Spatial Analysis of Trip Generation

Karthik K. Srinivasan and Vishnu Baburajan
Dept. of Civil Engineering, IIT Madras

UMCSP Conference
13th Jul 2012

Outline

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Introduction

- Urban travel demand is growing rapidly in many Indian cities
- Need to plan and forecast the demand accurately to try and meet the mobility requirements of users
- Currently demand forecasting is done using the four step planning process
- Trip generation is first and very important step in this process
- Accuracy of this stage is critical as other stages depend on its output
- From policy standpoint, trip generation phase is important for analysis of key transportation performance measures: Congestion, VKT, VHT, Emissions etc.

Synthesis of Literature Review

- Trip Generation has been extensively studied
- Most analysis at household level fewer at individual level
- Model structure: OLS, and ordered models tend to be widely used
- Commonly used variables: income, vehicle ownership, nworkers, hhsize
- Models assume spatial homogeneity and spatial independence

Spatial Analysis - Definitions

- Spatial Dependence: The responses of observations that are close in space influence each other
- Spatial Heterogeneity: The regression coefficients for explanatory variable (such as income, vehicle ownership) varies across respondents based on spatial location (zones).
- Global or non-spatial model: no spatial dependence and no spatial heterogeneity

Objectives

- Compare the effect of activity-based variables on (non-spatial) trip frequency model at individual level
- Analyze spatial heterogeneity and spatial dependence in trip frequency models at individual level
- Analyze spatial heterogeneity and spatial dependence at household level

Data description

- Chennai Household Travel Survey (CHTS 2004-05)
- Records with inconsistencies were removed
- The sample used for analysis had:-
  - 1433 individuals
  - 779 households
  - Workers and Non-workers used for analysis
  - Single day travel diary [Working day]

Descriptive statistics

Individual Level

Variable	Mean	Variance	Minimum	Maximum
Trips	2.54925	1.19101	2	9
Excess Stops	0.20978	0.35312	0	6
Tours	1.17009	0.17814	1	3

Individual Level

Variable	Mean	Variance	Minimum	Maximum
Trips	4.6775	7.09898	2	21
Excess Stops	0.38492	0.77613	0	6
Tours	2.14694	1.36770	1	9

Descriptive statistics

- Average household size - 4.29
- Average Monthly income - Rs. 13,681
- Percentage of households with
  - 0 Workers- 8.45
  - 1 Worker- 49.28
  - 2 Workers- 28.22
  - 3 or more workers- 14.04
- Fraction of households with working women- 0.261
- Mean Number of full-time workers- 1.546

Descriptive statistics

- Driving knowledge among
  - Men- 84.11
  - Women- 32.14
- Vehicle Ownership
  - 0 vehicle - 22.24
  - 1 vehicle - 43.43
  - 2 or more vehicles - 34.33
- Average vehicles per household- 1.28

Descriptive statistics

- Percentage of household's with
  - Bus-stops within 500 m - 86.74
  - Train station within 1 km - 33.42
  - % workers with bus-stop within 500 m from work-place - 83.09
  - % workers with trn-stn within 1 km from work-place - 37.83

Methodology

- Non-spatial Model
  - Dependent Variable: No. of trips per day of individual
  - Independent Variables: individual, household characteristics etc.
  - Model: Multiple Linear Regression
- Spatial Model
  - Geographically Weighted Regression
- Both models built at individual and household levels and compared.

Results of Non-Spatial Model at Individual Level

	Variable	Trips	
		Coef	T-sta
Constants Variables	Constant	2.36	27.06
Individual Characteristics	Diploma-holder	0.22	2.10
	Low-income worker	0.18	2.23
	Employed, no access to vehicle	0.12	1.73
Household Characteristics	Number of vehicles per adult	0.16	1.59
	Owns 2+ cars	-0.46	-2.61
Intra-Household Interaction	Head with kids of age < 5	0.28	3.03
	Head with kids of age 6 -18	0.12	2.74
	Spouse with kids of age < 5	0.33	2.51

Results of Individual Level Model

	Variable	Trips	
		Coef	T-sta
Work Characteristics	Distance to Work	-0.02	-5.19
	Flexible work hours	0.14	2.11
Accessibility Characteristics	Peri-urban area	0.17	2.55
	Train station within 1 km	0.24	3.82
	Cinema theatre within 1 km	0.18	3.00
Mode Chosen	Bicycle was used	-0.33	-2.63
	Walk is used	-0.27	-3.11
	Public Transport is used	-0.48	-6.49

Spatial Model Description

- Geographically Weighted Regression Model:

$$y_i = a_0(u_i, v_i) + \sum_k a_k(u_i, v_i)\, x_{ik} + \varepsilon_i$$

- The coefficients a0, a1, a2,.. vary with latitude and longitude (ui,vi)
- In GWR, each observation is weighted in accordance with its proximity to 'i'.
- Spatial Influence of observation j on observation i is given by:

$$W_{ij} = e^{(-d_{ij}^2/h^2)}$$

- Regression coefficients obtained using above weights:

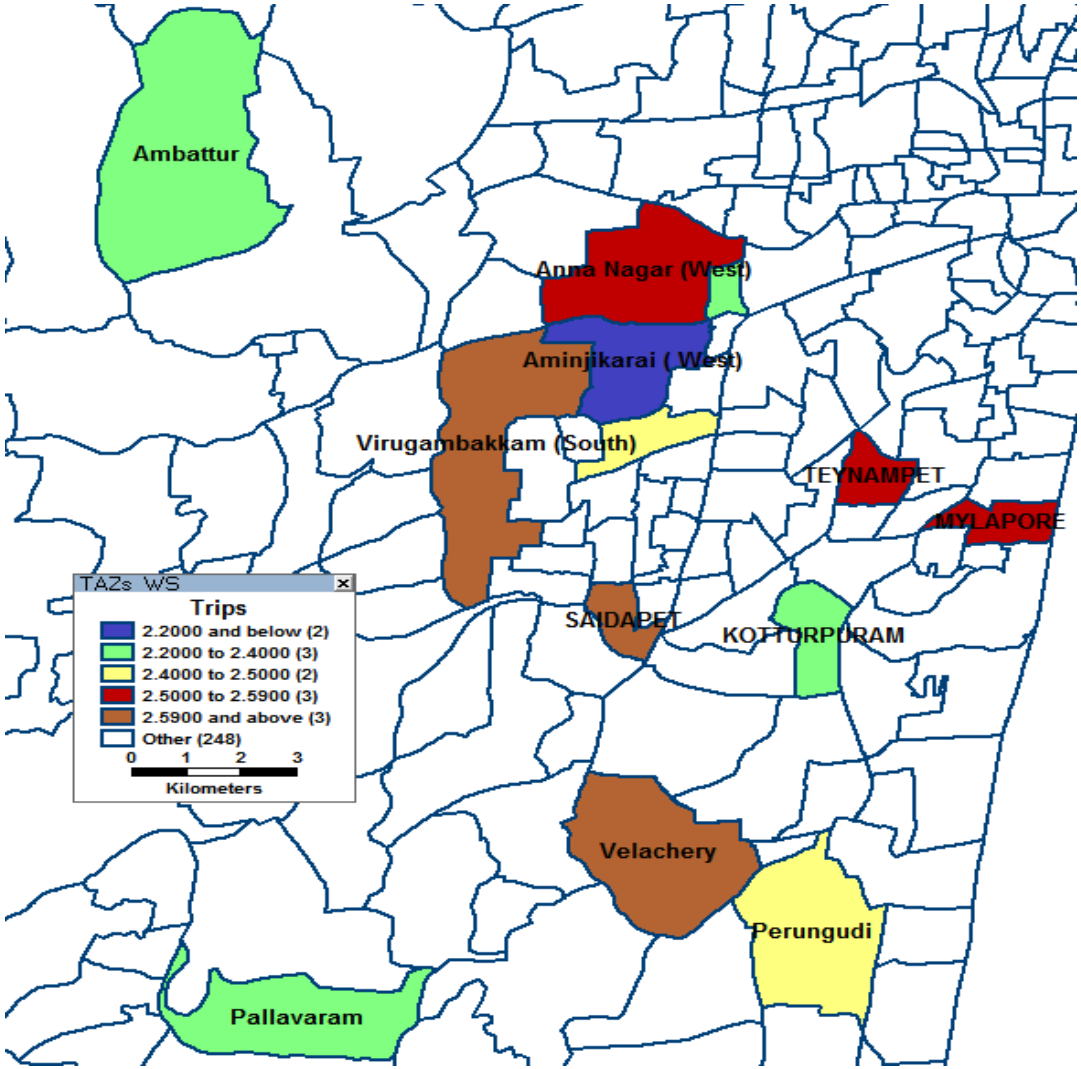
$a(u_i,v_i) = (X^tWX)^{-1}\, X^tW\, y$

where as usual regression assumes W = 1 if i= j and 0 otherwise.

Goodness of fit & Spatial Influence

- Individual Level
  - Non-spatial (conventional) R^2: 0.10
  - Spatial R^2: 0.27
  - AIC test also provides statistical evidence that spatial model is better
  - Spatial Influence Weight: 0.67, 0.45, 0.04 at 0.5, 1, and 2km

Spatial Variation in Trip Frequency



Saidapet – 3.42

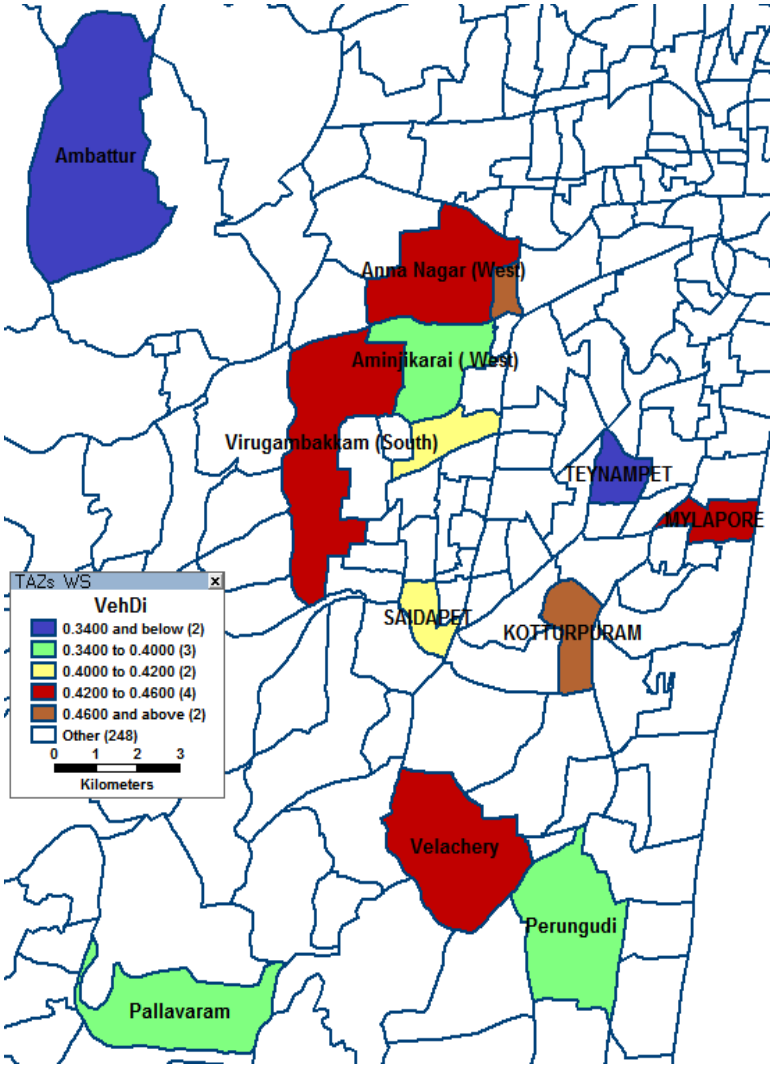
Aminjikarai West – 2.17

Spatial Heterogeneity at Individual Level

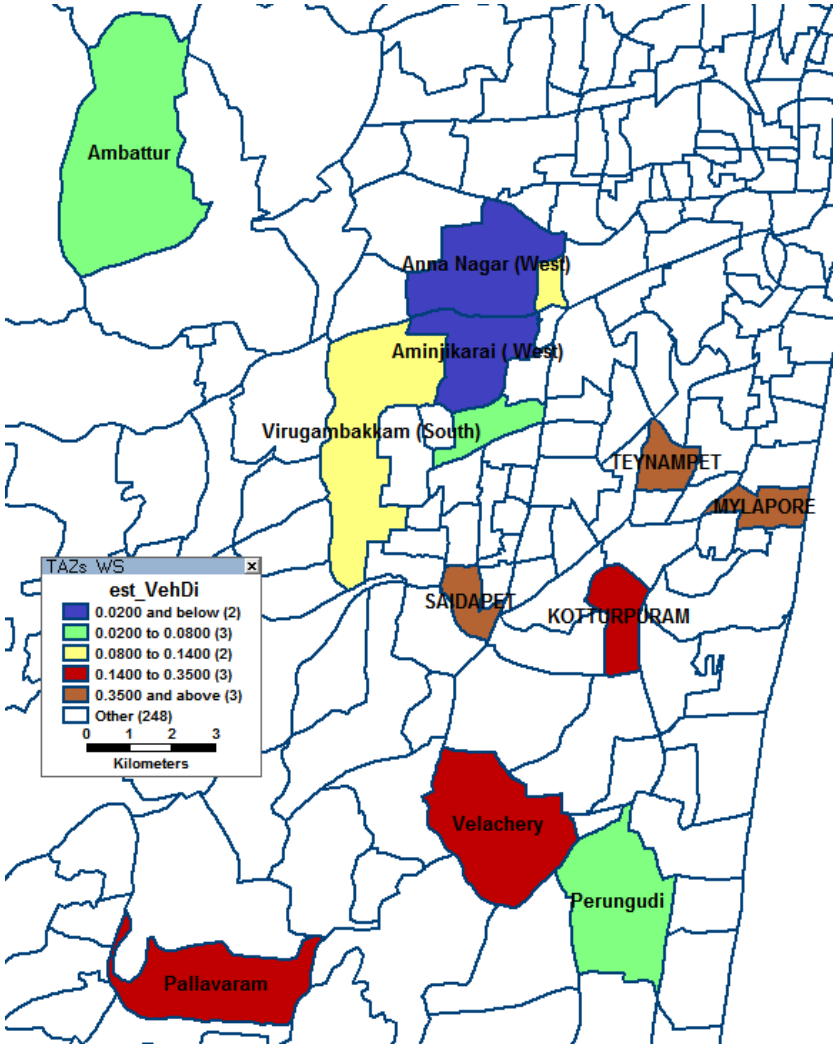
- Spatial Differences seen in
  - Vehicle availability per adult
  - Indicators for diploma-holder
  - Low-income worker
  - Work-time flexibility
  - Presence of train stations
  - Walk mode
  - Head of household with children
  - Spouse with children below 5 years
  - Work distance
- Non Spatial Variables
  - HH with multiple car
  - Bicycle use
  - Public transport use
  - Worker without vehicle access

Spatial Effects: Vehicle/adult

- Vehicle Availability

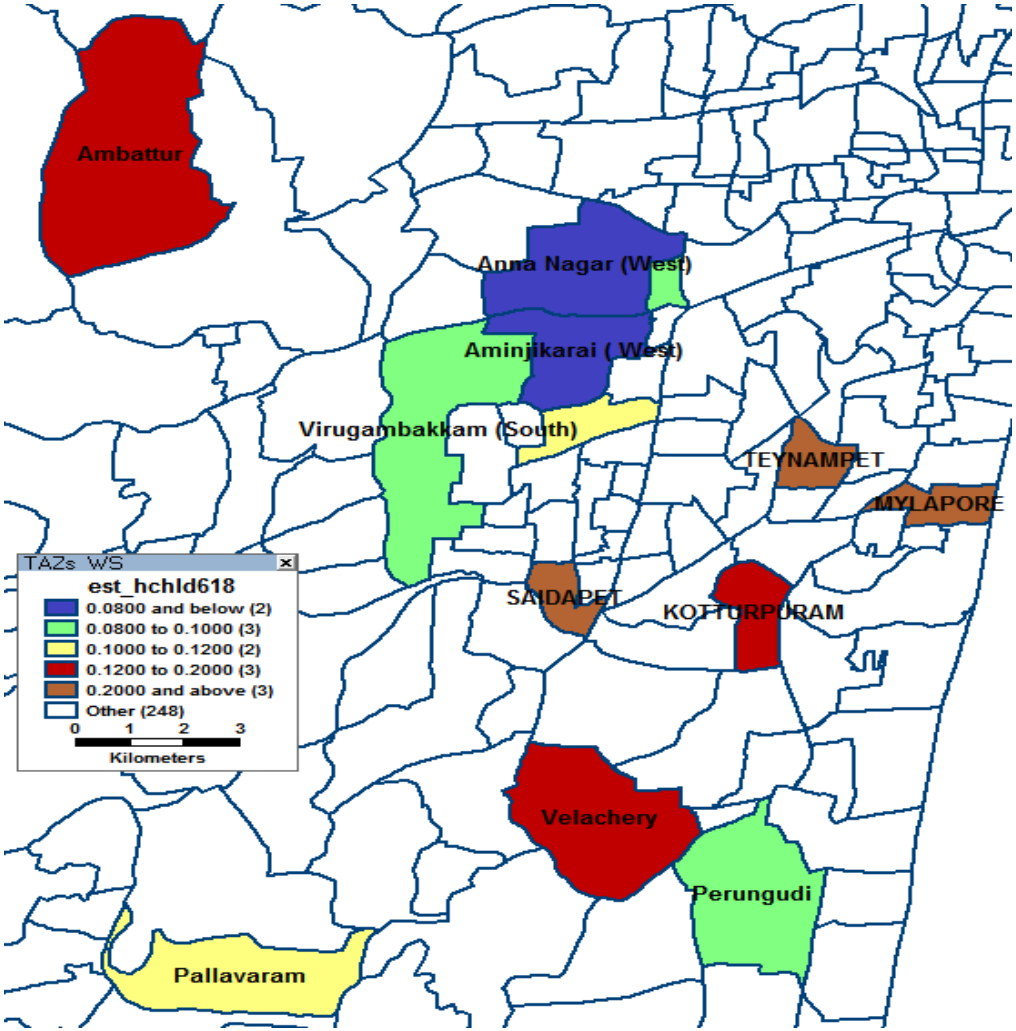


- Vehicle Availability Coefficient



Presence of Children

- Head with child 6+

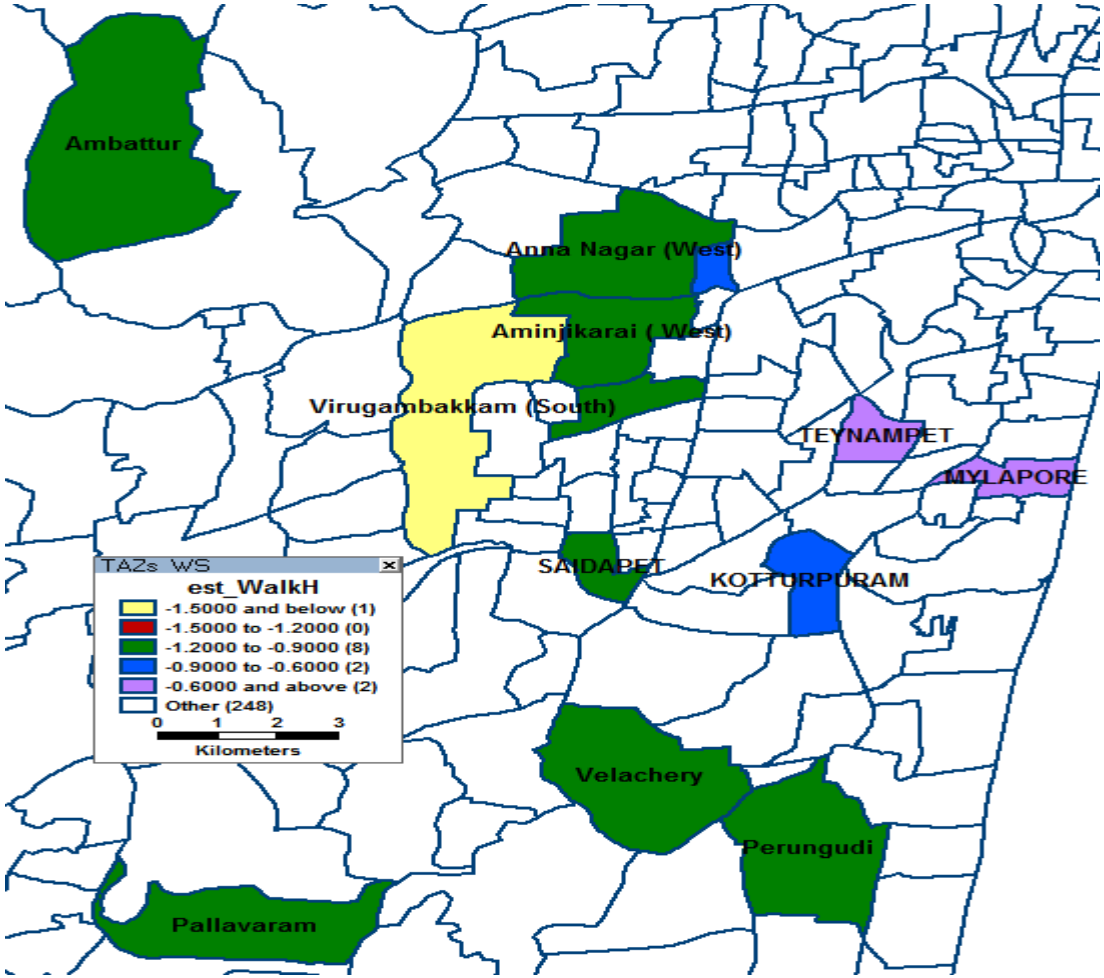


Household Level Model

- Household
  - Non-spatial (conventional) R^2: 0.63
  - Spatial R^2: 0.67
  - Improvement is not as large though still significant
  - Spatial Influence Weight: 0.61, 0.37, 0.02 at 0.5, 1, and 2km
- Few variables had spatial variation in coefficients
  - number of officers in HH, number of individuals choosing IPT and Walk modes

Spatial Variation at Household Level

- Walk mode is chosen



Household vs Individual Level Model

- Several variables significant in individual level models but not at the household level
- Several coefficients show spatial variation at individual but not household level
- Aggregation at household level can mask local variability present in individual trip making
- Potential for misinterpretation of role of explanatory variables at household level

Summary

- Non-Spatial and Spatial Models for Trip Frequency Developed at Individual and Household Level
- Activity characteristics, intra-household interactions, Work and accessibility characteristics affect individual trip frequency
- Spatial model leads to a notable improvement in goodness of fit at individual level (nearly 10 to 27%) and a modest increase at household level (63-67%)

- Evidence of spatial dependence of nearby observations is seen. This influence diminishes rapidly with increasing distance
- Strong spatial variation in coefficients seen for several variables at individual level, but fewer variables at household level
- Including these spatial effects at individual level can lead to more behavioural and accurate trip production models