigns to the pedestrian network

• Developed an executable program using C++ to calculate the shortest path for each pair of PAZs

• “All or nothing” assignment to network

• Sums pedestrian volume at each intersection.

• Limited by computational capacity of GIS
Model Output

- Volumes are accumulated on intersections and links.
- Result is estimate of 24 hour pedestrian volumes
Evaluation of Pedestrian Risk Exposure

Pedestrian-vehicle crash data police records

Risk Exposure = \frac{\text{# of collisions}}{\text{measures of demand}}

Model output gives pedestrian volumes at intersections
Evaluation of Pedestrian Risk Exposure

- Output of model provides missing data to estimate risk exposure
- Crash data available through police reporting, geo-referenced to nearest intersection
- Using equation, can rank intersections with highest risk exposure
Application Results
Application

• Apply and calibrate model in urban and suburban setting

• Baltimore City
  – Repeat same study area in prior study
  – Crash and count data available
  – Comparison of results

• Prince Georges County
  – Calibration in suburban area
  – Crash and count data available
## Study area comparison

<table>
<thead>
<tr>
<th></th>
<th>Baltimore City</th>
<th>Prince George’s County</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area Size (Square Miles)</strong></td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td><strong>Number of road segments</strong></td>
<td>4322</td>
<td>478</td>
</tr>
<tr>
<td><strong>Number of PAZ</strong></td>
<td>1709</td>
<td>860</td>
</tr>
<tr>
<td><strong>PAZ Type</strong></td>
<td>Block centroid</td>
<td>Block face</td>
</tr>
</tbody>
</table>
## Time cost estimates (hrs)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Baltimore City</th>
<th>Prince George’s County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of input files</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Network construction</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Land use calculation</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Trip generation</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Trip distribution (OD matrix)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Trip distribution (Tij table)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Trip assignment (File preparation)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Trip assignment (Processing)</td>
<td>48</td>
<td>6</td>
</tr>
<tr>
<td>Intersection volume</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>160</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>
Pedestrian Volumes

24 Pedestrian Volumes at Intersections

Results range from 0-1700 pedestrians per intersection per 24 hr period
Crash Data

900 crashes between the years of 2000 to 2003

Legend
Crashes
- 1
- 2 - 4
- 5 - 8
- 9 - 13

Sidewalk
# Top Intersections – Risk Exposure

## Baltimore City

<table>
<thead>
<tr>
<th>RANK</th>
<th>ADDRESS</th>
<th>CRASHES</th>
<th>EXPOSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crashes per million</td>
</tr>
<tr>
<td>1</td>
<td>NORTH &amp; GREENMOUNT</td>
<td>8</td>
<td>3865</td>
</tr>
<tr>
<td>2</td>
<td>PRATT &amp; CAROLINE</td>
<td>3</td>
<td>1449</td>
</tr>
<tr>
<td>3</td>
<td>FRONT &amp; FAYETTE</td>
<td>3</td>
<td>1449</td>
</tr>
<tr>
<td>4</td>
<td>CHARLES AND 20TH</td>
<td>7</td>
<td>845</td>
</tr>
<tr>
<td>5</td>
<td>MADISON &amp; BOND</td>
<td>2</td>
<td>725</td>
</tr>
<tr>
<td>6</td>
<td>BROADWAY &amp; EASTERN</td>
<td>6</td>
<td>724</td>
</tr>
<tr>
<td>7</td>
<td>CHASE &amp; HARFORD</td>
<td>3</td>
<td>724</td>
</tr>
<tr>
<td>8</td>
<td>FAYETTE &amp; CAROLINE</td>
<td>4</td>
<td>724</td>
</tr>
<tr>
<td>9</td>
<td>GUILFORD &amp; SARATOGA</td>
<td>3</td>
<td>483</td>
</tr>
<tr>
<td>10</td>
<td>CHARLES &amp; LAFAYETTE</td>
<td>3</td>
<td>483</td>
</tr>
</tbody>
</table>
## Exposure analysis time cost (hrs)

<table>
<thead>
<tr>
<th>Steps</th>
<th>Time cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geocode crash records</td>
<td>4</td>
</tr>
<tr>
<td>Spatially aggregate crashes at intersections</td>
<td>1</td>
</tr>
<tr>
<td>Spatially join volumes to number of crashes</td>
<td>1</td>
</tr>
<tr>
<td>Calculate exposure rates</td>
<td>1</td>
</tr>
<tr>
<td>Identify high risk locations</td>
<td>2</td>
</tr>
</tbody>
</table>
Challenges and Limitations
Challenges and Limitations

- Pedestrian network and PAZs – limits on number of PAZs GIS system can handle ~ 1700
- Only two trip purposes – home-based and non-home based walk trips – due to limitations of NHTS
- Computational capacity for network assignment – long time to run
- Limited availability of pedestrian counts to re-validate model
Implementation
Implementation
Suggestions for Maryland

• Develop Website at National Center for Smart Growth to disseminate model, protocol, results and other information

• Provide workshops through SHA or NCSG to train pedestrian planners on how to use the model

• Outreach to specific communities as demonstration project

• Refinement of model with each new application
Questions?
Count Validation

Obtained peak hour counts for Baltimore City

- 7-9 AM, 11 AM-1PM and 4-6 PM
- For 8 directions

- Estimated volumes with Pedestrian Demand Model
  - 24 hours
  - Summed to the 4 nodes of the intersection

- Used NHTS to calculate percentage of walk trips that occurred during peak hours:
  - AM peak – 12.1%; Mid day peak – 16.1%; PM peak – 17.7%

- Calculated volume share for peak hours from the estimated volumes

- Compared average peak hour counts to estimated volumes for each intersection
Pedestrian Counts
Pedestrian Crashes

Pedestrian Crashes (2003-2005)