Integrating Urban Systems Modeling: From Land Use to Emissions

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Presented at the 3rd Innovations in Travel Modeling Conference
Phoenix, Arizona
May 10-12, 2010

ILUTE

Presentation Outline

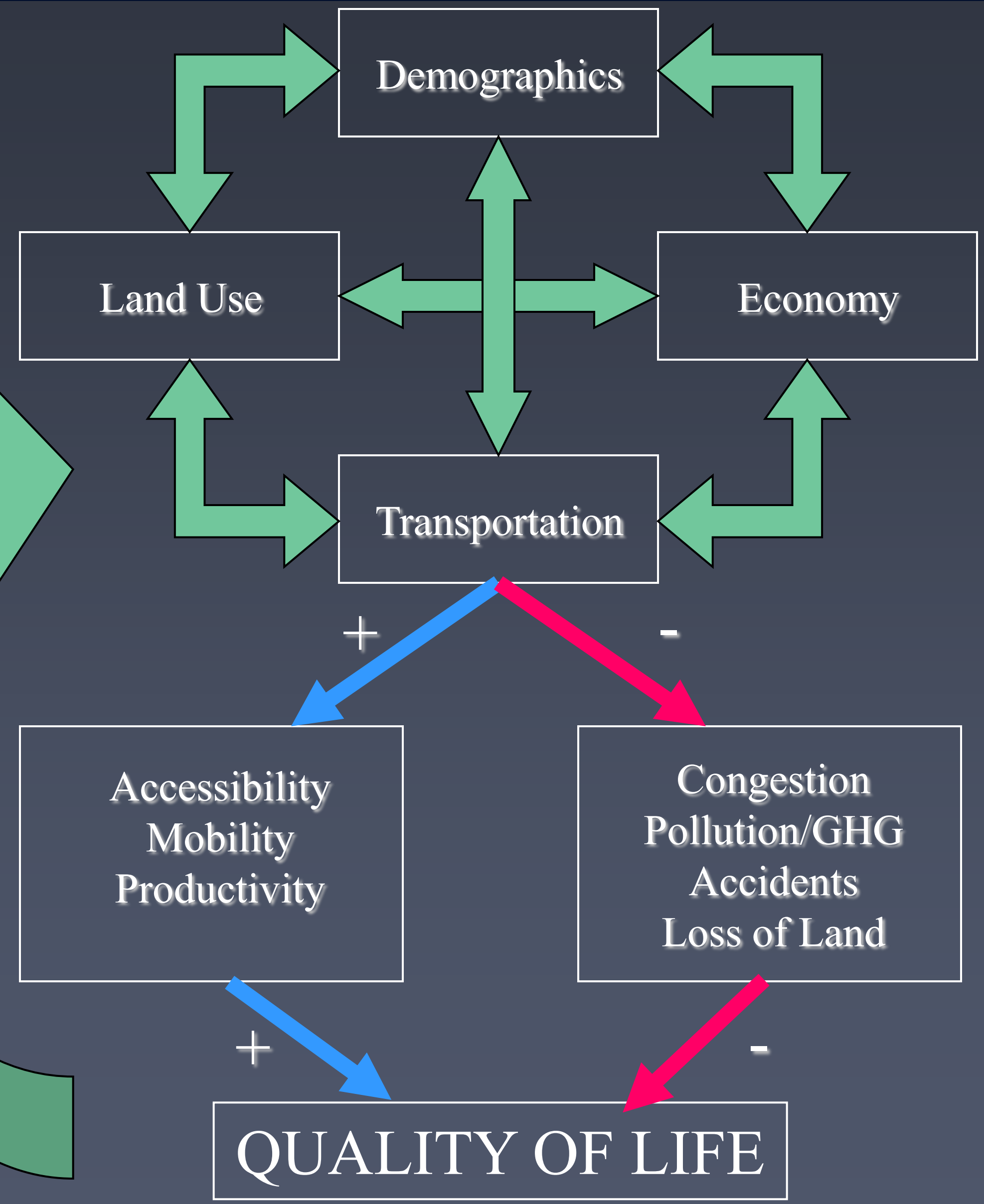
- Urban form and transportation
- Integrated urban modelling
- Agent-based microsimulation & urban models
- An application: environmental impact modelling

URBAN FORM & TRANSPORT

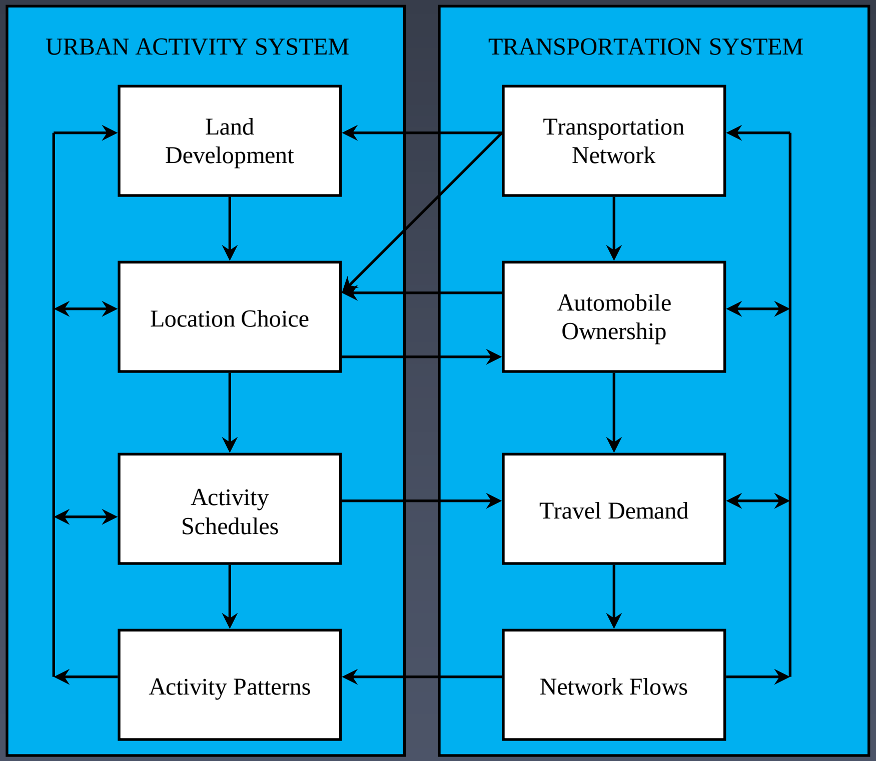
The Transportation – Land Use Connection

Transportation and urban form are fundamentally linked. How we build our city directly determines travel needs, viability of alternative travel modes, etc.

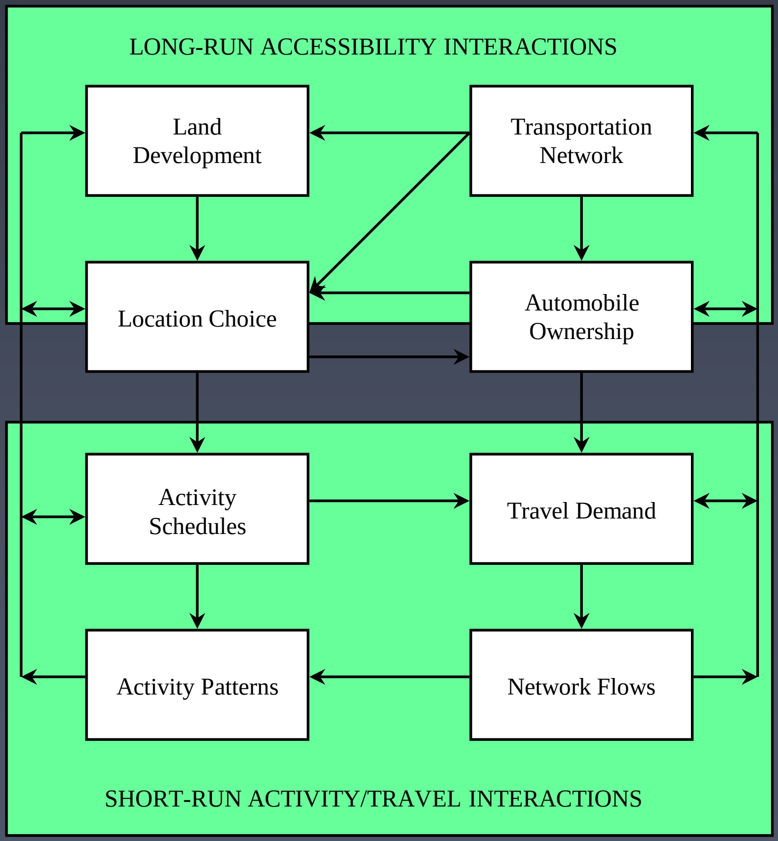
Transportation, in turn, influences
land development and location choices of people & firms.



Transportation - Activity System Interactions

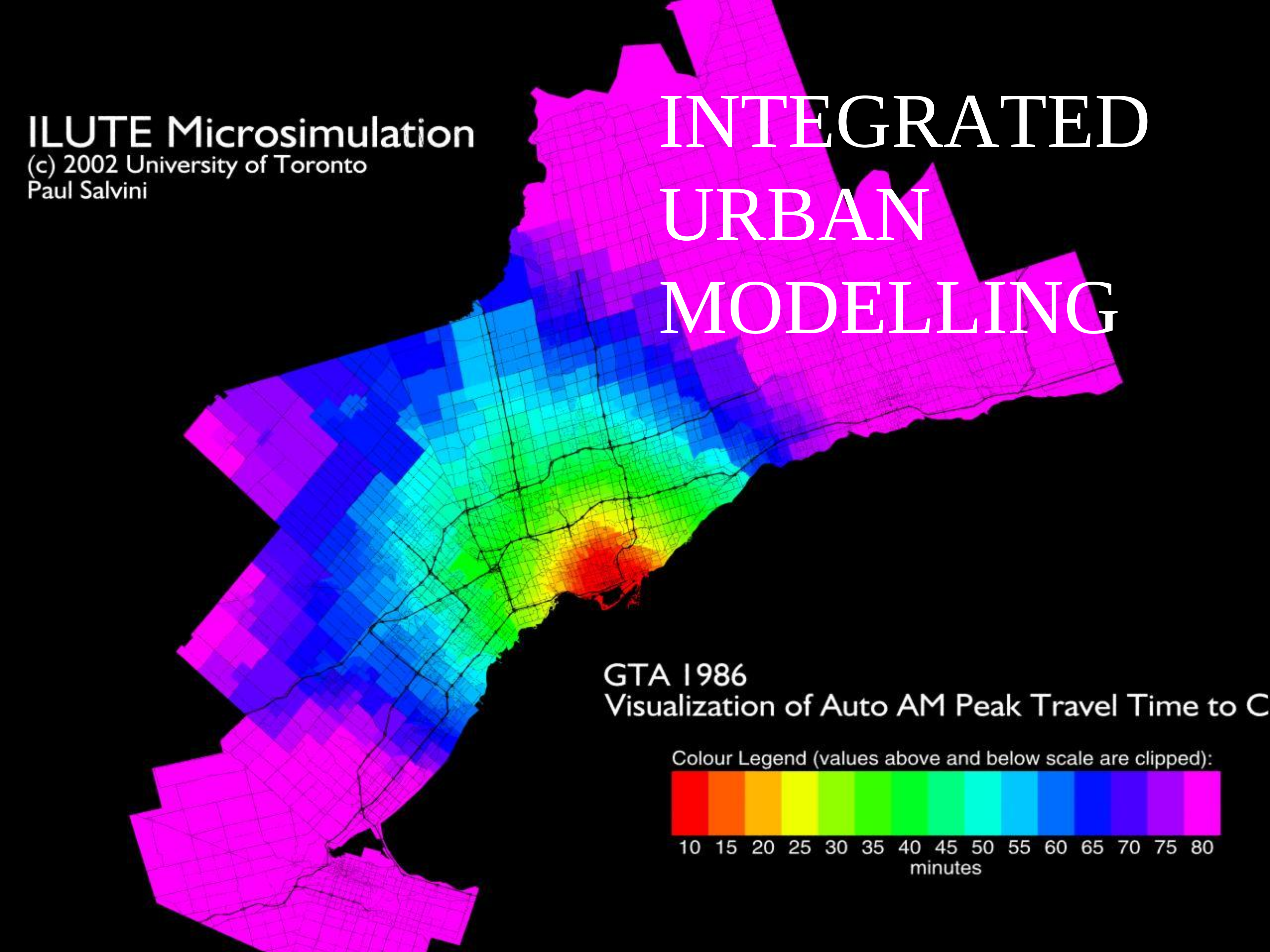


(a) The Urban Activity and Transportation Systems



(b) System Interactions

INTEGRATED URBAN MODELLING



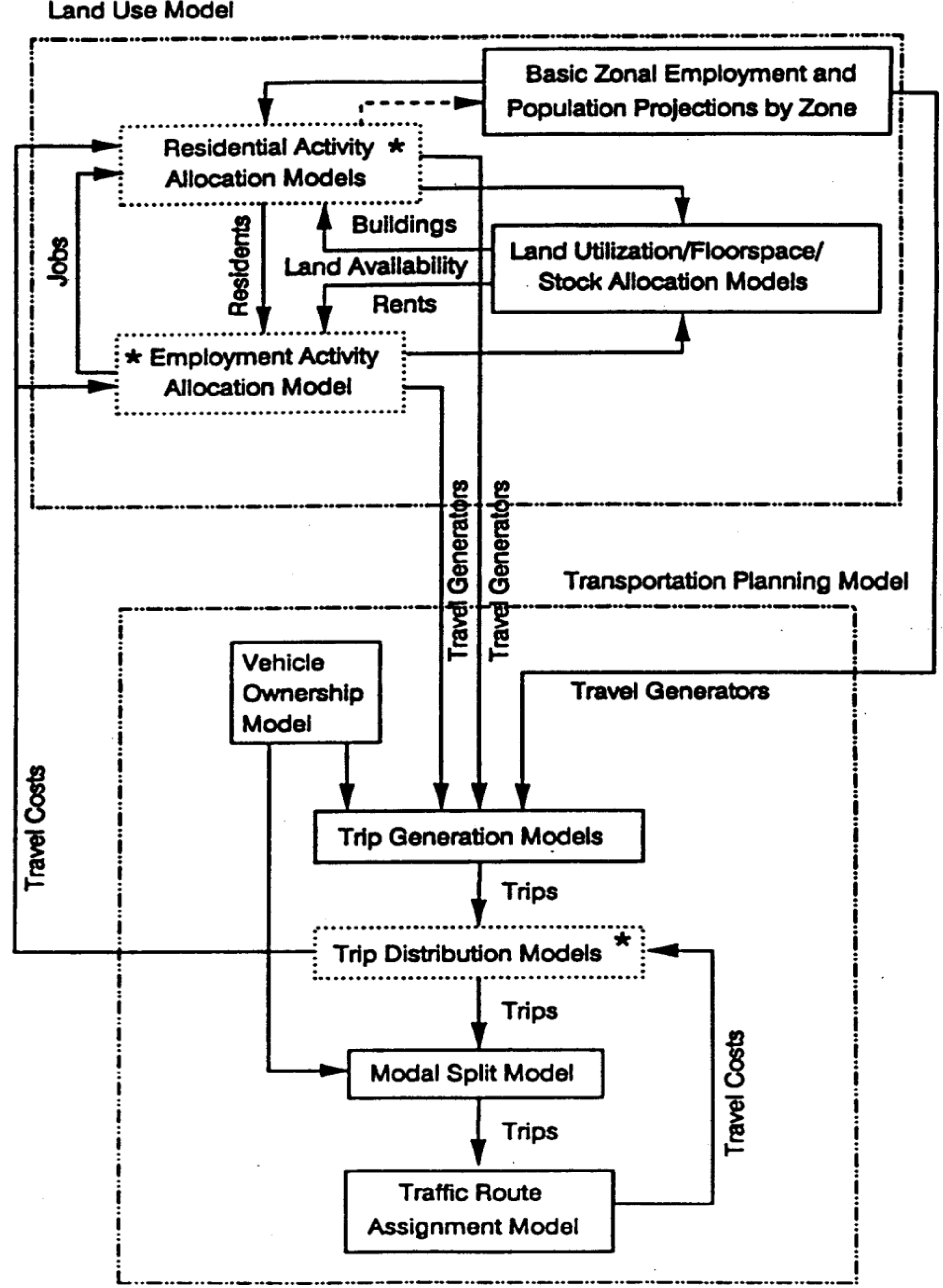
Land Use Models

Formal models which try to capture the transportation - land use interaction are usually referred to as **land use models**, **integrated land use - transportation models**, or **integrated urban models**.

Such models have existed since the early 1960's.

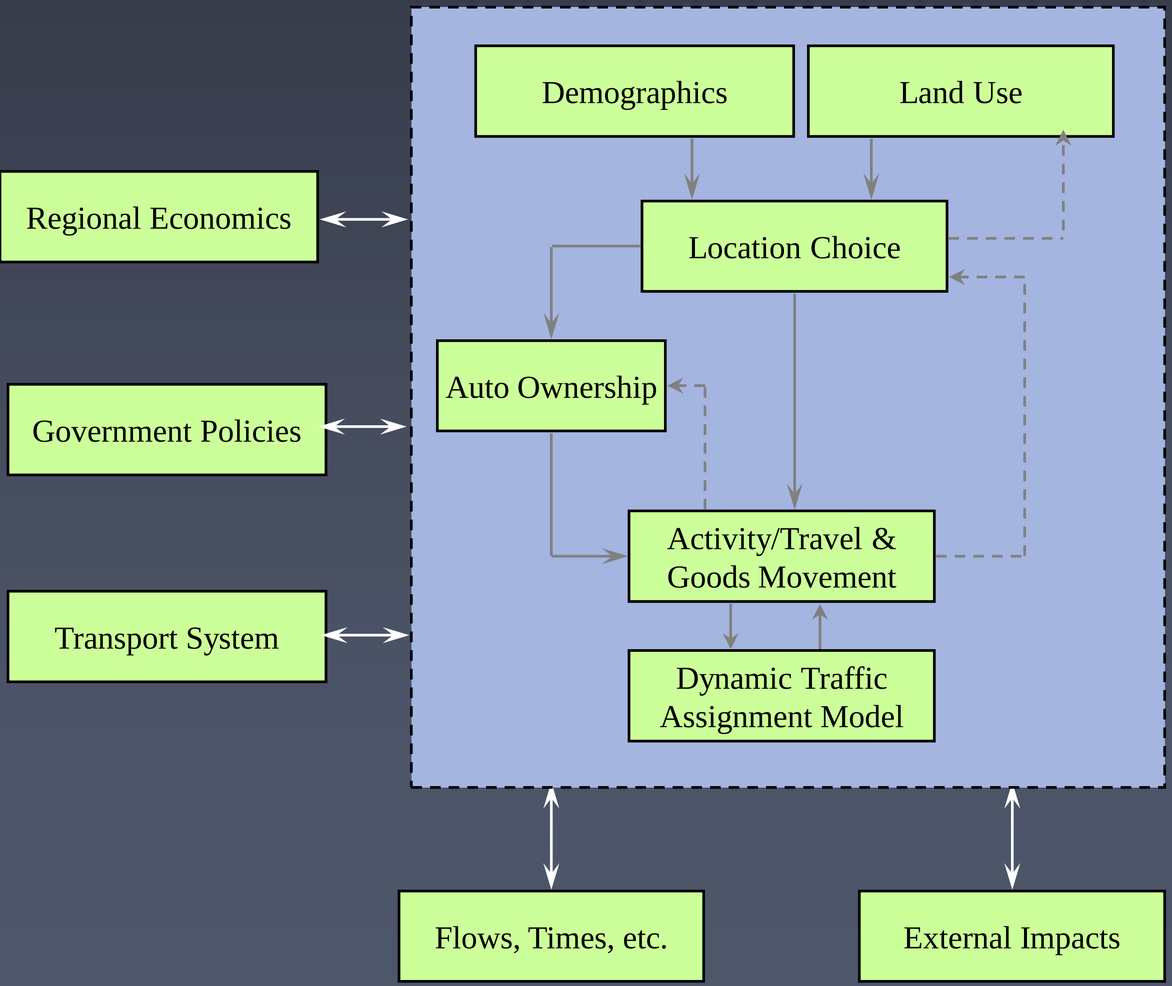
They have had mixed success, with the result that relatively few urban areas currently use formal models.

Integrated urban models, however, are receiving increasing attention and are being actively developed and used in many U.S. & European cities.



* In some systems these are substitutable spatial interaction models

What is an integrated model?



An integrated urban model is intended to represent the spatial evolution of a given study region system state over time as a function of various socio-economic, demographic and political processes. Key words:

- Spatial
- Time, evolution
- Socio-economic, demographic, political

Urban region system state

An urban region’s system state at any point in time is highly multi-dimensional. It usually includes:

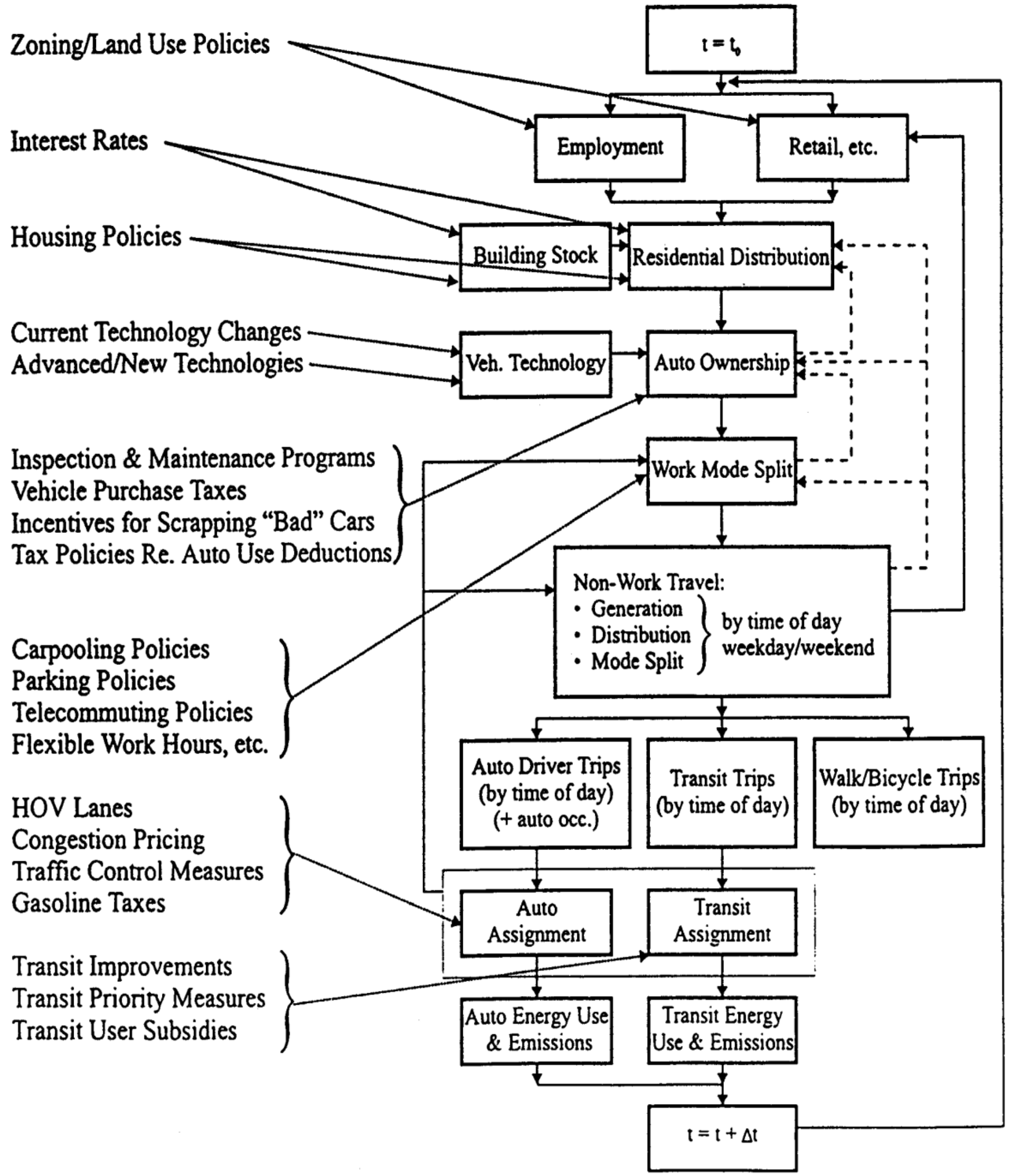
- The spatial distribution of the resident population (and its attributes)
- The spatial distribution of the region’s employment & other out-of-home activity locations (and their attributes)
- Person travel within the region during a representative time period (e.g., a “typical” weekday)
- Flows of goods/services within the region during a representative time period

Why build integrated models?

Integrated models provide the opportunity to consistently and comprehensively explore the intended and unintended, interconnected consequences of transportation and land use polices in complex urban regions.

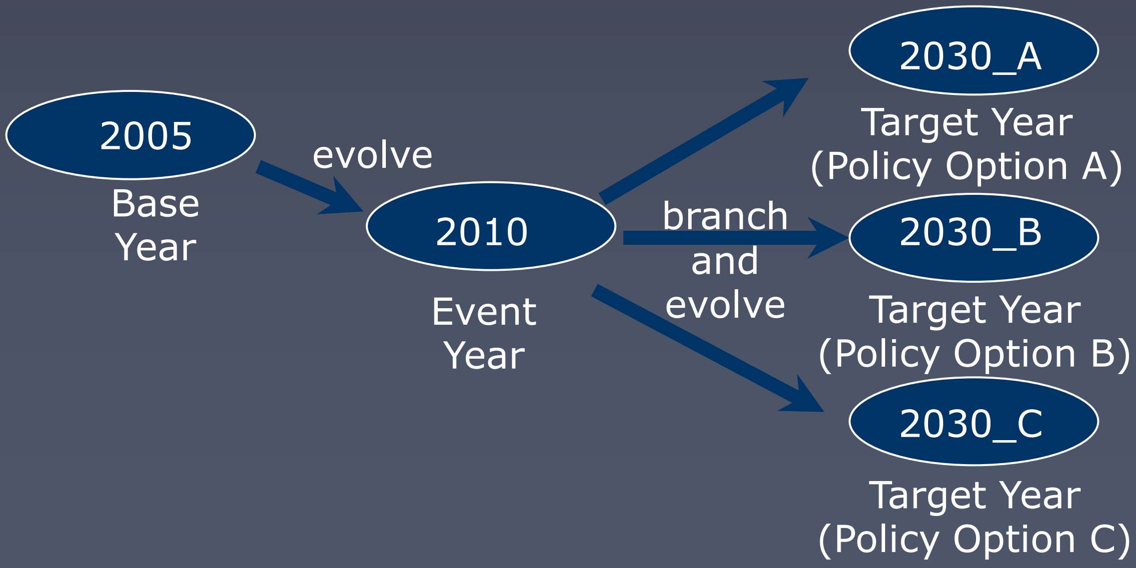
Without an integrated analysis of **both** land use and transportation, may well "miss" key system responses, and/or over/under-estimate the system responses which are being explicitly modelled.

Many "transportation" issues (especially wrt sustainability) have their origins (and perhaps their solutions as well) in land use design.



Example Application: Removing a Downtown Freeway

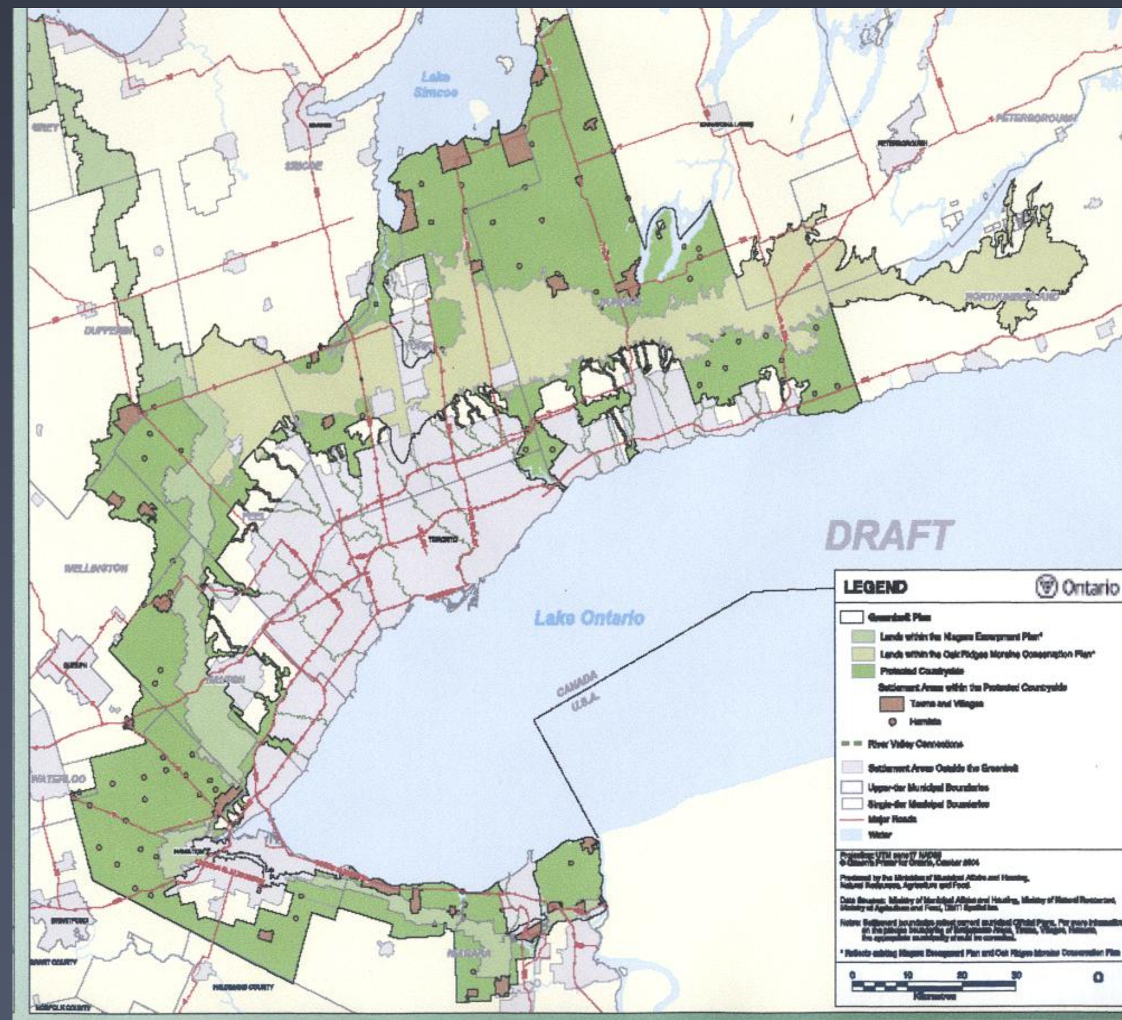
What would be the impact of tearing down the Gardiner Expressway? What if it wasn't replaced? What transit options might exist? What would be the impact on population & employment distributions? …



Example Application: Urban Greenbelt

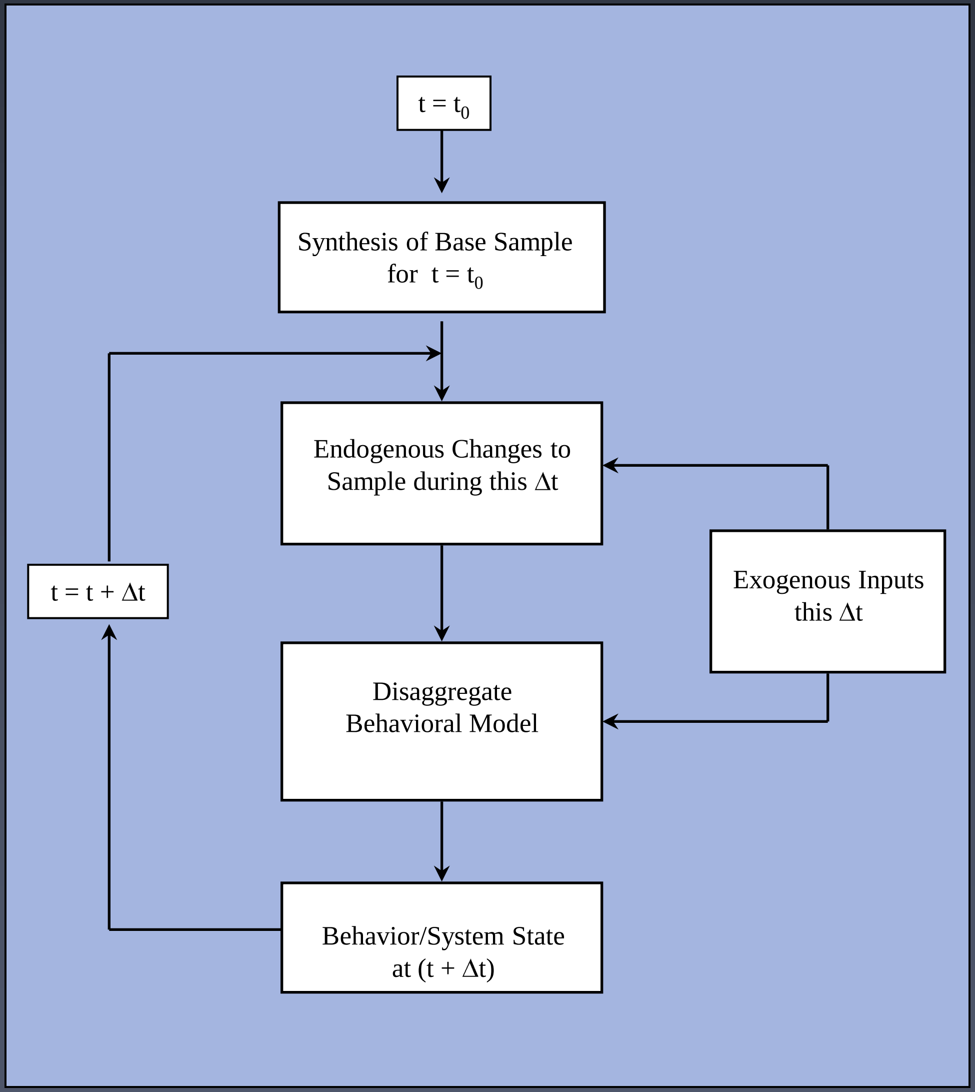
What will be the impact of a greenbelt on:

- housing density & prices?
- employment concentration?
- transit viability?
- congestion?
- emissions?
- …



Operational Urban Models: Examples

- MEPLAN http://www.fhwa.dot.gov/planning/toolbox/sacramento_methodology_land.htm
- TRANUS http://www.modelistica.com/download.htm
- DELTA http://www.davidsimmonds.com/index.php?section=33
- URBANSIM http://www.urbansim.org
- PECAS http://people.ucalgary.ca/~jabraham/Papers/pecas/summary.html
- CUBE LAND (MUSSA) http://www.citilabs.com/cube-land.html
- Others …

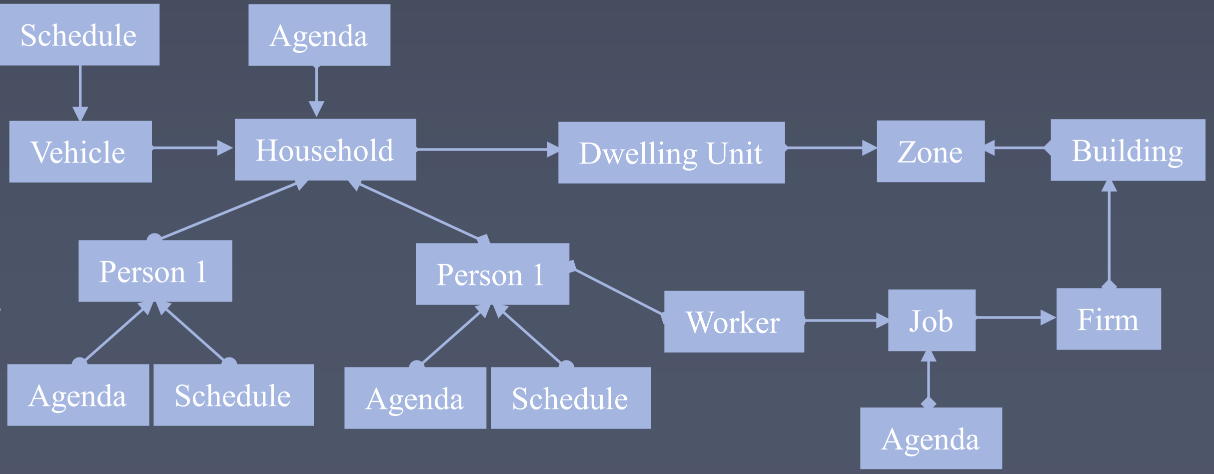


Agent-Based Microsimulation and Integrated Urban Modelling

Agent-based microsimulation

- An *agent* is an autonomous entity that perceives the world around it, acts within its world, and (potentially) learns and adapts based on its experiences.
- *Microsimulation* is simulation at the very disaggregate level of individual decision-makers / agents. Aggregate system-level behaviour *emerges* out of the behaviour of the individual agents.

Agent-based microsimulation is what makes a disaggregate, behavioural approach to urban systems modelling feasible.



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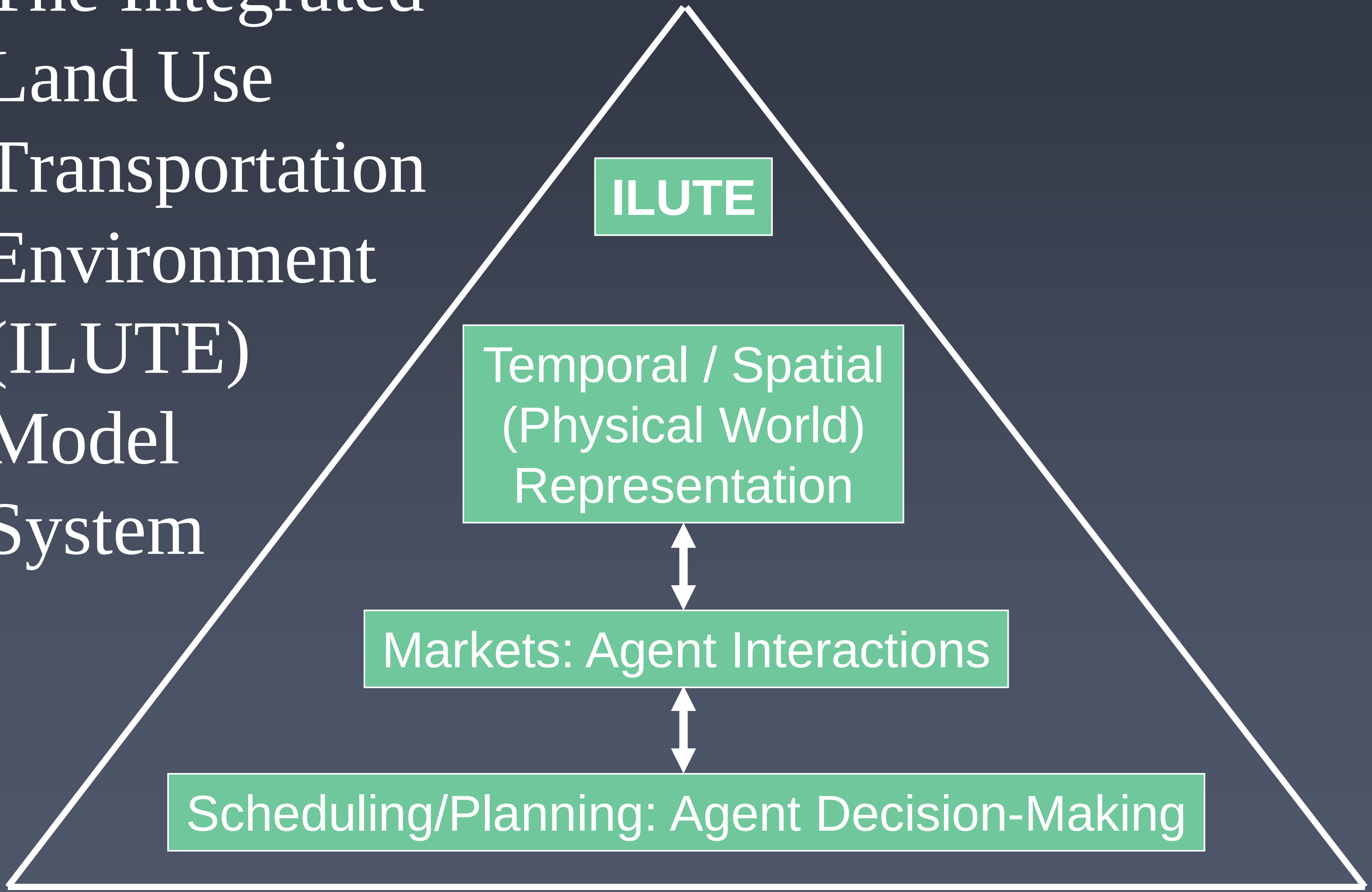
The Integrated Land Use Transportation Environment (ILUTE) Model System



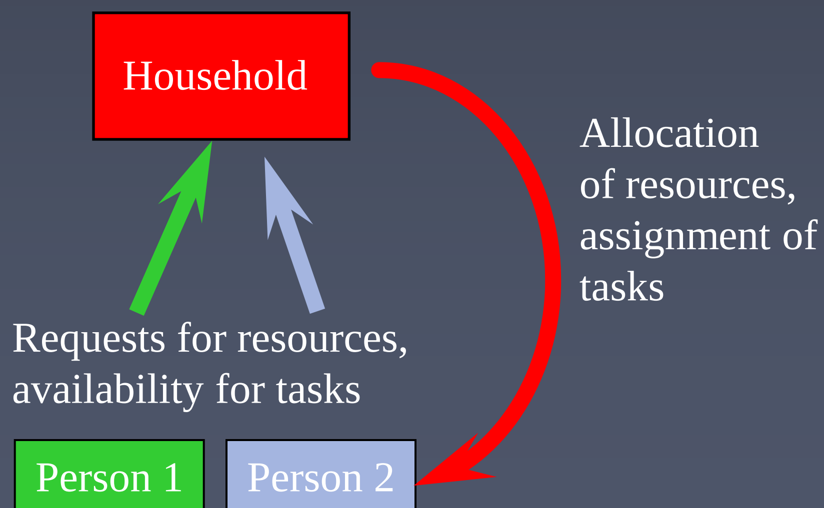
Household-Level Models

Household-level models are required to “properly” deal with many system components:

- Housing location/type choice
- Automobile ownership
- Demographics/household structure/lifecycle stage evolution
- Activity/travel scheduling

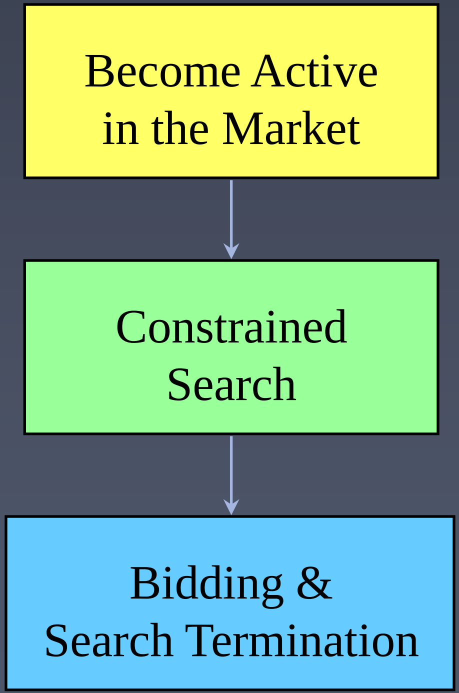
Households:

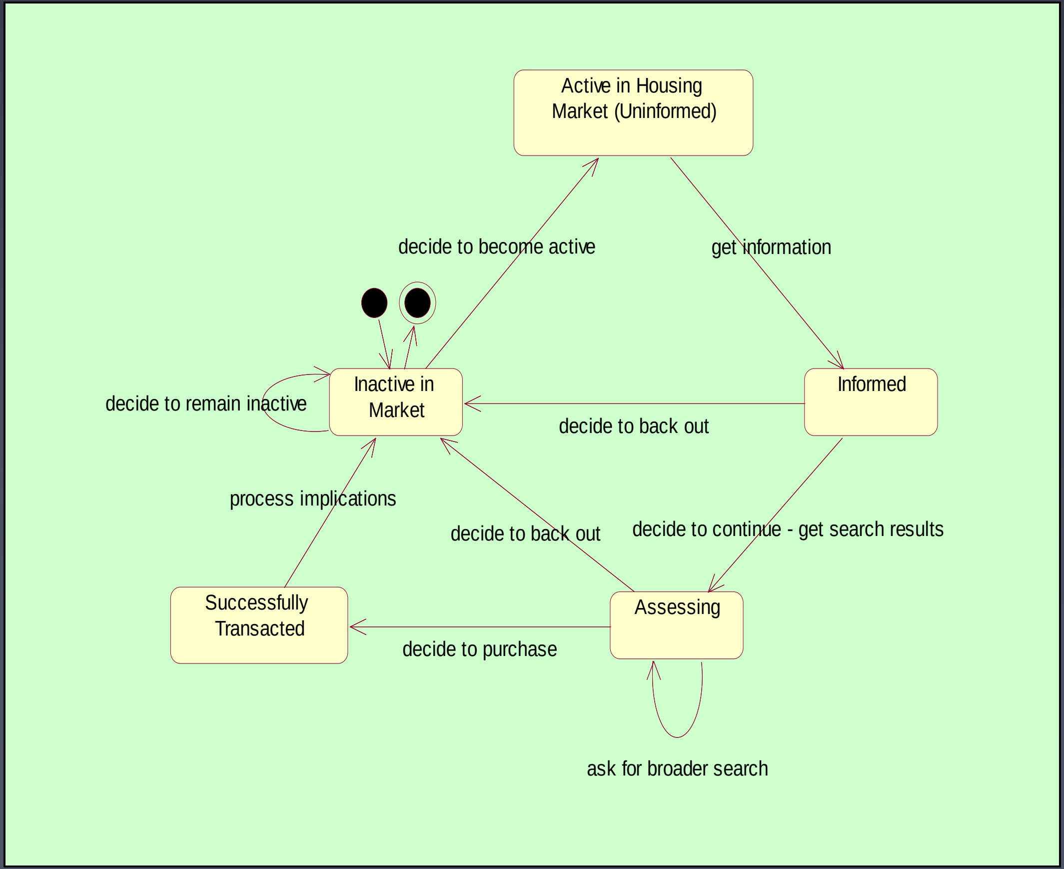
- Acquire durable goods (housing, vehicles, etc.)
- Allocate household resources (money, vehicles)
- Allocate household activities/responsibilities to household members (serve-dependents, household “chores”, joint household activities)



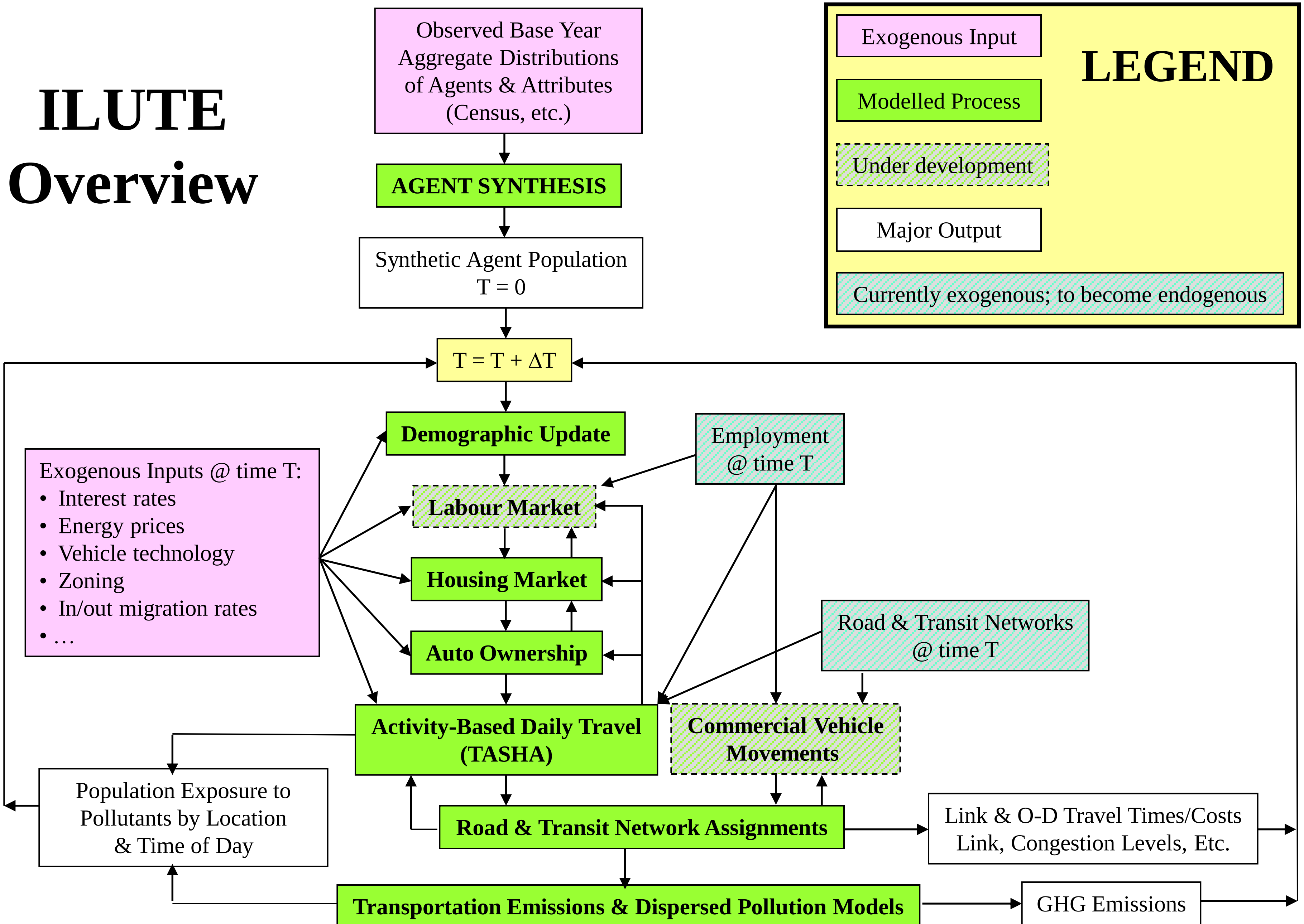
Microsimulating Markets

Many *markets* are of interest within ILUTE (housing, labour, commercial real estate, etc.). Market interaction is a three-stage process:





ILUTE Overview



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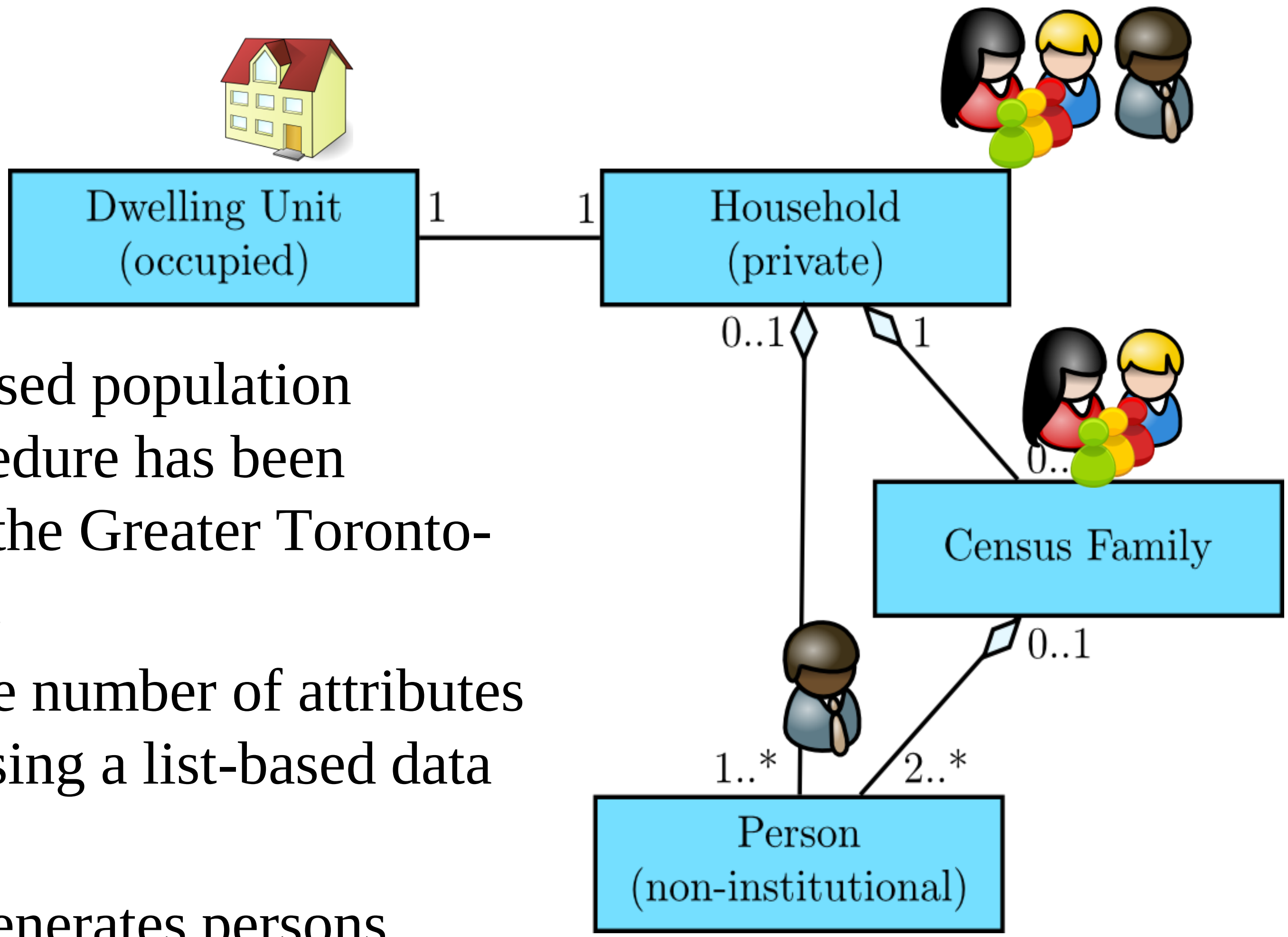
Population Synthesis

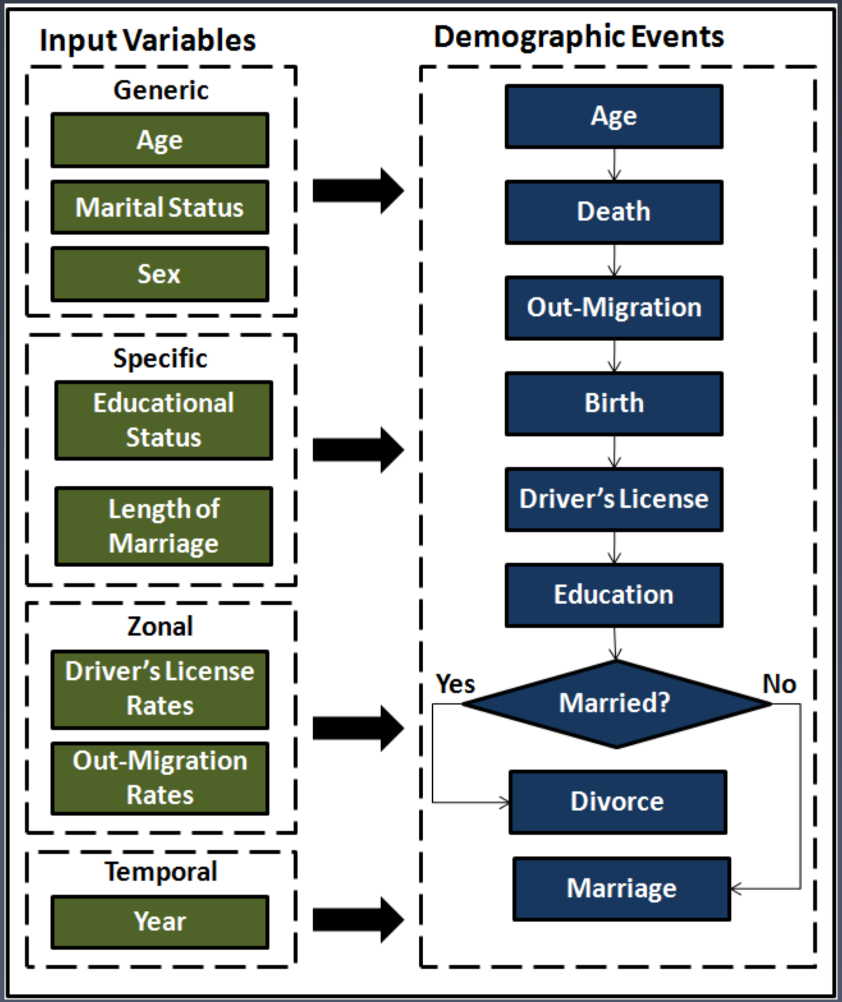


- A new, IPF-based population synthesis procedure has been developed for the Greater Toronto-Hamilton Area
- Handles a large number of attributes per agent by using a list-based data structure
- Consistently generates persons, families, households and dwelling units

See Pritchard & Miller, 2009 TRB Meeting

Demographic Updating

- A demographic updating procedure has been developed for the GTHA that updates household, family & person attributes each year in a simulation run.
- Observed rates by year, categorized by agent attributes are used.



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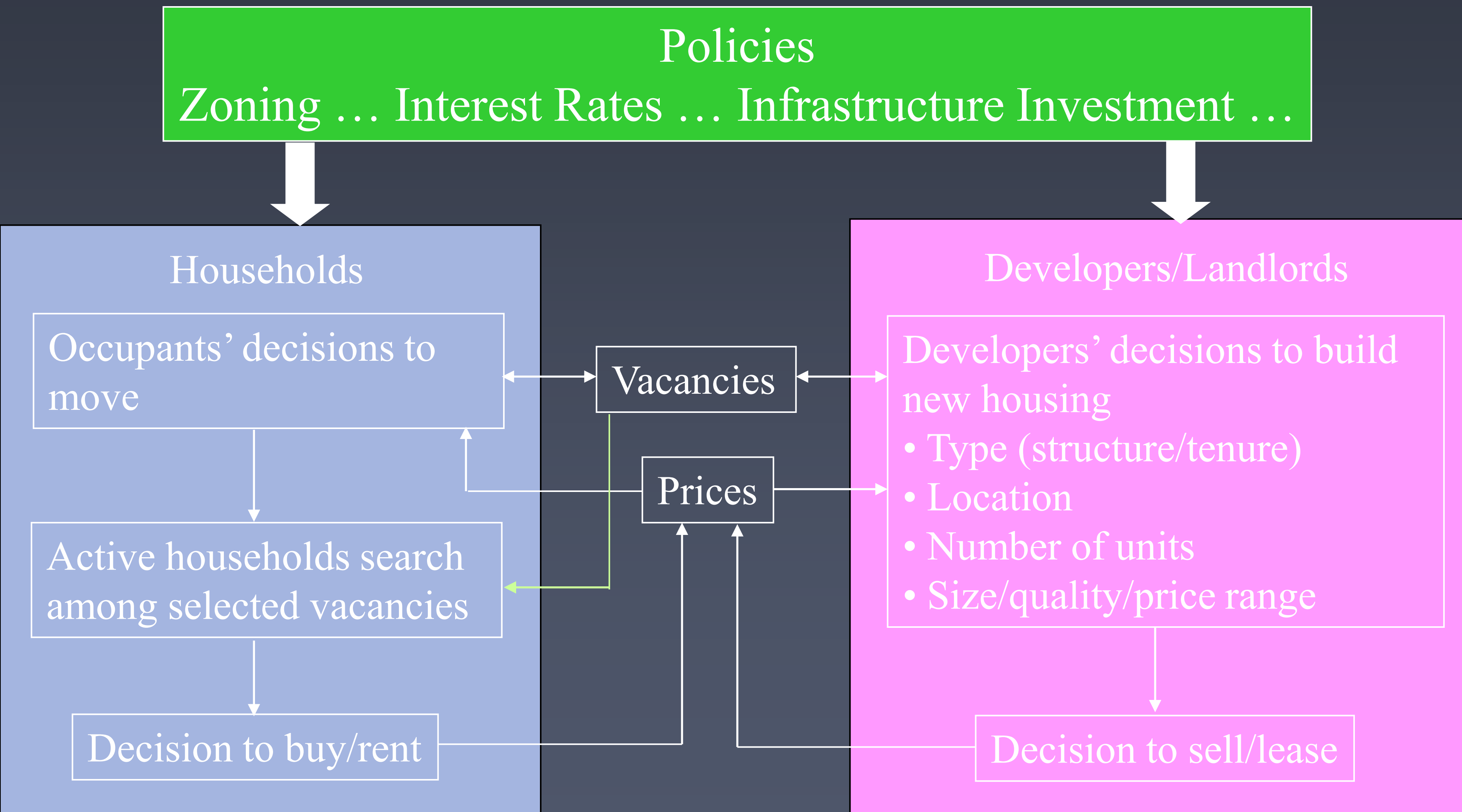
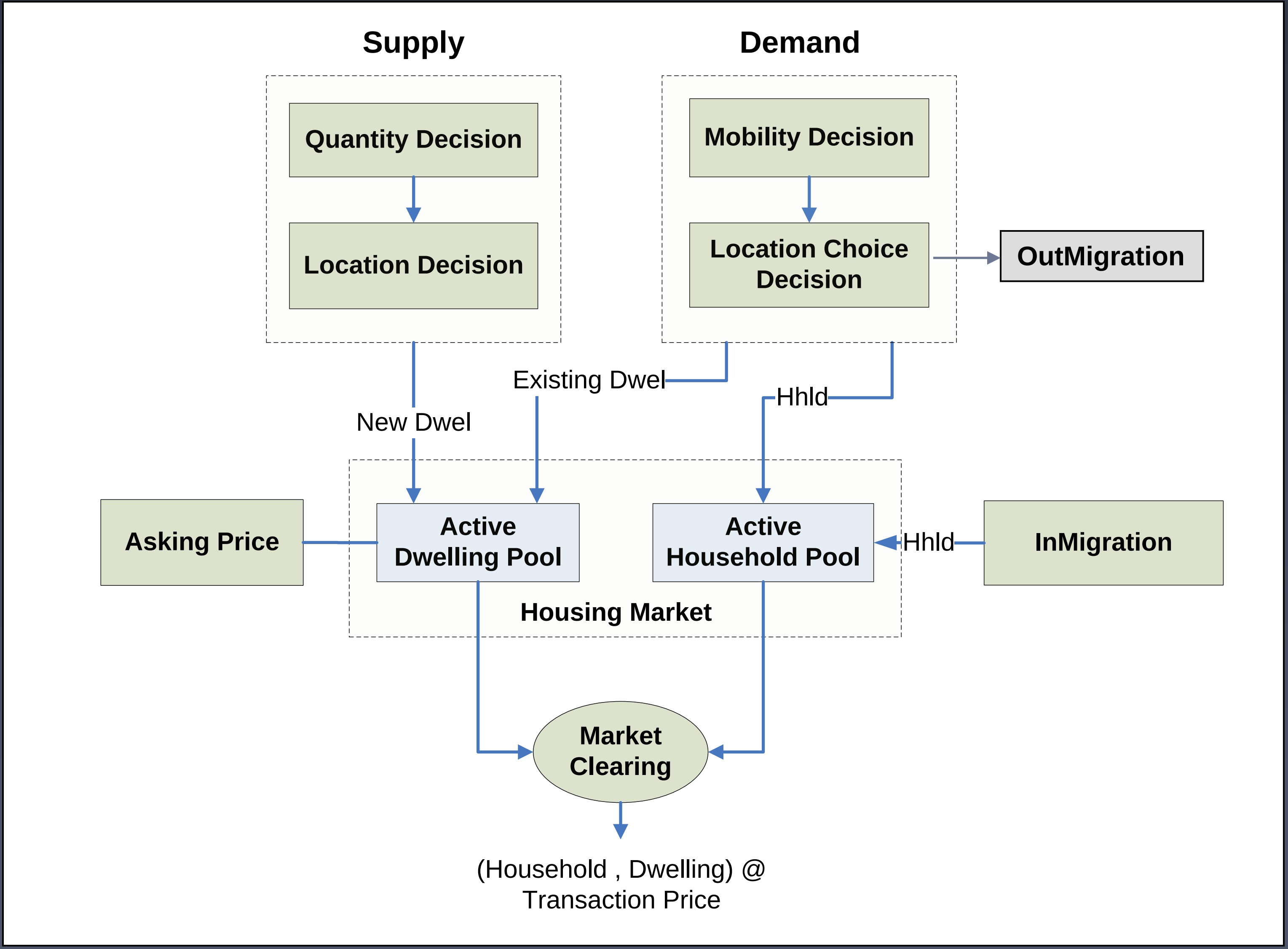
Modelling Housing Markets



Housing Market Microsimulation Model



Historical Test Runs

We are currently running 20-year historical simulations to test & improve the model system.

1986 Census

1986 Initial State

Twenty-year simulation run, 1986-2006

1991 Census

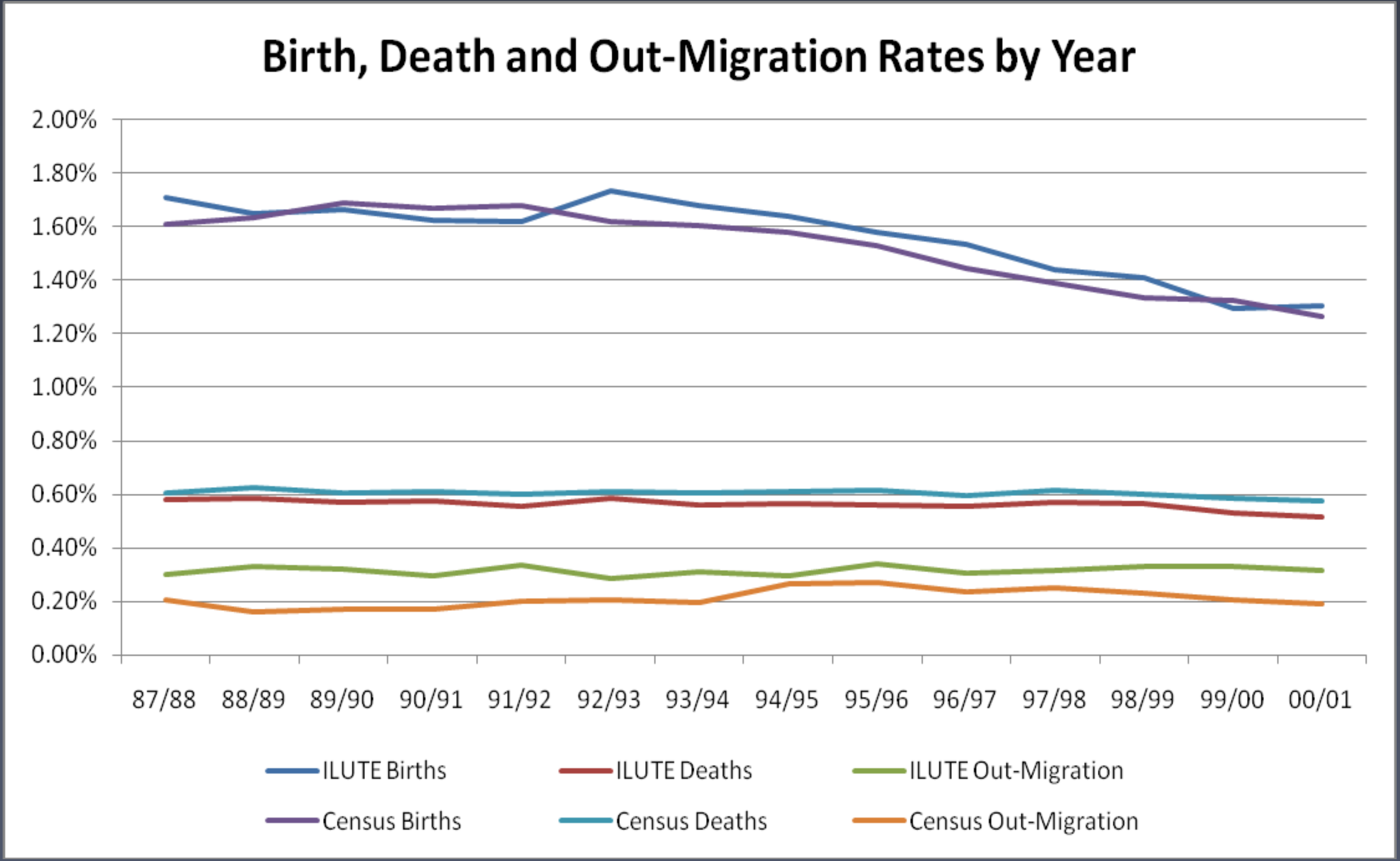
1996 Census

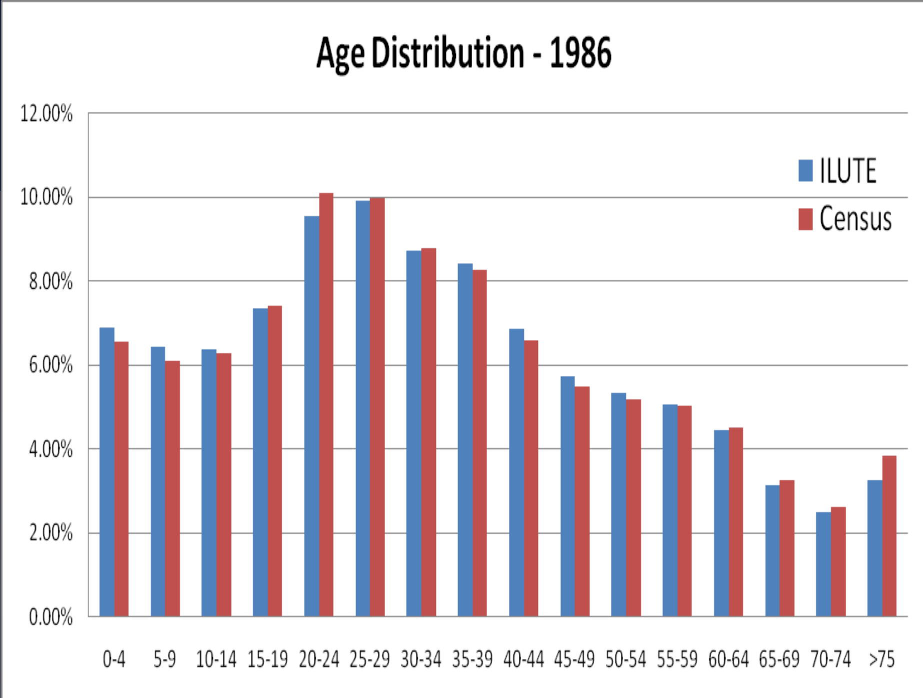
2001 Census

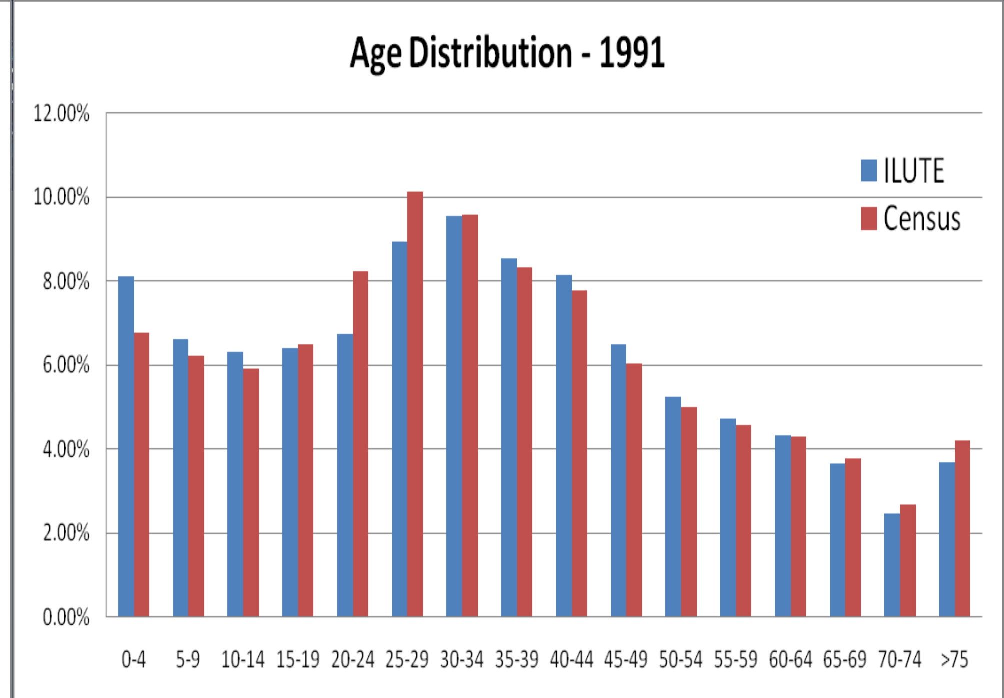
2006 Census

Other time-series historical datasets (CMHC, TREB, TTS, …)

Predicted vs Observed Births, Deaths & Out-Migration




Age Distribution - 1986
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
ILUTE
Census
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
>75


Age Distribution - 1991
12.00%
10.00%
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6.00%
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ILUTE
Census
0-4
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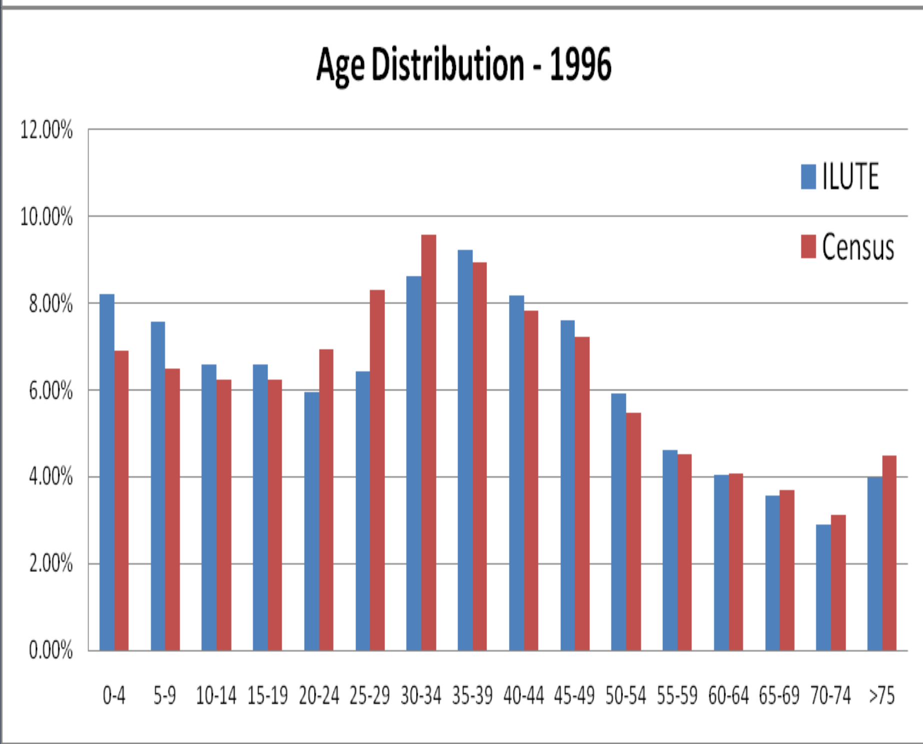
Age Distribution - 1996
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10.00%
8.00%
6.00%
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ILUTE
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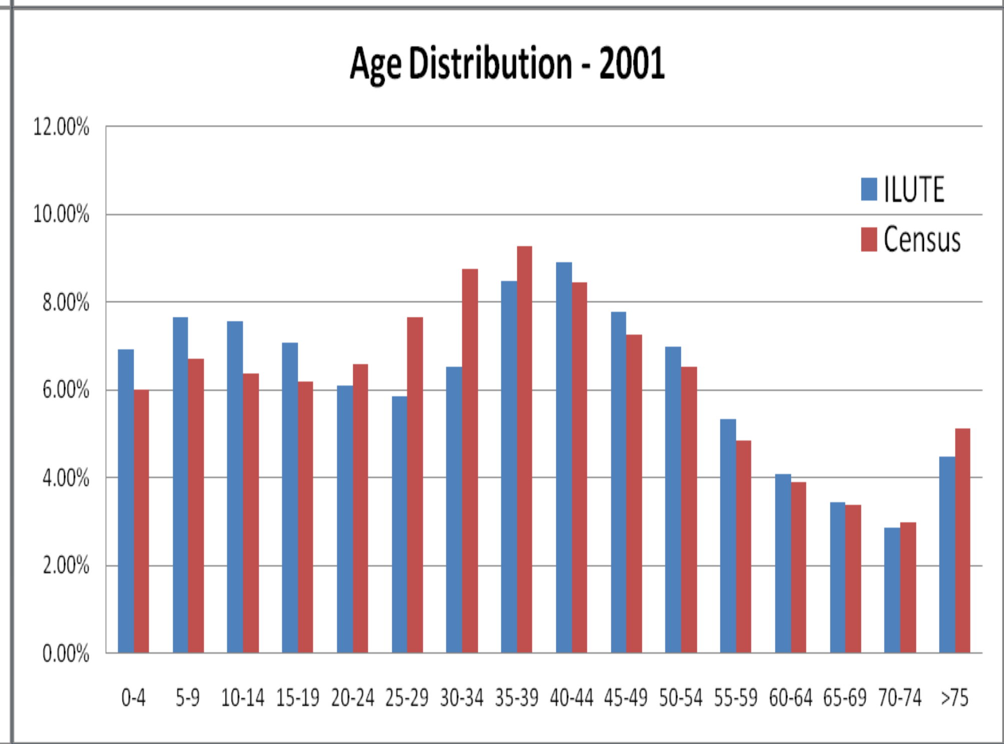
Age Distribution - 2001
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
ILUTE
Census
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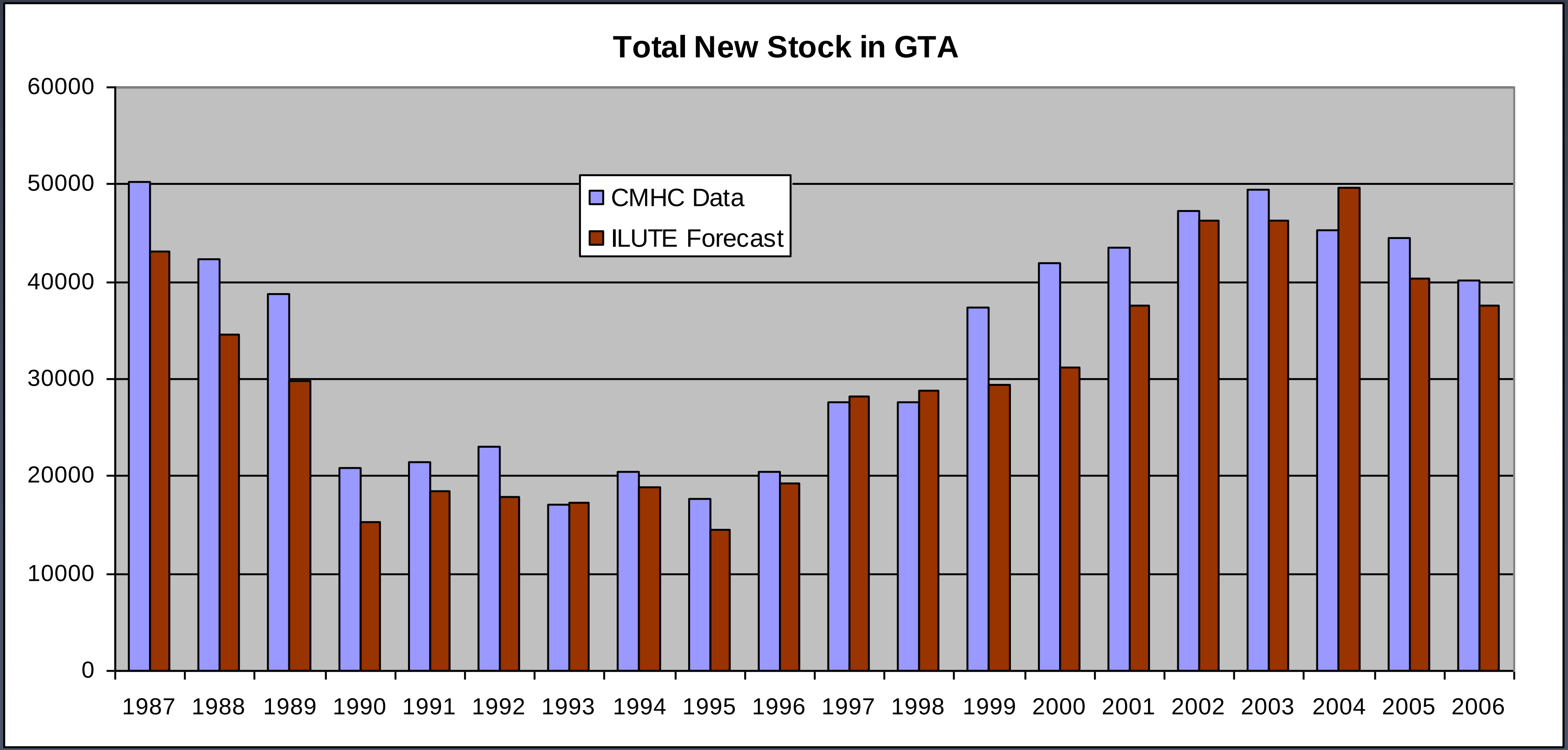
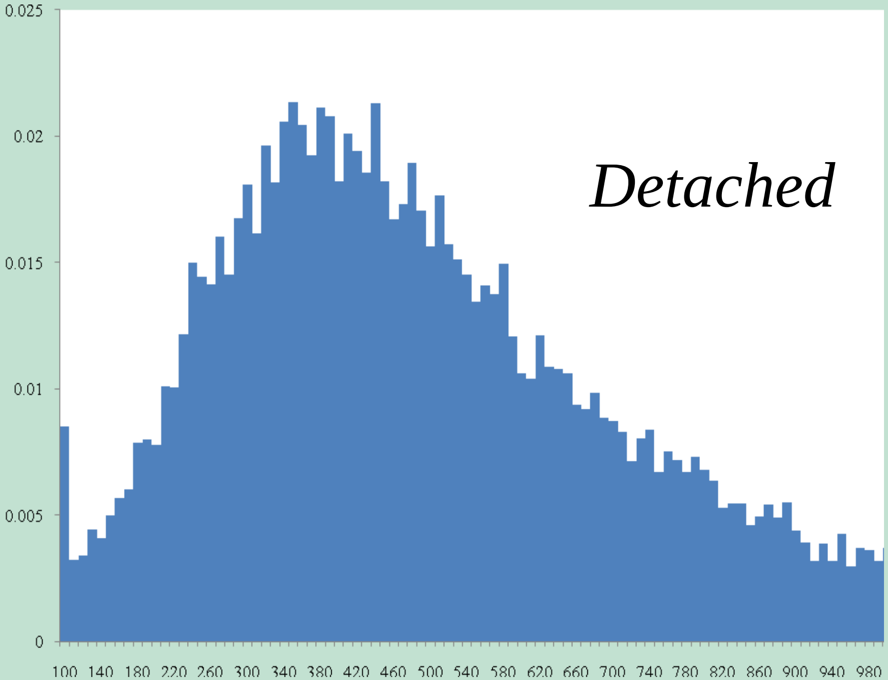
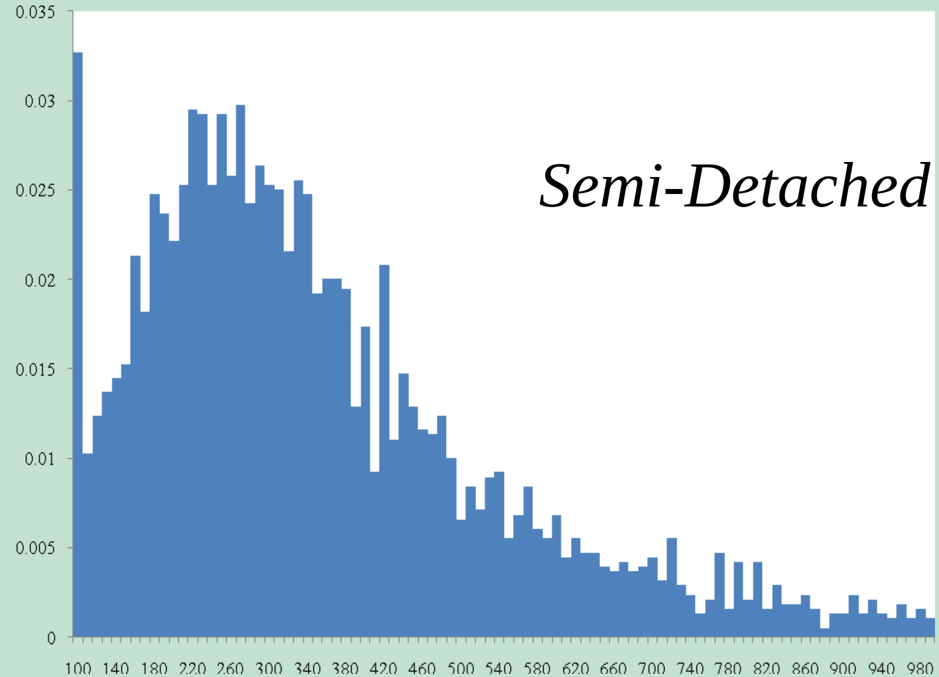
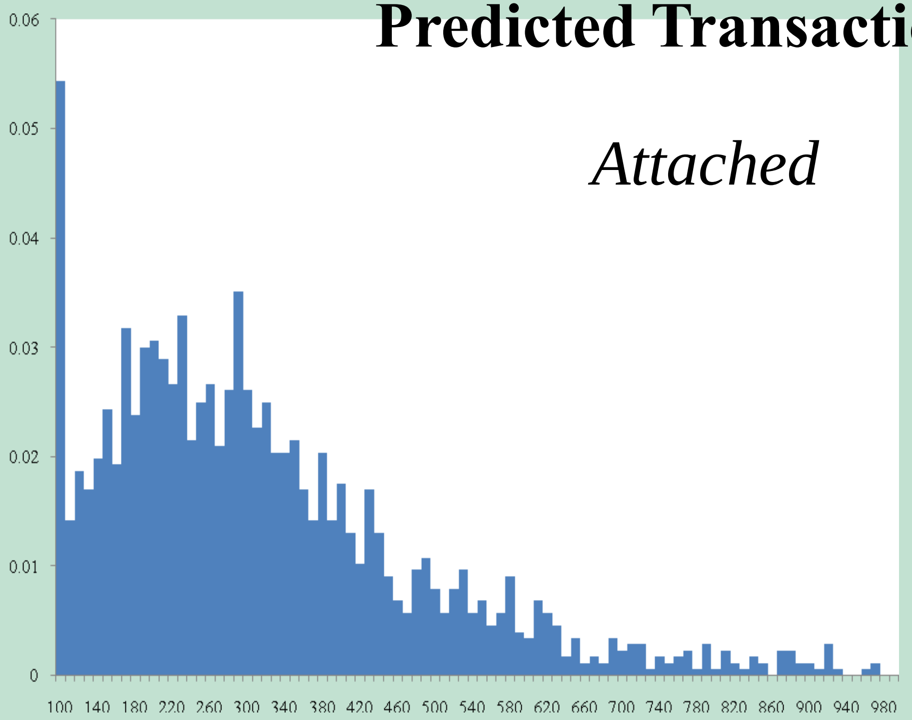
Simulated Total Housing Starts, 1987-2006

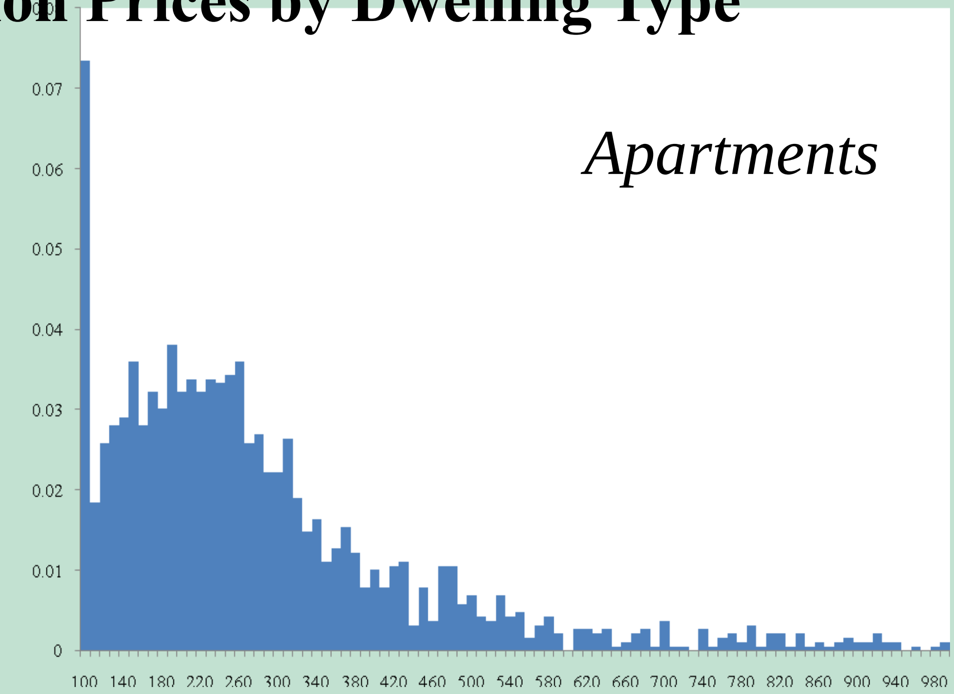


Predicted Transaction Prices by Dwelling Type





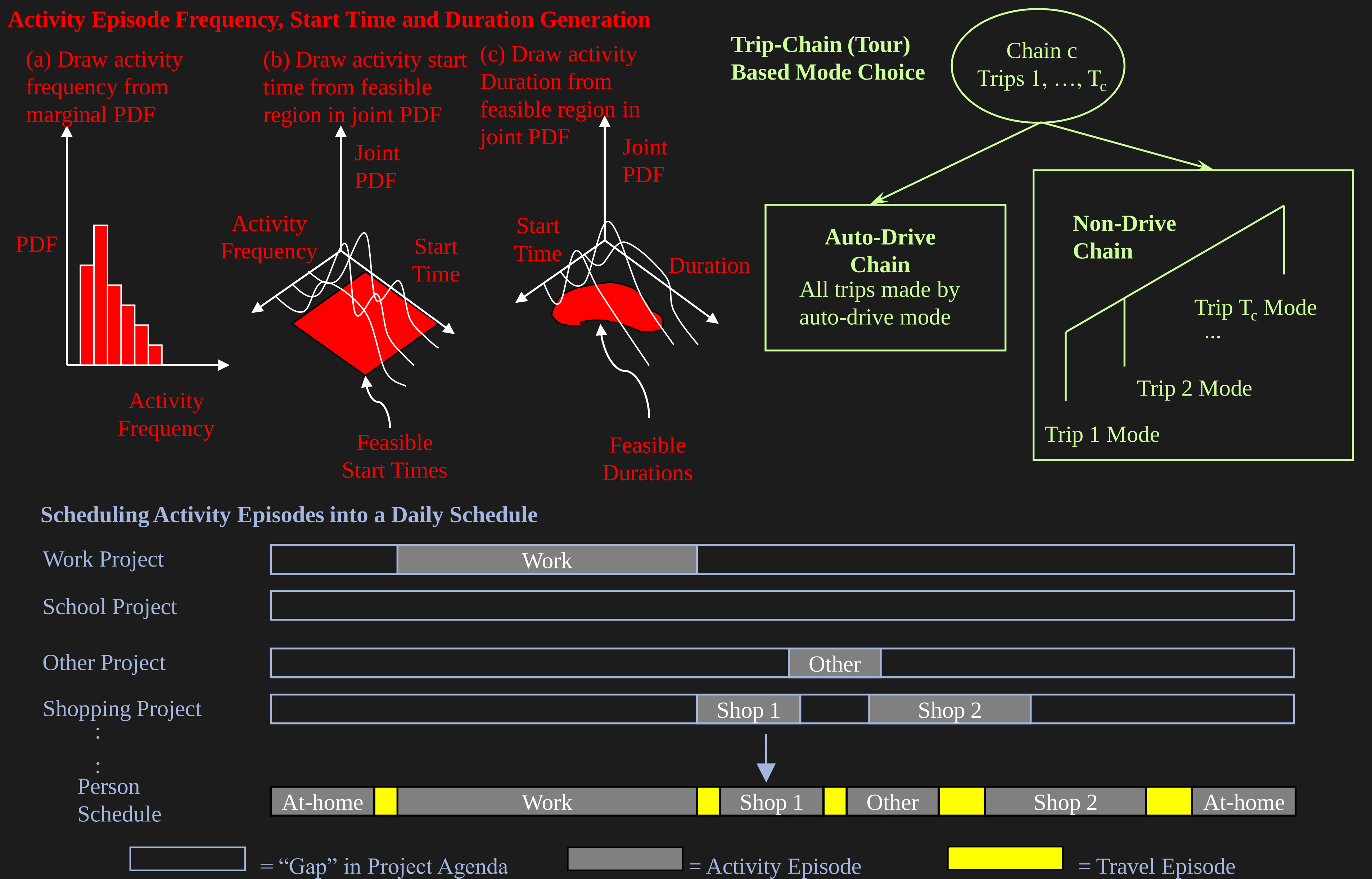




Modelling Daily Activity & Travel

TASHA (Travel/Activity Scheduler for Household Agents) has been developed at UofT. Key features include:

- Activity-based
- Household-based (only such model currently in existence)
- Microsimulation-based
- Agent-based, object-oriented
- Capable of interfacing with either conventional aggregate modelling systems or new disaggregate microsimulators at both "input" and "output" ends of the model (unique to this model)



Travel/Activity Scheduler for Household Agents (TASHA)

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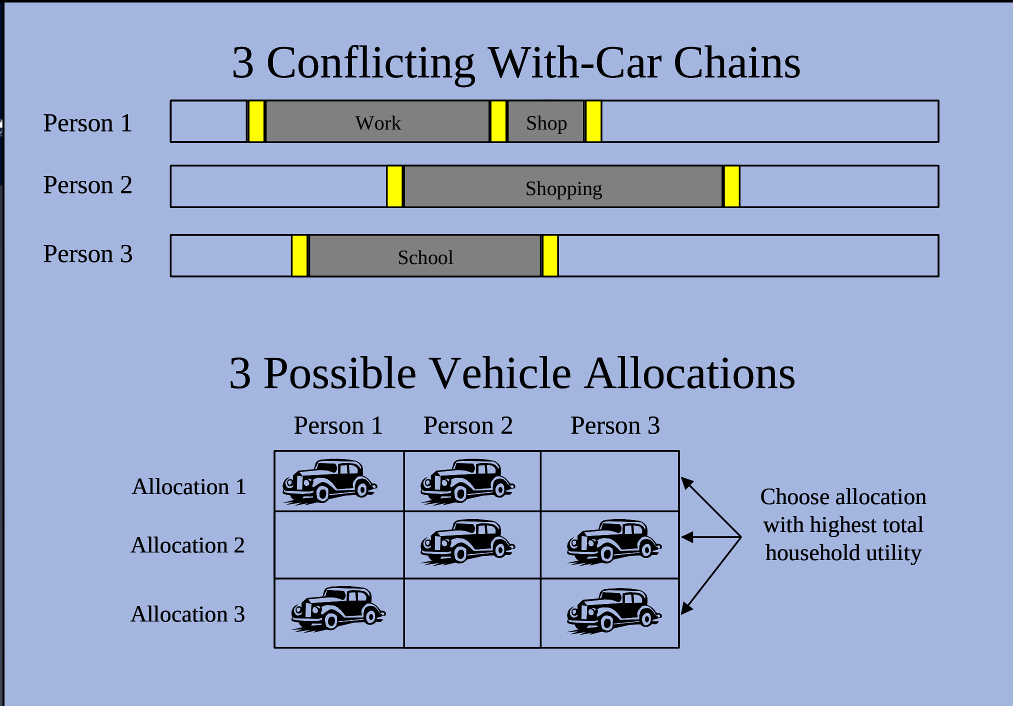
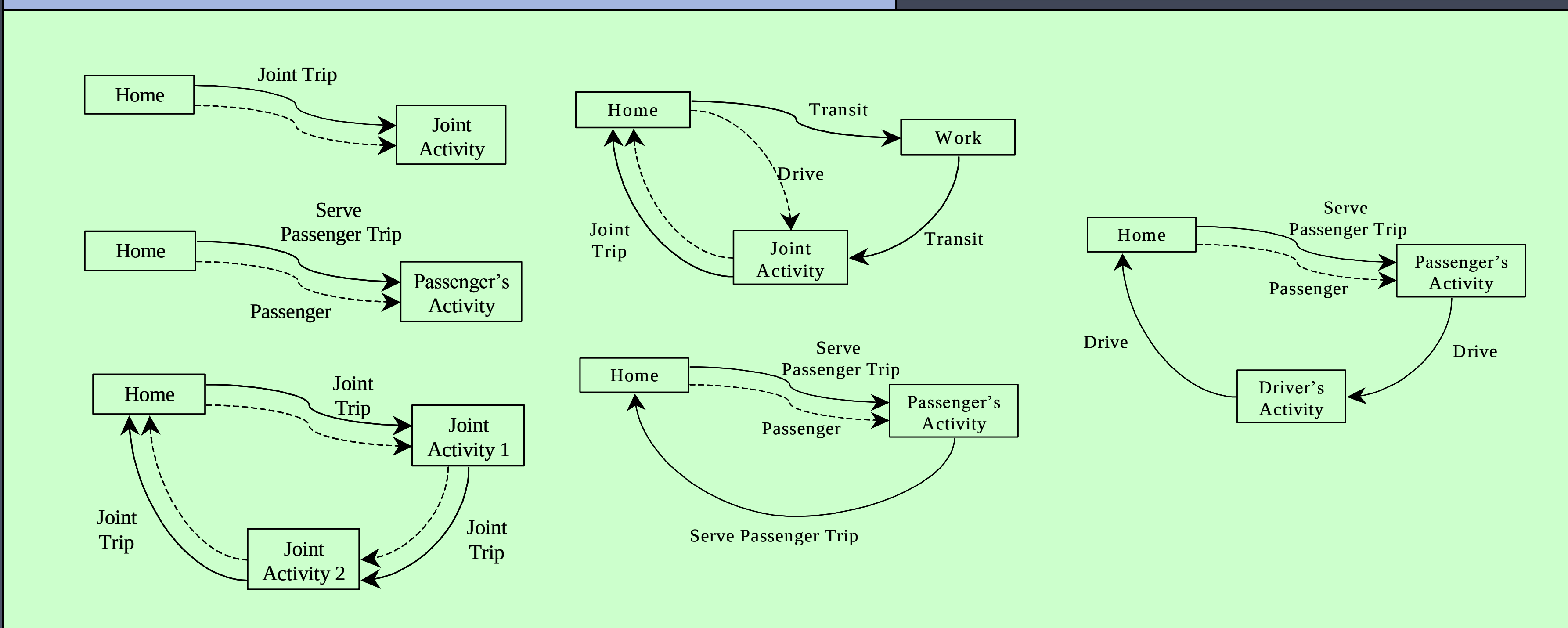
Household –Level Vehicle Allocation & Ridesharing in TASHA



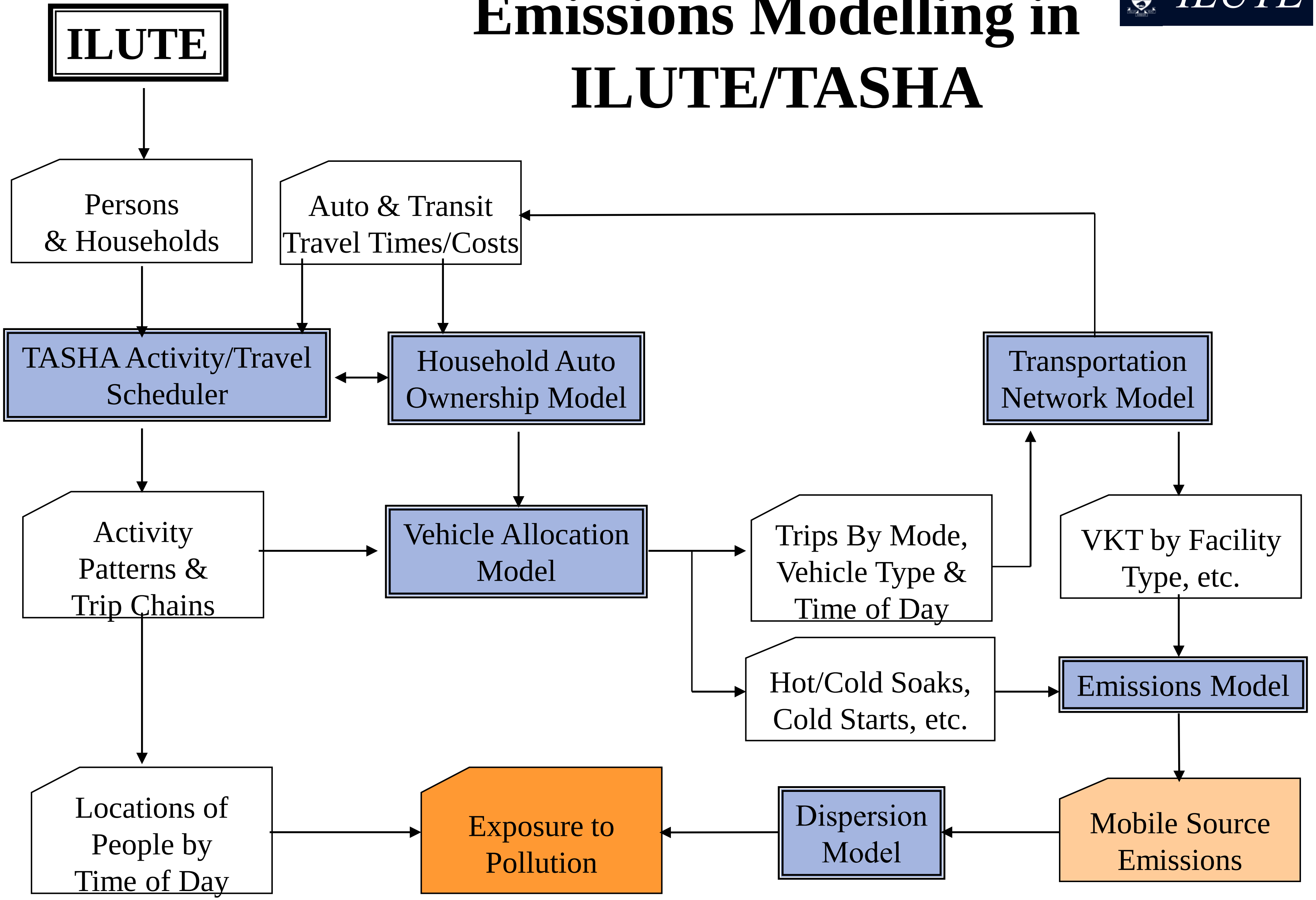


Environmental Modeling with TASHA

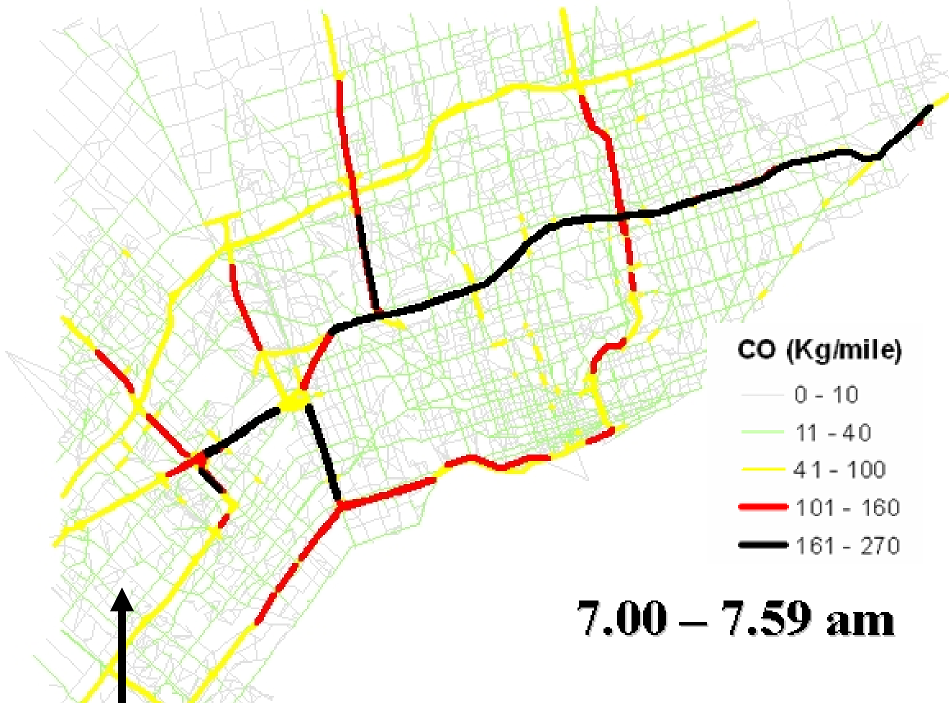
- TASHA has been connected with:
  - MATSim road network simulator (auto link speeds, times, costs & volumes by hour of day)
  - EMME transit network assignment model (transit travel times and costs by time of day)
  - MOBILE6.2C emissions model (link emissions by type by link by time of day)
  - CALMET meteorological model (wind speed & direction by time of day)
  - CALPUFF dispersion model (pollutant concentrations by zone by time of day)

→ Dynamic population exposure to pollution by zone by time of day.

Emissions Modelling in ILUTE/TASHA

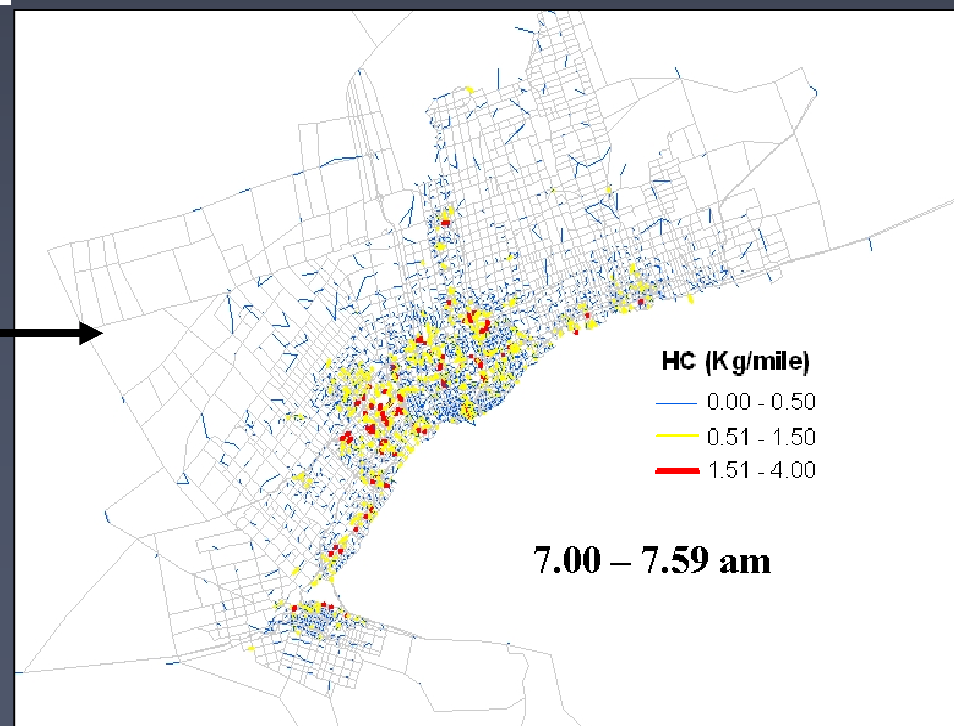


Auto Emissions by location and time of day



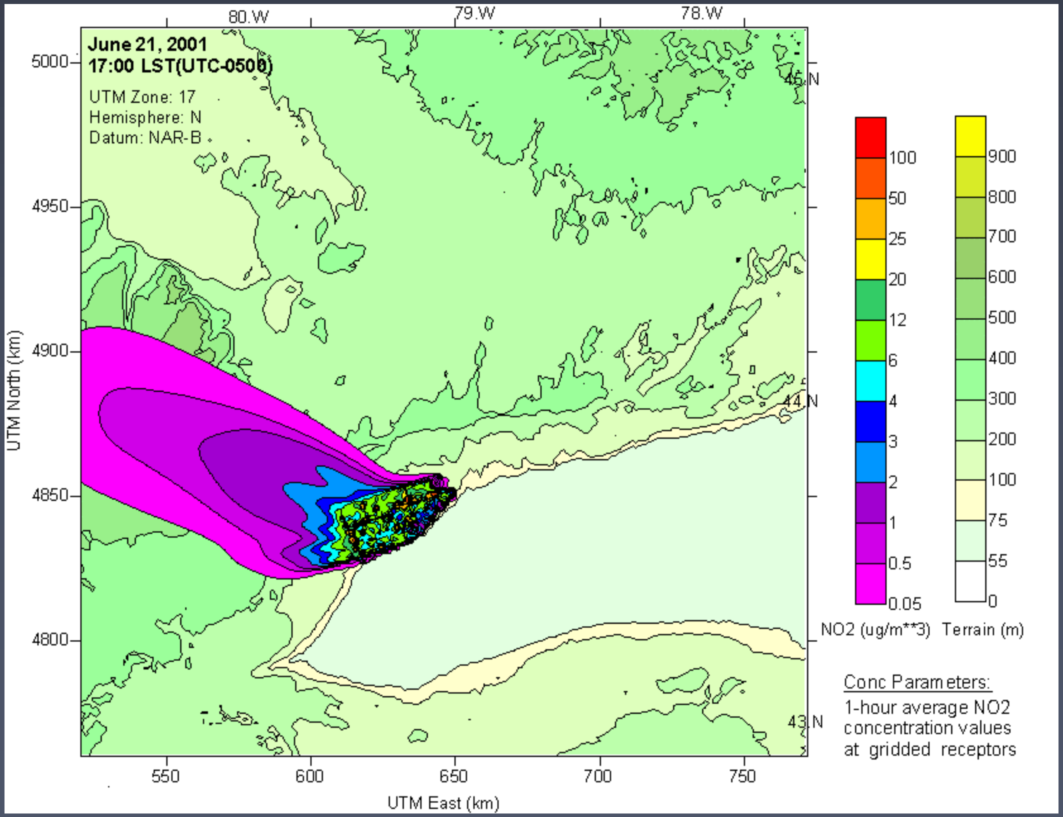
Link-based running emissions by time of day

Zone-based soak emissions by time of day

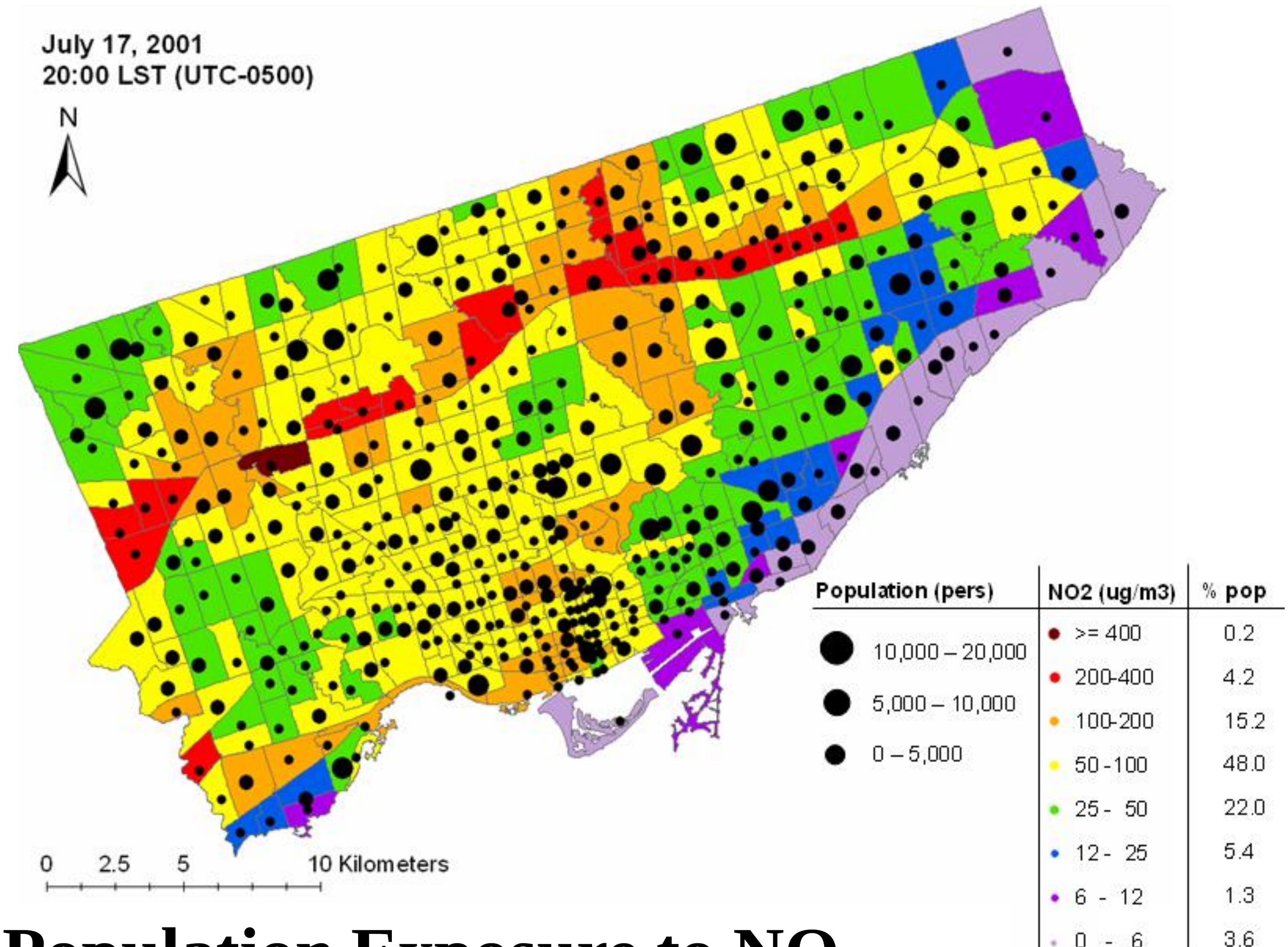


Source: Hatzopoulou, 2008.

Dispersion of Emission Concentrations



Source: Hatzopoulou, 2008.



Population Exposure to NO_2

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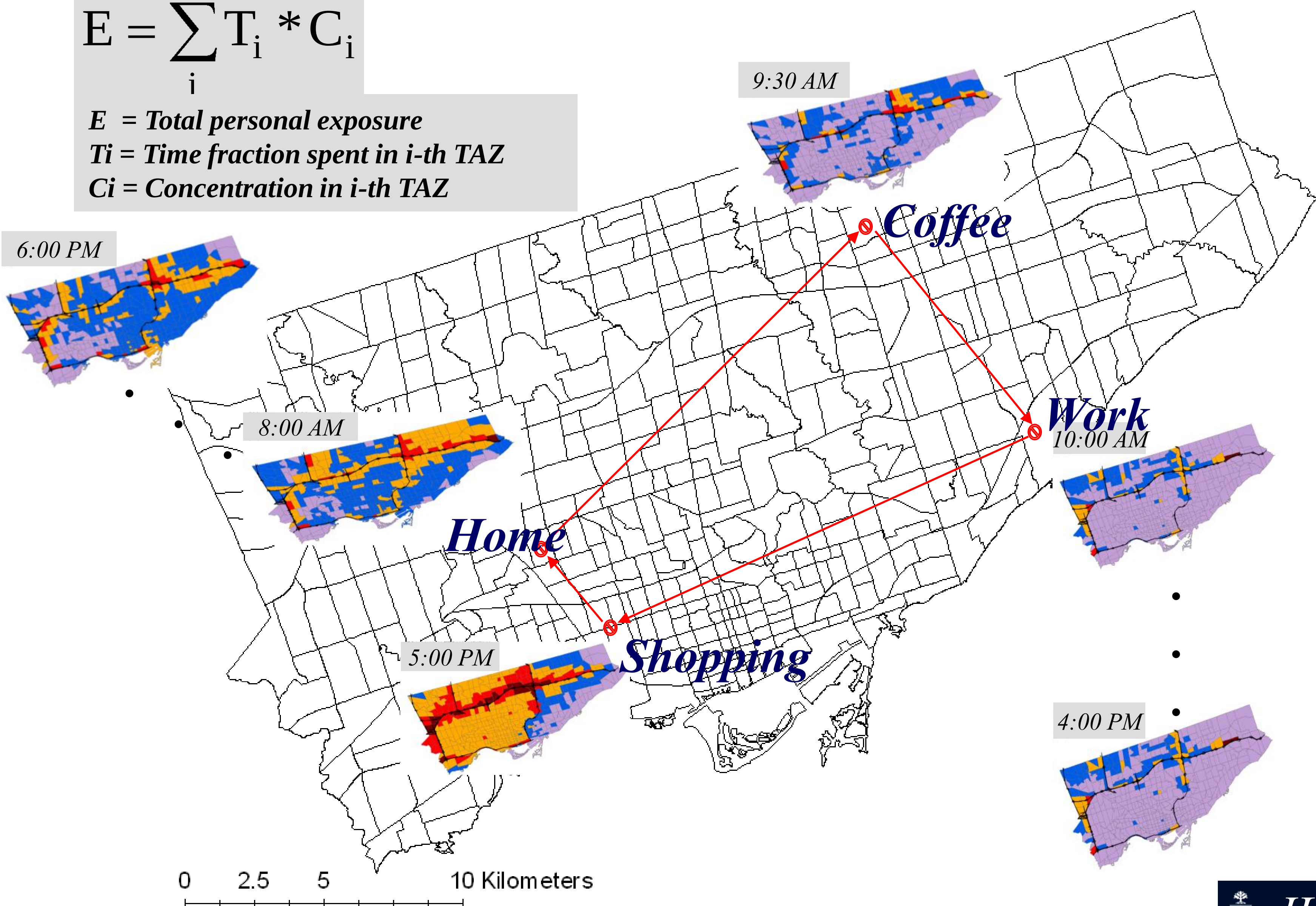
$$E = \sum_{i} T_i * C_i$$

E = Total personal exposure
Ti = Time fraction spent in i-th TAZ
Ci = Concentration in i-th TAZ



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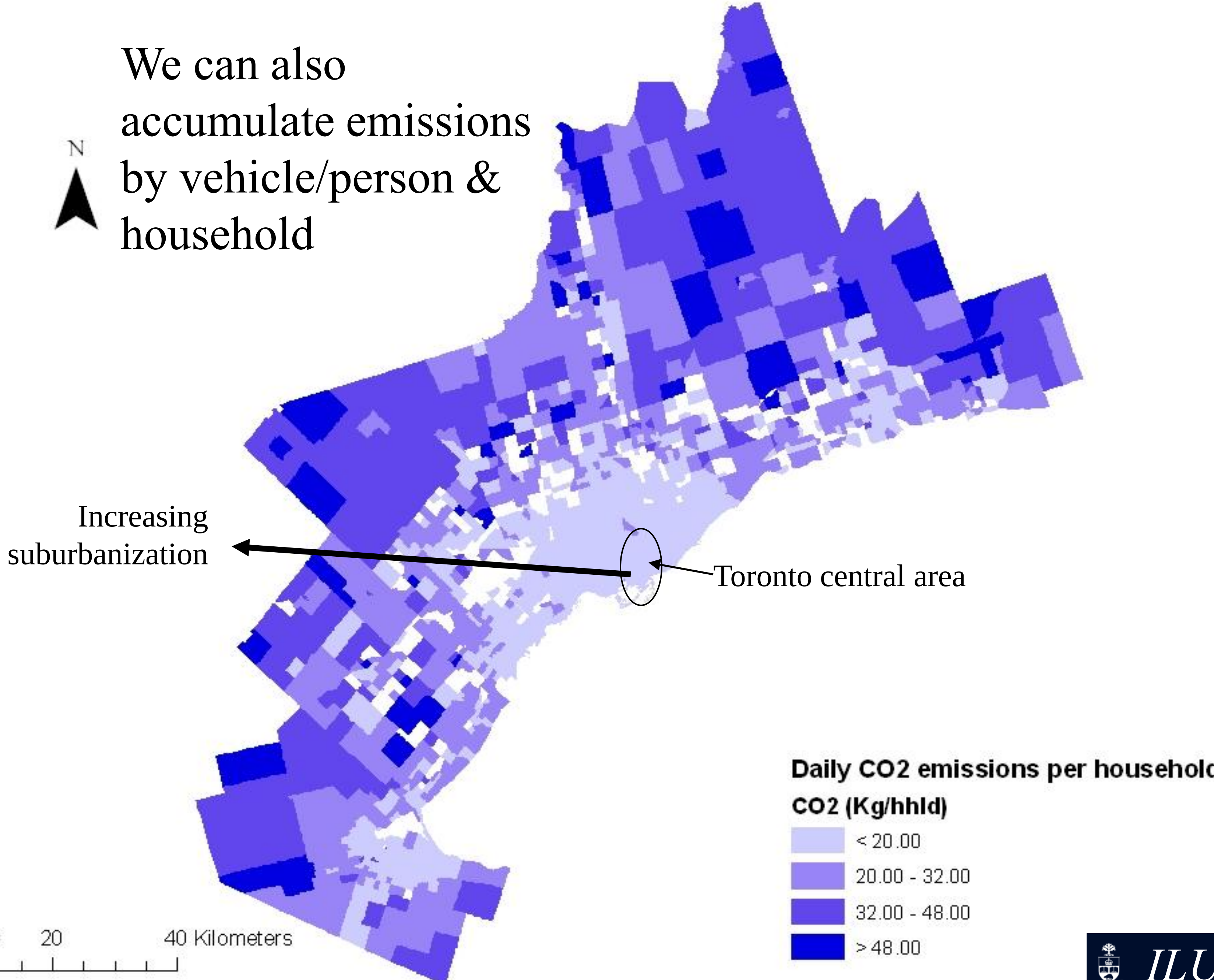
We can also accumulate emissions by vehicle/person & household



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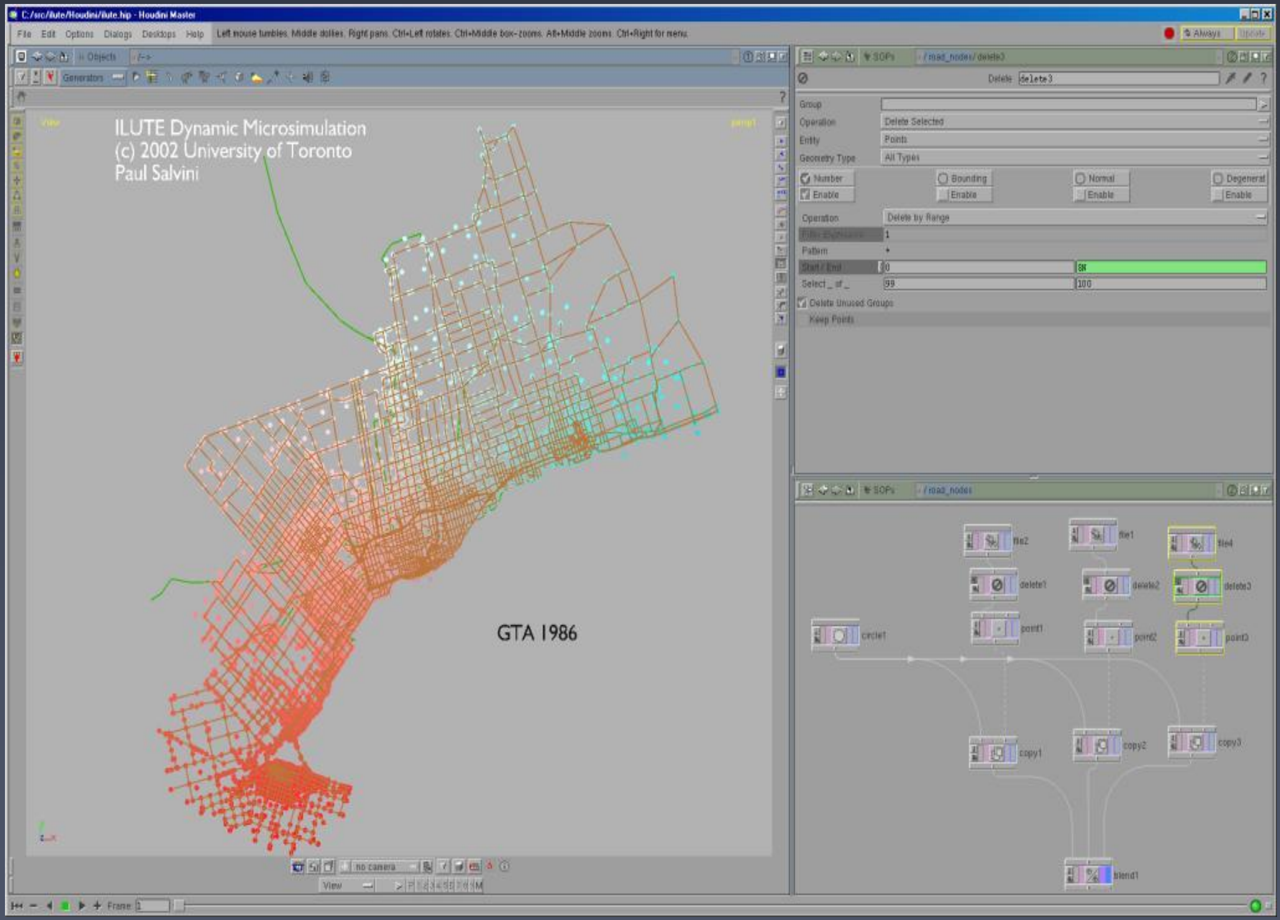
Acknowledgements to the ILUTE project team (past & present):

- Juan Carrasco
- Franco Chingcuanco
- Len Eberhard
- Ilan Elgar
- Bilal Farooq
- Wenli Gao
- Martin Giroux-Cook
- Ahsan Habib
- Khandker Habib
- Murtaza Haider
- Michael Hain
- Jiang Hao
- Marianne Hatzopoulou
- Marek Litwin
- David McElroy
- Kouros Mohammadian
- Anna Mori (Pushkar)
- David Pritchard
- Matt Roorda
- Paul Salvini
- James Vaughan
- David Wang



THANK YOU! QUESTIONS?