Spatial Representation and Destination Choice: What are the Consequences of Modifying Reality?

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Outline

A. Research program
B. Research objectives & questions
C. Some basic concepts
D. Comparison of PPA algorithms
E. Evaluation of MAUP effects
F. Scale effect & grocery shopping
G. Lessons learned
H. Future research

GEOIDE
NSERC CRSNG
National Science Foundation
WHERE DISCOVERIES BEGIN

A. Research Program

- Goals
  - Enhance our understanding of decision processes underlying activity/travel behavior
  - Incorporate said understanding in policy-sensitive activity/travel demand models (e.g., MUSCAMAGS Project)

- Tools
  - Statistical and econometric techniques
  - GIS (realistic travel environment, variable generation, software applications)

A. Research Program

- Data
  - GIS layers (e.g., street networks, opportunities, land uses)
  - Existing activity/travel surveys (e.g., TTS for GTA, TDS for Louisville KY)
  - New data collection techniques (e.g., Halifax STAR Project & GPS)

B. Research Objectives & Questions

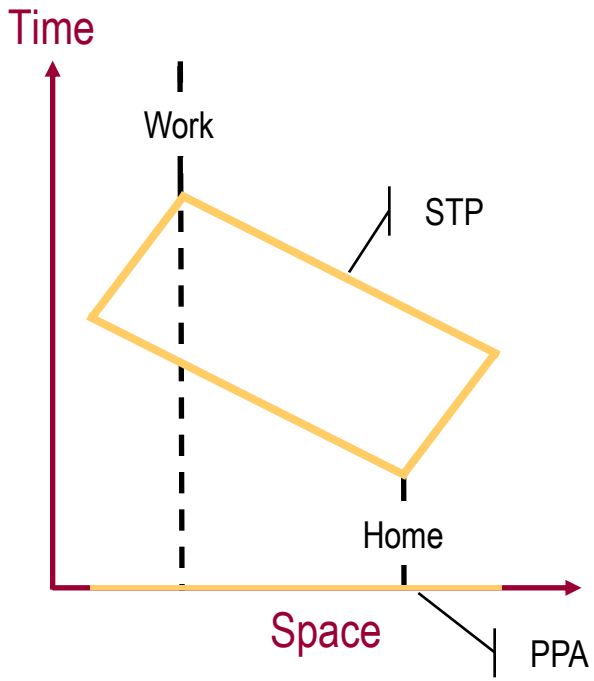
- Objectives
  - Incorporate spatio-temporal constraints into destination choice
  - Estimate constrained destination choice models
    - Sylvia He (2004-06) – shopping location

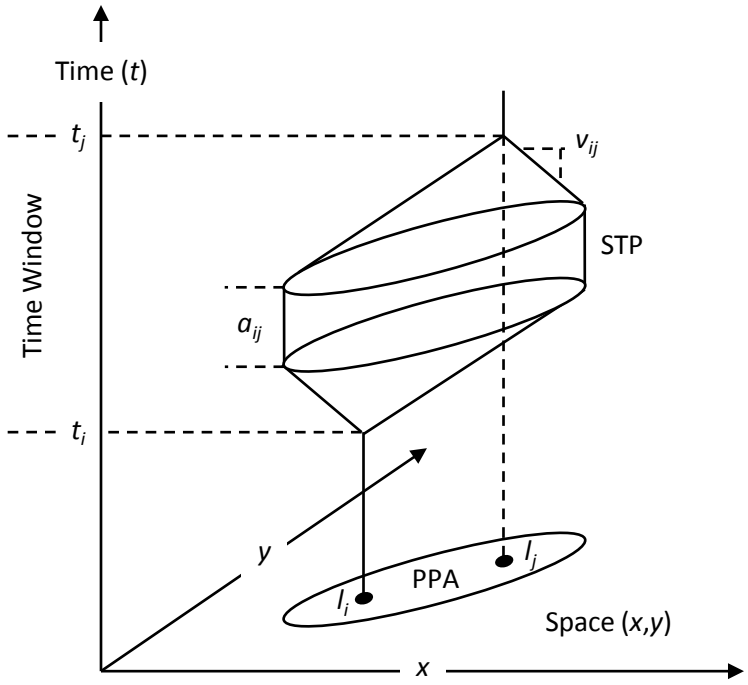
- Questions
  - How do I do this?
  - How does spatial representation impact choice sets?

C. Some Basic Concepts

- Space-time prism (STP)
  - Time geography (Hägerstrand, 1970)
  - Spatial and temporal limits for decisions concerning out-of-home activity participation
  - Constrained destination choice sets
  - 3D
- Potential path area (PPA)
  - 2D representation of STP
  - Implemented via GIS

C. Some Basic Concepts





C. Some Basic Concepts

C. Representation

- Objects:
  - 3 primitives: 0-dimensional points, 1-dimensional lines, 2-dimensional areas
  - Vector data model in GIS

- Fields:
  - Continuous surface (values change at all locations)
  - Raster data model in GIS

C. Points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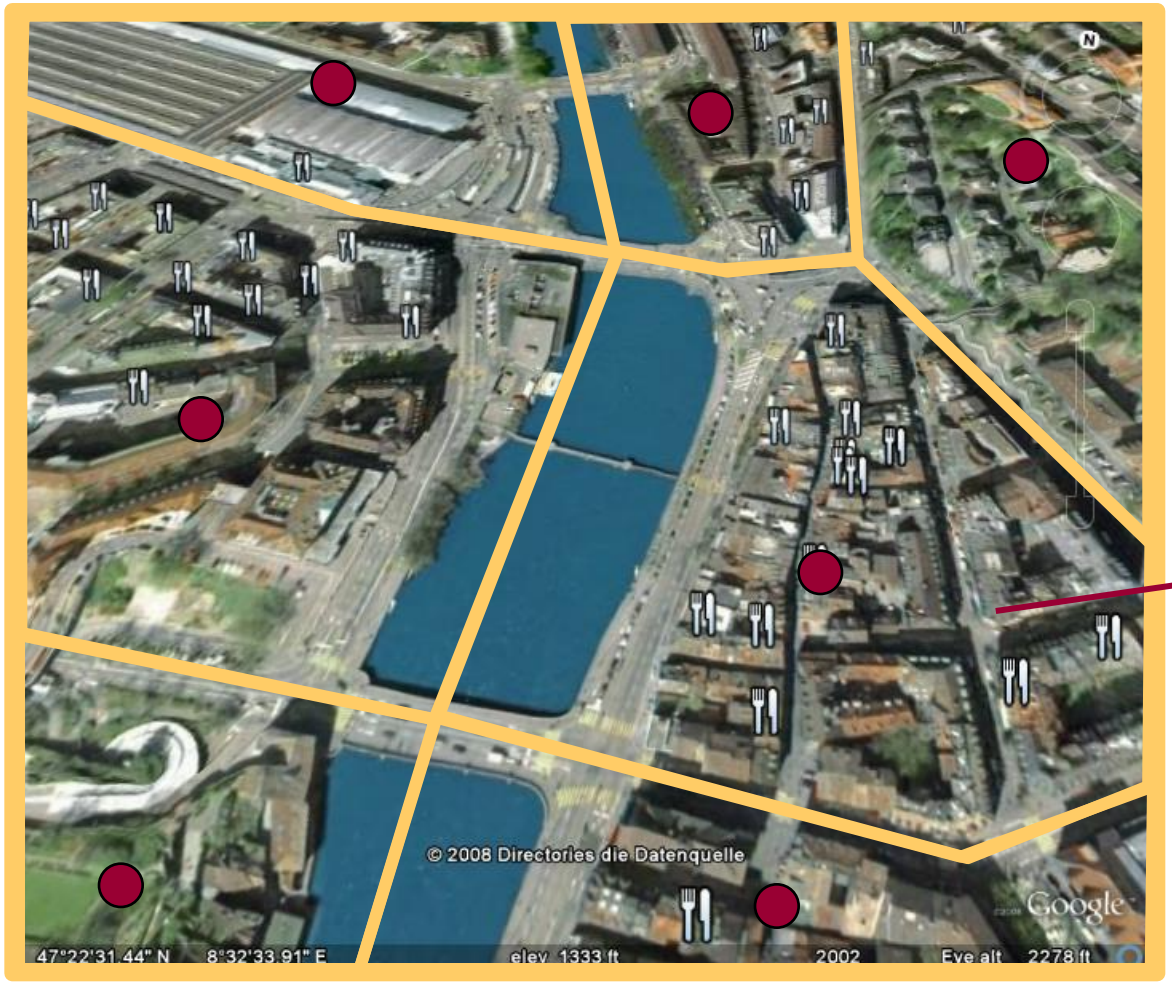
Google
47°22'31.44" N 8°32'33.91" E elev 1333 ft 2002 Eye alt 2278 ft

C. Areas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Google
47°22'31.44" N 8°32'33.91" E elev 1333 ft 2002 Eye alt 2278 ft

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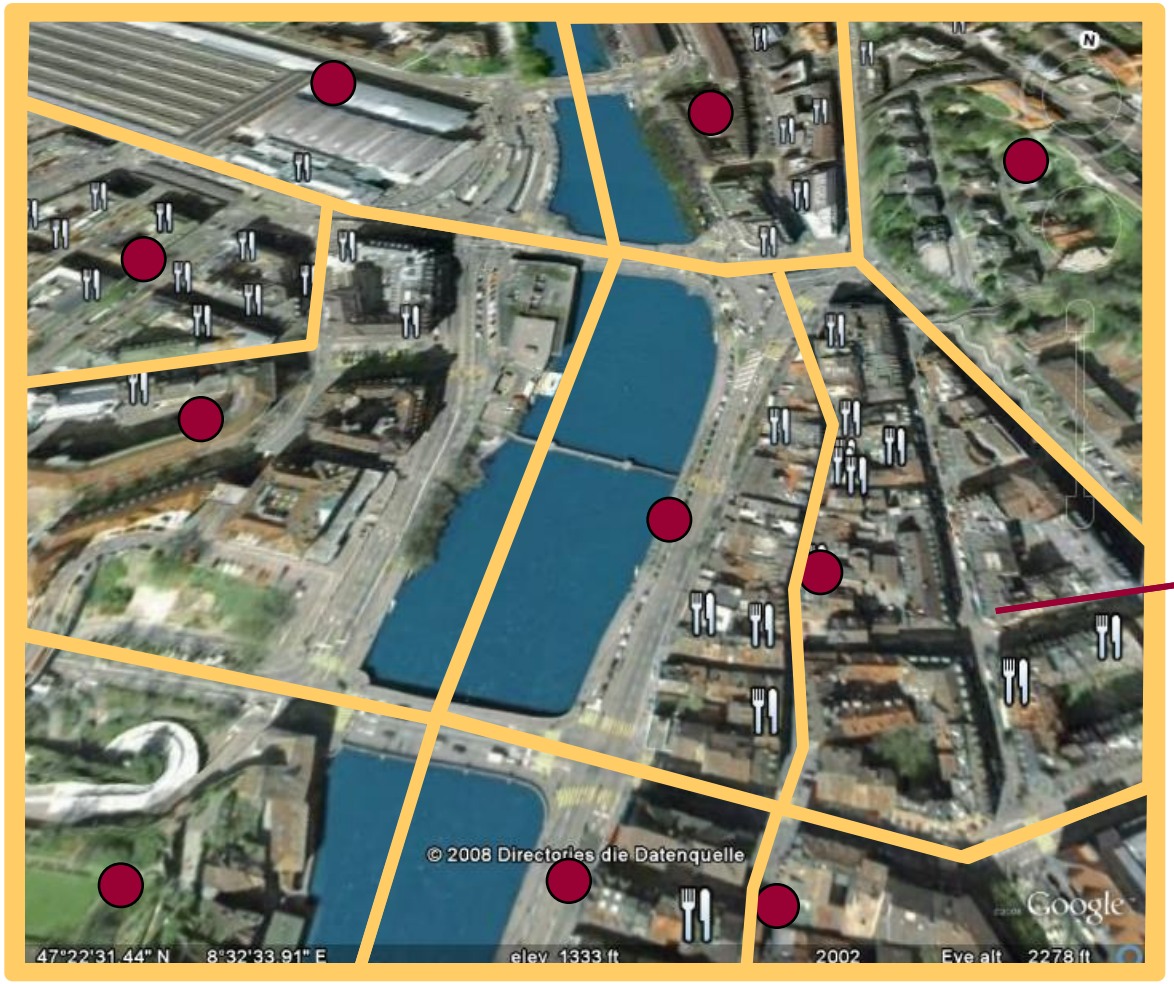
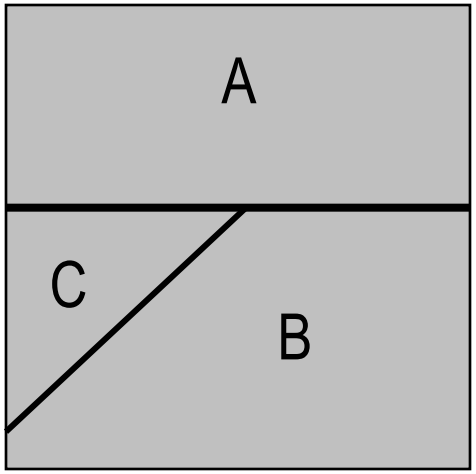
C. Some Basic Concepts

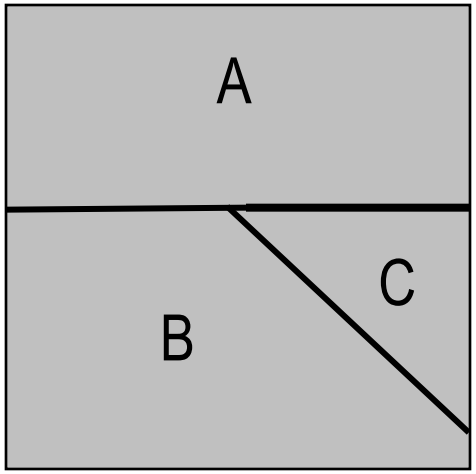
- Modifiable Areal Unit Problem (MAUP)
  - Well-known spatial analytical issue that has yet to be solved
  - Arises due to the fact that an infinite number of zoning systems can be constructed to subdivide space into smaller areal units
  - Scale effects
    - Level of spatial resolution
  - Zoning effects
    - Configuration of the zoning system given a fixed level of spatial resolution

C. MAUP: Scale Effects



C. MAUP: Zoning Effects

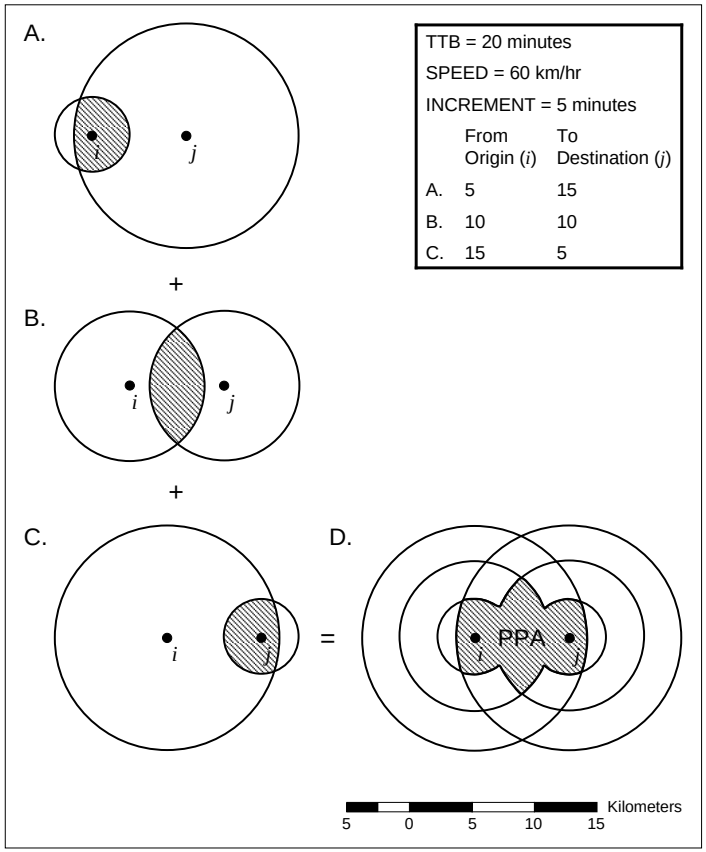




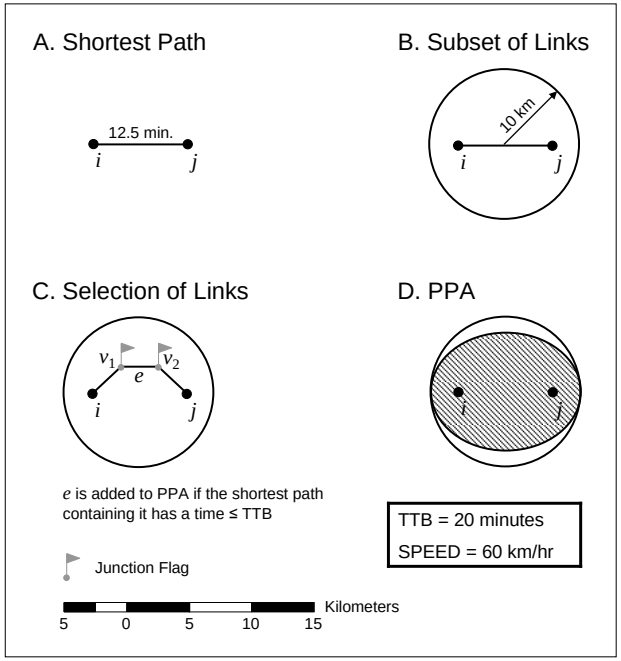
D. Comparison of PPA Algorithms

- Objective
  - Compare two GIS-based algorithms for generating space-time prisms (specifically PPAs) to assess which one will offer more realistic results if implemented within the framework of an activity/travel demand model
  - Algorithm 1, based on the work of Kwan and Hong (1997), is implemented within ArcView GIS
  - Algorithm 2, developed by Scott, is implemented within ArcGIS

D. Algorithm 1: Overlay Approach

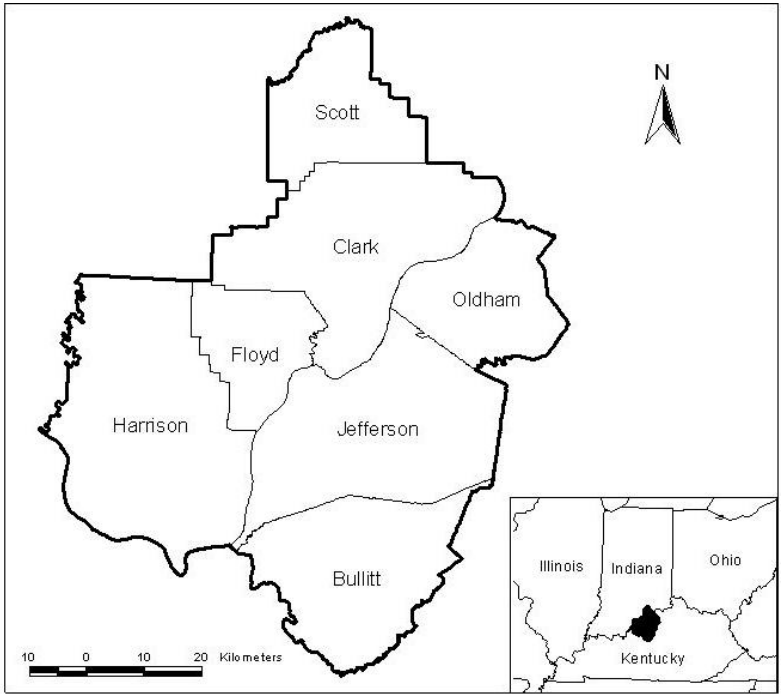


D. Algorithm 2: Shortest Path Approach

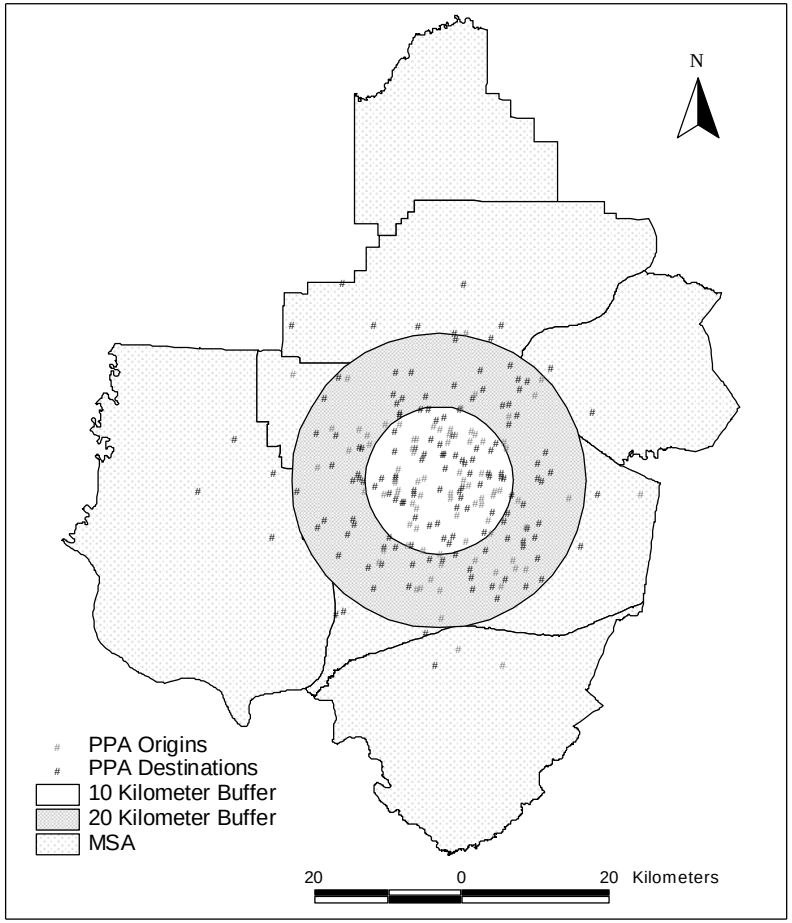


D. Study Area and Data

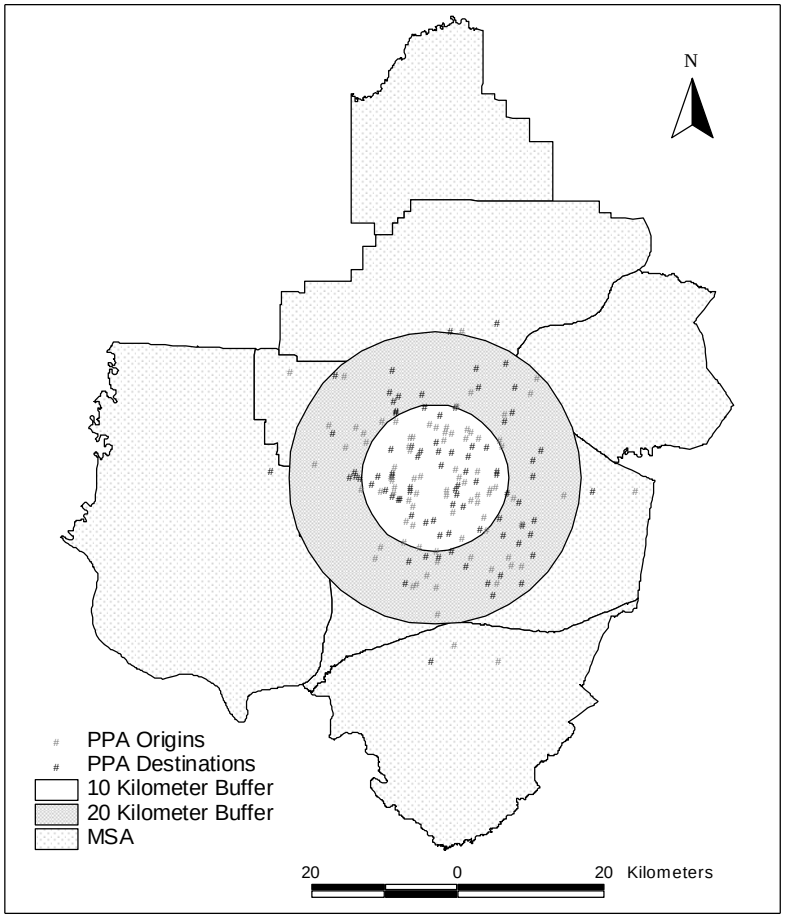
- Activity/travel
  - Synthetic data set
    - Random sampling program (GAUSS)
    - Normal distributions of coordinate pairs for origins and destinations of trips
  - Observations
    - Unique identifier
    - Origin latitude
    - Origin longitude
    - Destination latitude
    - Destination longitude
    - 20-minute travel time budget



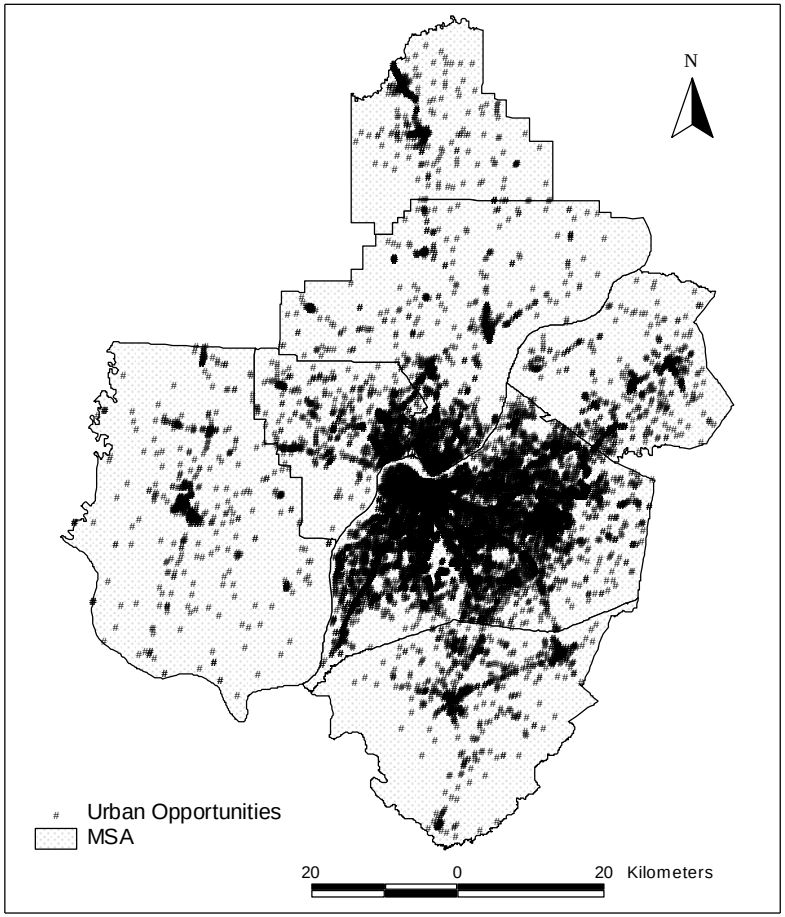
D. Original Data Set



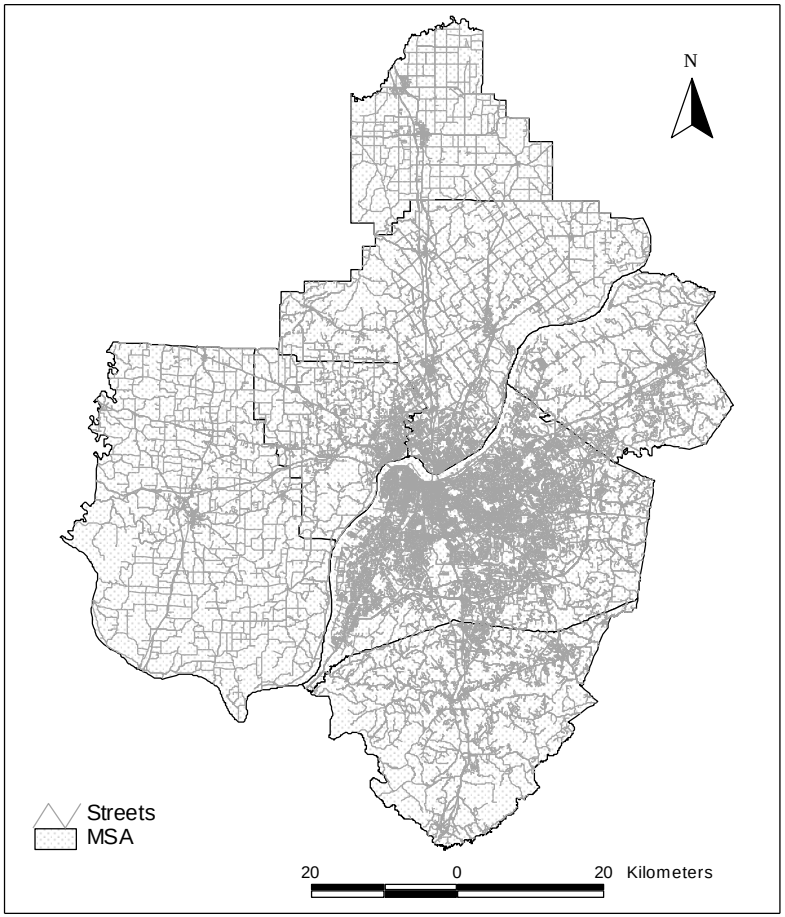
D. Reduced Data Set



D. Opportunities



D. Street Network



D. Definition of Variables

Variable	Definition
INT-1	PPAs created by Algorithm 1 using a one minute time interval
INT-2	PPAs created by Algorithm 1 using a two minute time interval
INT-3	PPAs created by Algorithm 1 using a three minute time interval
INT-4	PPAs created by Algorithm 1 using a four minute time interval
INT-5	PPAs created by Algorithm 1 using a five minute time interval
INT-6	PPAs created by Algorithm 1 using a six minute time interval
INT-7	PPAs created by Algorithm 1 using a seven minute time interval
INT-8	PPAs created by Algorithm 1 using a eight minute time interval
INT-9	PPAs created by Algorithm 1 using a nine minute time interval
INT-10	PPAs created by Algorithm 1 using a ten minute time interval
ALG2	PPAs created by Algorithm 2

D. Buffer Area Comparison

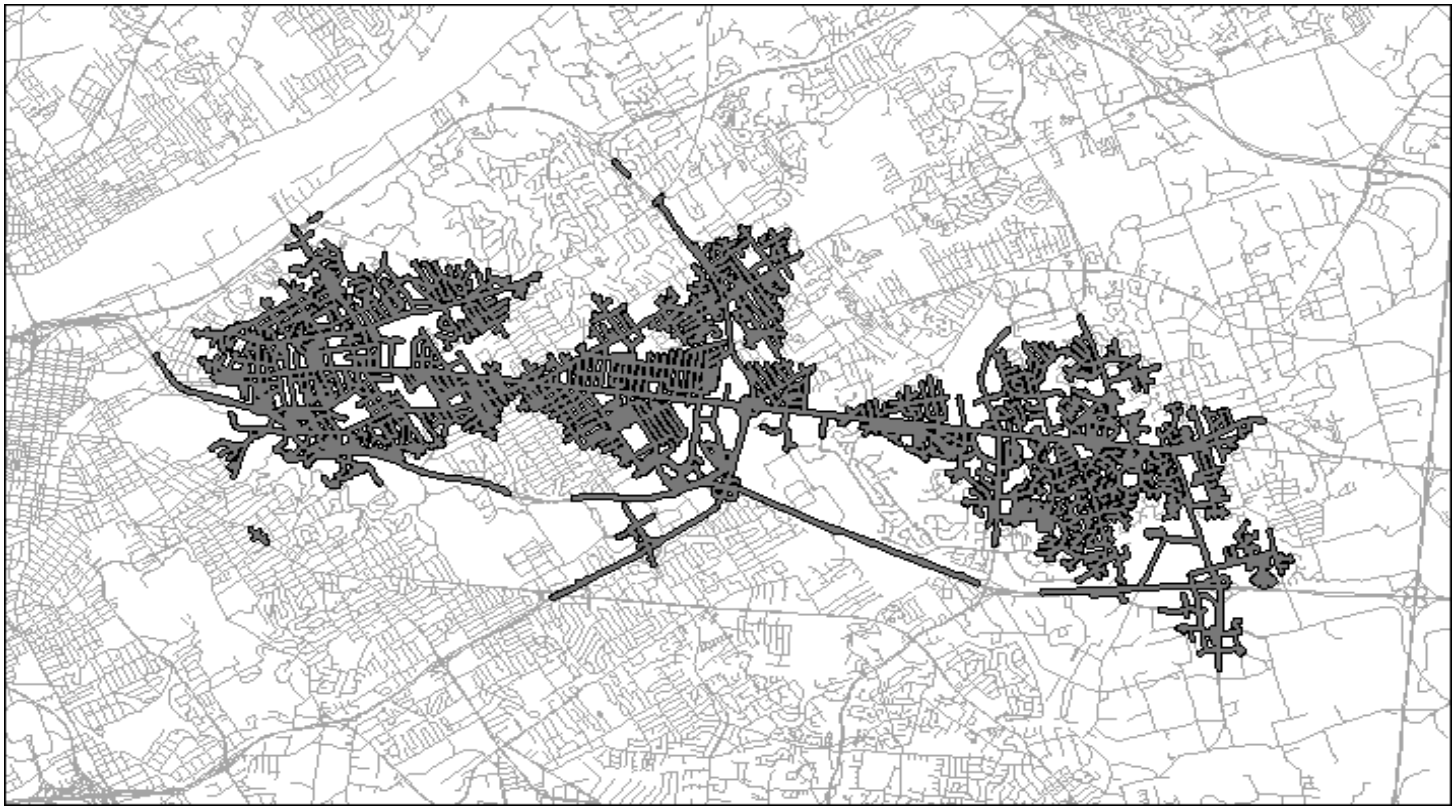
	Signed Rank Test Statistic[a]									
	INT-2	INT-3	INT-4	INT-5	INT-6	INT-7	INT-8	INT-9	INT-10	ALG2
INT-1	1350***	1350***	1350***	1351***	1347***	1388***	1378***	1362***	1352***	-1755***
INT-2		1183***	1200***	1238***	1247***	1361***	1346***	1337***	1342***	-1777***
INT-3			1236***	1425***	1332***	1425***	1392***	1381***	1361***	-1797***
INT-4				1055***	1168***	1419***	1404***	1402***	1375***	-1803***
INT-5					705***	1267***	1218***	1171***	1167***	-1812***
INT-6						1378***	1276***	1252***	1287***	-1822***
INT-7							-706***	-441**	-472**	-1828***
INT-8								-333*	-381**	-1828***
INT-9									-249	-1828***
INT-10										-1828***

[a] Differences for the signed rank test statistic are computed as row variable minus column variable. This means that if the statistic is positive, the row variable has the larger buffer area. In turn, if the statistic is negative, the column variable has the larger buffer area.

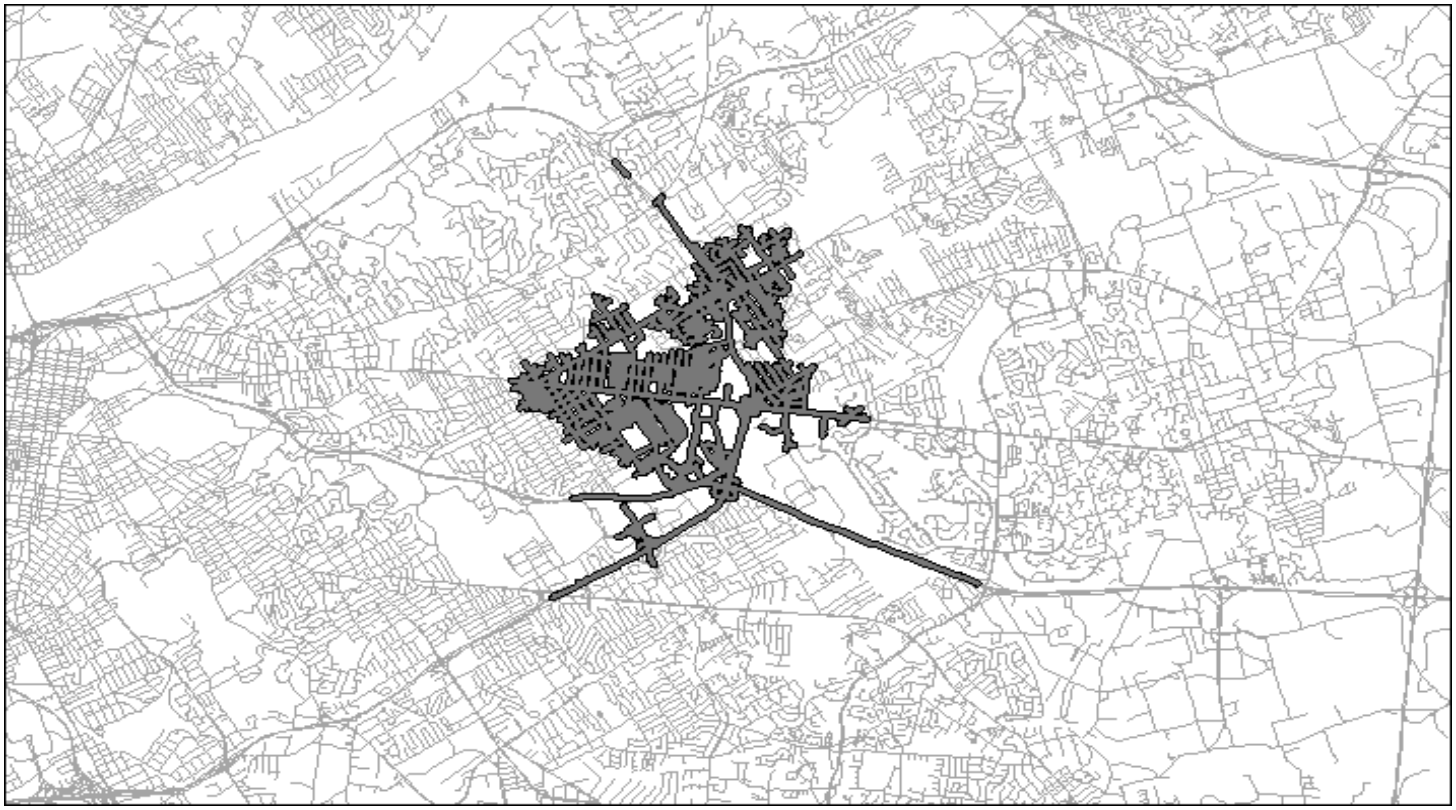
Note: * significant at the 0.10 level; ** significant at the 0.05 level; *** significant at the 0.0001 level.

D. Algorithm 1: INT-1

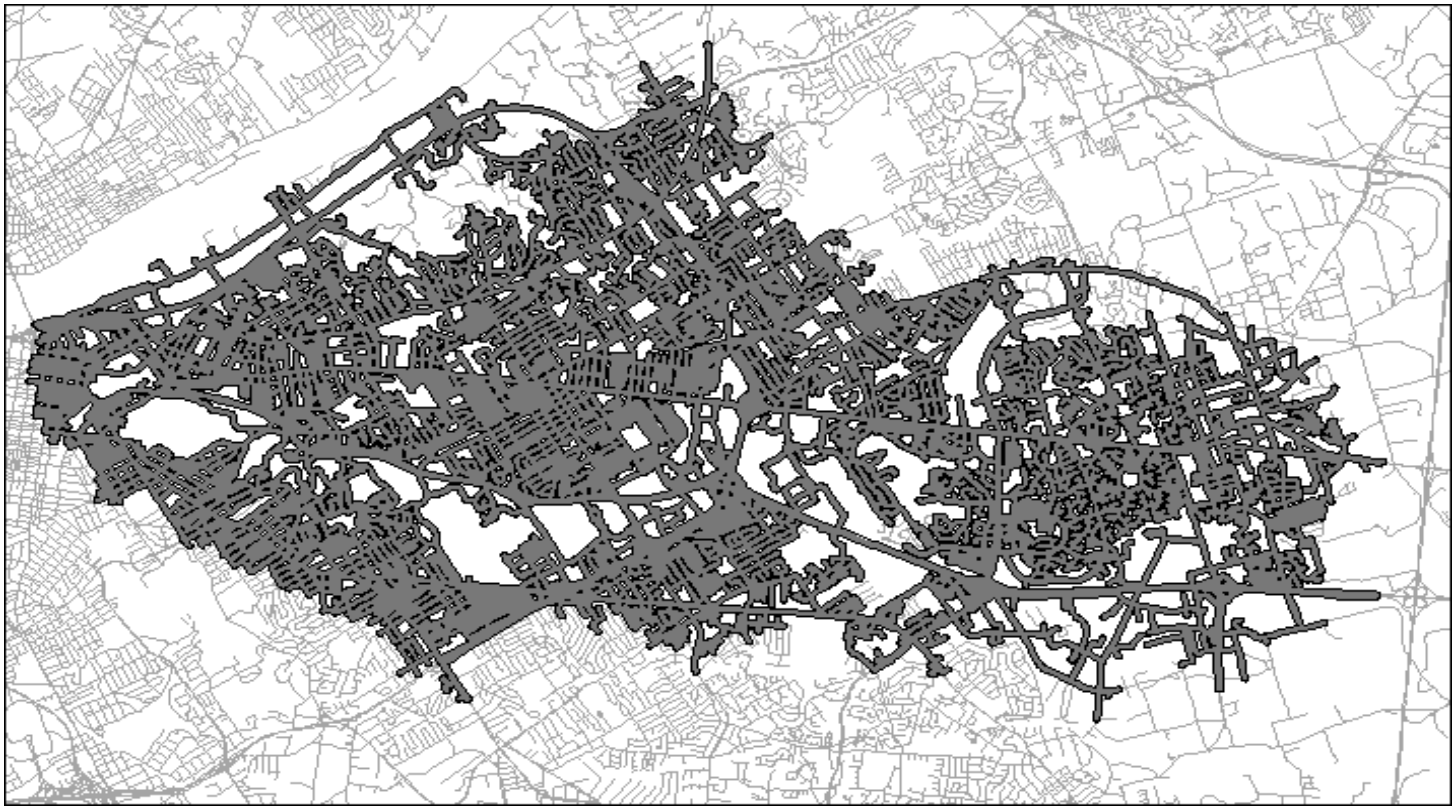
D. Algorithm 1: INT-5



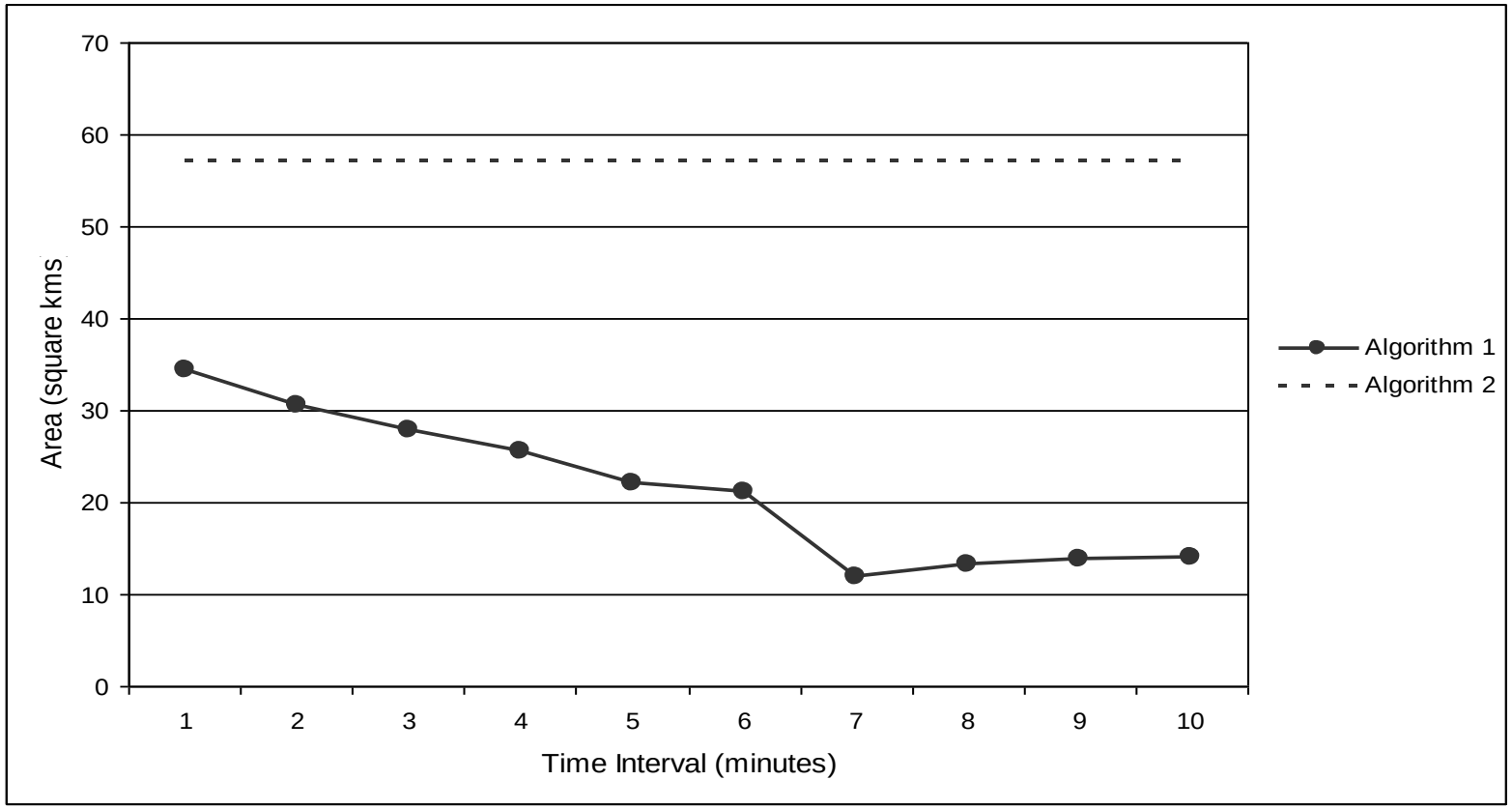
D. Algorithm 1: INT-10



D. Algorithm 2



D. Buffer Area Comparison: Averages



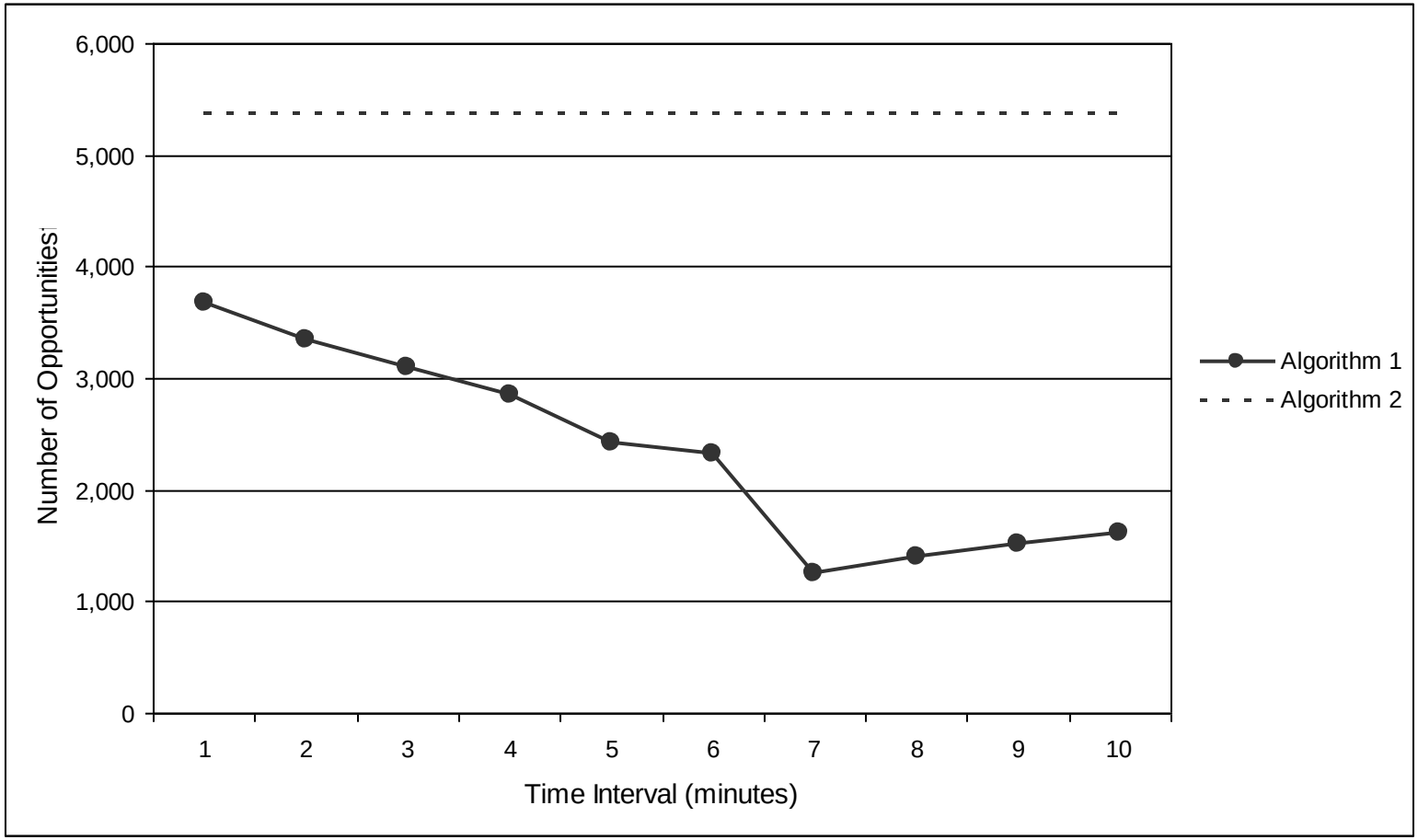
D. Opportunity Comparison

	Signed Rank Test Statistic[a]									
	INT-2	INT-3	INT-4	INT-5	INT-6	INT-7	INT-8	INT-9	INT-10	ALG2
INT-1	1313***	1314***	1278***	1315***	1314***	1360***	1350***	1333***	1316***	-1313***
INT-2		1015***	1123***	1221***	1266***	1339***	1323***	1325***	1345***	-1373***
INT-3			833***	1280***	1351***	1379***	1323***	1351***	1369***	-1352***
INT-4				761***	1068***	1330***	1343***	1333***	1295***	-1367***
INT-5					560**	1108***	1025***	1070***	1185***	-1366***
INT-6						1188***	970***	1084***	1081***	-1375***
INT-7							-652***	-592***	-575**	-1388***
INT-8								-611**	-523**	-1388***
INT-9									-354**	-1388***
INT-10										-1388***

[a] Differences for the signed rank test statistic are computed as row variable minus column variable. This means that if the statistic is positive, the row variable has the larger number of urban opportunities. In turn, if the statistic is negative, the column variable has the larger number of urban opportunities.

Note: * significant at the 0.10 level; ** significant at the 0.05 level; *** significant at the 0.0001 level.

D.9. Urban Opportunity Comparison: Averages



D. Conclusions

- PPAs, which delimit “realistic” or constrained destination choice sets, should be implemented within activity-based travel demand models
- As demonstrated, however, the GIS-based algorithms available to generate them can significantly impact results
- If accuracy is to be ensured, a shortest path approach should be used instead of an overlay approach

E. Evaluation of MAUP Effects

- How should destinations for out-of-home activities be represented?
  - Points vs. polygons
  - Implications for “constrained” destination choice modeling
- Outside the MATSIM world, points present challenges when developing activity-based travel demand models
  - Traffic assignment models
  - Updating urban opportunities through time
  - Computational cost (lots of opportunities)

E. Evaluation of MAUP Effects

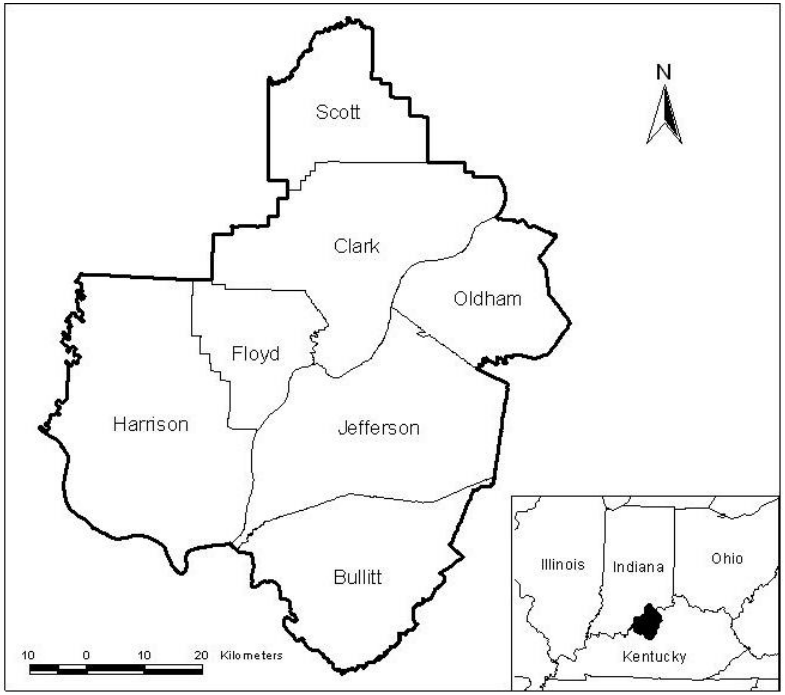
- Area-based (i.e., zonal) representation of space is typical
  - MAUP effects: scale effect (resolution) and zoning effect (configuration)
  - Effects will inflate the number of urban opportunities contained within space-time prisms (network-based prisms become grid-based) and their PPA 2D equivalents
  - To what degree?

E. Evaluation of MAUP Effects

- Challenge
  - Use a zoning system that incorporates spatio-temporal constraints in such a way that MAUP effects are minimized
- Objective
  - Evaluate MAUP effects on space-time prisms, and therefore, destination choice sets

E. Data and Methods

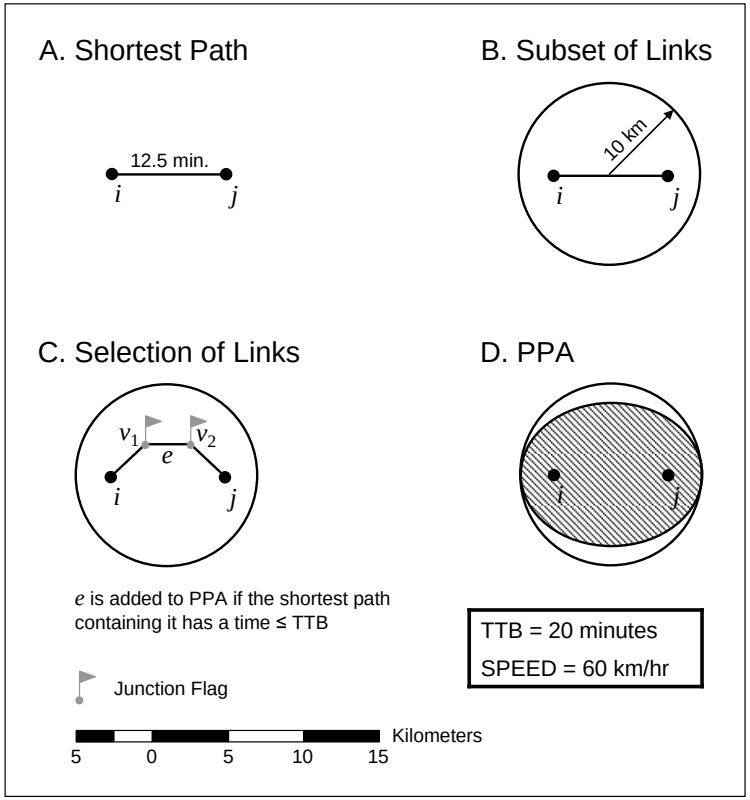
- Primary data
  - Travel diary survey
    - KIPDA, 2000
    - 4,383 households
    - 200 randomly selected for analysis
  - Opportunity database
    - infoUSA
    - 34,440 opportunities
  - Street network
    - Dynamap/Transportation 4.0
    - > 92,000 links

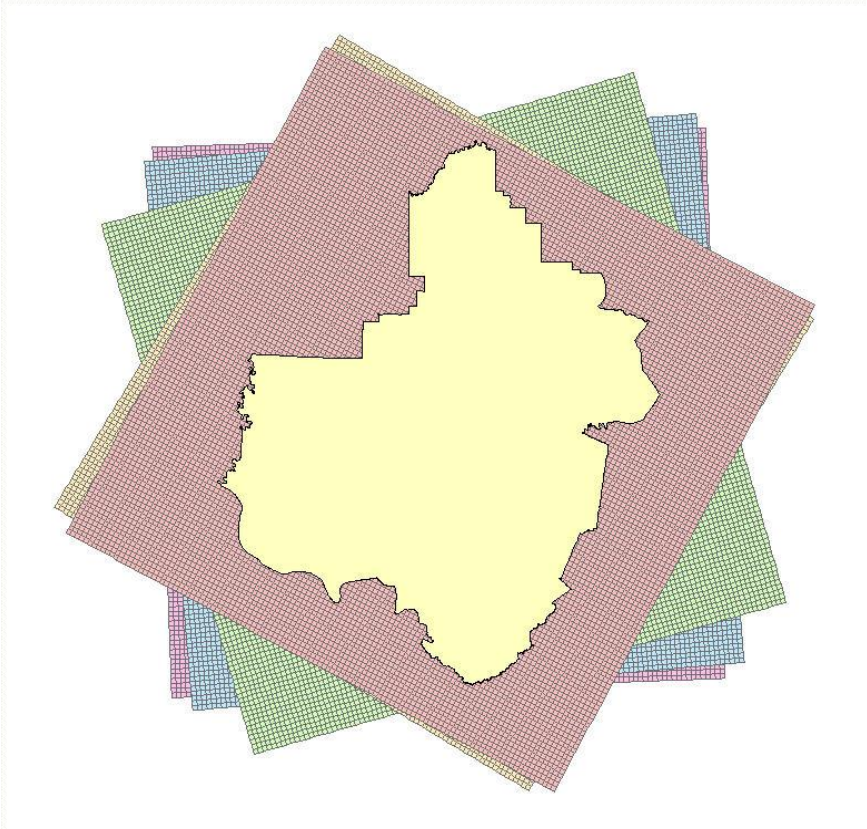


E. Data and Methods

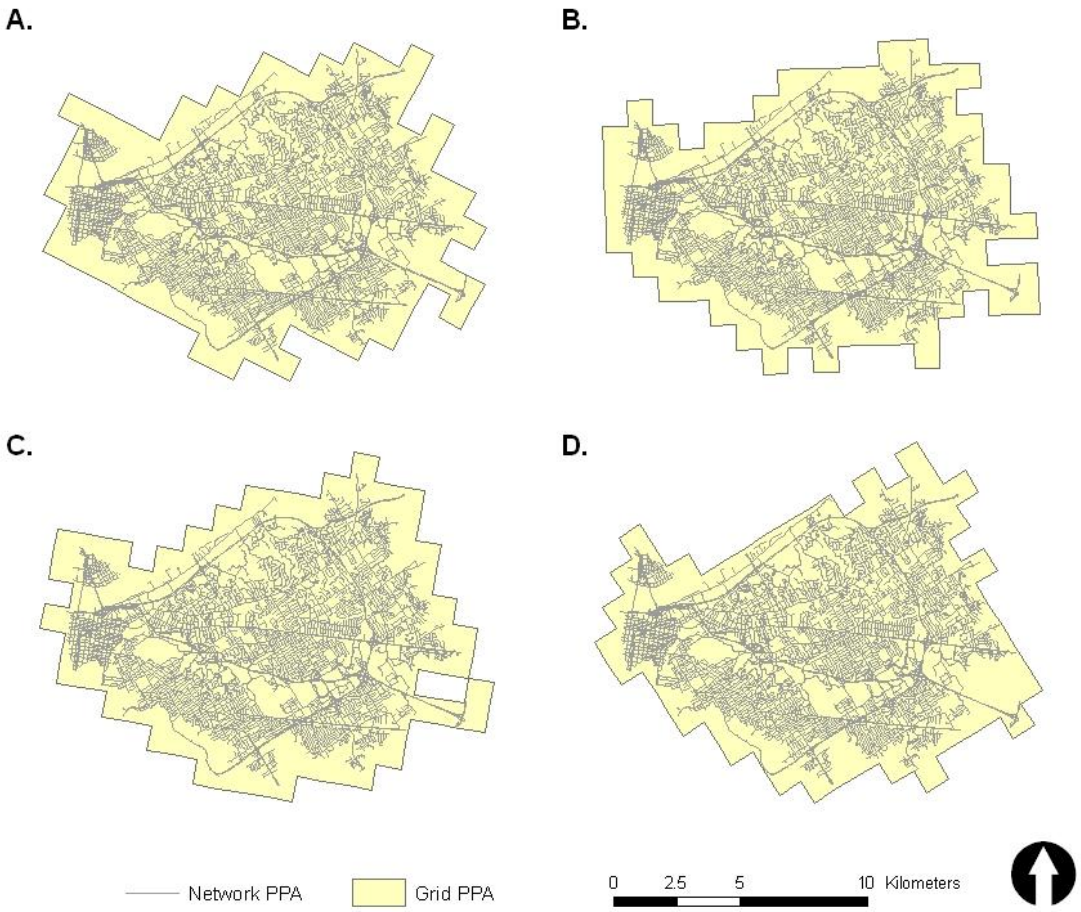
- Derived data:
  - 289 network-based PPAs
    - Actual travel behavior of household members
    - Criteria: ≥ 16 years, automobile
    - Shortest path approach (software written in ArcGIS)
  - 144,500 grid-based PPAs
    - 500 randomly generated grids
      - 50 for each of 10 pre-specified grid sizes (1 to 10 sq. km)
      - Random horizontal shift (up to resolution), random vertical shift (up to resolution), random rotation (0 to 360 degrees)
    - Network-based PPAs intersected with each grid
  - Comparative measures: number of opportunities (total and by type), weights of opportunities (total and by type) and segment length (km)
    - Number of all opportunities used in analysis

E. Data and Methods

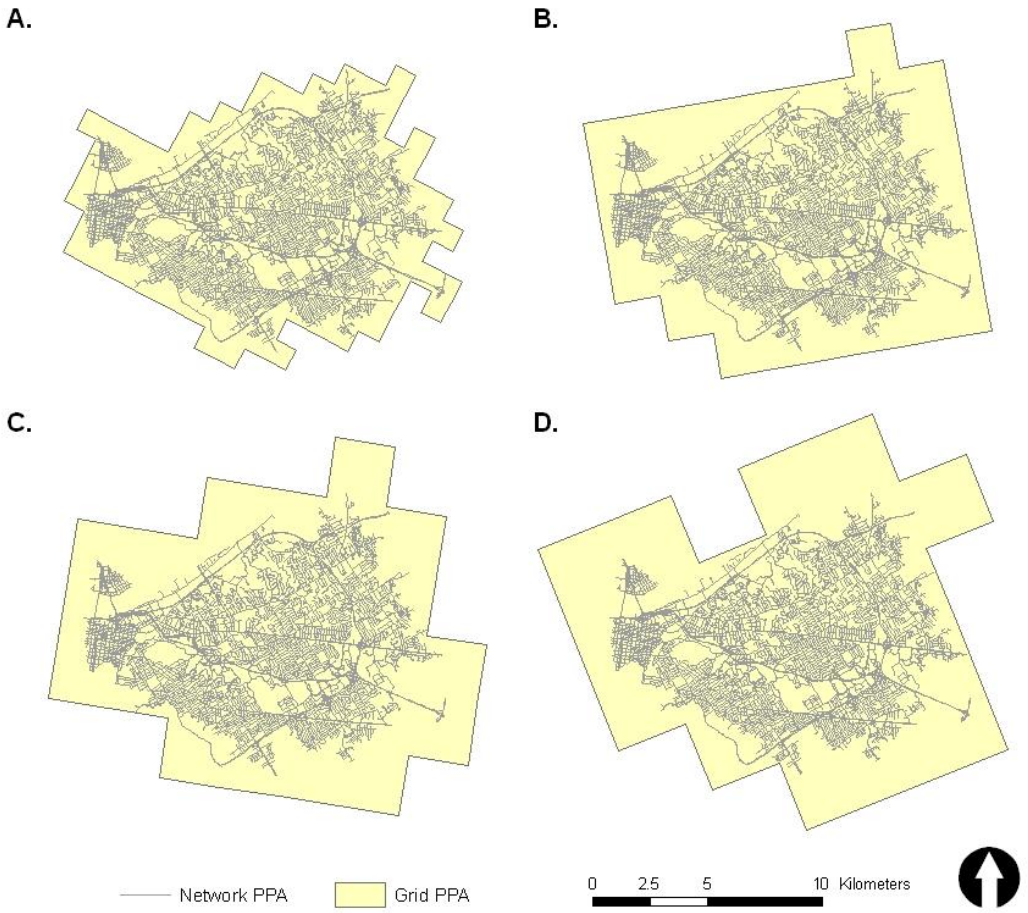




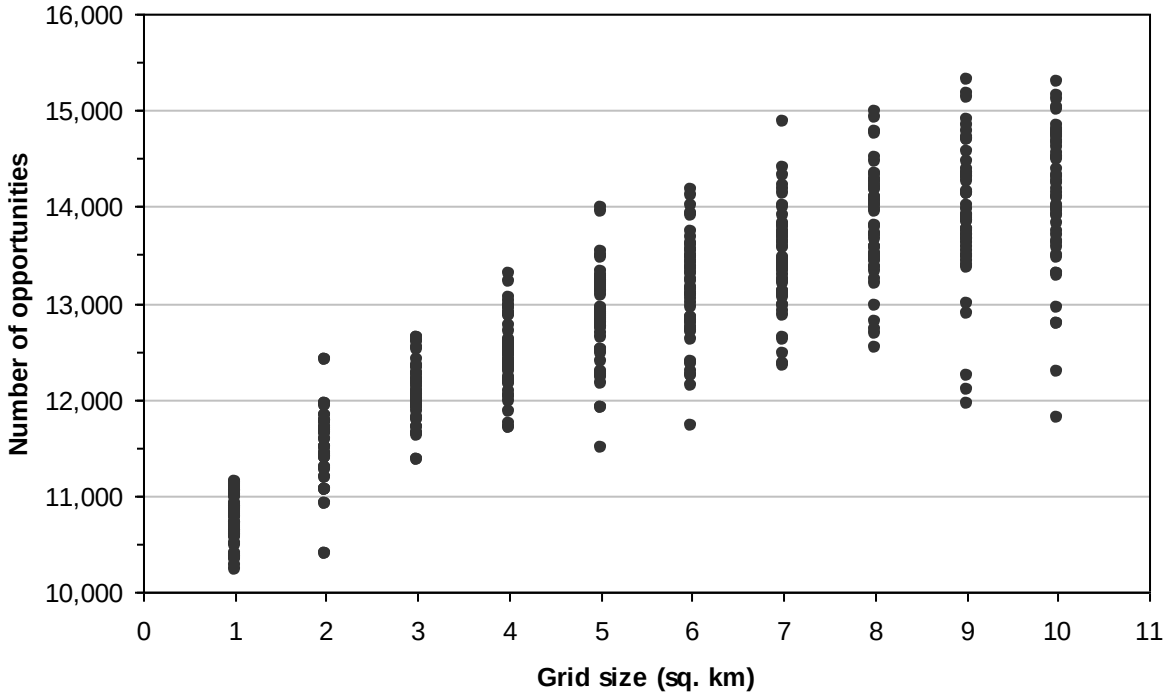
E. Evaluation of Zoning Effects: Example PPA



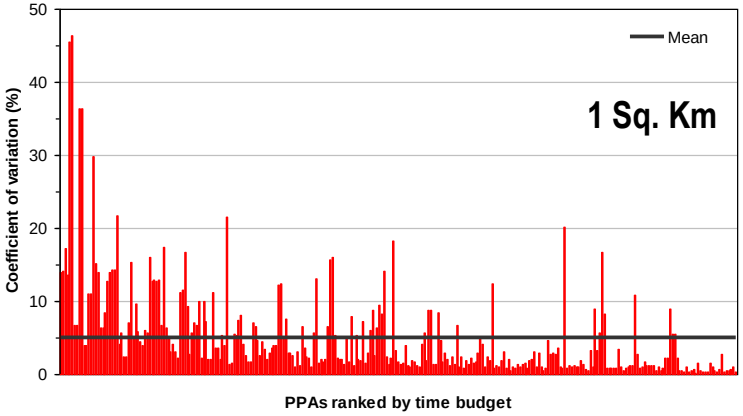
E. Evaluation of Scale Effects: Example PPA

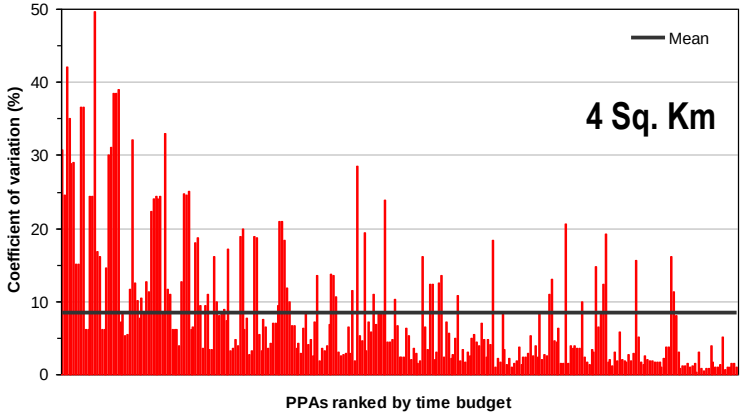


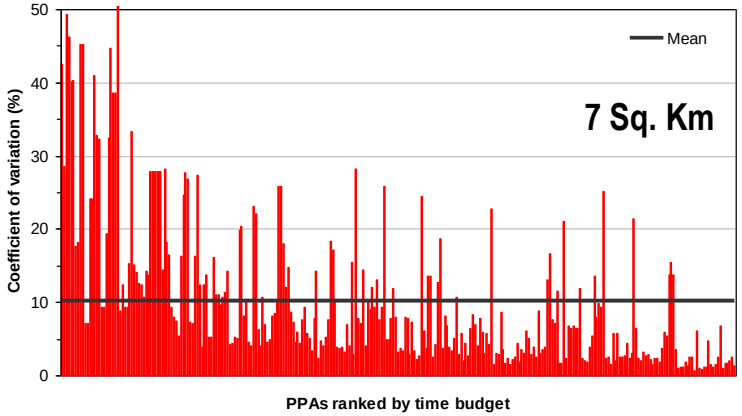
E. Evaluation of MAUP Effects: Example PPA (3)

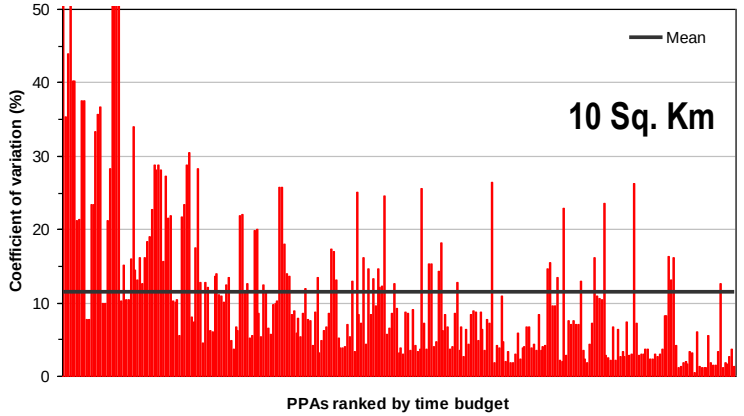


E. Evaluation of Zoning Effect: Data Set

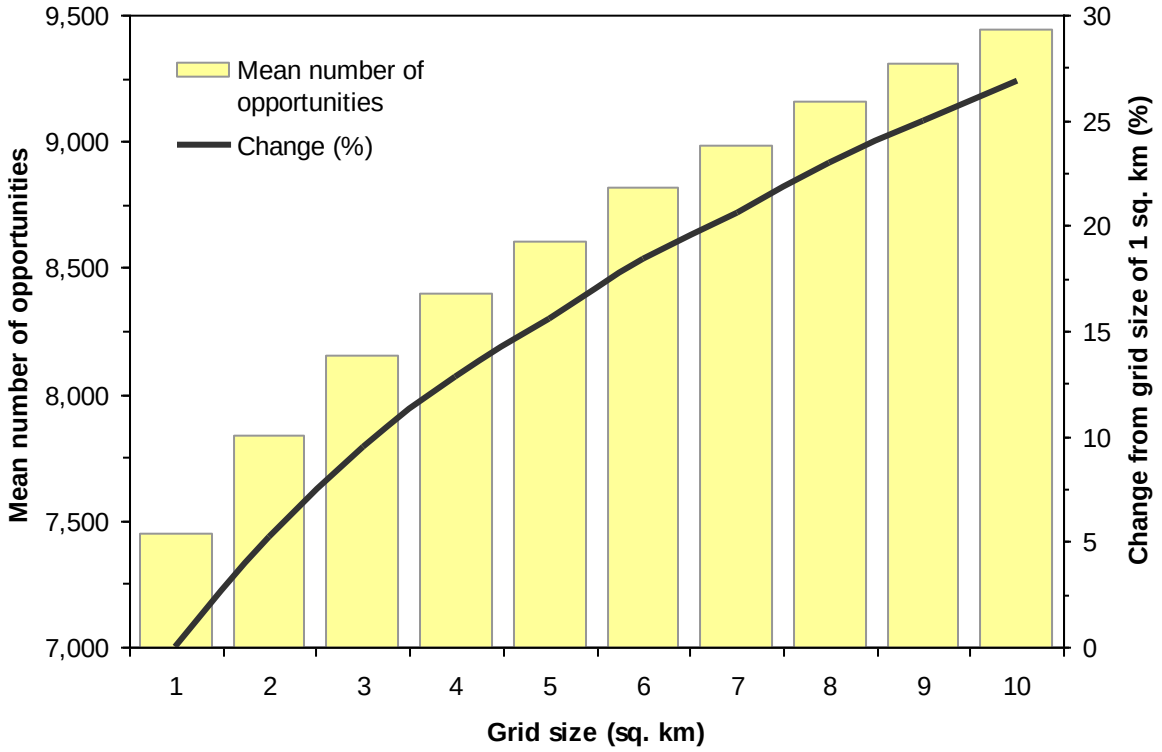




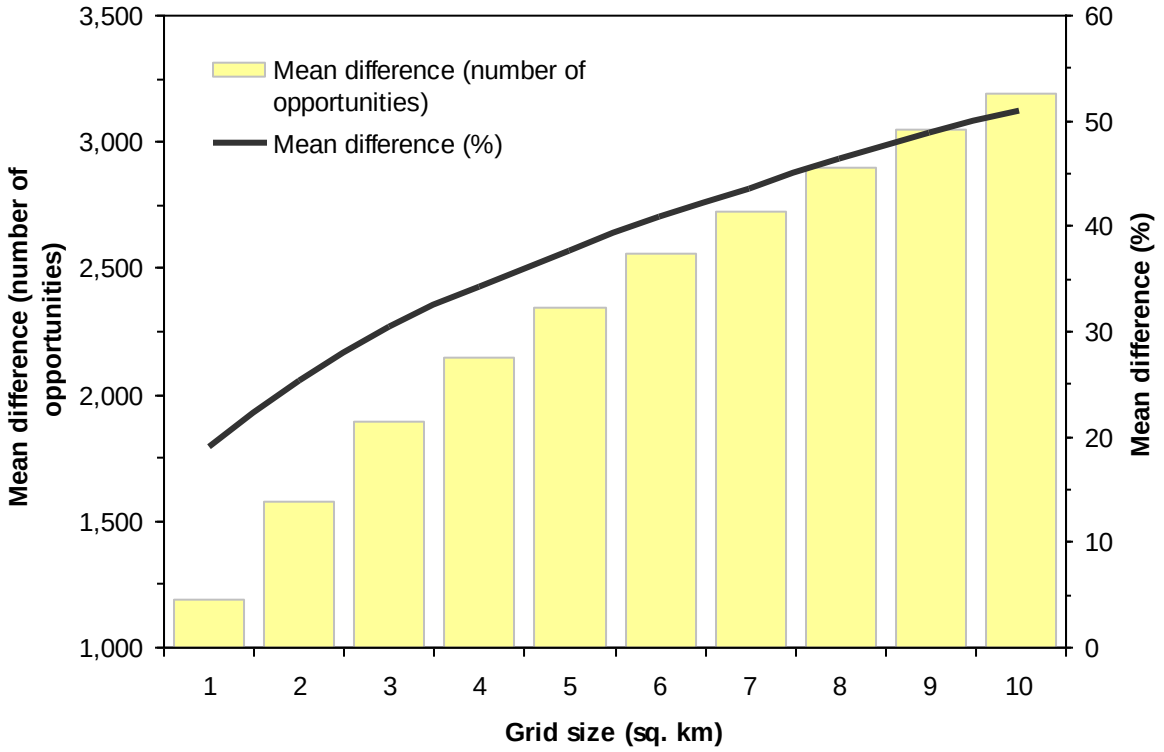




E. Evaluation of Scale Effect: Data Set



E. Comparison of Grid and Network PPAs



E. Conclusions

- Both zoning and scale effects are present in the grid-based PPAs
  - Zoning effect tends to be less severe than the scale effect
  - Suggests that at any scale, different zoning configurations should produce similar results when estimating constrained destination choice models
- All zoning configurations “distort” reality
  - Suggests that even at small grid sizes, more information will be built into constrained destination choice models than exists in reality

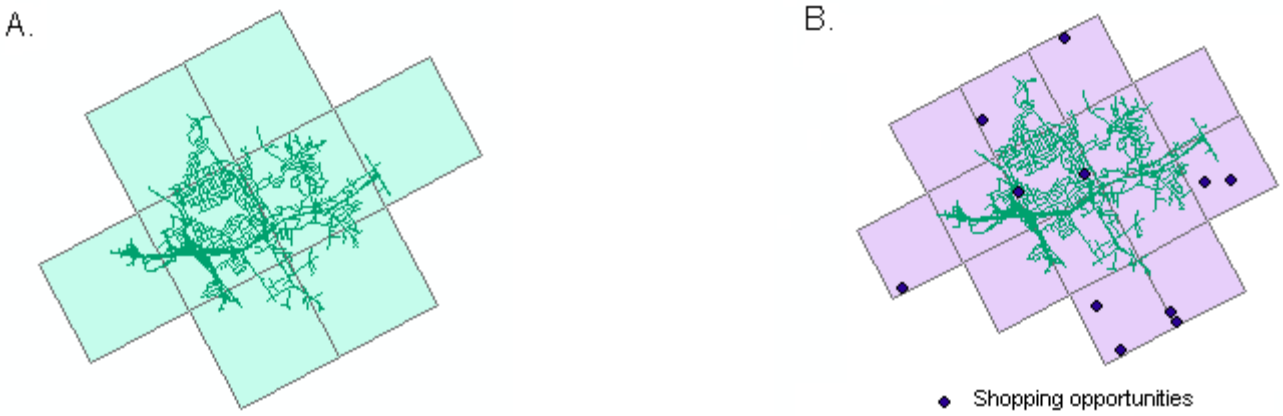
F. Scale Effect & Grocery Shopping

- Objective:
  - Investigate the scale effect on constrained destination choice models for shopping (general, grocery, non-grocery)
- Research conducted by Sylvia He (2004-06)
- Only results for grocery shopping are reported

F. Data and Methods

- 11 zoning systems (TAZ plus 1 km^2 to 10 km^2 grids in 1 km^2 increments)

- 295 single-purpose grocery shopping trips for KIPDA travel diary survey valid for all zoning systems

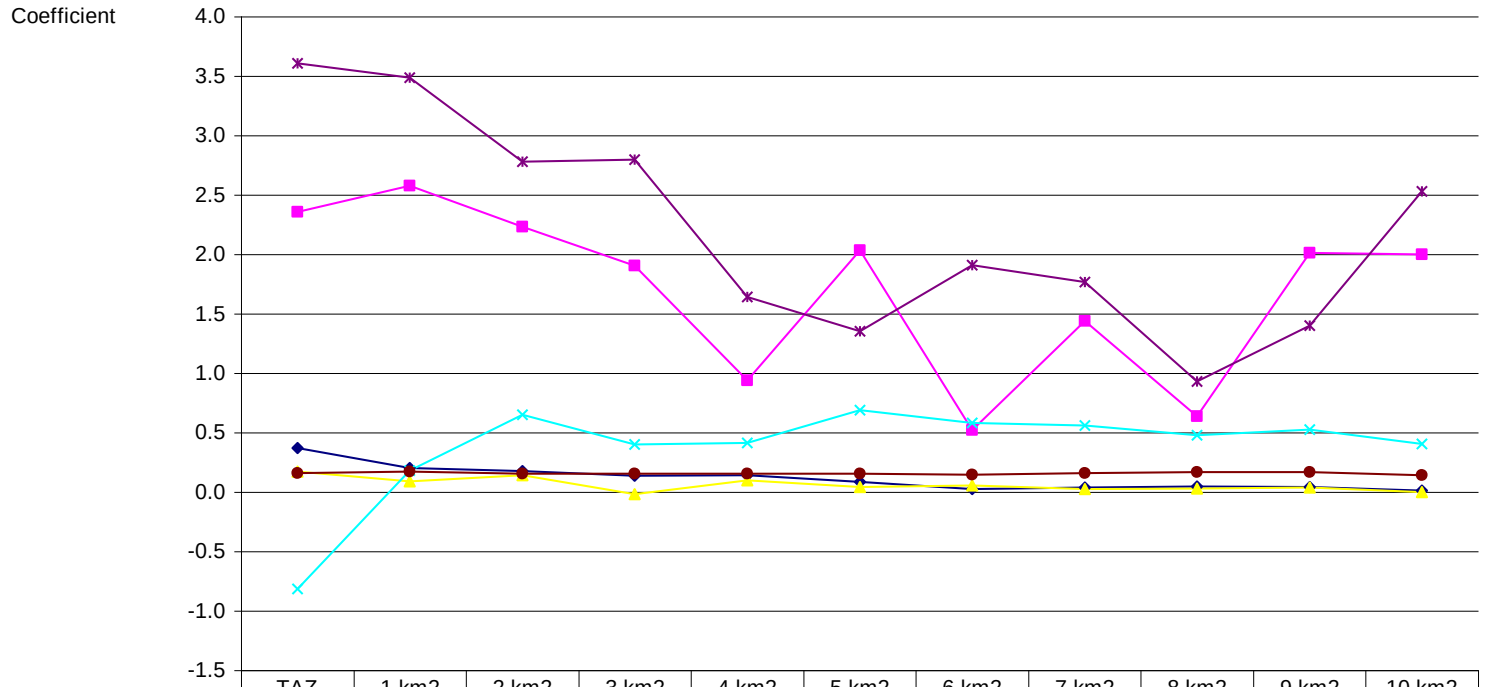


F. Data and Methods

- Multinomial logit model estimated for each zoning system
  - Random sampling of alternatives (chosen plus 9 others)
  - Independent variables: number of opportunities (by SIC), activity duration, store diversity index

Zone	Universal Choice Set	Constrained Choice Set (Mean for General Shopping)
TAZ	818	338
1 km^2	5,713	563
4 km^2	1,493	163
7 km^2	872	99
10 km^2	625	73

F. Model Results



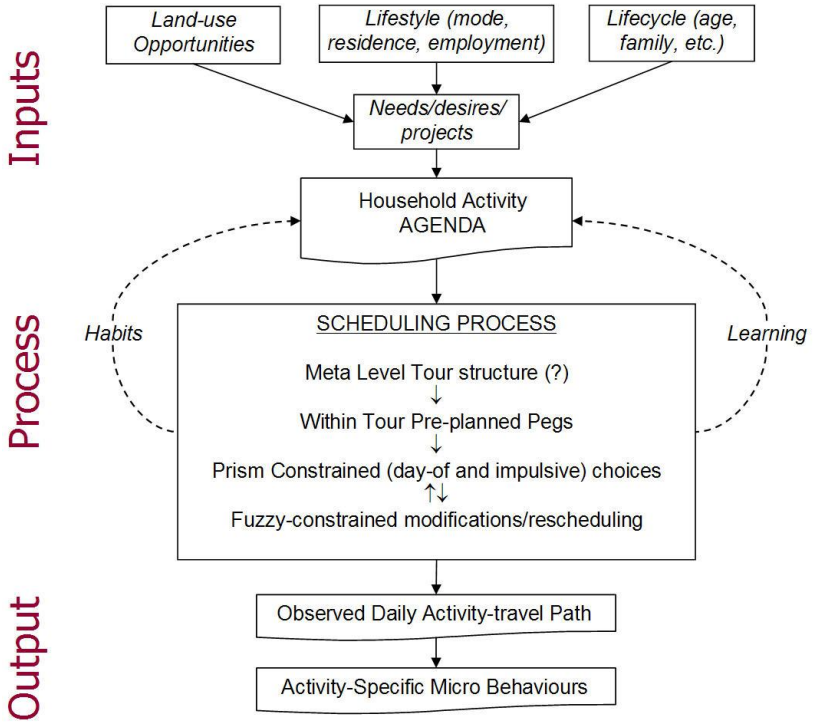
	TAZ	1 km2	2 km2	3 km2	4 km2	5 km2	6 km2	7 km2	8 km2	9 km2	10 km2
Grocery stores	0.3713	0.2006	0.1772	0.1374	0.1404	0.0848	0.0253	0.0381	0.0458	0.0421	0.0119
Meijer	2.3582	2.5796	2.2325	1.9036	0.9405	2.0338	0.5236	1.4401	0.6389	2.0147	2.0008
Department stores	0.1709	0.0925	0.1404	-0.0163	0.0972	0.0434	0.0555	0.0263	0.0300	0.0404	0.0000
Variety stores	-0.8145	0.1810	0.6525	0.4026	0.4144	0.6917	0.5805	0.5623	0.4794	0.5274	0.4041
Store diversity	3.6061	3.4863	2.7781	2.7978	1.6443	1.3525	1.9090	1.7684	0.9298	1.4005	2.5305
Activity duration	0.1613	0.1721	0.1546	0.1546	0.1551	0.1549	0.1451	0.1585	0.1661	0.1678	0.1440

G. Lessons Learned

- ESRI, ESRI, ESRI…
- Time, and lots of it!
- Approach works, as shown in the case of grocery shopping destination choice
- Must consider scale effects if using a zoning system

H. Future Work

- Fixity vs. flexibility
- Implementation of approach in MUSCAMAGS project
  - PCASPS
- Point-based representation



Questions?