

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

Bilal Farooq

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Location: Room 601, Skempton (Civil Eng) Bldg, Imperial College London

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.



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Content

- UTRAC
- Introduction to ILUTE
- Demographic Evolution in ILUTE
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 - Housing Market
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- Preliminary Results

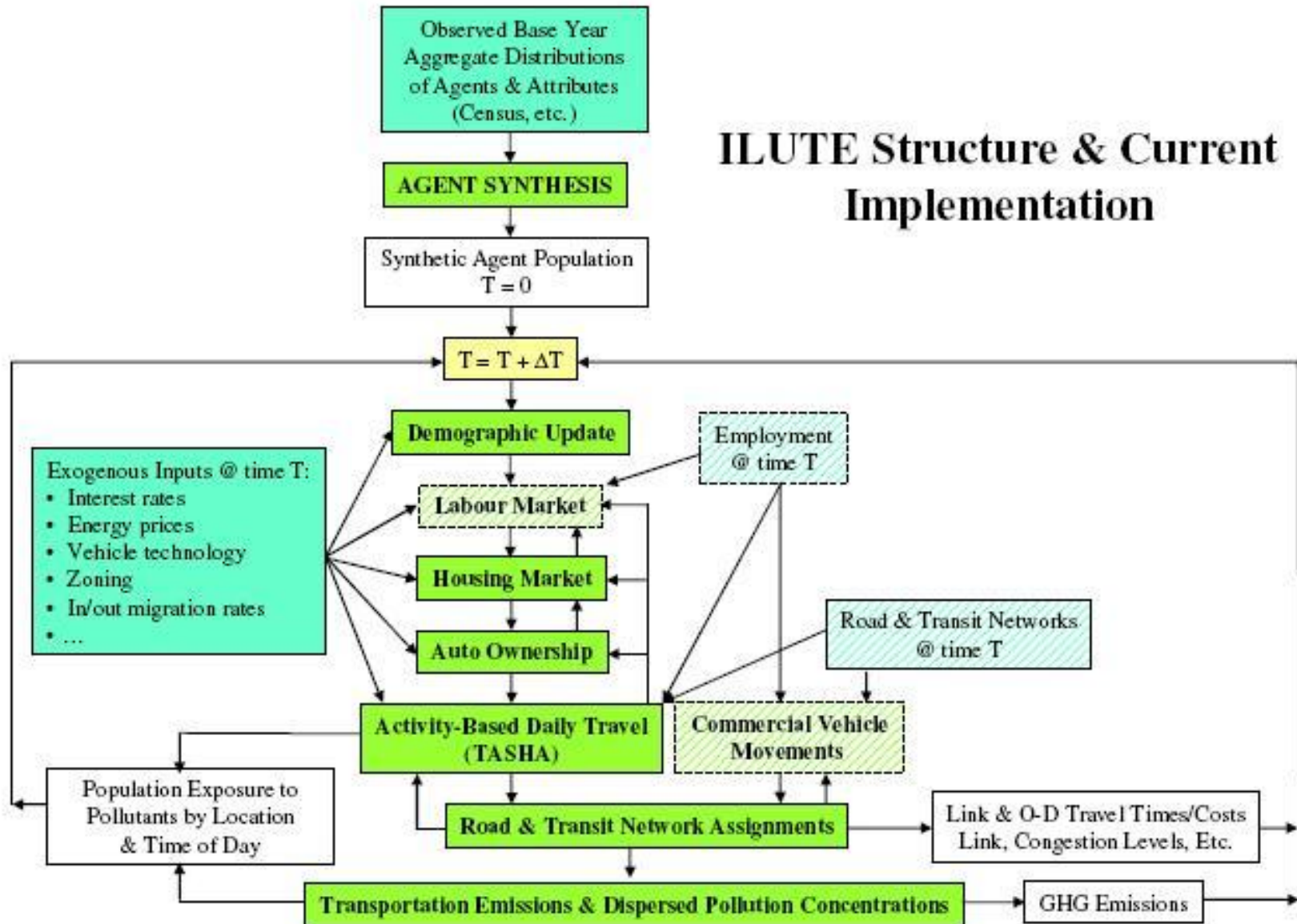
Urban Transportation Research and Advancement Centre (UTRAC)

- 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

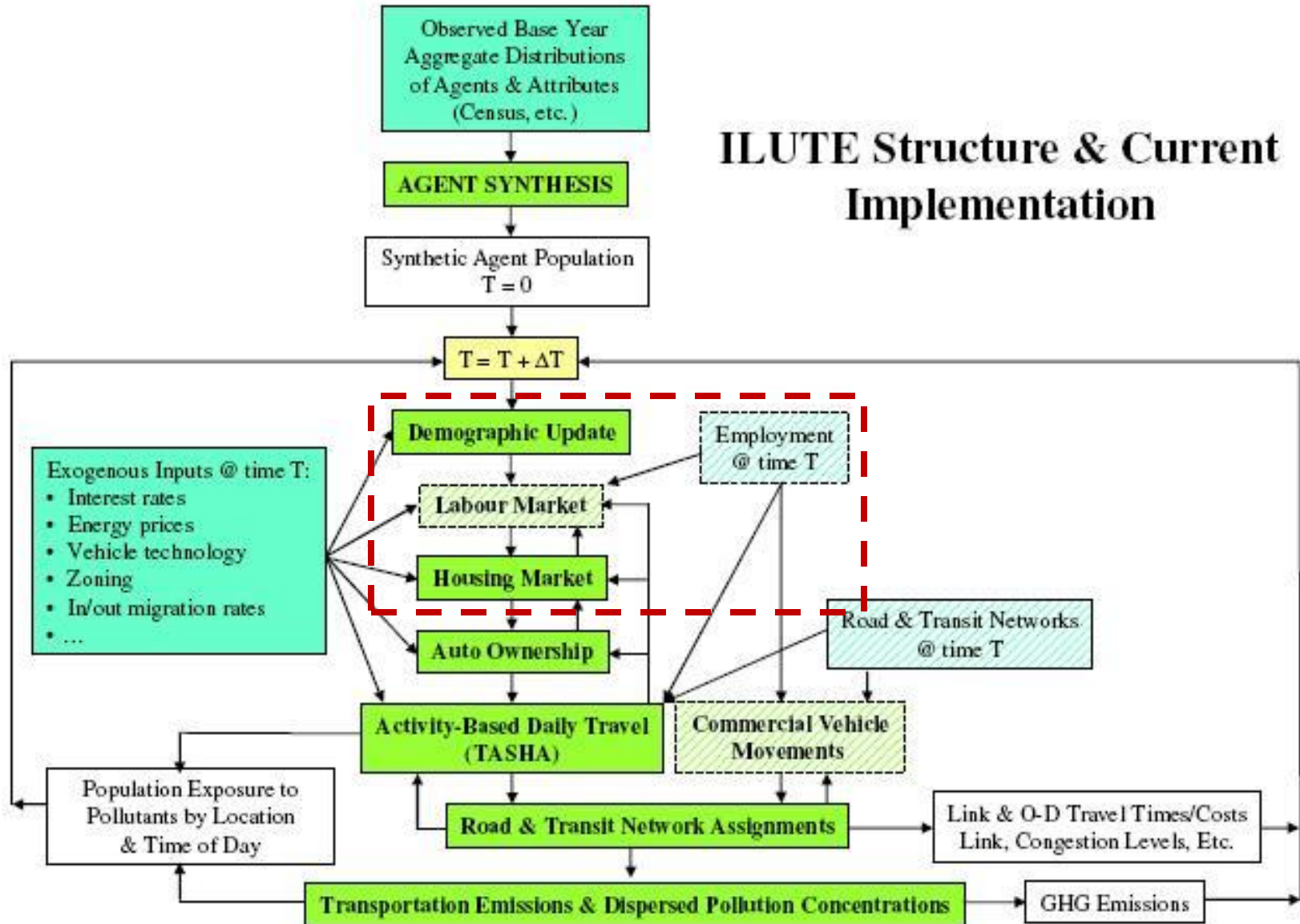
ILUTE Modelling Framework

- 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

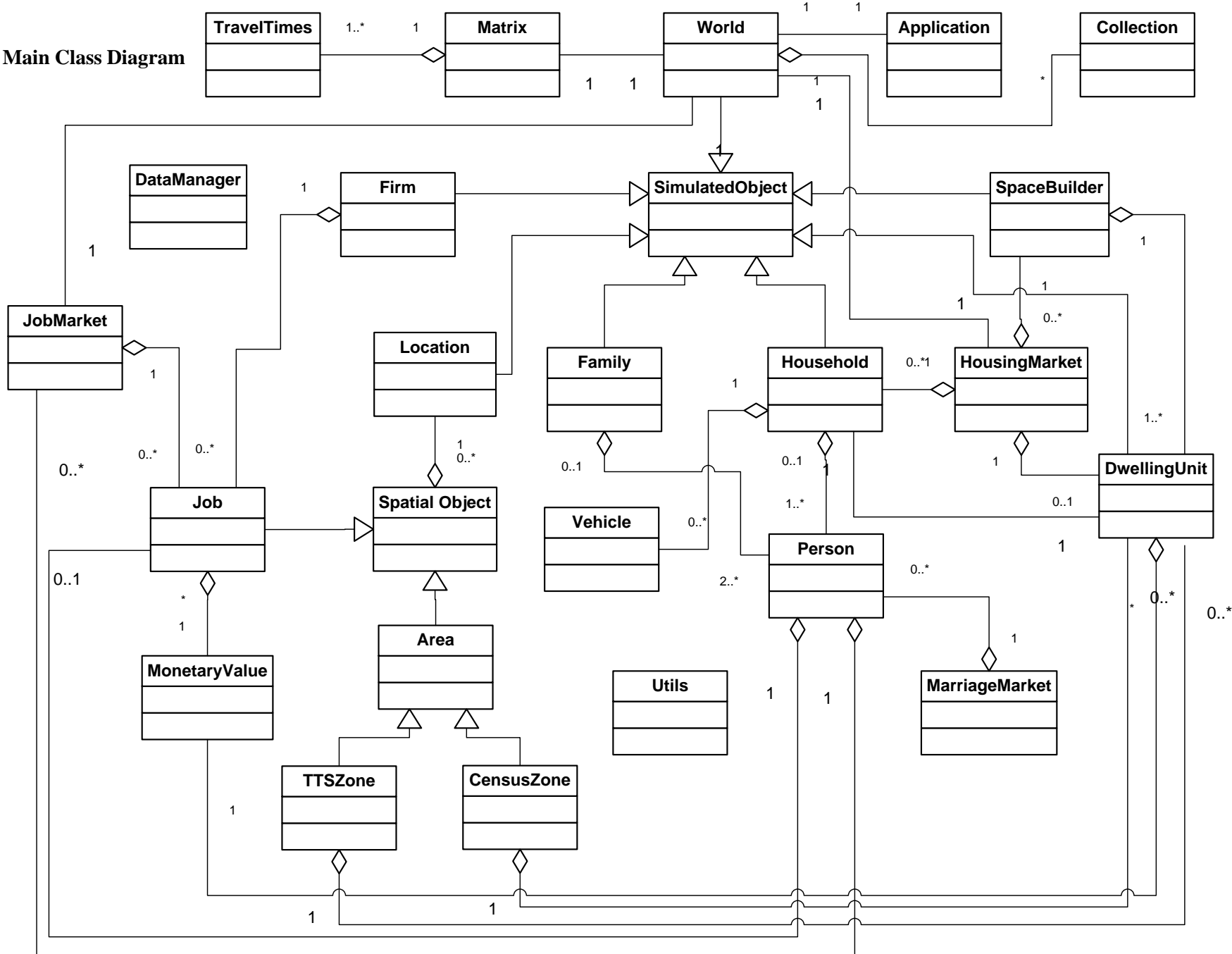
ILUTE Structure & Current Implementation



ILUTE Structure & Current Implementation



ILUTE Main Class Diagram



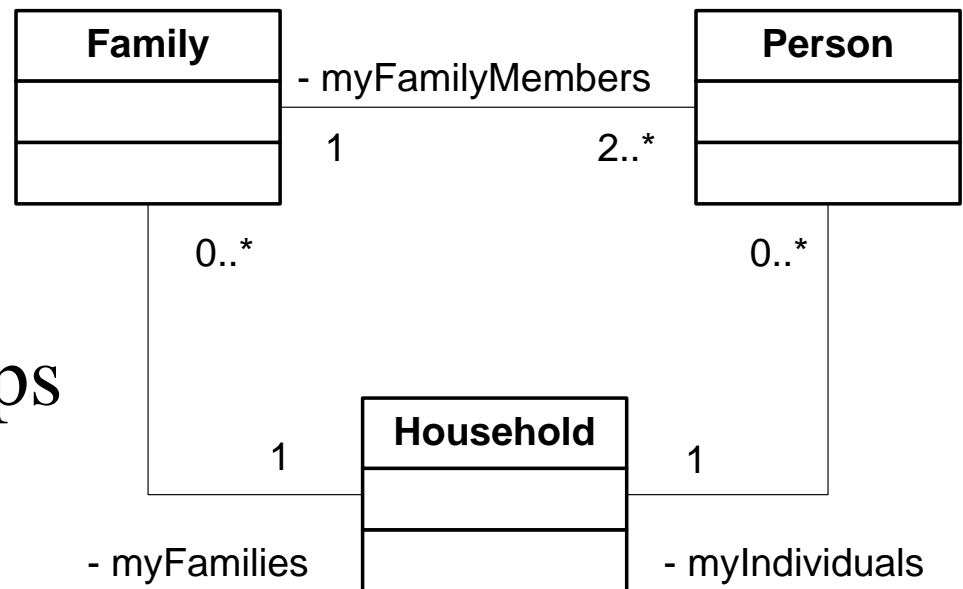
Demographics in ILUTE

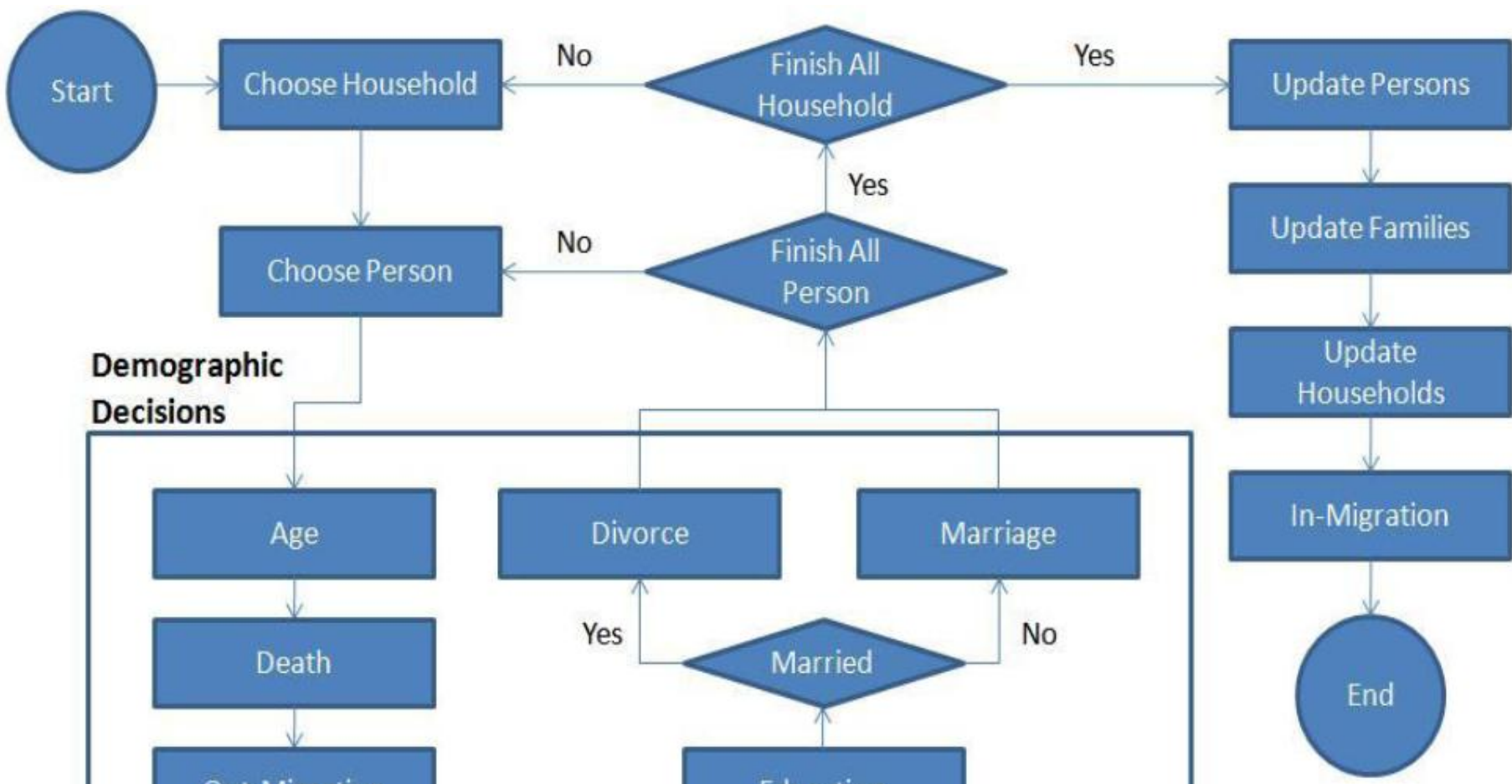
- Agents

- Person
- Household
- Family

- Types of relationships

- Kinship
- Husband/Wife





**DEMOGRAPHIC
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

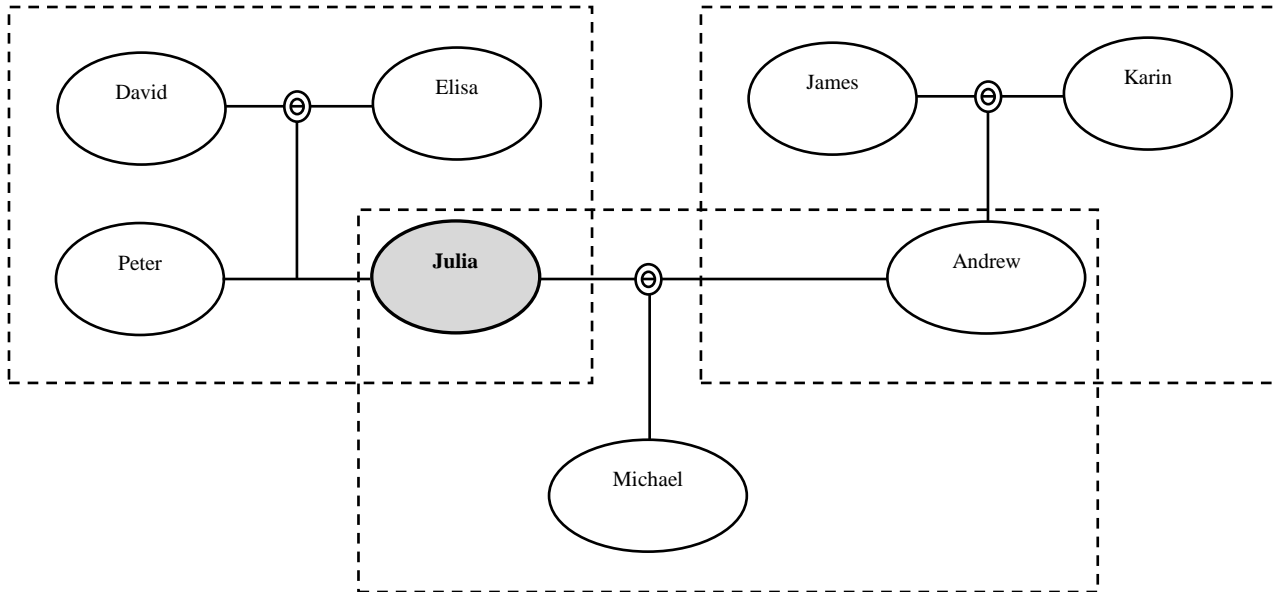
Time Line

- 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

Family Tree

The Flintoffs

The Watsons



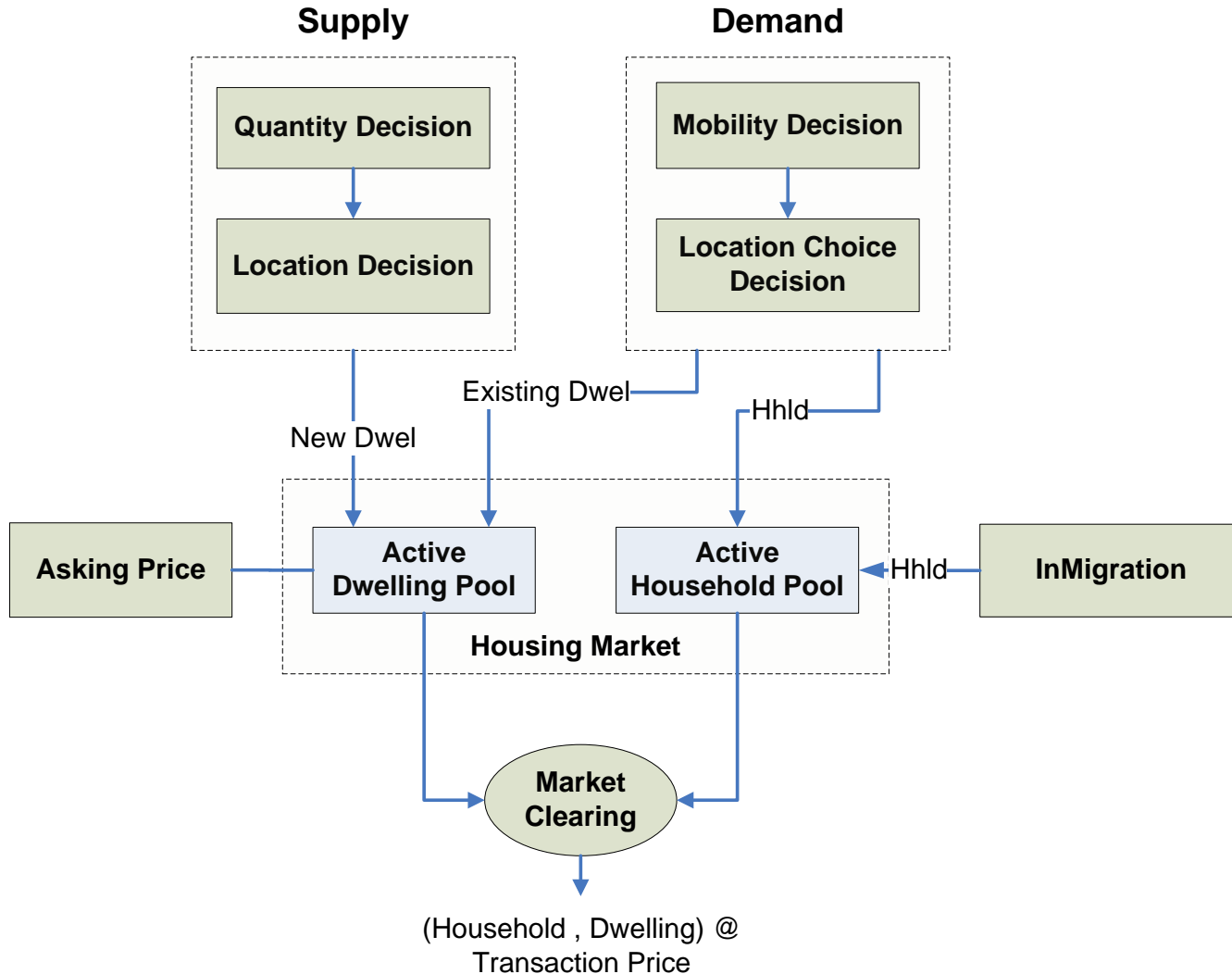
Land Use in ILUTE

- 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



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

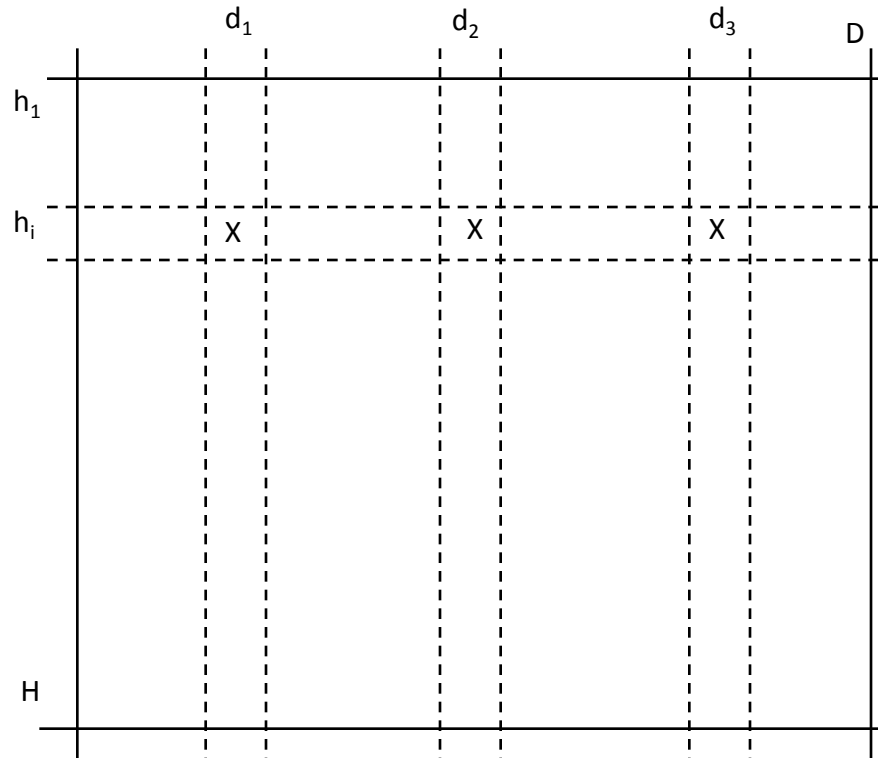
Market Clearing: Theory

- Operational, Integrated Land-Use and Transportation Modelling Frameworks
 - MUSSA
 - Bid-Choice Model (Martinez, 1992)
 - Price, out come 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

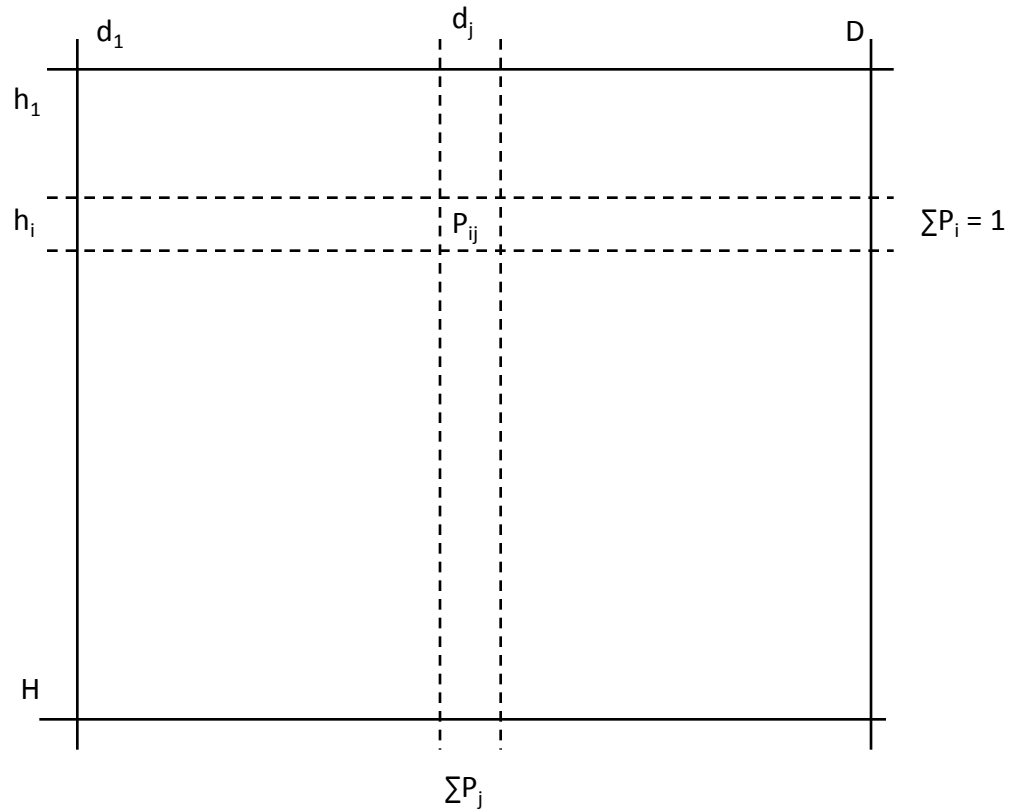
Market Clearing: Theory

- 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

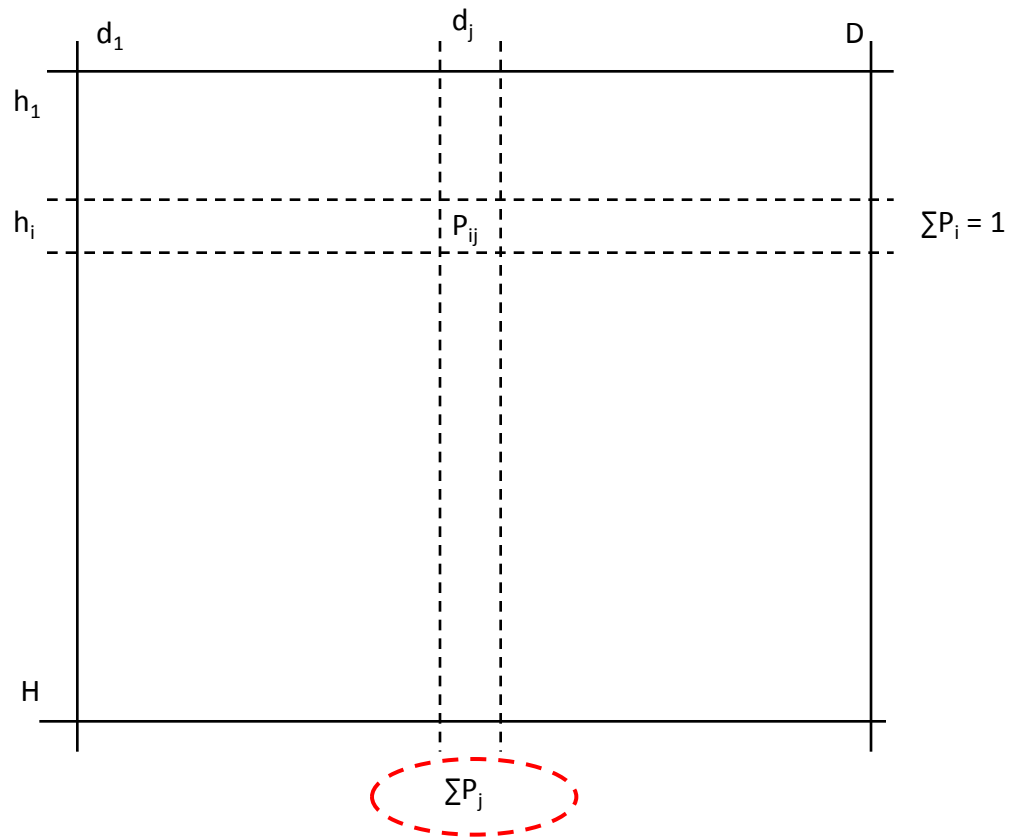
Market Clearing: Theory



Market Clearing: Theory



Market Clearing: Theory



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

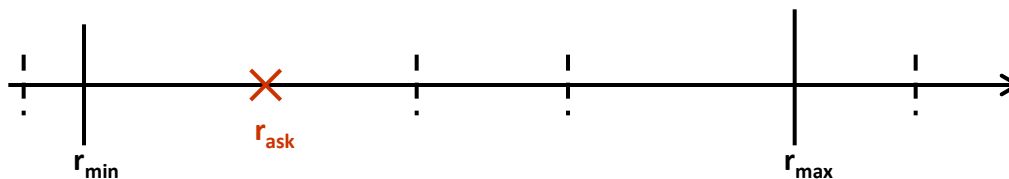
Housing Market: Price Finding

- Finding solution of:

$$\sum_{h=1}^H P_h(d) - 1 = 0$$

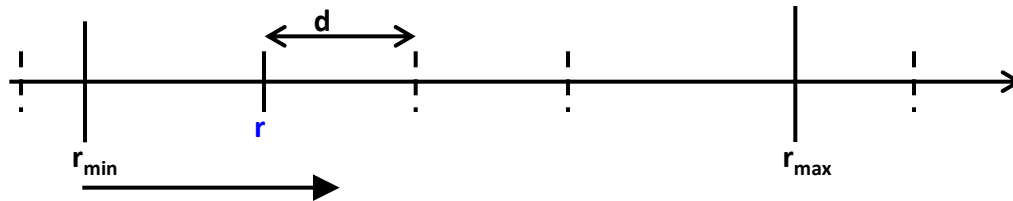
$$\sum_{h=1}^H \left(\frac{r}{r + C_h} \right) - 1 = 0$$

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



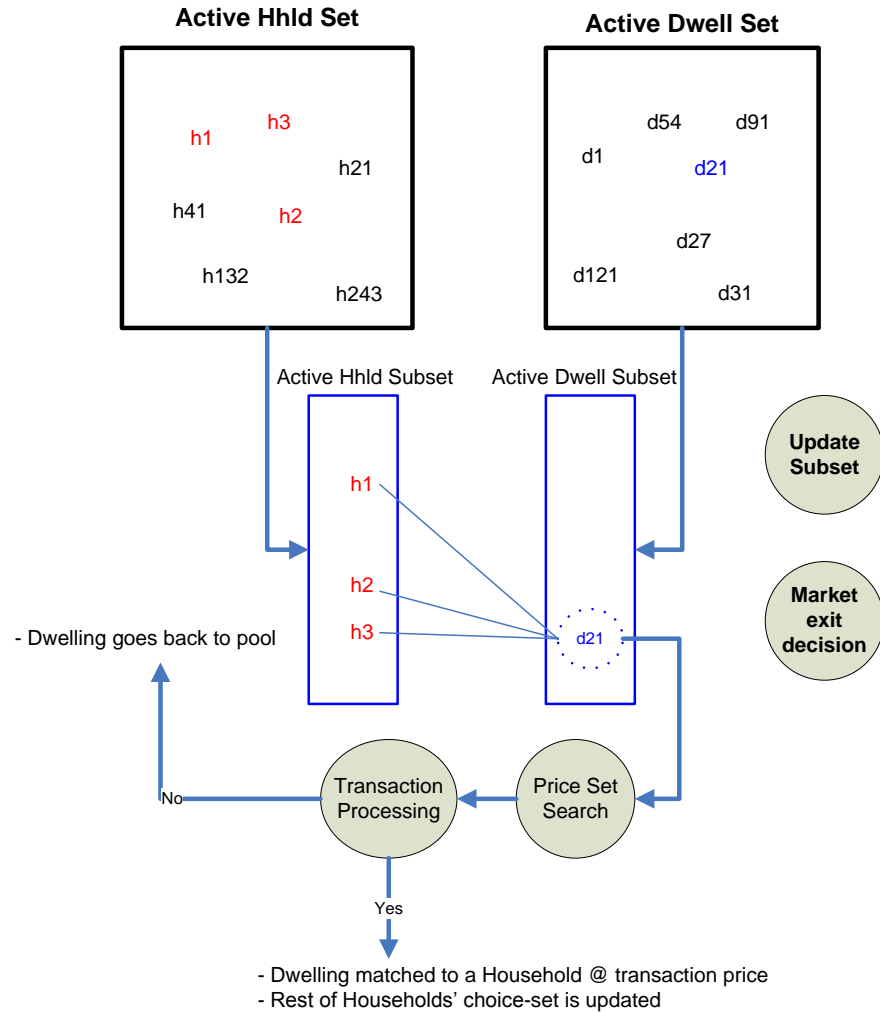
Housing Market: Price Finding

- 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



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

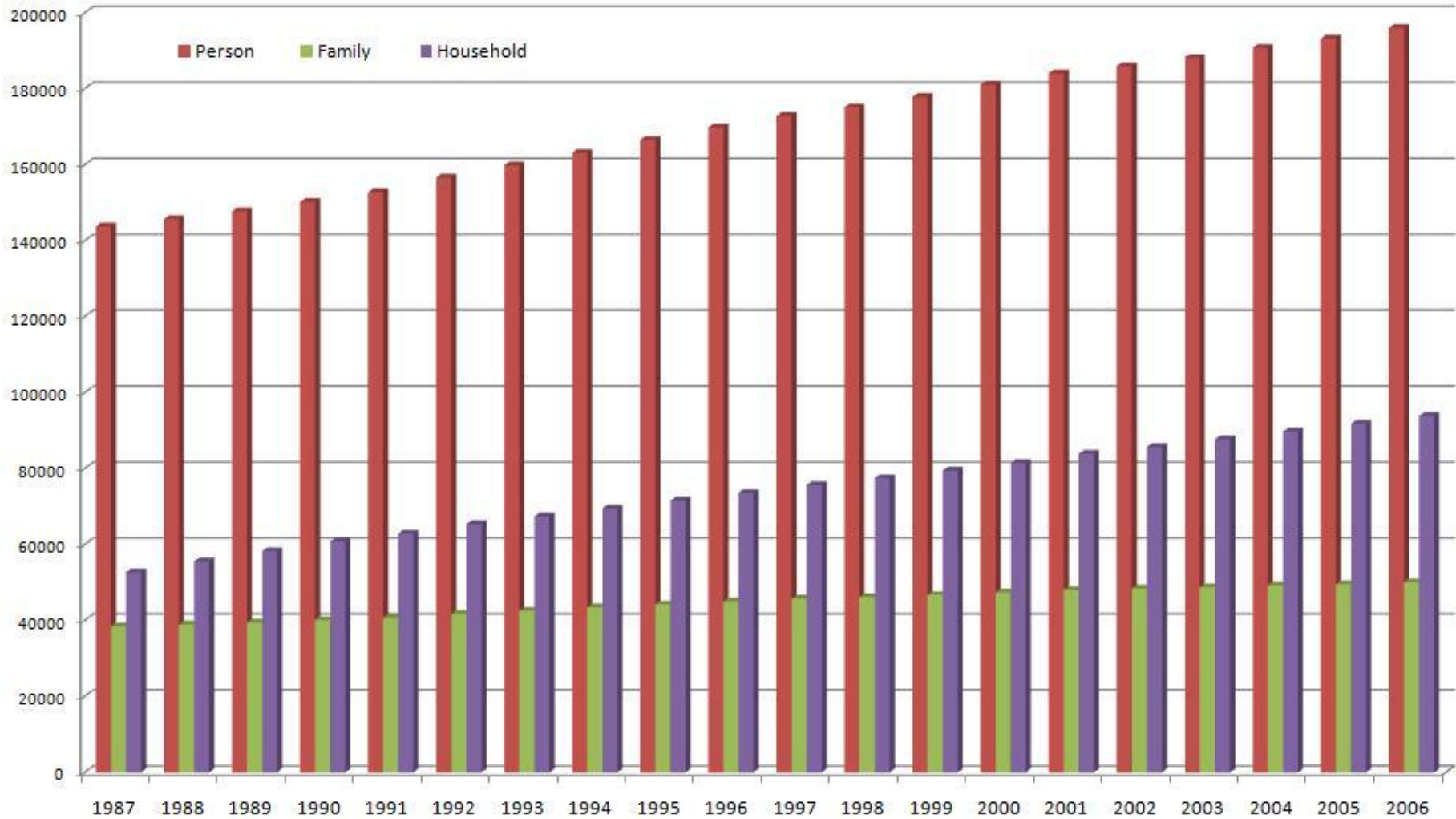
- Buyer's vs Seller's market (Cont:)
 - Disaggregation by both *Type* and *Neighbourhood*
 - Shift in Choice-set of Buyers
- Supply of New Housing
 - Lagged effect of market activity

Office Market

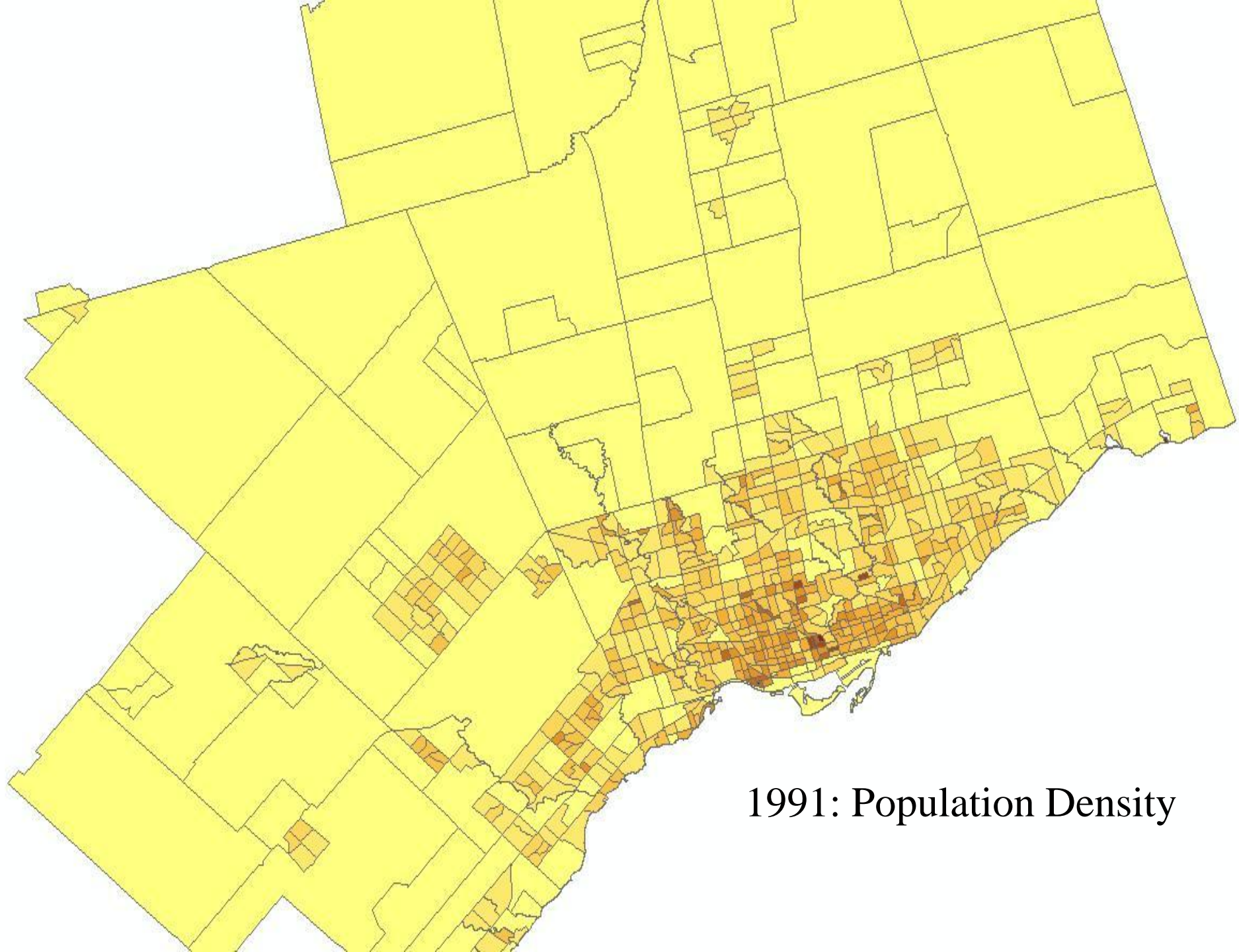
- Location choice modelling
 - First time and relocation decisions of office firms
(Elgar, Farooq, and Miller 2009)
- Office asking rent modelling
(Farooq, Miller, & Haider 2010)
- New office space location choice modelling
- Office market clearing

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

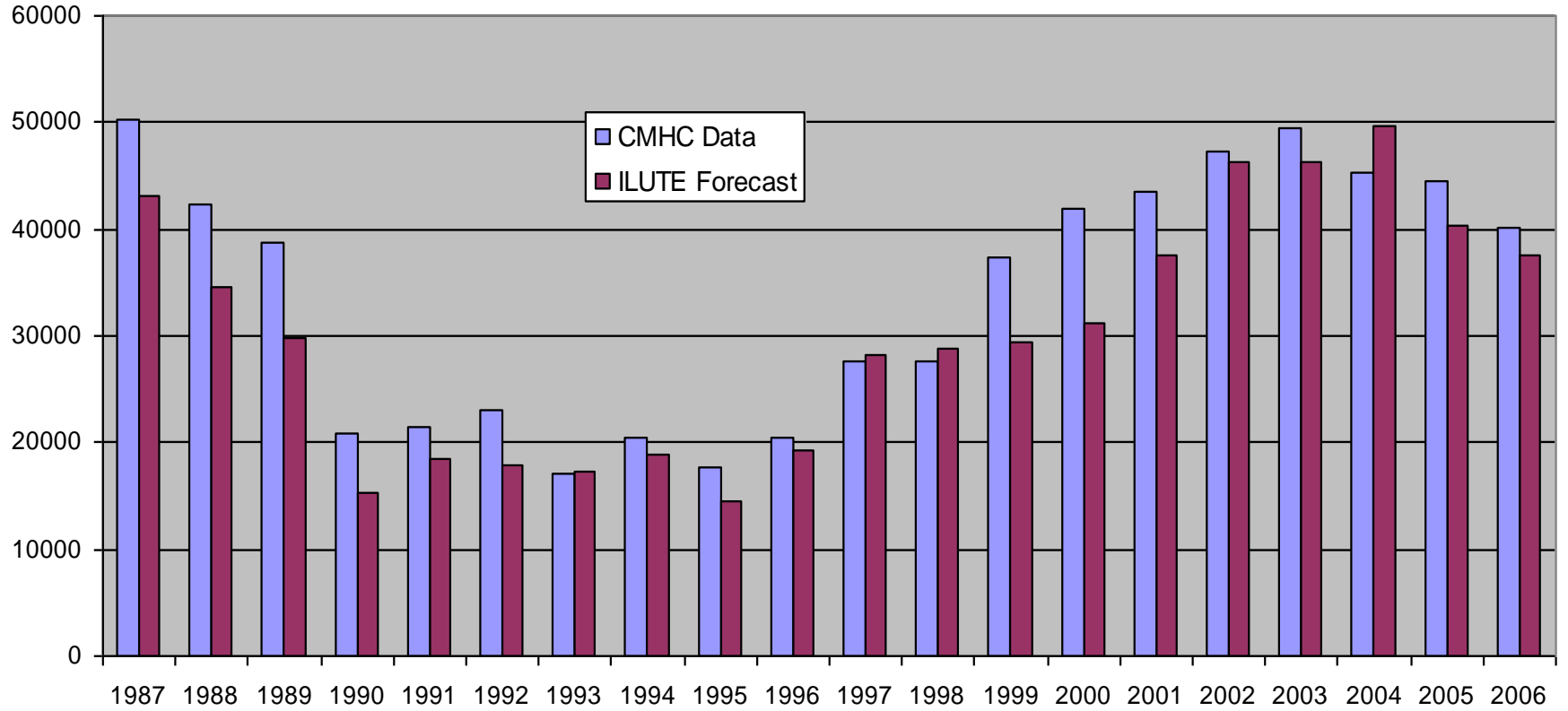


Population Trend

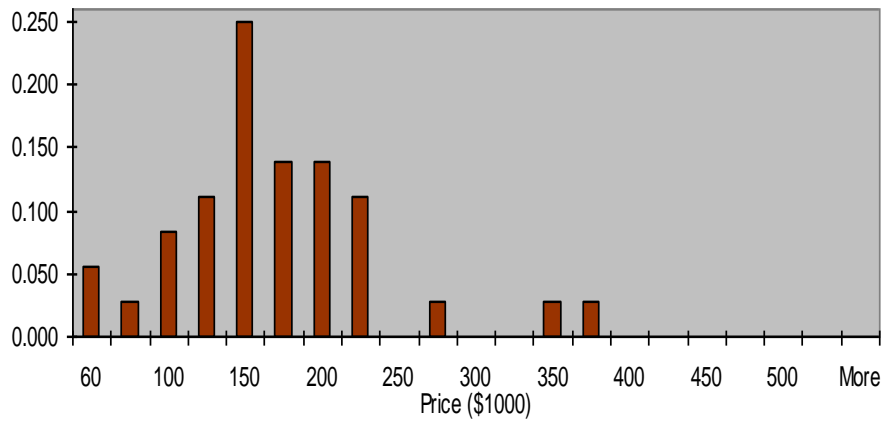


1991: Population Density

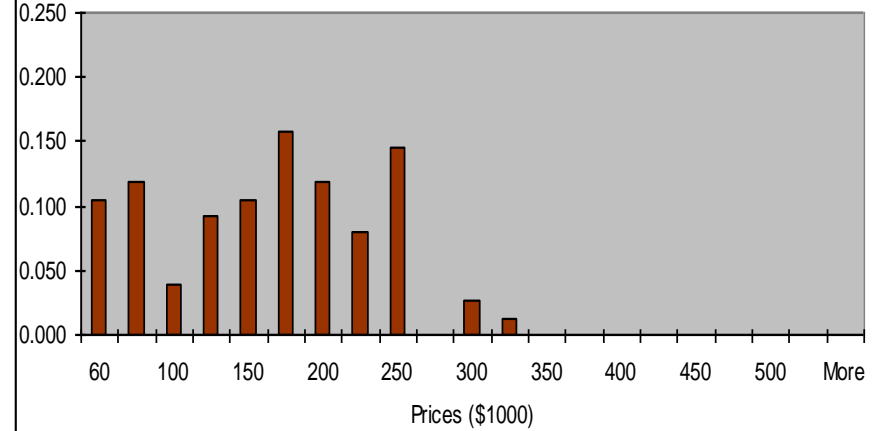
Total New Stock in GTA



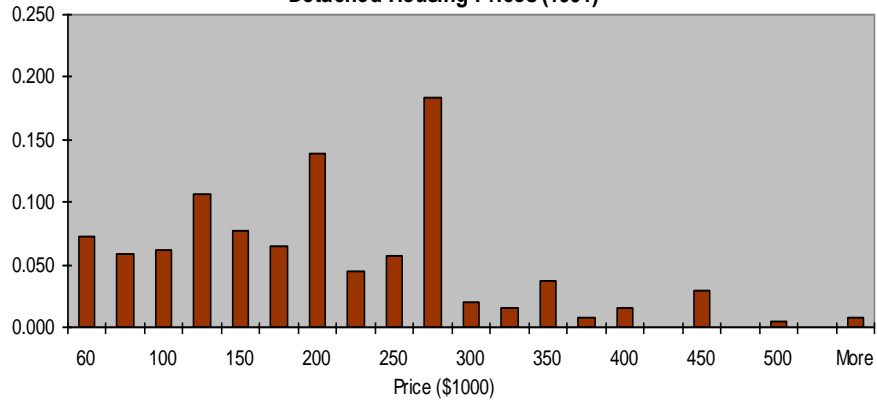
Attached Housing Prices (1991)



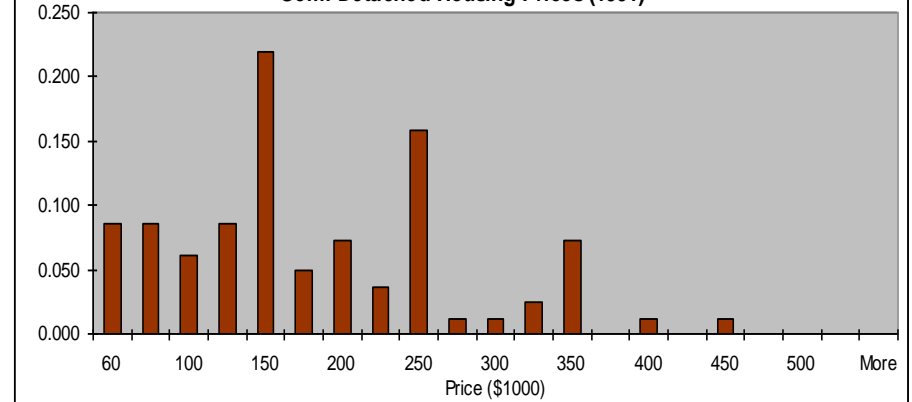
Apartment Housing Prices (1991)



Detached Housing Prices (1991)



Semi-Detached Housing Prices (1991)



Questions & Comments?