Collaborative Sciences Center for ROAD SAFETY

www.roadsafety.unc.edu

R15: Integrating spatial safety data into transportation planning processes

Amin M. Hezaveh, Chris Cherry – University of Tennessee

Louis Merlin – Florida Atlantic University

June 3, 2021

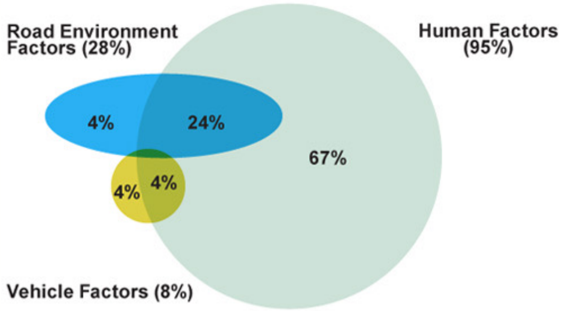
Integrating spatial safety data into transportation planning processes

- **Main Idea:** If we treat safety as something that is influenced by culture, demographics, geography, neighborhood and crashes are something we want to manage (like we treat everything else in transportation planning models) then we should re-think safety analysis at the planning-level.

Factors Influencing Road Safety

Factor influencing road safety

- **Road and Environment**
- **Vehicle**
- **Human Factor**



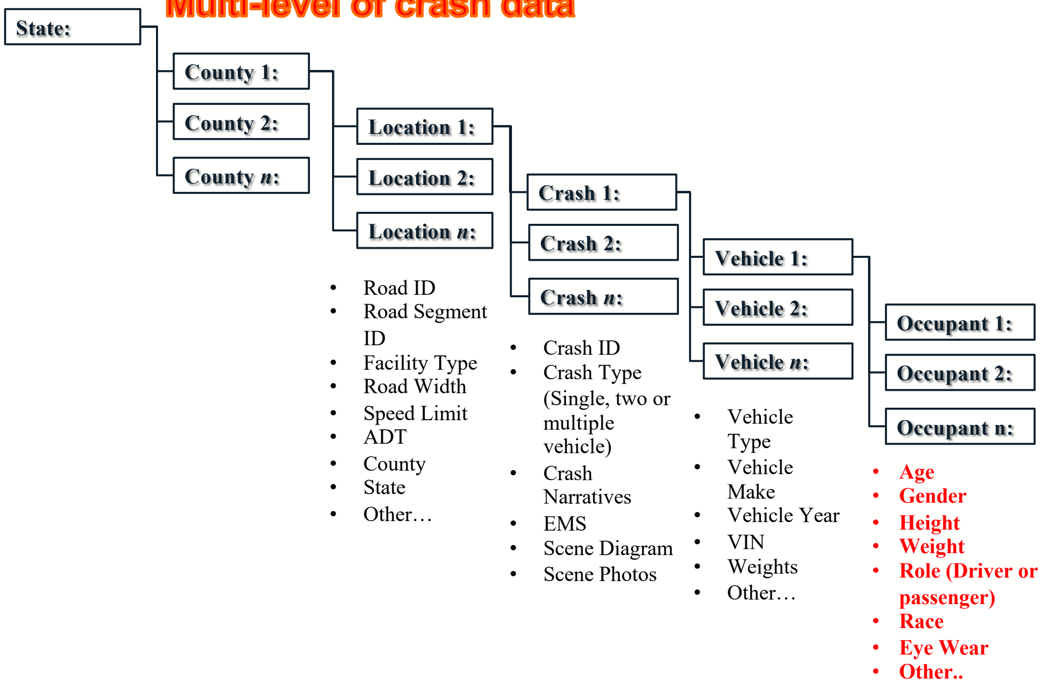
Source: NSW Roads and Traffic Authority, 1996.

Most of the countermeasures target Engineering and Enforcement
See for example HSM (AASHTO 2010), Handbook of Road safety (Elvik et al. 2010)

It is a little bit difficult to consider human element in the analysis…

Limitation to Current Practice

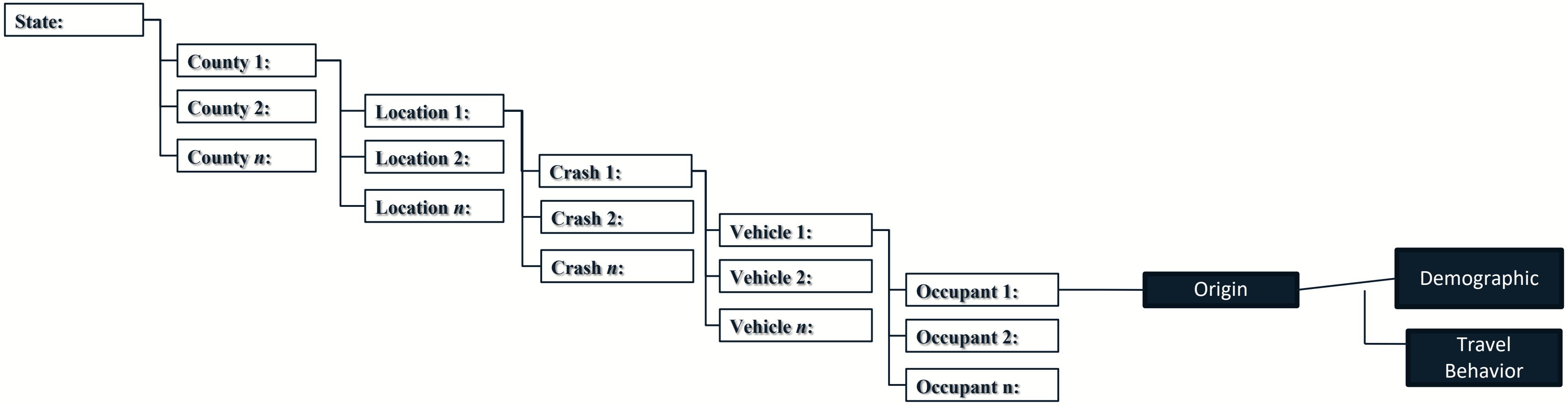
Multi-level of crash data



Very **limited information** about human travel behavior

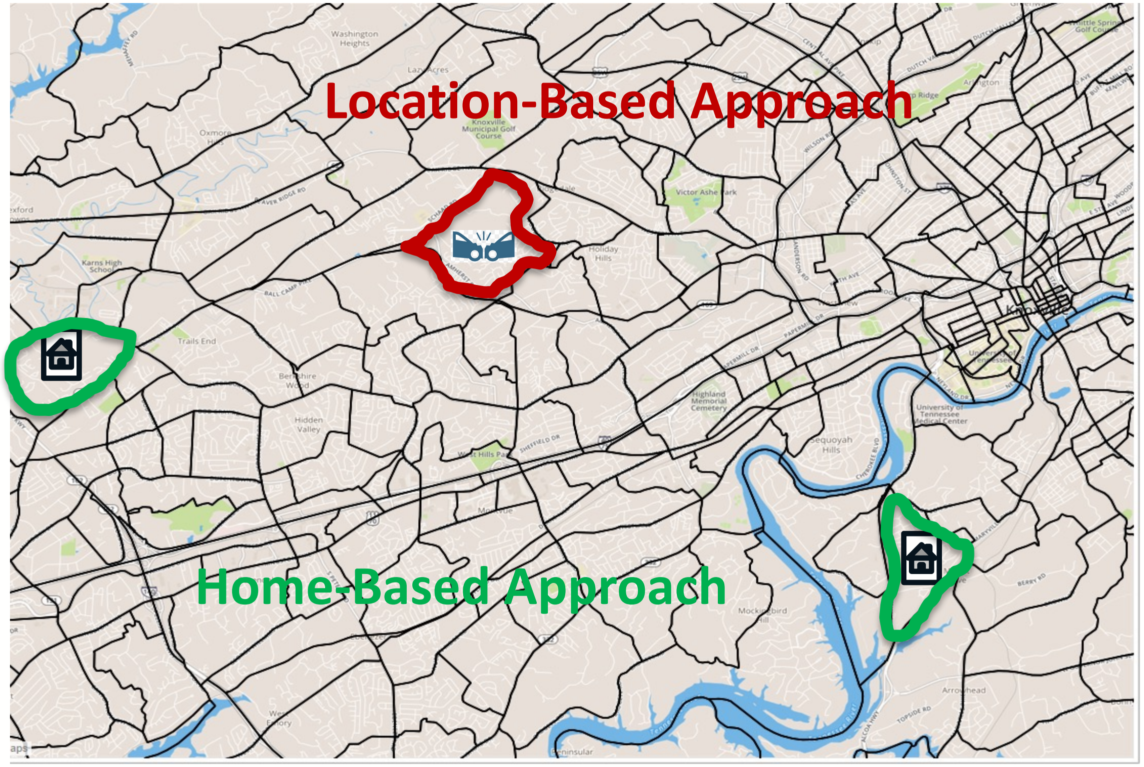
How we can give a **bigger share** to human behavioral element in safety analysis?

Multi-level of crash data



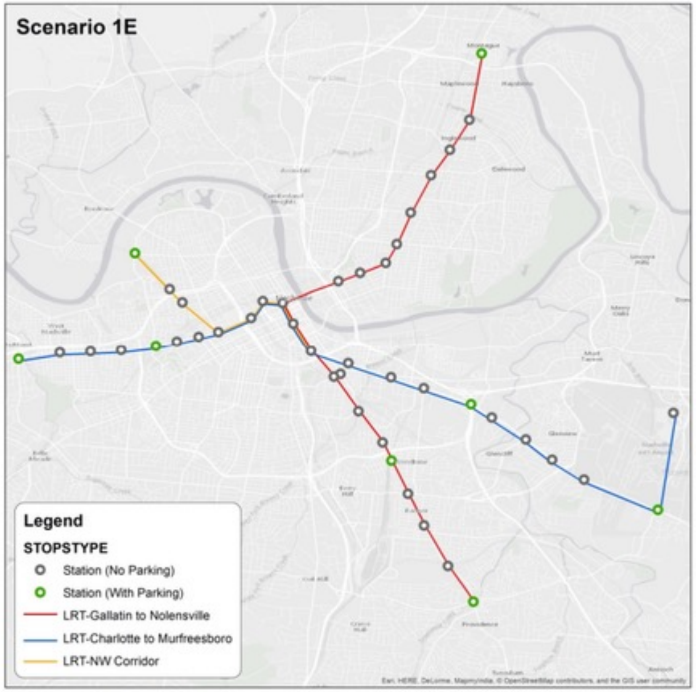
Two Approaches

- Location Based Approach:
  - Attribute crash to the location of traffic crashes
- Home Based Approach:
  - Attribute crashes to the road users' home-address



Predictive Application

- Consider Nashville’s Failed Transit Oriented Ballot Initiative
- Utilized Metro Transit’s Planning Scenario Models vs BAU scenario
- Transit scenario predicted more transit trips, changes in land use etc.
- We applied NB crash generation models to estimate changes in crash rate and across modal travel demand, estimating changes in crashes (based mostly on PMT)
- i.e., combination of population, trip rate, distribution, and mode shift.



Source: HDR Engineering

Figure 1 Transit lines in the proposed scenario

Predictive Application

- ”Home Based” Safety Performance Function (HSPF)=Predicting crash rates of TAZs or Individuals
- Aggregate model has no explicit treatment of infrastructure change effects (TOD’s should come with safer pedestrian infrastructure)

Table 5 Comparison of the EC-2033 and Transit scenario

	Daily Million Miles Traveled			HBA Crash Frequency			Annual Crash Rate × (HBA Crash Frequency per Million Miles Traveled)		
	Base	EC-2033	Transit-2033	Base	EC-2033	Transit-2033	Base	EC-2033	Transit-2033
All Road users	36.80	56.12 (53)	54.71 (49) *	122,048	173,208	171,970	9.09	8.46	8.61
Drivers only	26.30	41.29 (57)	40.31 (53) *	92,720	132,215	131,293	9.66	8.77	8.92
Motorized Road Users	35.30	53.65 (52)	52.06 (47) *	121,382	174,993	173,680	9.42	8.94	9.14
Transit, Walk & Bike (combined)	1.53	2.47 (61) *	2.65 (73) *	666**	761	759	1.19	0.84	0.78
Transit	1.05	1.68 (60) *	1.86 (76) *	666**	761	759	1.74	1.24	1.12
Walk & Bike	0.48	0.78 (64) *	0.79 (65) *	666**	761	759	3.80	2.67	2.63

× HBA crash frequency / (365* Daily Million miles traveled)
* % change compared to the based scenario
** Vulnerable road user crashes

HBA Application 1: Factors influencing road users' likelihood of involvement in traffic crashes at the zonal level

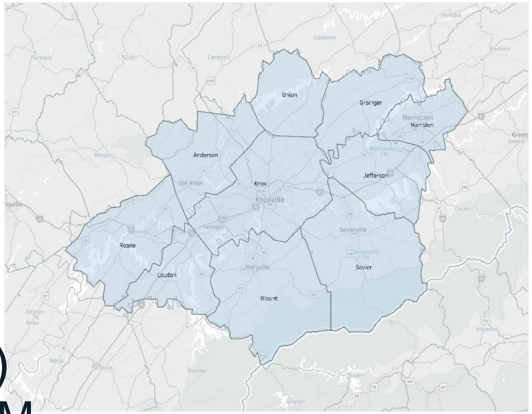
- Home-Based Approach (HBA) crash frequency:
  - the expected number of crashes that road users who live in a certain geographic area experience during a specified period
- HBA Crash Rate –HBA-CR:
  - HBA crash frequency divided by population (1,000)

Aim:

- Explore the association between sociodemographic variable, travel behavior and HBA-CR
- Exposure variable

Data

- Data from 2015-16
  - 60,104 crashes
  - 148,666 individuals
- Geocoding success rate (95%)
  - 110,312 (78%) address in KRTM
- Knoxville Regional Travel Demand Model
  - 10 counties.
  - 1,186 TAZs
  - Population close to 1 million.



Variable	Mean	S. D.	Min	Max
Household Income ($)	46655	21075	2349	168227
Workers Per Household	1.21	0.24	0.00	2.10
Students Per Household	0.39	0.18	0.00	1.11
Intersection Density (per square miles)	152.55	198.42	3.11	1656.58
Percent Road with Sidewalk	0.21	0.32	0.00	1.00
Percent Near Bus Station	0.18	0.36	0.00	1.00
Population Density (Per Square Mile)	1377.27	2736.12	2.38	44071.94
Average Speed (MPH)	39.09	8.33	20.00	65.00
VMT on Interstate from TAZ (miles)	9625	32673	0	287762
VMT on Arterial from TAZ (miles)	11398	17657	0	163821
VMT on Others from TAZ (miles)	7146	8294	0	76596

Measuring Road Users' Exposure

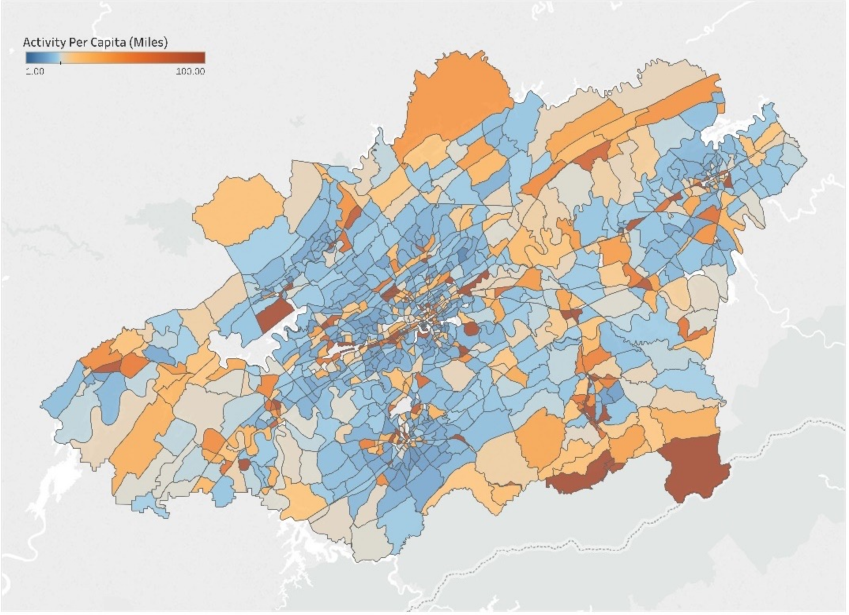
- In the literature:
  - VMT, Road Length, AADT
  - Population, Trip Rate
- We need to define a new data element that capture trip length and frequency
- Average Zonal Activity

$$PMT_i = \sum_{j=1}^{n} \frac{P_{ij} L_{ij}}{Pop_i}$$

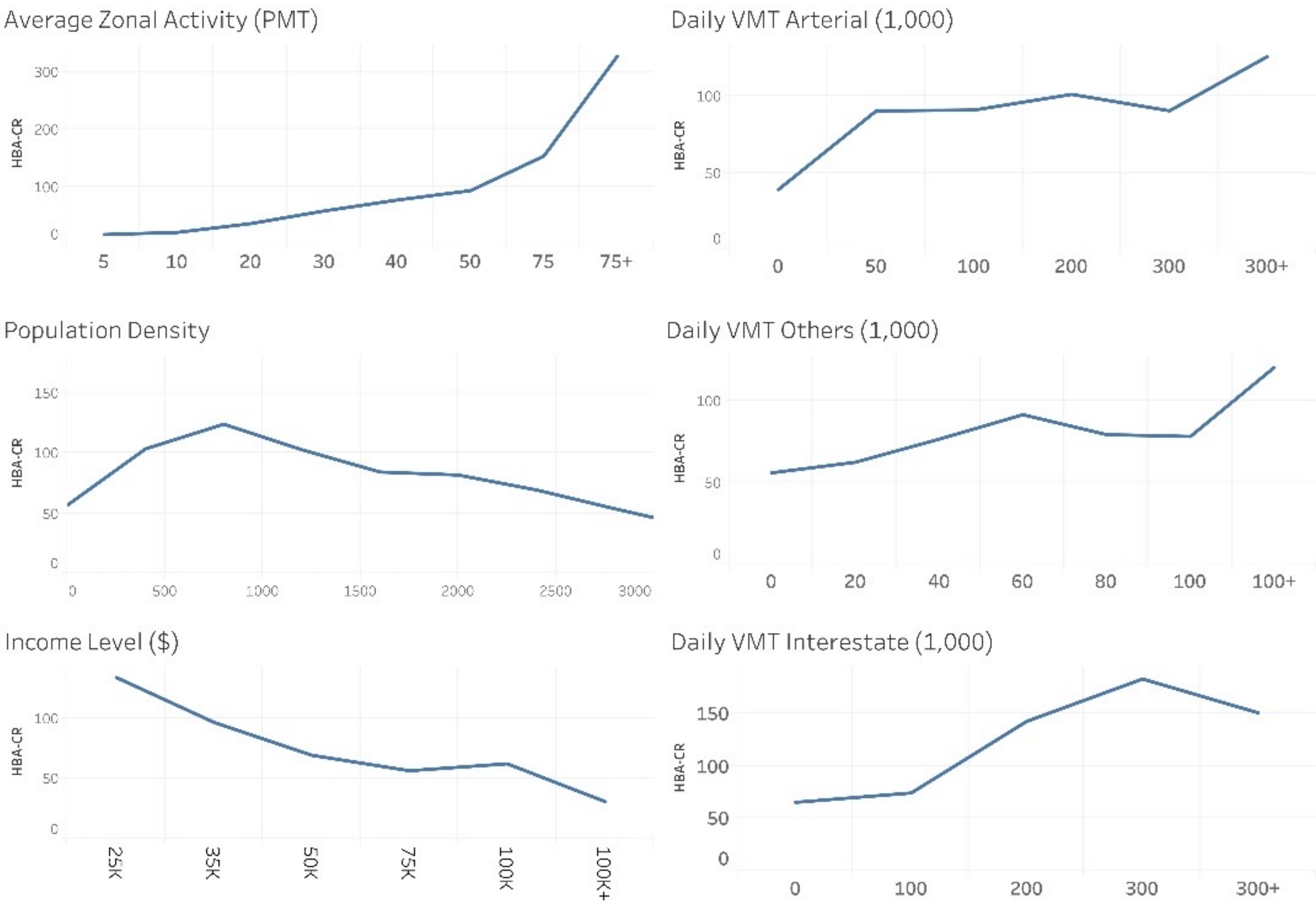
P_{ij} is the number of trip produced from TAZ

Pop_i presents the population of the zone

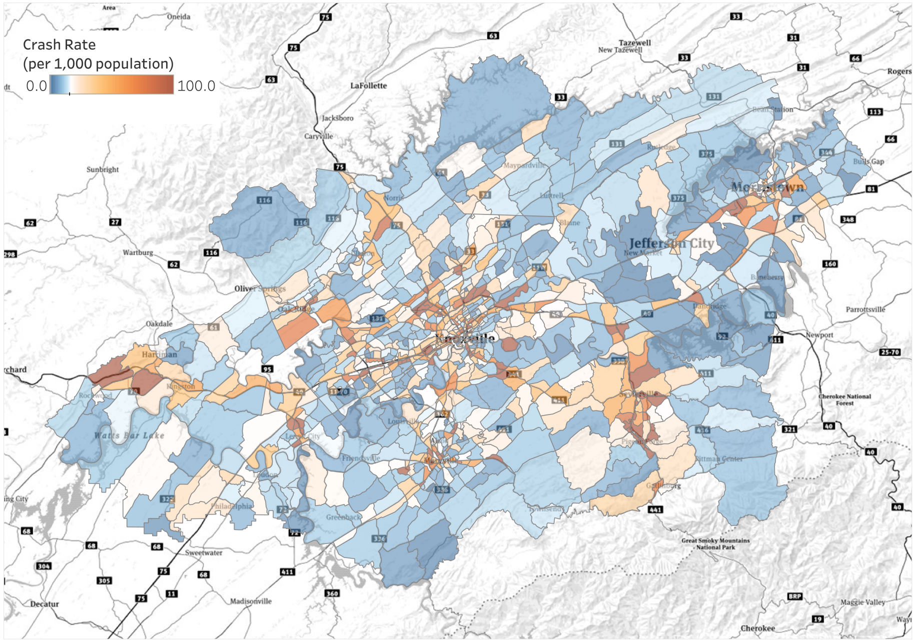
L_{ij} is the shortest network path between TAZ i to TAZ j



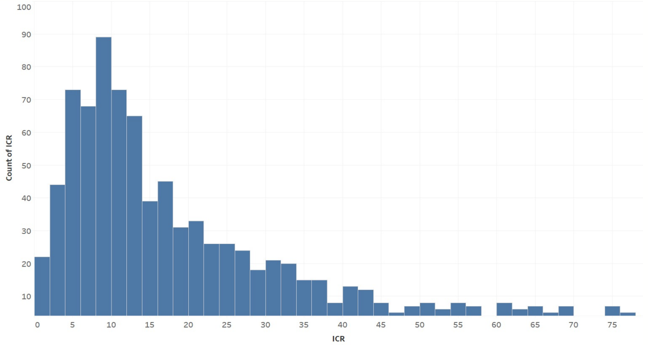
HBA-CR


Average Zonal Activity (PMT)
HBA-CR
300
200
100
0
5
10
20
30
40
50
75
75+
Daily VMT Arterial (1,000)
HBA-CR
100
50
0
0
50
100
200
300
300+
Population Density
HBA-CR
150
100
50
0
0
500
1000
1500
2000
2500
3000
Daily VMT Others (1,000)
HBA-CR
100
50
0
0
20
40
60
80
100
100+
Income Level ($)
HBA-CR
100
50
0
25K
35K
50K
75K
100K
100K+
Daily VMT Interestate (1,000)
HBA-CR
150
100
50
0
0
100
200
300
300+

HBA-CR



HBA-CR distribution in KRTM



Histogram of HBA-CR at the TAZ level

Autocorrelation exist. Use Spatial Model

Spatial Analysis: Detection and modeling

Detect Spatial autocorrelation:

Moran's I= $\frac{\sum_i \sum_j w_{ij}(y_i-\mu)(y_j-\mu)}{\sum_i (y_i-\mu)^2}$

- OLS
- Spatial Error Model

Lagrange Multiplier for deciding the suitable model

$$LM_{SEM} = \frac{\left(\frac{e'W_e}{s^2}\right)^2}{T}$$

$$LM_{SLM} = \frac{\left(\frac{e'W_e}{s^2}\right)^2}{\frac{(WXb)'\mathrm{M}(WXb)}{s^2}+T}$$

- Spatial lag model

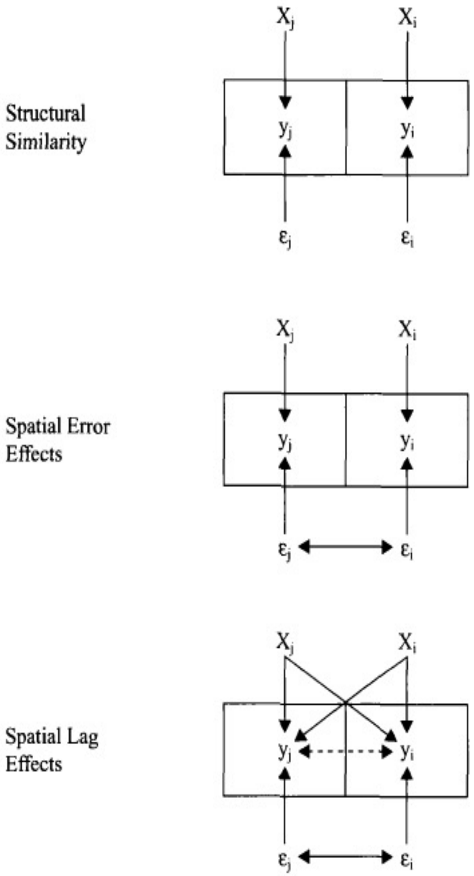
Eq1: $y = X\beta + \varepsilon$

Eq2: $\varepsilon = \lambda W_\varepsilon + u = (I - \lambda W)^{-1}u$

Eq3: $y = \lambda W_y + X\beta + \lambda \mathrm{WX}\beta + \mathrm{u}$

Eq4: $y = \rho W_y + X\beta + \varepsilon$

Eq5: $y = (I - \rho W)^{-1}X\beta + (I - \rho W)^{-1}\varepsilon$



HBA CR: Estimated model

Spatial lag model is more suitable

Results of lagrange multiplier statistics

TEST	VALUE	PROB
Moran's I (error)	5.304	0.000
Lagrange Multiplier (lag)	39.998	0.000
Robust LM (lag)	15.321	0.000
Lagrange Multiplier (error)	25.067	0.000
Robust LM (error)	0.390	0.532

OLS, SLM, and SEM Estimations

	OLS				SLM				SEM			
Variable	Coef.	S. E.	T-test	P-value	Coef.	S. E.	T-test	P-value	Coef.	S. E.	T-test	P-value
Sociodemographics												
Income ($10,000)	-4.794	1.968	-2.437	0.015	-3.232	1.914	-1.689	0.091	-3.623	2.192	-1.653	0.098
Worker Per Household	55.423	17.698	3.132	0.002	47.926	17.170	2.791	0.005	43.076	18.158	2.372	0.018
Student Per Household	-7.747	21.608	-0.359	0.720	-1.856	20.979	-0.088	0.930	-7.179	22.286	-0.322	0.747
Activity Per Capita (Miles Traveled)	1.390	0.069	20.224	0.000	1.347	0.067	20.062	0.000	1.362	0.068	19.916	0.000
Population Density (per Square miles)	-0.007	0.002	-4.587	0.000	-0.007	0.002	-4.617	0.000	-0.007	0.002	-3.990	0.000
Network												
Intersection Density	0.075	0.027	2.801	0.005	0.059	0.026	2.259	0.024	0.067	0.028	2.412	0.016
% Road with Sidewalk	86.125	16.927	5.088	0.000	79.027	16.464	4.800	0.000	86.042	17.427	4.937	0.000
% Near Bus Stop	24.546	14.287	1.718	0.086	18.232	13.875	1.314	0.189	21.932	15.894	1.380	0.168
VMT Interestate	9.767	1.687	5.791	0.000	9.025	1.639	5.505	0.000	9.499	1.714	5.541	0.000
VMT Arterial	12.457	2.058	6.054	0.000	11.181	2.004	5.578	0.000	11.564	2.041	5.665	0.000
VMT Other Roads	-9.411	2.334	-4.032	0.000	-8.455	2.266	-3.731	0.000	-8.779	2.363	-3.716	0.000
Constant	-38.818	20.856	-1.861	0.063	-52.070	20.407	-2.552	0.011	-27.301	22.032	-1.239	0.215
Lag coeff. (Rho)					0.249	0.040	6.256	0.000	0.238	0.047	5.047	0.000
R-squared	0.426				0.453				0.445			
Log likelihood (Full)	-5838.1				-5820.7				-5826.9			
AIC	11700.1				11667.5				11677.8			

HBA Application 2: Exploring the Cost of Traffic Crash at the Traffic Analysis Zone Level

- Crash Frequency or Crash Rate; not a good index to measure road safety

since it does not consider crash severity

  - crash frequency in urban areas is higher than rural areas on average;
  - Crash severity is relatively higher in rural areas

TRR

Research Article

Transportation Research Record
2020, Vol. 2674(12) 360–371

DOI: 10.1177/0361198120953431
journals.sagepub.com/home/trr
SAGE

Applying a Home-Based Approach to the Understanding Distribution of Economic Impacts of Traffic Crashes

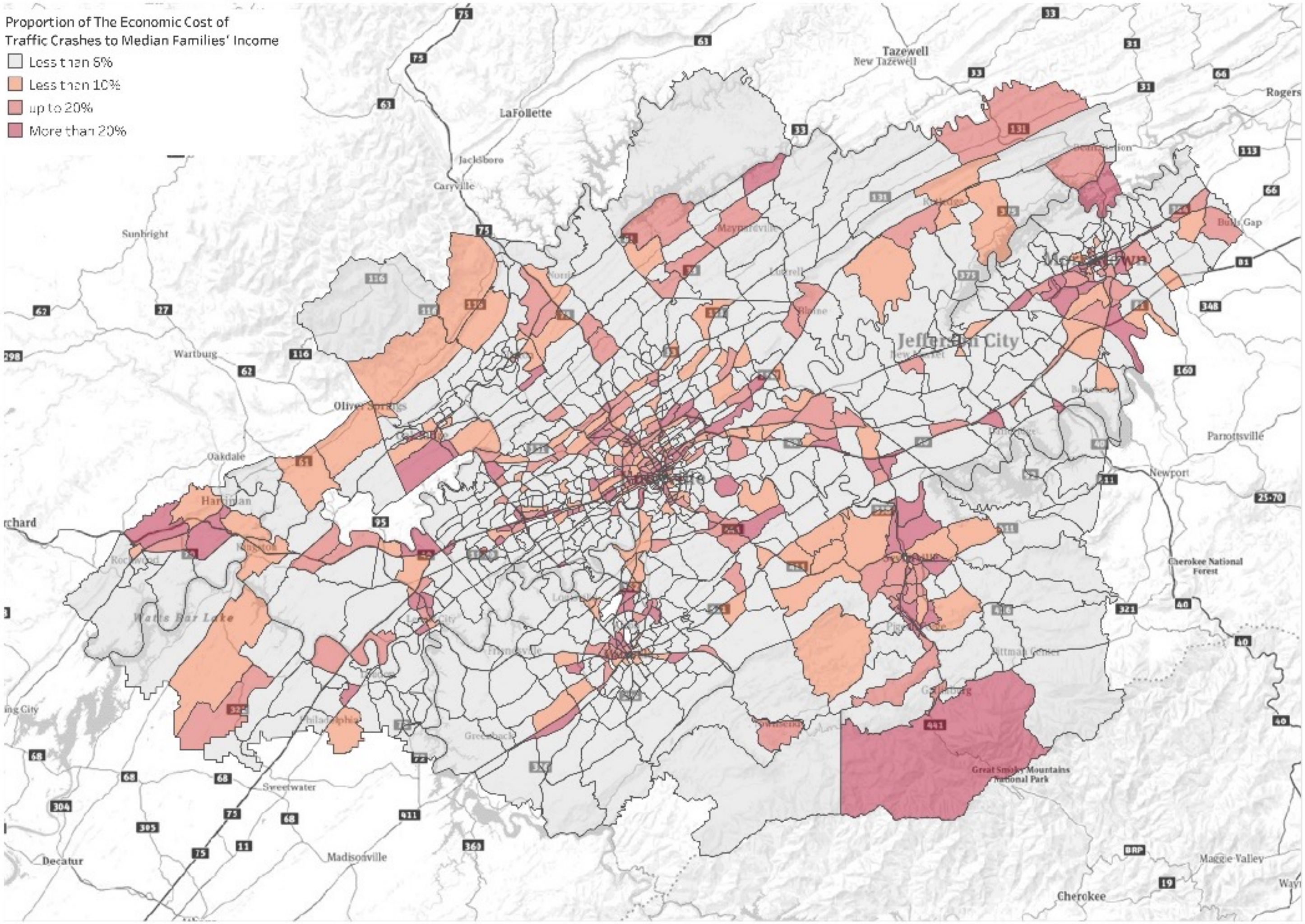
Amin Mohamadi Hezaveh[1] and Christopher R. Cherry[1]

Background

- Traffic crashes cost 1-2% of Gross Domestic Product (GDP) of high-income countries and 3% of GDP in low and middle-income countries
- USA: The economic cost and societal harm of traffic crashes were estimated to be over $242 billion and $871 billion in 2010 ($780 per person; $2,800).

ECCPC Per Income

- Crash toll



Improvement in Transportation design

- Burden of traffic crashes is higher for those who travel more or have a lower income.
- VMT
  - Diverging high-speed traffic from residential areas
  - Managing the accessibility of the residents near the high-speed, high volume roads.
- Average zonal activity
  - Eliminating a portion of trips
  - Reduce trip length by increase in diversity, mixed land-use design, and non-motorized oriented design

HBA Application 3: Factors influencing cost of traffic crash at the traffic analysis zone level: incorporating spatial effects

HBA Application 4: A Statewide Geographically Weighted Regression to Estimate the Comprehensive Cost of Traffic Crashes at a Zonal Level


Accident Analysis and Prevention 131 (2019) 15–24

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

A geographically weighted regression to estimate the comprehensive cost of traffic crashes at a zonal level

Amin Mohamadi Hezaveh, Ramin Arvin, Christopher R. Cherry*

Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, United States

Summary

- HBA is a promising way to assign crashes to neighborhoods.
- Like “Trip Generation” or activity-based planning models, we can develop predictive models and estimate crashes (rate and severity) at the TAZ level based on travel, geographic, demographic, and social influences.
- Planning scenario analysis can tools can explicitly includes safety as a planning outcome.