**Land Use and Population Evolution in the Integrated Land Use, Transportation, and Environment (ILUTE) Modelling Framework**

*Bilal Farooq*

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**Abstract**
Land use and population evolution play an important role in shaping up the travel patterns of an urban area. Various dynamic microsimulation models are developed within the ILUTE framework to capture these complex interactions. In this presentation the development of main models and processes that are managing the evolution of land use and population in ILUTE simulation is discussed. These processes and models are a mix of econometric, stochastic, Monte Carlo, and rule based techniques. A full population simulation for the Greater Toronto and Hamilton Area for a period of 20 years from 1986 until 2006 is in the process of running. The results are validated using Census, Transportation Tomorrow Survey (TTS), housing data, and various other sources. This presentation also presents some of the initial results.

**Biography**
Bilal Farooq is currently doing his PhD with Prof. Eric J. Miller at Urban Transportation Research and Advancement Centre (UTRAC), University of Toronto. Prior to starting his PhD, he worked as a software engineer for 3 years in the software industry. Bilal has a Master degree in Computer Science and Bachelor in Engineering. His research interests include econometric modelling, multi-level spatial and temporal interactions of agents in micro simulations, urban energy consumption modelling, and environmental impact of transportation.
Land Use and Population Evolution in the Integrated Land Use, Transportation, and Environment (ILUTE) Modelling Framework

Bilal Farooq

PhD Student
Urban Transportation Research and Advancement Centre (UTRAC)

University of Toronto

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• UTRAC
• Introduction to ILUTE
• Demographic Evolution in ILUTE
• Land Use Evolution
  – Housing Market
  – Office Market
• Preliminary Results
Urban Transportation Research and Advancement Centre (UTRAC)

• Data Management Group
  – Transportation Tomorrow Survey (TTS)
• Intelligent Transportation Systems (ITS)
• Integrated Land Use, Transportation, & Environment (ILUTE) Modelling Group
• Public Transportation Operations & Planning
• Sustainable Transportation Group
• Freight Transportation Group
ILUTE Modelling Framework

- A microsimulation framework for modelling Land Use, Transportation, and Environment (ILUTE)
  - Disaggregate
    - Spatial
    - Temporal
    - Agent
  - Dynamic
    - State dependence
    - No imposed equilibrium assumptions
  - Completely Object Oriented
  - Full population
ILUTE Structure & Current Implementation

Observed Base Year Aggregate Distributions of Agents & Attributes (Census, etc.)

AGENT SYNTHESIS

Synthetic Agent Population \( T = 0 \)

\( T = T + \Delta T \)

Demographic Update

Employment @ time T

Labour Market

Housing Market

Auto Ownership

Activity-Based Daily Travel (TASHA)

Commercial Vehicle Movements

Road & Transit Networks @ time T

Road & Transit Network Assignments

Link & O-D Travel Times/Costs

Link, Congestion Levels, Etc.

Transportation Emissions & Dispersed Pollution Concentrations

Population Exposure to Pollutants by Location & Time of Day

GHG Emissions

Exogenous Inputs @ time T:
- Interest rates
- Energy prices
- Vehicle technology
- Zoning
- In/out migration rates
- ...

Population Exposure to Pollutants by Location & Time of Day
ILUTE Main Class Diagram
Demographics in ILUTE

• Agents
  – Person
  – Household
  – Family

• Types of relationships
  – Kinship
  – Husband/Wife
DEMOMOGRAPHIC UPDATING IN ILUTE
Story of “2105278” a.k.a. Julia in the ILUTE simulation

• Other Characters
  Father  96 a.k.a. David Flintoff
  Mother  885589 a.k.a. Elisa Flintoff
  Sibling  1835869 a.k.a. Peter Flintoff
  Spouse  1735 a.k.a. Andrew Watson
  Son  72811 a.k.a. Michael Watson
  In-Laws  2991000 a.k.a. James Watson
            3252322 a.k.a. Karin Watson
Time Line

• From 1987 till 1989, Julia who was aged 26 at the start of the simulation lived with her parents near Victoria park and HWY 401 (CT: 3363).
  – Her mother Elisa (53) was married to her father, David (62).
  – Her brother, Peter (20) also lived with them

• In 1990 she met a 32 years old, handsome man named Andrew Watson, who was living near Finch and Leslie (CT: 2584).
  – They got married soon, formed a new family and started living in the same neighbourhood
Time Line

• In 1992 she gave birth to a healthy baby boy and named him Michael T. Watson
• In 1997, James Watson, Julia’s father-in-law died
• By 1998, Julia’s family out-migrated from Toronto
Land Use in ILUTE

• Zoning System Classes
  – Census Tracts and Dissemination Areas
  – Traffic Analysis Zones

• Land Use processes
  – Housing Market
  – Office Space Market
Housing Market

- Housing Market in an Integrated Model
  - Highly disaggregate, spatial and temporal distribution of:
    - Built space (residential)
    - Households
  - Two-way interaction with other components
  - Allows testing of wide range of policy scenarios
Housing Market: Sub-Processes

• Demand
  – Mobility decision of individual household
    • Heterogeneity among individual household’s taste (Ahsan & Miller, 2006)
  – Asking price for the individual dwelling
    • Dwelling, zonal, and neighbourhood attributes (Ahsan & Miller, 2008a)
  – Household choice set generation
    • Individual dwellings as choice
  – Location choice decisions
    • Multinomial logit formulation with loss and gain concept (Ahsan & Miller, 2008b)
Housing Market: Sub-Processes

• Supply
  – Quantity by type decisions
    • Monthly new stock of new housing by 4 different types (Haider & Miller, 2003)
  – Location choice decisions
    • Multinomial logit formulation for probabilities of type of dwelling to be located (Haider & Miller, 2003)
  – Distribution of new stock
    • Monte-Carlo sampling process based on location choice probabilities
Housing Market: Sub-Processes

• **Market Clearing** (Farooq et al. 2008)
  – Microsimulation clearing process
    • Dwellings cleared individually and not by type or any other level of aggregation
  – Auction based
  – No equilibrium assumption
  – Endogenous price-formation
  – Location choice probabilities of bidding households, used to clear the market
Market Clearing: Theory

• Operational, Integrated Land-Use and Transportation Modelling Frameworks
  – MUSSA
    • Bid-Choice Model (Martinez, 1992)
      – Price, outcome of an equilibrium assumption in which:
        » Demand = Supply
        » *Sellers maximize profits, and buyers maximize consumer surplus* (Willingness to pay – price)
      – Resolved for types of households and dwellings
  – UrbanSIM
    • Uses Bid-Choice framework with no equilibrium assumption (Waddell, 2000)
      – Household is matched to the highest utility alternative
        » Ratio of demand and supply is used to determine the transaction price
      – Resolved for more disaggregate types of households and dwellings
Market Clearing: Theory

• Theoretical framework of residential housing markets (Miller & Haroun, 2000)
  – Microsimulation approach
    • Individual buyers and sellers
  – Used a “second-price” type auction to clear dwellings at individual levels
  – Based on total utility (utility of location, expenditures, savings/investments) of a household h, at given time t
Market Clearing: Theory
Market Clearing: Theory

\[ \sum P_i = 1 \]
Market Clearing: Theory

\[ \sum_{i} P_{i} = 1 \]
Market Clearing: Theory

- $\sum P_j$ is the predicted demand for dwelling $j$ at the given asking price
- High values of $\sum P_j$ for a dwelling
  - At given asking price, dwelling has a high demand
- Low values of $\sum P_j$ for a dwelling
  - At given asking price, dwelling has a low demand
Market Clearing: Theory

• Price adjustment effects
  – Decreasing the price
    • More buyers get interested in the dwelling
      – \( \sum P_j \) value rises
  – Increasing the price
    • Less buyers get interested in the dwelling
      – \( \sum P_j \) value lowers
  – Resulting cases
    • Only one buyer remains that has the highest utility of the dwelling in its choice-set (\( \sum P_j \rightarrow 1 \))
    • All the buyers remaining in the choice-set have equal utility for the dwelling (\( \sum P_j \rightarrow 1 \))

• Adjusting the asking price so that
  \( \sum P_j = 1 \)
  – Potential buyer
  – Potential transaction price
Housing Market: Price Finding

- Finding solution of:
  \[ \sum_{h=1}^{H} P_h(d) - 1 = 0 \]
  \[ \sum_{h=1}^{H} \left( \frac{r}{r + C_h} \right) - 1 = 0 \]

- Function with non-unique solution
  - Every Bidder will have a maximum feasible price
    - Give everything else remains constant
- Solutions only around the asking price
Housing Market: Price Finding

- Developed a two level *constrained* and *directed* search process that find price around the asking price
  - Laguerre

- Newton-Raphson

- Transaction price selected from the available roots
Market Clearing: Flow Diagram

Active Hhld Set

- Dwellings: h1, h2, h3, h4, h132, h243

Active Dwell Set

- Dwellings: d1, d21, d27, d121, d54, d91

Active Hhld Subset

- Dwellings: h1, h2, h3

Active Dwell Subset

- Dwellings: d21

- Dwellings goes back to pool

Update Subset

Market exit decision

Transaction Processing

Price Set Search

Yes

No

- Dwellings matched to a Household @ transaction price
- Rest of Households’ choice-set is updated
Market Clearing: Properties

• Endogenous price formation
  – No equilibrium assumption
• Households and dwellings entering and exiting the market
  – Based on available options and their utilities
• Stable set of matchings between active households and dwellings
  – There will not be any pair of agents (household-dwelling) in the simulation that are assigned an unacceptable match
    • Based on utility and profit maximization
Market Clearing: Properties

• Stable matchings (cont:)
  – There will not be any pair left in the active-market that are not matched to each other, but will mutually prefer to be matched to one another

• Flexibility
  – Incorporating many different
    • Location choice formulation
    • Choice-set generation process

• Buyer’s vs Seller’s market
  – More sellers than buyers
  – More buyers than sellers
Market Clearing: Properties

• Buyer’s vs Seller’s market (Cont:)
  – Disaggregation by both Type and Neighbourhood
  – Shift in Choice-set of Buyers

• Supply of New Housing
  – Lagged effect of market activity
Office Market

• Location choice modelling
  – First time and relocation decisions of office firms
    (Elgar, Farooq, and Miller 2009)

• Office asking rent modelling
  (Farooq, Miller, & Haider 2010)

• New office space location choice modelling

• Office market clearing
ILUTE Simulation Runs

• Current state of progress
  – Twenty year run for Greater Toronto and Hamilton Area
    • 1986–2006
  – Sample size
    • 10% to 100% of population
  – Computational features
    • Single core implementation
    • Full population can be loaded within 8Gbyte memory
  – Validating results with various data sources
1991: Population Density
Total New Stock in GTA

CMHC Data
ILUTE Forecast

Questions & Comments?