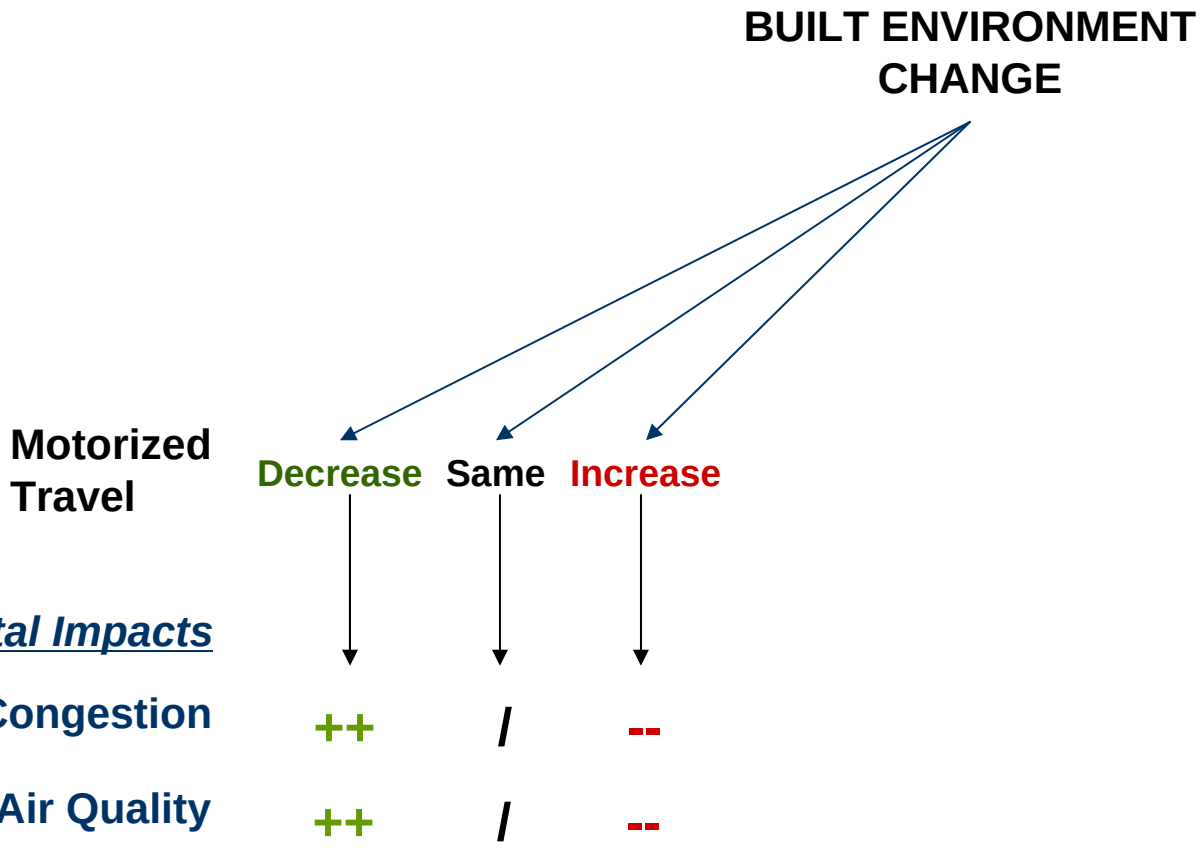
An Economic Evaluation of Health-Promotive Transportation Infrastructure

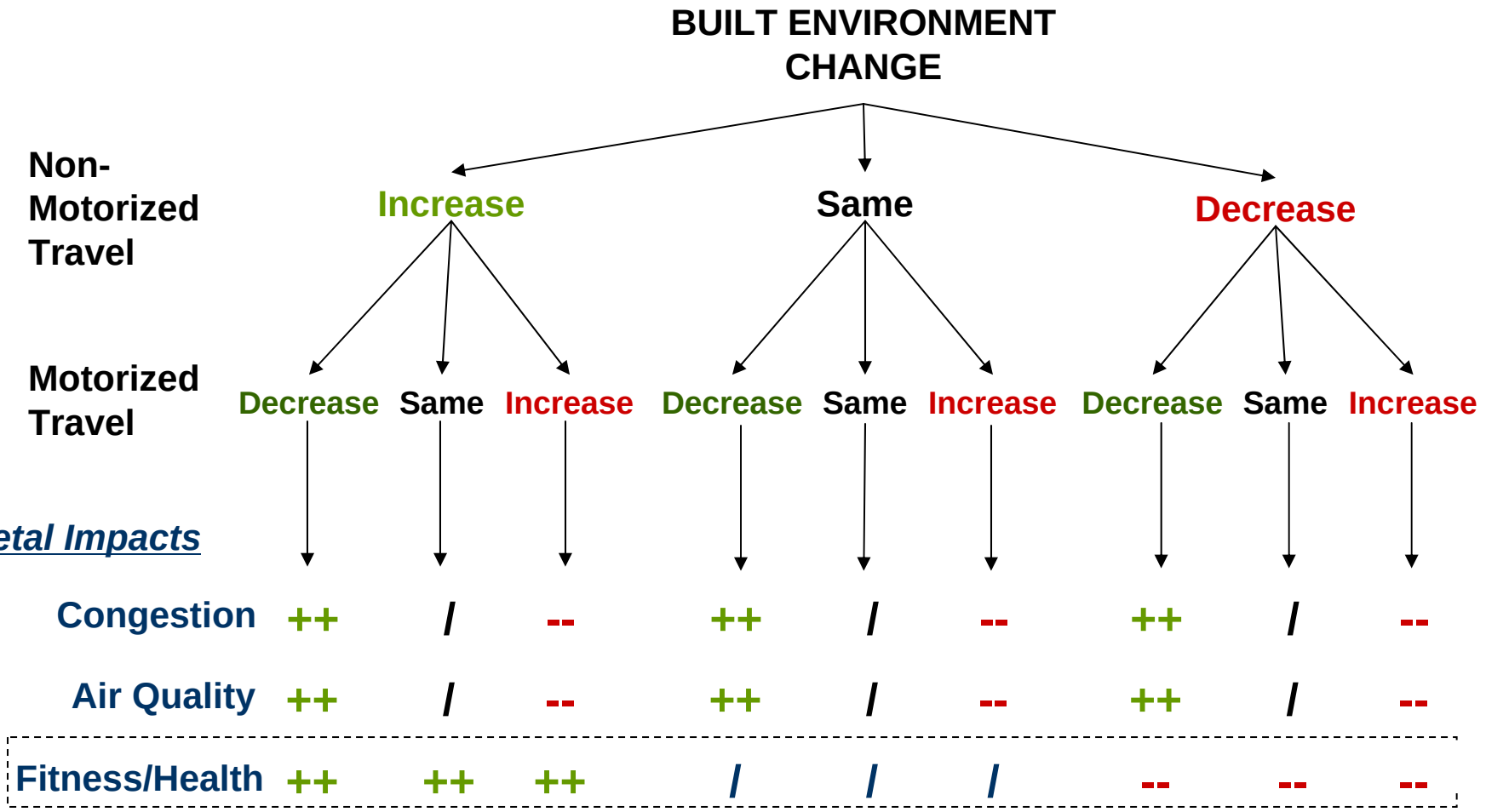
By Jessica Guo
Sasanka Gandavarapu
Civil and Env. Engineering
University of Wisconsin

2009
Active Living Research
Annual Conference

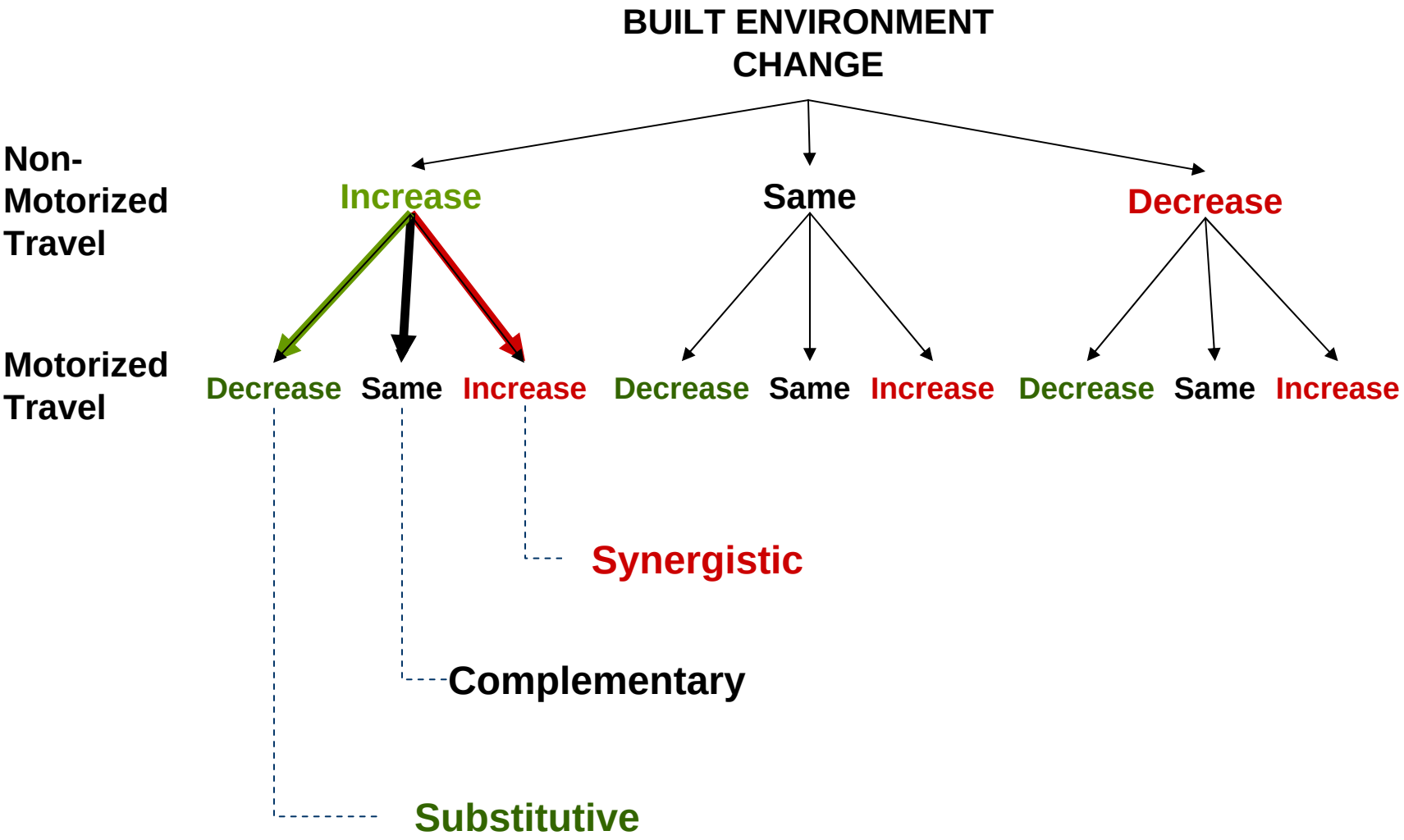
Impacts of Built Environment



Impacts of Built Environment



Impacts of Built Environment



Goal of Study

TUSALAB

Identify and evaluate win-win transportation infrastructure improvement strategies that would promote public health through both reduced driving and increased active transport

- Econometric Analysis Framework of Travel
- ROI Assessment Framework of Infrastructure Improvement

Existing Literature

TUSALAB

Built Env. ⟷ **Amount of Driving**

or

Built Env. ⟷ **Amount of Biking / Walking**

or

Built Env. ⟷ **Mode Choice**

or

Built Env. ⟷ **Overall PA**

or

Built Env. ⟷ **BMI**

Existing Literature

TUSALAB

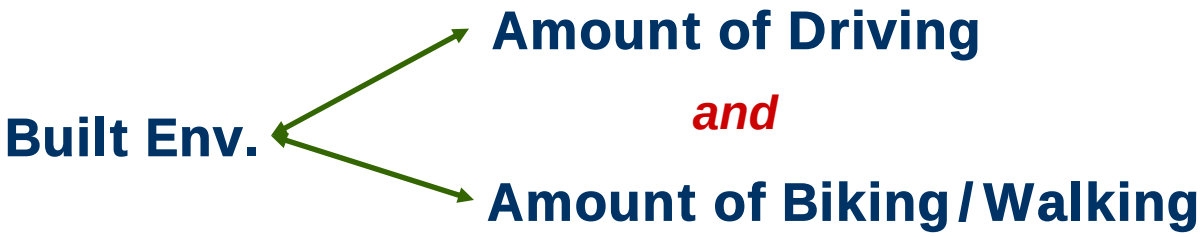
- Most studies do not needed insight into the trade-offs between motorized and non-motorized travel
- Empirical evidence on the impacts of BE remains very mixed
- Few studies have translated travel and health outcome to economic benefit of transportation investment

Existing Literature

TUSALAB

- Very few scenario analysis tools exist to readily and comprehensively support transportation investment decision making
- Little sensitivity analysis of how benefit estimates vary by modeling methods

Econometric Analysis



- Extends from Guo et al (2007), which was frequency-based
- Dependent variables:
  - daily vehicle miles traveled (VMT), and
  - miles walked/biked (MWB)

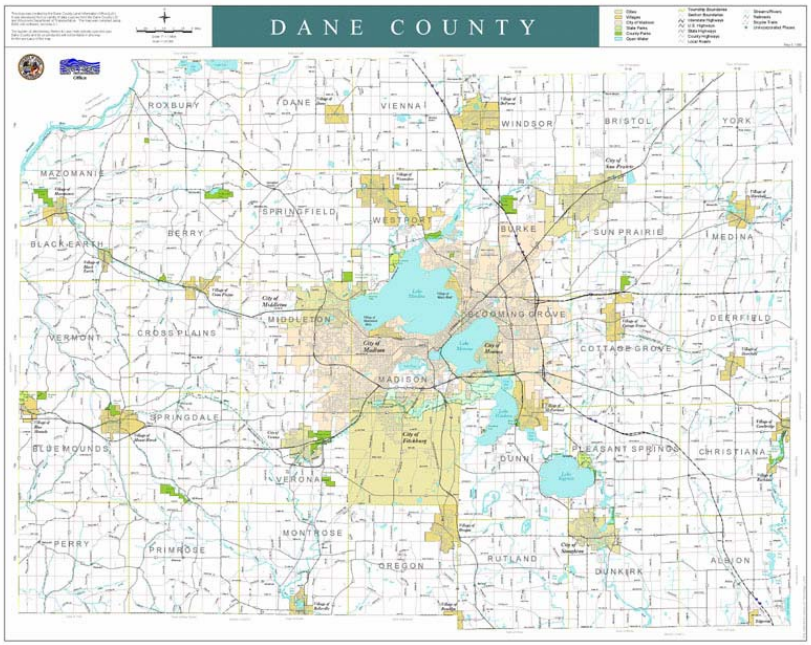
Econometric Analysis

TUSALAB

- Individual-level analysis based on widely available travel survey data
- Identify unique contribution of different built environment elements
- Control for socio-demographic and weather factors
- Allow for heterogeneous sensitivity to BE factors across different population groups

Data for Analysis

- 2001 National Household Travel Survey
- Population Census
- Weather – precipitation & temperature (NCDC)
- Land use data
- Employment data
- Bicycle, pedestrian facilities
- Roadway network



Exogenous Variables

- Trip-Maker Characteristics
- Trip Day Characteristics: temperature, snowfall, weekend, weekday trips
- Built Environment Characteristics

  Regional level:
  retail, recreation, and employment accessibility measures

  Neighborhood level:
  0.25 and 1 mile network buffers around sampled households. Include:
  - Socio-demographic distribution
  - Land use mix
  - Multimodal transportation facilities

Sample Characteristics

TUSALAB

- 50% of 4974 persons in the final sample

	Sample %	Average Miles Walked/Biked (MWB) per person	Average Vehicle Miles Traveled (VMT) per person
Entire Sample	**100**	**0.512 (1.90)**	**18.269 (22.24)**
Age			
17 to 30 years	16.5	0.761 (2.39)	18.624 (22.39)
31 to 45 years	42.1	0.484 (1.95)	17.239 (22.89)
46 to 60 years	27.6	0.499 (1.82)	20.109 (21.05)
Above 60 years	13.8	0.323 (1.03)	17.312 (22.16)
Gender			
Male	42.6	0.564 (1.90)	18.409 (22.18)
Female	57.4	0.473 (1.89)	18.166 (22.28)
Household Income per Annum			
Low (less than $25K)	9.5	0.685 (1.95)	13.104 (19.63)
Medium (>$25K to $50K)	25	0.501 (1.72)	17.111 (20.15)
High (>$50K to $75K)	23.7	0.501 (1.85)	19.666 (22.23)
Very High (more than $75K)	35.8	0.512 (2.11)	20.031 (24.69)
Ethnicity			
White	92	0.528 (1.95)	18.761 (22.49)
African American	1.8	0.245 (0.83)	12.733 (19.53)
Asian	2.2	0.633 (1.81)	10.103 (14.72)

Sample Characteristics

Retail Accessibility			
Quartile 1	25	0.344 (1.59)	23.838 (25.35)
Quartile 2	25	0.328 (1.31)	19.325 (21.77)
Quartile 3	25	0.426 (1.56)	16.997 (21.80)
Quartile 4	25	0.952 (2.75)	12.864 (17.97)
Population Density - 1mi buffer			
Quartile 1	25	0.351 (1.49)	21.754 (22.32)
Quartile 2	25	0.375 (1.47)	19.932 (22.36)
Quartile 3	25	0.433 (1.67)	17.390 (23.45)
Quartile 4	25	0.893 (2.67)	13.951 (19.90)
Population Density – ¼ mi buffer			
Quartile 1	25	0.364 (1.48)	22.113 (22.35)
Quartile 2	25	0.443 (1.75)	18.598 (23.64)
Quartile 3	25	0.483 (1.93)	17.093 (19.89)
Quartile 4	25	0.764 (2.34)	15.168 (22.37)
Road length with bike lane - 1 mi buffer			
Quartile 1	25	0.408 (1.65)	20.412 (24.52)
Quartile 2	25	0.436 (1.72)	18.106 (22.82)
Quartile 3	25	0.514 (1.76)	17.966 (20.70)
Quartile 4	25	0.696 (2.39)	16.230 (20.19)
Road length with bike lane – ¼ mi buffer			
Quartile 1	25	0.427 (1.66)	19.675 (21.66)
Quartile 2	25	0.411 (1.53)	18.314 (21.35)
Quartile 3	25	0.397 (1.57)	19.902 (26.11)
Quartile 4	25	0.800 (2.60)	14.889 (19.17)

Model Structure

- Seemingly Unrelated Regression (SUR) Model

$$y_1 = X_1\beta_1 + \varepsilon_1$$
$$y_2 = X_2\beta_2 + \varepsilon_2$$

$$\Sigma = \begin{bmatrix} \sigma_{ff} & \sigma \\ \sigma & \sigma_{gg} \end{bmatrix}$$

Intra-person correlation

- Spatial SUR Model

$$y_1 = X_1\beta_1 + \lambda_1 W_1\varepsilon_1 + \mu_1$$
$$y_2 = X_2\beta_2 + \lambda_2 W_2\varepsilon_2 + \mu_2$$

Intra-person correlation

Inter-person correlation due to spatial dependence

Estimation Results

TUSALAB

	SUR MODEL				SPATIAL SUR MODEL			
	MWB		VMT		MWB		VMT	
Explanatory Variables	**Coeff.**	**z-stat**	**Coeff.**	**z-stat**	**Coeff.**	**z-stat**	**Coeff.**	**z-stat**
Person/Household/Trip Day Characteristics								
Person is employed	0.1663	2.976***	14.4811	9.583***	0.0610	0.894	16.9346	7.994***
Person is young (17 to 30 years old)	0.2255	2.929***	--	--	0.1271	1.36741		
Person is Caucasian	0.2729	2.761***	--	--	0.2582	2.172**		
Person holds a driving license	--	--	11.6439	12.446***			10.5879	8.136***
Person has a degree (Bachelor's or higher)	--	--	2.3258	3.570***			2.0657	2.281**
Number of bicycles owned by household	0.1480	8.309***	--	--	0.1452	6.524***		
Household has no car	0.3548	1.803*	--	--	0.0439	0.186		
Family income per year (in $10,000)	--	--	0.2956	2.266**			-0.1229	-0.661
Number of cell phones in household	--	--	0.8638	2.806***			1.5234	3.480***
Housing type is either an apartment or a dormitory	0.1704	1.985**	2.2296	2.495**	0.1968	1.800*	2.1285	1.578
Lowest temperature on travel day	0.0073	4.805***	--	--	0.0066	3.609***		
Travel day is on a weekend	--	--	-6.8482	-2.343**			-13.1987	-3.397***

Estimation Results

TUSALAB

	SUR MODEL				SPATIAL SUR MODEL			
	MWB		VMT		MWB		VMT	
Explanatory Variables	Coeff.	z-stat	Coeff.	z-stat	Coeff.	z-stat	Coeff.	z-stat
Built Environment Characteristics								
Regional factors								
Rural setting	--	--	1.3241	1.553			0.9449	0.721
Retail accessibility	0.0399	3.341***	-0.5785	-3.438***	0.0437	2.693***	-0.0145	-0.053
interacted with individual's work status	--	--	-1.2072	-5.624***			-1.7220	-5.601***
Neighborhood socio-demographic composition								
% high income households in neighborhood – 1 mile buffer	-0.9233	-3.846***	9.7954	3.561***	-0.8449	-2.767***	15.9405	3.782***
Household density (per acre) – ¼ mile buffer	--	--	0.2823	2.833***			0.2084	1.167
Neighborhood land use characteristics								
Land use mix – 1 mile buffer	-0.5786	-3.466***	-6.0547	-2.874***	-0.3574	-1.684*	-10.0319	-3.207***
interacted with vehicles per person in household	--	--	4.7199	4.334***			4.5087	2.889***
interacted with travel day being on a weekend	--	--	8.1199	1.786*			17.1592	2.816***
Neighborhood transportation network characteristics								
Length of roadway with no sidewalk – 1 mile buffer	-0.0483	-3.288***	0.3397	2.128**	-0.0554	-2.784***	0.6447	2.399**
Length of roadway with bike lane – ¼ mile buffer	0.2140	2.265**	--	--	0.1005	0.801		
Number of intersections (per acre) – ¼ mile buffer	0.0503	2.261**	--	--	0.0160	0.550		

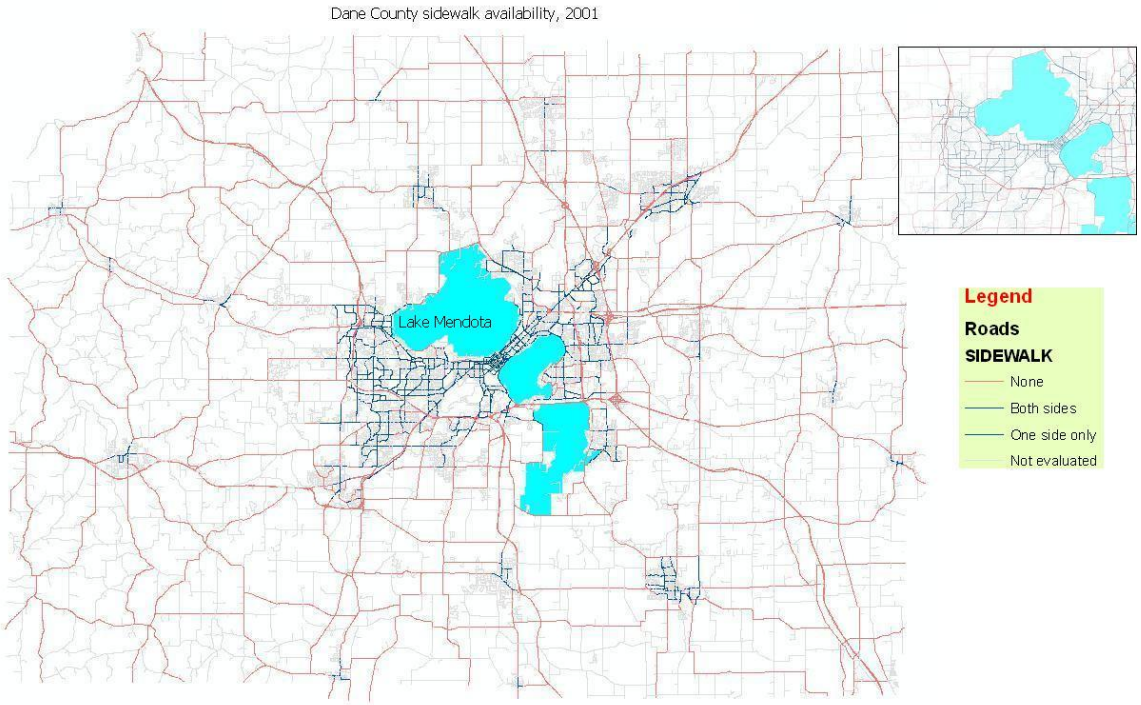
Model Goodness-of-Fit

- Spatial autocorrelation is statistically significant
- SSUR has a higher overall r-square (0.1507 vs. 0.1261)

Variance					
SUR			SSUR		
	MWB	VMT		MWB	VMT
MWB	2.6744	-2.3153	MWB	2.7389	-2.5286
VMT	-2.3153	415.7054	VMT	-2.5286	429.8206
Cross-equation correlations					
SUR			SSUR		
	MWB	VMT		MWB	VMT
MWB	1.0000	-0.0694	MWB	1.0000	-0.0737
VMT	-0.0694	1.0000	VMT	-0.0737	1.0000

Scenario Analysis

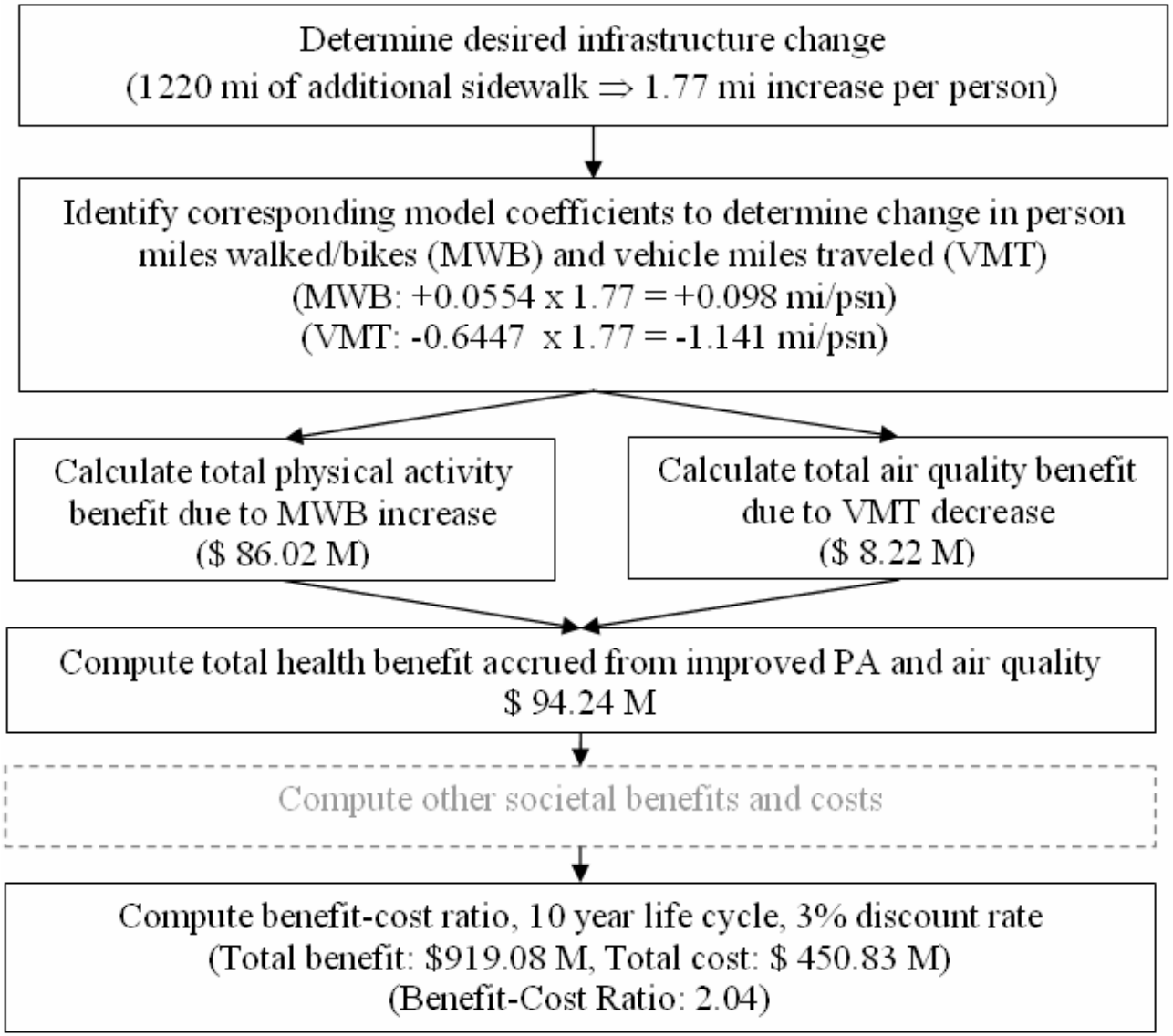
- What if all roadways in Dane County were fitted with sidewalks at least on one side?
  - 1220 mi of 4509 mi did not have sidewalk on either side of the road



Scenario Analysis

- Construction Cost
  - Cost for concrete curbs is approximately $15 per linear foot and $11 per ft^2 for walkways
  - FHWA and ITE recommended minimum width of 5 ft is estimated at $70 per linear foot
  - Total cost estimated at $450.83M

Scenario Analysis



Scenario Analysis

TUSALAB

- Physical Activity Benefit
  - 1mi increase in sidewalk, 0.0483 mi increase in individual's daily distance walked/biked
  - 0.098 additional miles walked/biked, 1.68 minutes of additional physical activity per person per day (3.5 mph speed)
  - additional 10.97 kcal burnt for an averaged (180 lb) person (Warburton et al, 2006)
  - offset weight gain in about 35% of the population (Hill et al, 2003)
  - annual cost estimate of $560 per person associated with weight gain/obesity (Strum et al, 2002)
  - Given 438,881, total avoided cost is $86.02M

Scenario Analysis

- Air Quality Benefit
  - 1mi increase in sidewalk, 0.6447mi decrease in individual's daily VMT
  - VMT reduction of 1.141mi per person-day
  - total of 182.80 million miles reduced across the entire population
  - Given average unit cost of $0.045 per vehicle-mile for motor vehicle air pollution, total annual air pollution cost saving is $8.22M

Sensitivity

TUSALAB

	SSUR	SUR
Parameter on sidewalk for MWB	0.0554	0.0483
Parameter on sidewalk for VMT	-0.6447	-3.288
BCR	2.04	1.77

Conclusions

TUSALAB

- Need to recognize the substitutive, complementary and synergistic effects of BE on travel behavior
- SSUR model is statistically superior to the SUR model, but more difficult to estimate
- Win-win transportation related strategies found: increased regional retail accessibility and increased prevalence of sidewalks within 1 mile neighborhood buffers
- Economic evaluation framework ready for neighborhood/regional application
- Making sidewalks available to all the residents in Dane County yields an estimated BCR of 1.73, suggesting economic viability

Next Steps

TUSALAB

- Need a more solid method for estimating the per mile benefit of walking and biking
- Incorporate other societal benefit/cost categories (e.g. safety, land value)
- Integrate with GIS-based planning tools