How Does Built Environment Effects on Travel Behavior Change Over the Geographical Space: A Spatial Analysis of the Connections between Land Use and Vehicle Miles Traveled for the State of Maryland

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Introduction

- Urban sprawl, traffic congestion, increase in oil consumptions and climate change are some of today's most worrisome concerns in most countries
- The objective of this paper is threefold: (1) to reexamine the impacts of the built environment on travel behavior; (2) to investigate the variability of the built environment effects on the travel behavior based on the geographical characteristics; and (3) to address a possible source for the inconsistency in the literature regarding the statistical significance of the effects of built environment measures on VMT.
- The case study area is the entire state of Maryland.

Data and Methodology

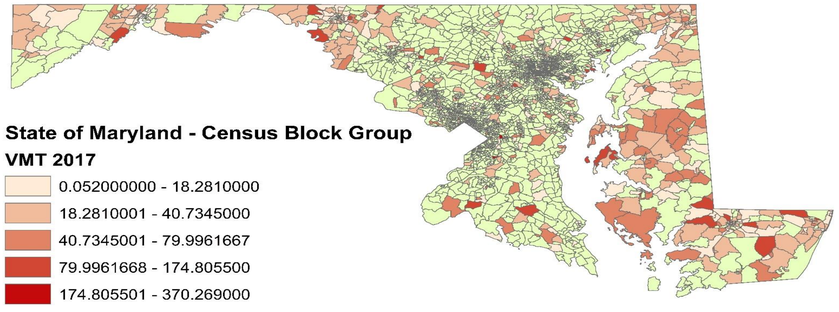
- This study used 2017 NHTS and smart location database (SLD) to understand the built environment effects on VMT.

Measures	Definition	expected effect on VMT	Descriptive statistics	
			Mean	SD
Edu	Binary variable: 1 for some college or higher, 0 Otherwise	Positive	0.6544	0.47565
Work	Binary variable: 1 if a person's work status is yes, 0 Otherwise	Positive	0.5527	0.4973
hhfaminc	Categorical variable, includes 11 level from less than $10,000 to $200,000 or more	Positive	$50,000 to $74,999	
R_sex	Binary variable: 0 for male, 1 for female	Negative	0.5102	0.5291
R_Age	Age of the respondent	Positive	47.5431	21.4474
Age^2	Square of the age of the respondent	Negative	2720.15	1954.92
D1d	Gross activity density (employment + housing units) on unprotected land	Negative	7.4330	14.6149
D2c_wremix	Household workers per job equilibrium index	Negative	0.2650	0.3085
D3a	Total road network density	Negative	15.4937	44.8557
D5ar	Jobs within 45 minutes auto travel time, time-decay (network travel time) weighted	Negative	133043.7	87318.87

- The 2017 NHTS provides trip information for 1475 households in the Maryland.
- The diversity index of household workers per job equilibrium is defined as follows:

$$\text{Diversity equilibrium index} = \exp\left(-\left|\left(\frac{\#\text{Workers}}{\#\text{Total Employment}}\right)-1\right|\right)$$

- The VMT per person profile for the year 2017 within the state of Maryland is shown in the following figure:



- In 2017 NHTS, a mapping component was employed in the online survey for the first time that derived the trip distances using the shortest-path algorithm, while Prior surveys used the self-reported trip distance.
- To empirically measure the impacts of the built environment on VMT, two models have been developed: multiple linear regression model and geographically weighted regression (GWR) model. the mathematical formation of the both models are presented in the following equation, respectively.

$$Y_i = \beta_0 + \sum_k \beta_k X_{ik} + \varepsilon_i \qquad Y_i = \sum_j x_{ij}\beta_j(p_i) + \varepsilon_i$$

- $\beta_j(P_i)$ denotes that estimated coefficient in GWR model is a function of P_i which is the observation location.
- Adaptive Gaussian weighting function has been used in this study to form the weighting matrix.

$$\alpha_{ik} = \exp\left(\frac{-d_{ik}^2}{h_{i(k)}^2}\right) \qquad W_i = \begin{bmatrix} \alpha_{i1} & 0 & \cdots & 0 \\ 0 & \alpha_{i2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \alpha_{in} \end{bmatrix}$$

- The kernel bandwidth (h_i) has been calculated using the CV criterion in a data driven approach:

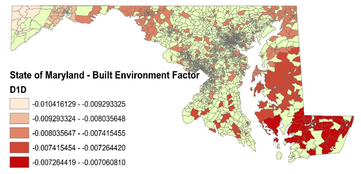
$$\text{CV criterion} = \arg\min_h \sum_i \left[y_i - \hat{y}_{\neq i}(\beta)\right]^2$$

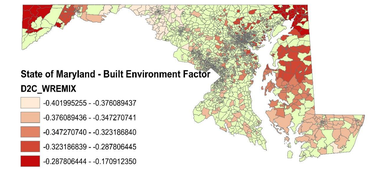
Results and Conclusions

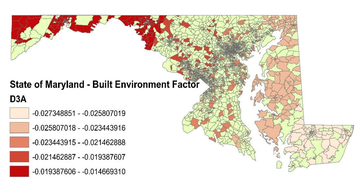
- GWR model showed its superiority over the linear regression model.

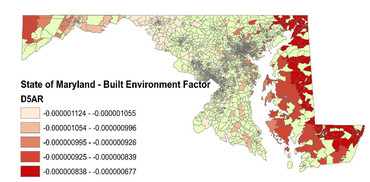
Measures	Global Regression Model			Geographically Weighted Regression Model						
	Estimate	t value	p value	Min	1st Quartile	Median	Mean	3rd Quartile	Max	Percent of significant *
intercept	0.816	5.15	2.8E-07	0.386	0.752	0.81	0.83	0.906	1.199	100
edu	0.315	4.85	1.3E-06	0.237	0.274	0.297	0.301	0.324	0.381	100
work	0.706	10.8	2E-16	0.684	0.691	0.7	0.703	0.707	0.811	100
hhfaminc	0.0485	4.31	1.7E-05	0.038	0.041	0.044	0.047	0.049	0.073	100
R_sex	-0.108	-2.2	0.0271	-0.233	-0.103	-0.095	-0.1002	-0.088	-0.073	67.479
R_Age	0.056	8.63	2E-16	0.045	0.056	0.059	0.057	0.06	0.061	100
Age^2	-0.0005	-6.7	3.1E-11	-6E-04	-5E-04	-0.0005	-0.00049	-0.0005	-0.0002	98.571
D1d	-0.0075	-3.3	0.00097	-0.01	-0.007	-0.0074	-0.00749	-0.0073	-0.007	100
D2c_wremix	-0.332	-4.1	3.5E-05	-0.402	-0.363	-0.3405	-0.338	-0.3188	-0.1709	98.319
D3a	-0.0226	-5.1	4.1E-07	-0.027	-0.025	-0.0221	-0.02249	-0.0205	-0.0146	98.487
D5ar	-9E-07	-2.2	0.03018	-1E-06	-1E-06	-1E-06	-9.5E-07	-8E-07	-7E-07	63.655
Number of observation	2380			2380						
R-squared	0.2657			0.2786						
AIC	7852.414			7817.857						
Sum of Square Error	3737.709			3687.612						

- The variability of the estimated coefficients over the study area:

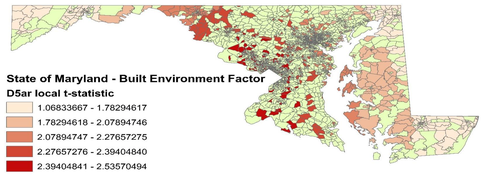








- The spatial pattern of the t-statistic for the local estimator can be analyzed in GWR model:



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