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

Research Problem

Pedestrian risk exposure is an important measure of safety but often difficult to evaluate.

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

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We tend to have these data from police records

Pedestrian Crashes

City of Baltimore

2001-2003

Research Problem

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 demand data (counts) are less common

Research Objective

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

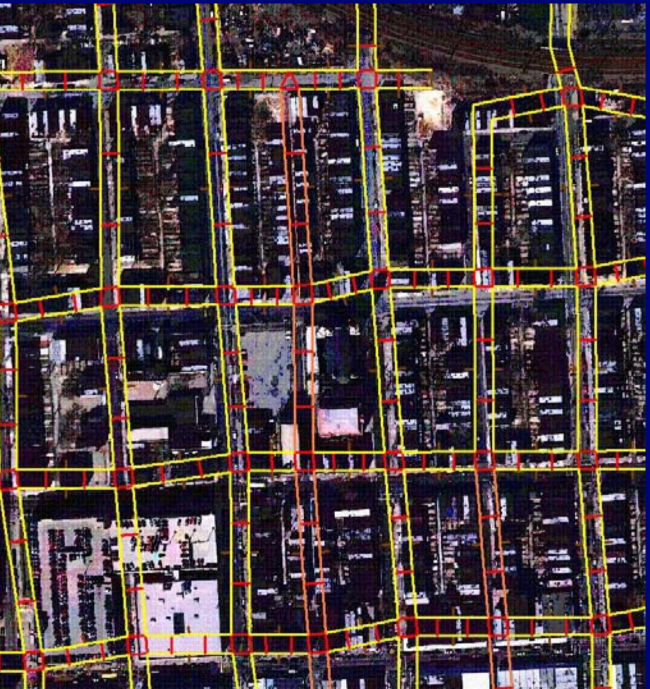
Data Needs

- **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



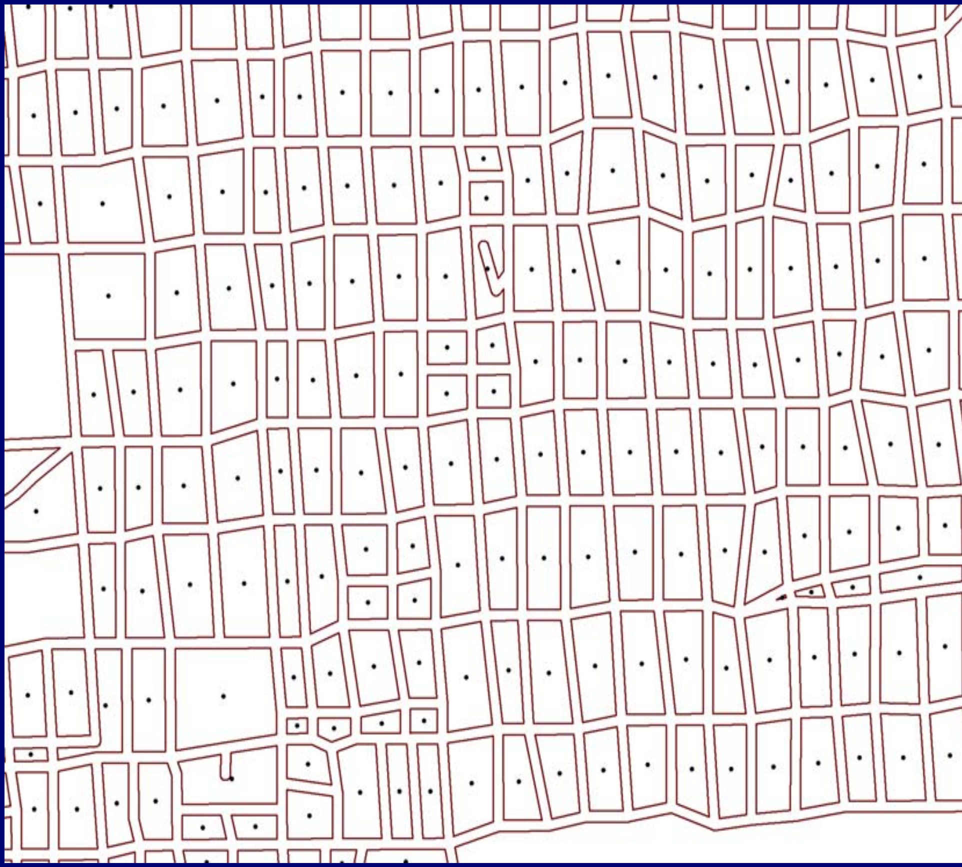
Use aerial photos to make corrections and add links (paths, trails, facilities not adjacent to road network

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

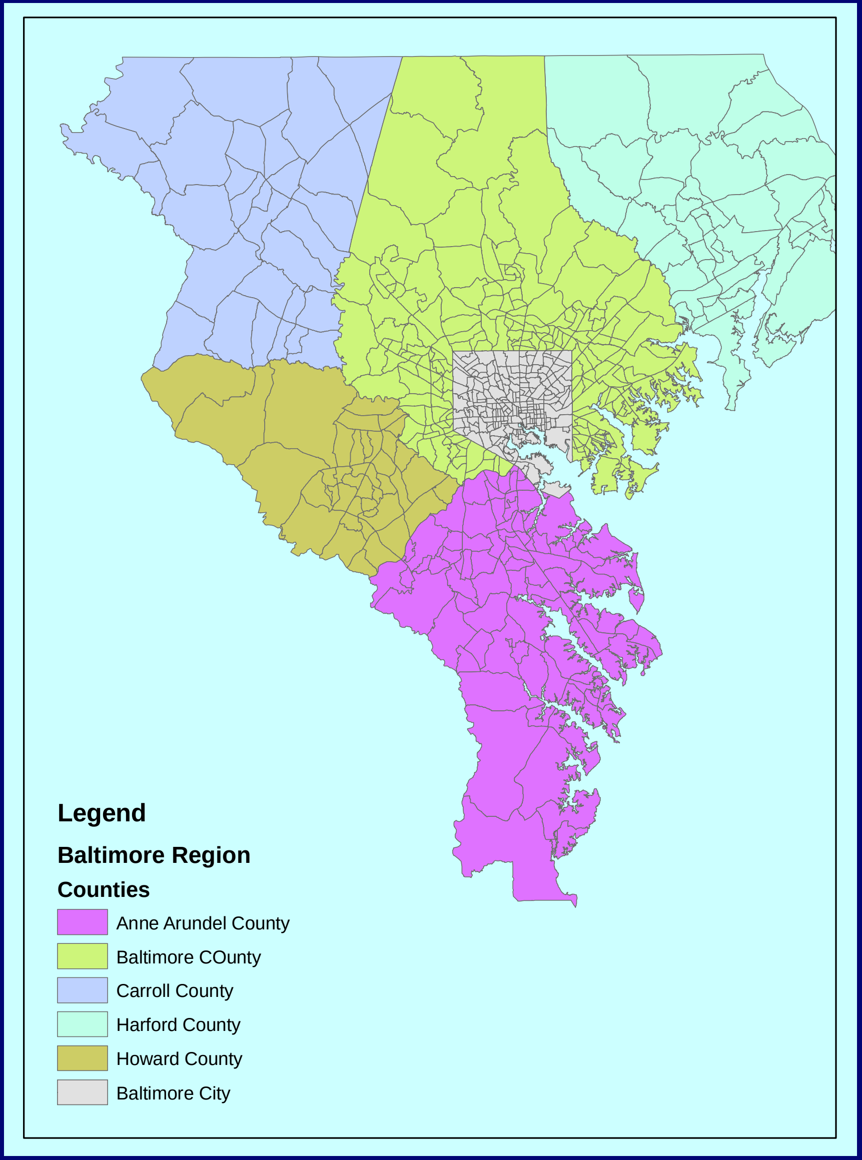


Trip Generation

- **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*vehicle ownership +2.371351*street connectivity +0.0070639*percent commercial +0.0001527*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:

HBWalk/PAZ (walk trips/PAZ) =

HBWalk (walk trips/hh) * 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 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

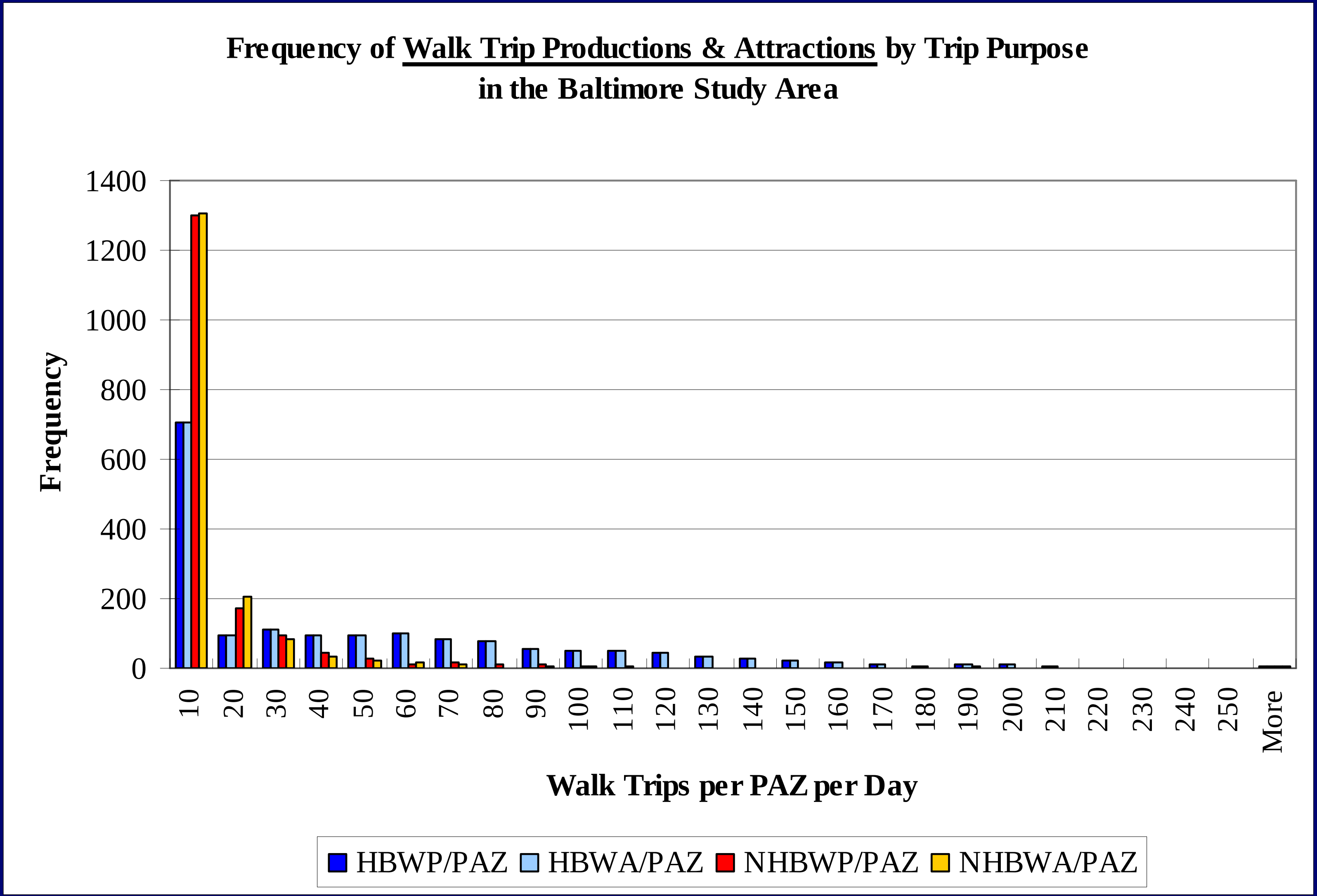
Note: variables in this model are calculated at the ¼ mile buffer of the trip end.

Trip Generation – NHB Walk

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

HBWalk/PAZ (walk trips/PAZ) =
HBWalk (walk trips/hh) * total dwelling units in the PAZ

1. Trip Generation



Trip Distribution

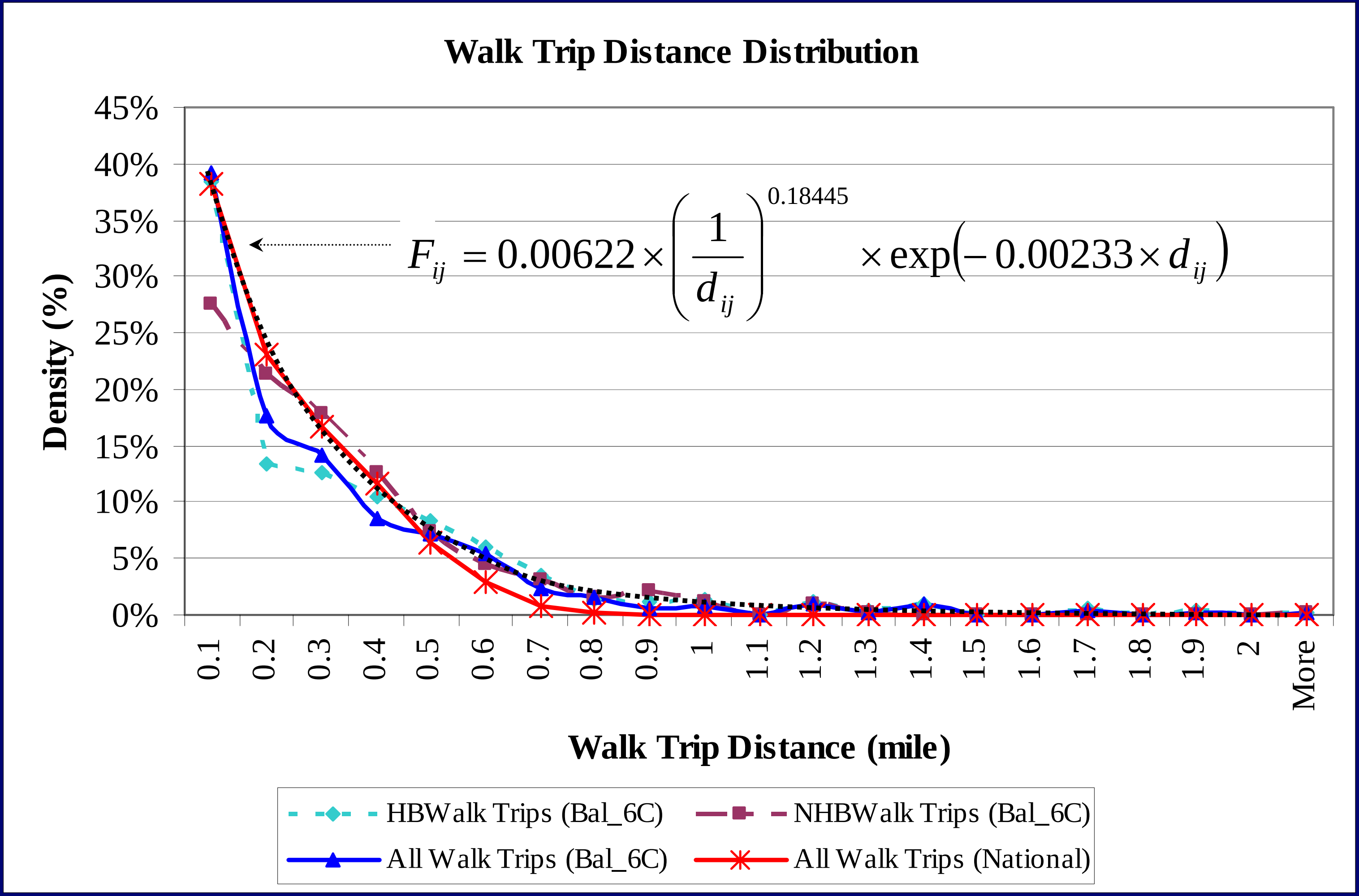
- **Estimates the flows between origins and destinations**
- **Results in a trip table or OD matrix**
- **Use traditional approach – gravity model**
- **Distributes trips based upon the number of attractions and the distance separating PAZs.**

Trip Distribution

- Apply Gravity Model for Pedestrian Trip Distribution

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_j A_j F_{ij} K_{ij}} \right]$$

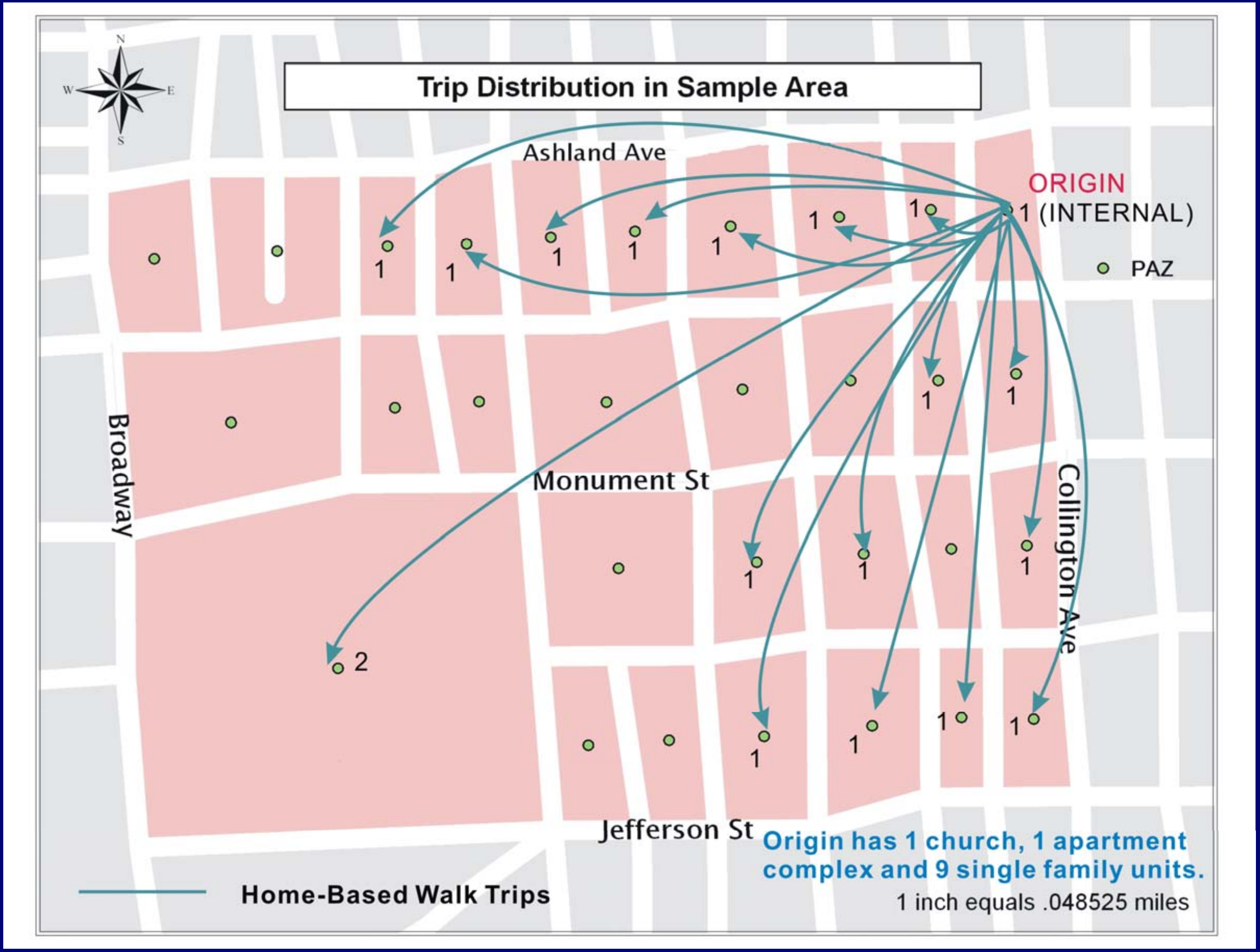
Trip Distribution - Distance



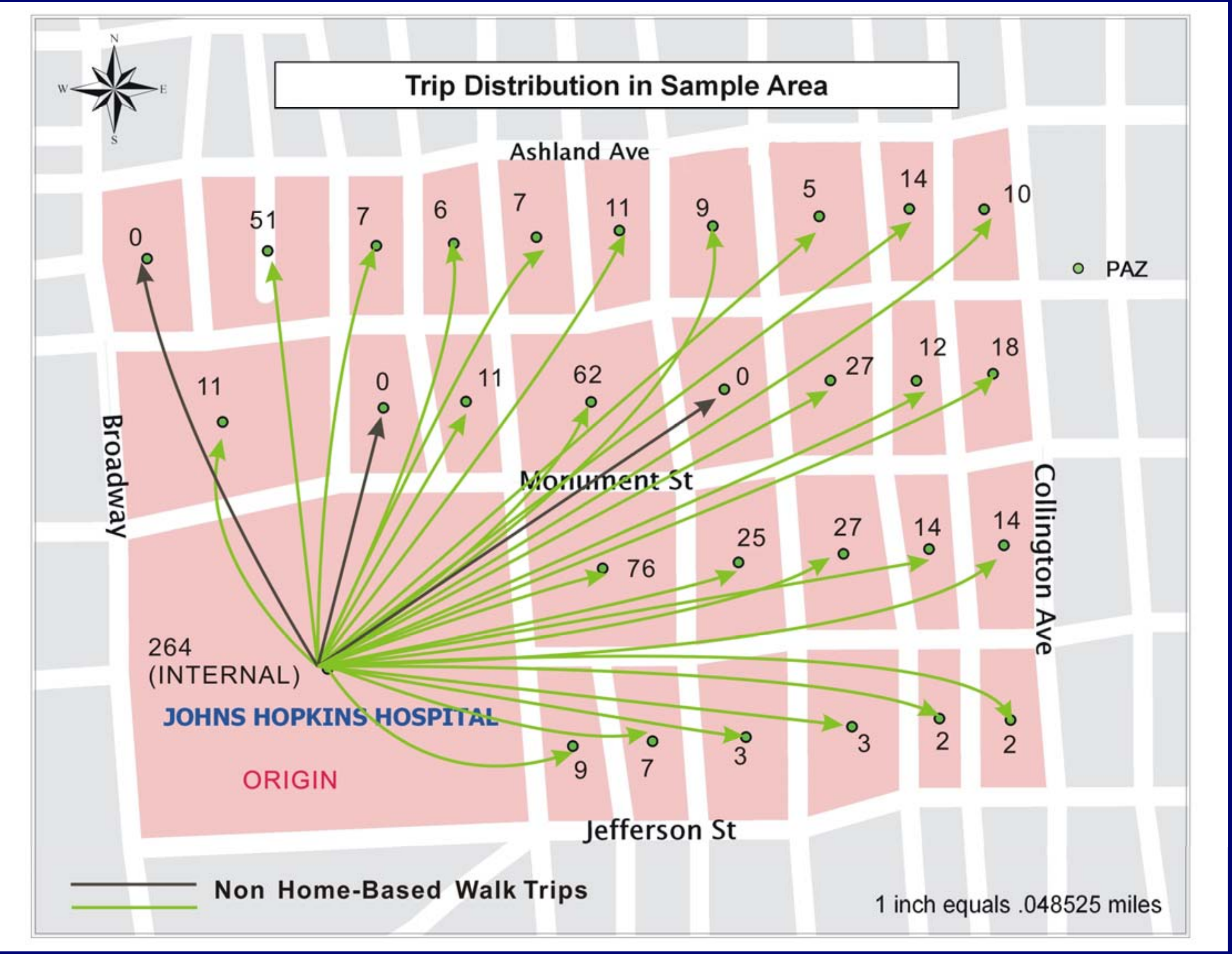
Where, Fij = Friction factor
dij = walk trip distance (meter)

Data source: 2001 NHTS

Trip Distribution: Home Based Walk Trips



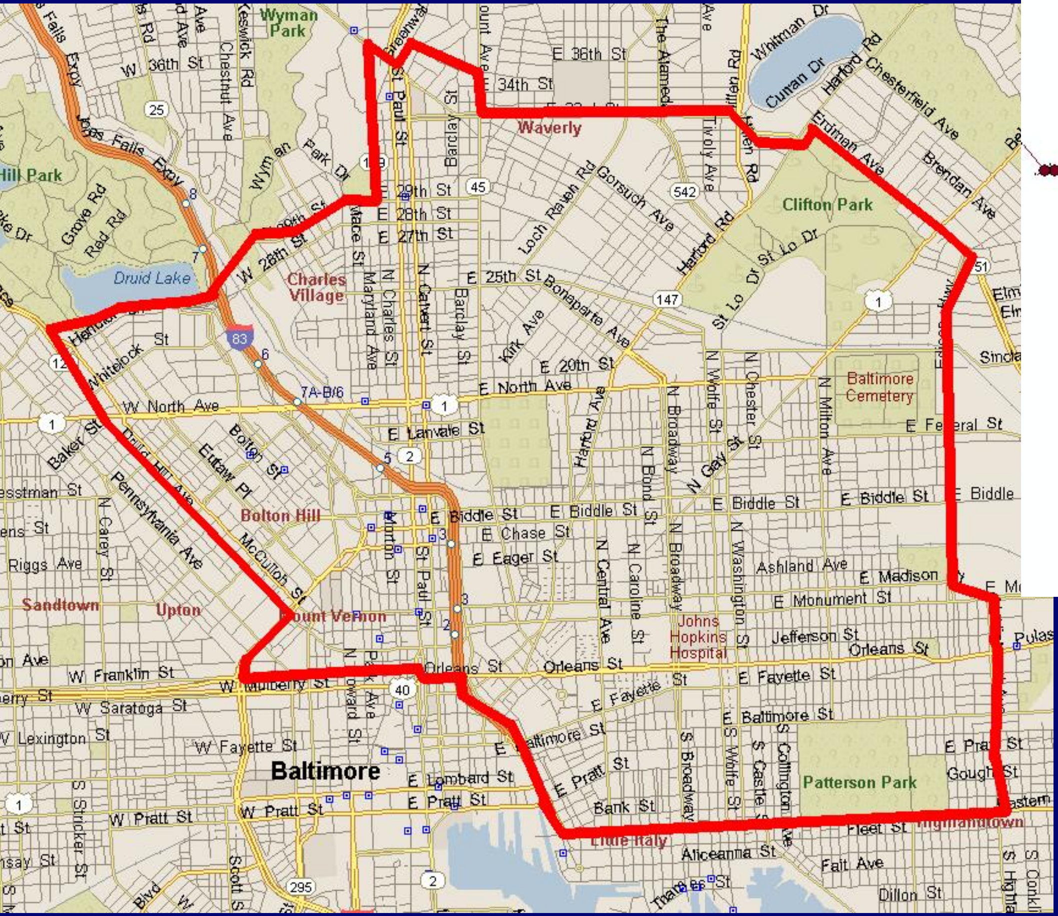
Trip Distribution: Non-Home Based Walk Trips

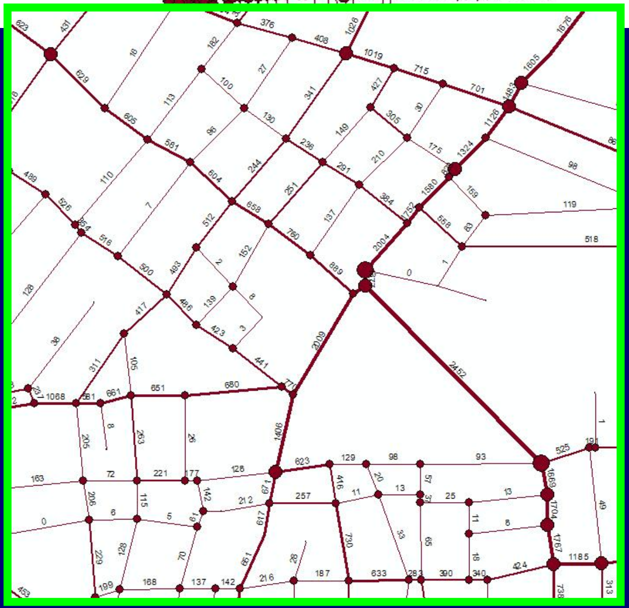


Route Assignment

- 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

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

Model output gives pedestrian volumes at intersections

Evaluation of Pedestrian Risk Exposure

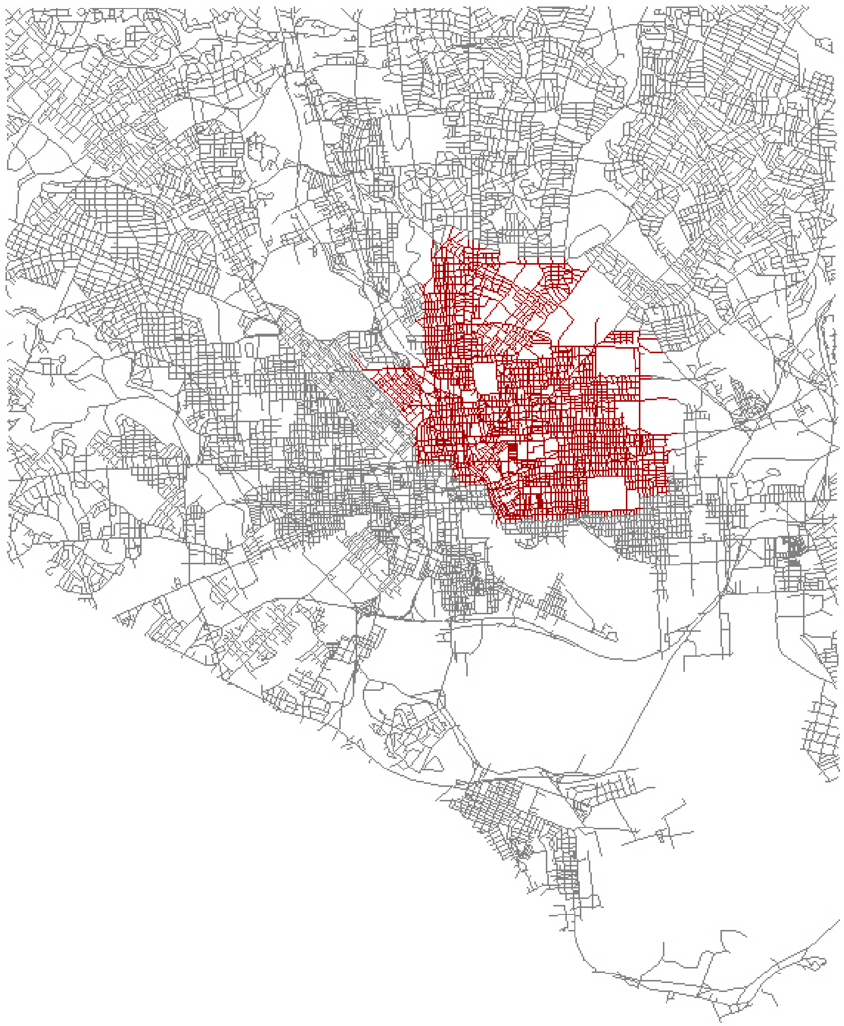
- Output of model provides missing data to estimate risk exposure
- Crash data available through police reporting, geo-referenced to nearest intersection
- Using equation, can rank intersections with highest risk exposure

Application Results

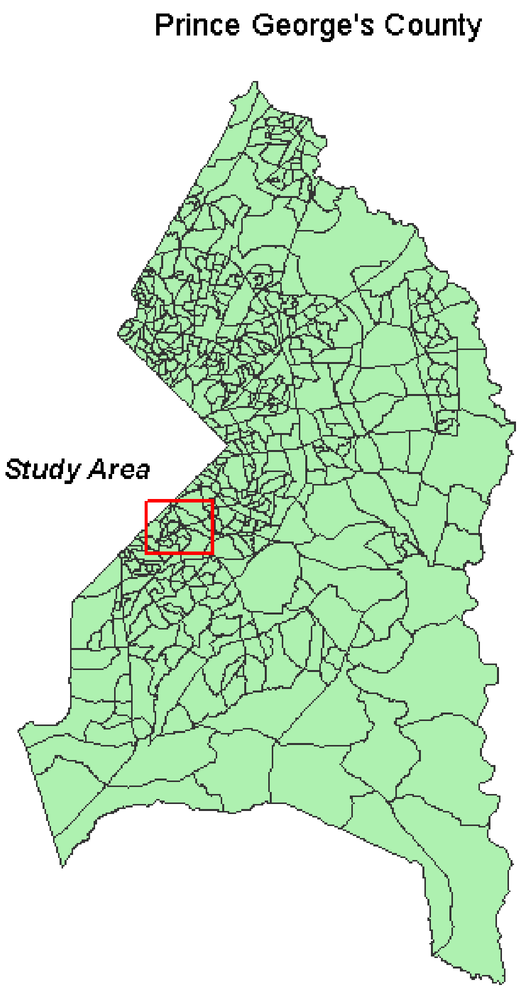
Application

- **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

Baltimore City



Prince George's County



Study area comparison

	Baltimore City	Prince George's County
Area Size (Square Miles)	10	4
Number of road segments	4322	478
Number of PAZ	1709	860
PAZ Type	Block centroid	Block face

Time cost estimates (hrs)

	Baltimore City	Prince George's County
Preparation of input files	4	4
Network construction	16	16
Land use calculation	16	8
Trip generation	5	5
Trip distribution (OD matrix)	4	1
Trip distribution (Tij table)	4	4
Trip assignment (File preparation)	4	4
Trip assignment (Processing)	48	6
Intersection volume	2	2
Total	160	54

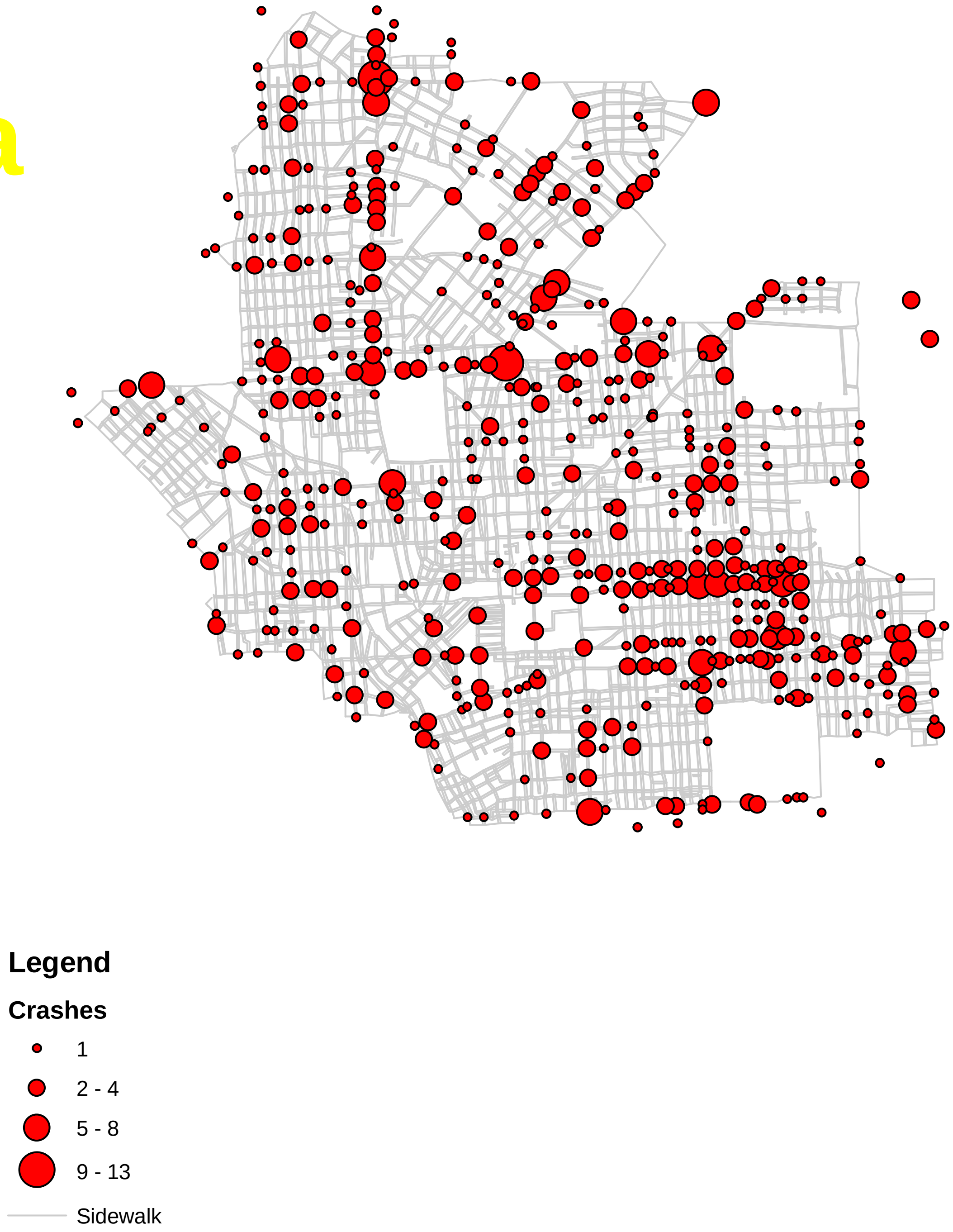
Pedestrian Volumes

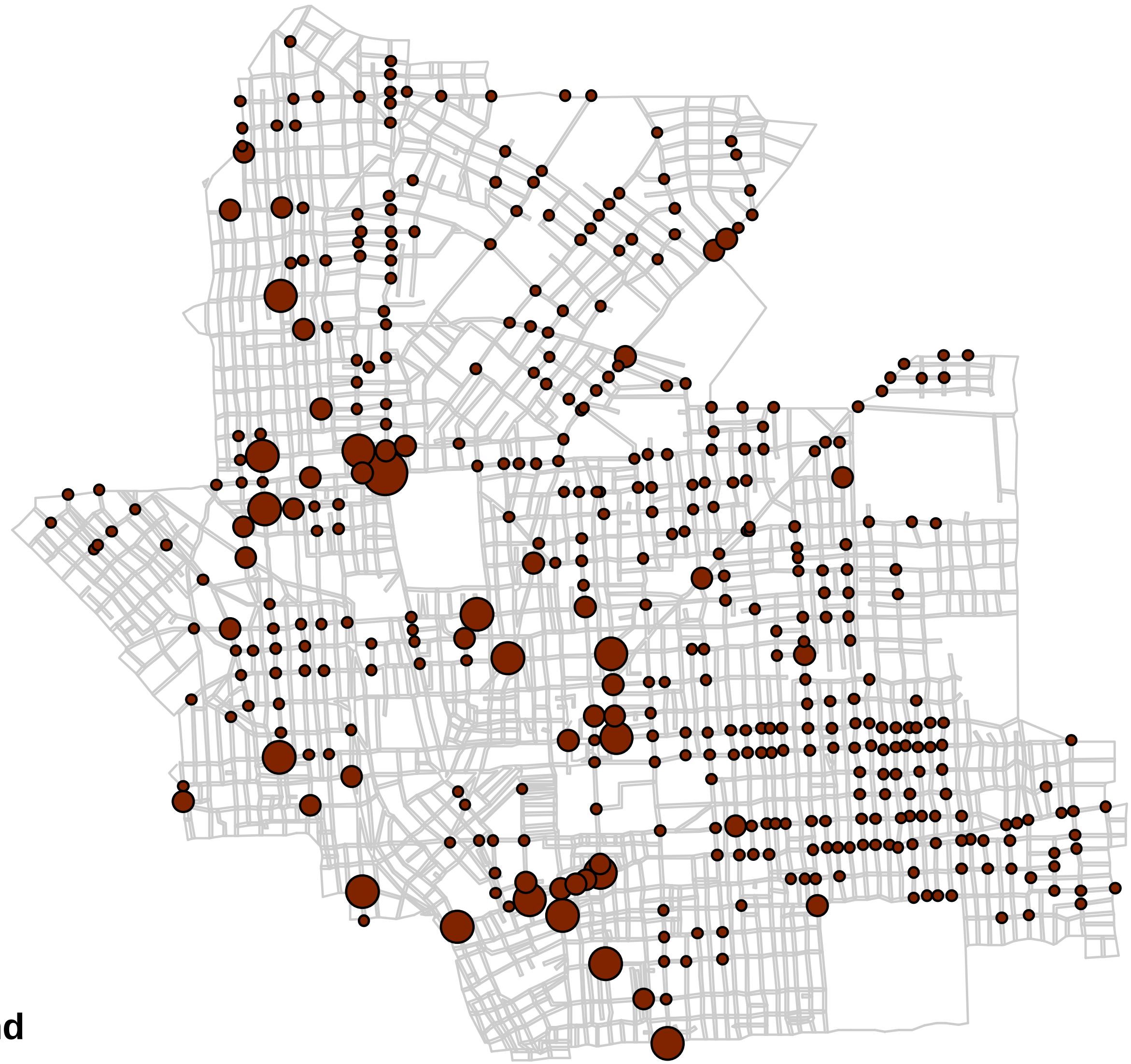
24 Pedestrian Volumes at Intersections

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

Crash Data

900 crashes between the years of 2000 to 2003





Legend

Sidewalk

Exposure Rate

0 - 150.00

150.01 - 450.00

450.01 - 1500.00

1500.01 - 3865.58

Pedestrian Risk Exposure

Top Intersections – Risk Exposure

Baltimore City

RANK	ADDRESS	CRASHES	EXPOSURE Crashes per million
1	NORTH & GREENMOUNT	8	3865
2	PRATT & CAROLINE	3	1449
3	FRONT & FAYETTE	3	1449
4	CHARLES AND 20TH	7	845
5	MADISON & BOND	2	725
6	BROADWAY & EASTERN	6	724
7	CHASE & HARFORD	3	724
8	FAYETTE & CAROLINE	4	724
9	GUILFORD & SARATOGA	3	483
10	CHARLES & LAFAYETTE	3	483

Exposure analysis time cost (hrs)

Steps	Time cost
Geocode crash records	4
Spatially aggregate crashes at intersections	1
Spatially join volumes to number of crashes	1
Calculate exposure rates	1
Identify high risk locations	2

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

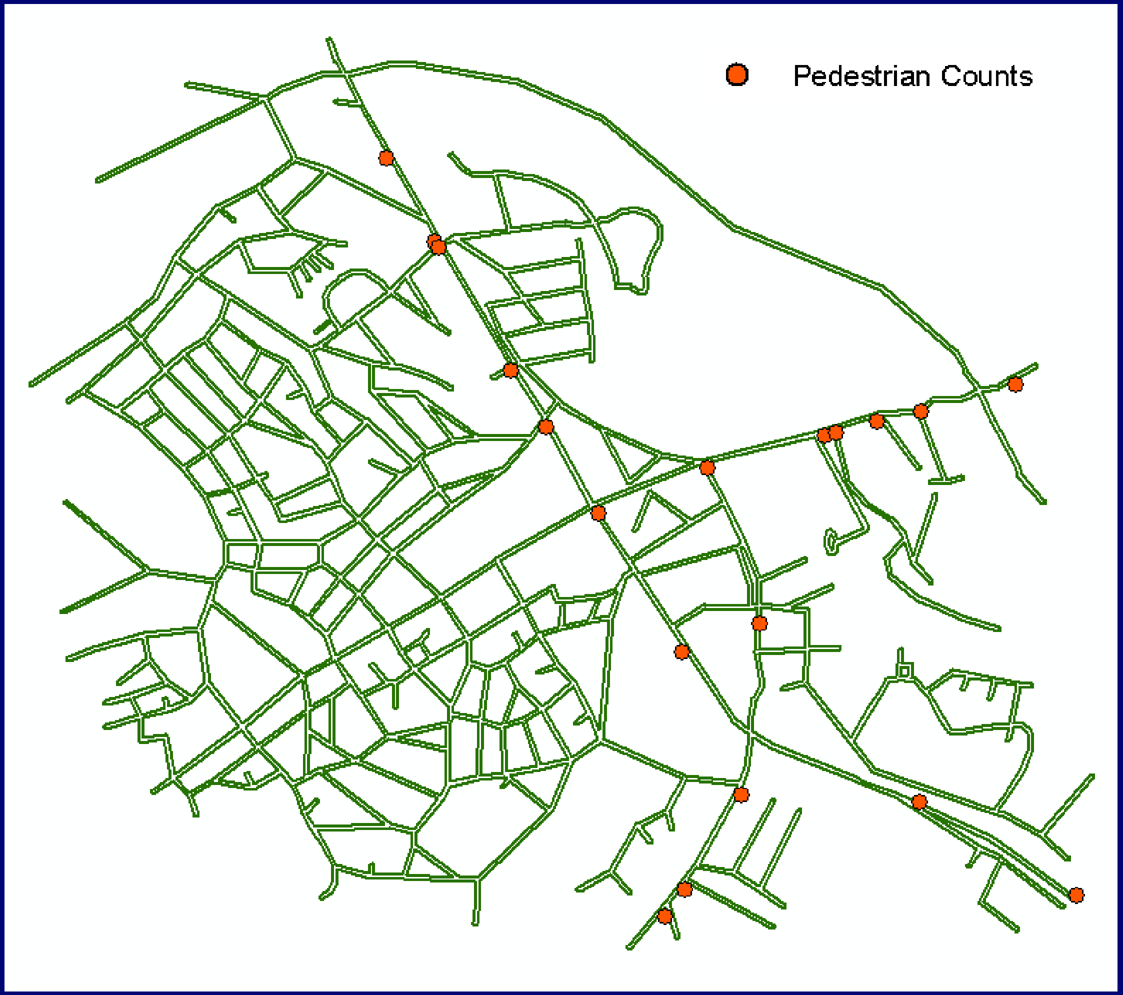
- **Used NHTS to calculate percentage of walk trips that occurred during peak hours:**

  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