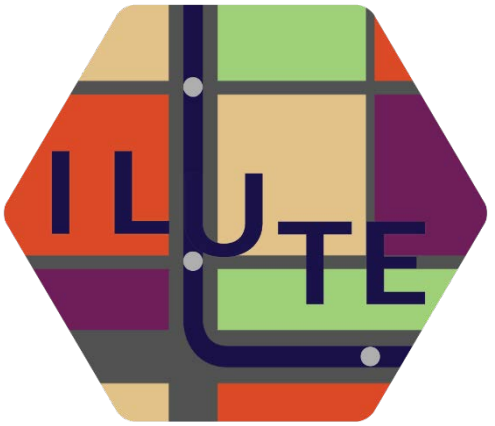
Towards the Next Generation of Integrated Urban Models



3rd Annual iCity-ORF Research Day

University of Toronto

June 22, 2018

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

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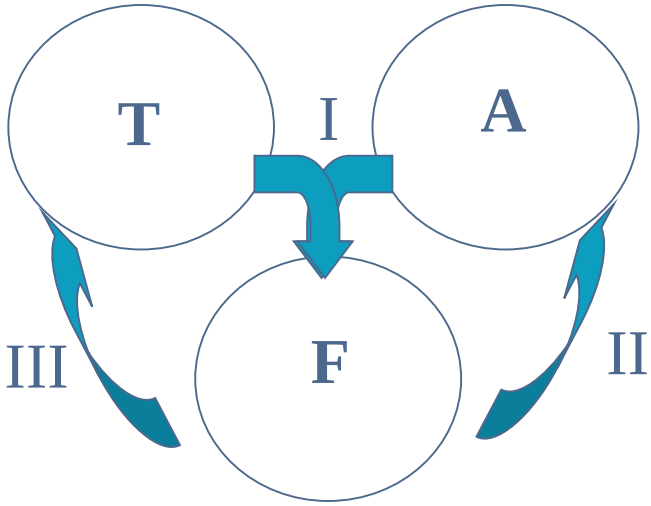
Director, UTTRI
University of Toronto

Presentation Overview

- What is an integrated urban model?
- Why integrated models?
- Agent-based microsimulation (ABM)
- ILUTE
- The ILUTE Reboot

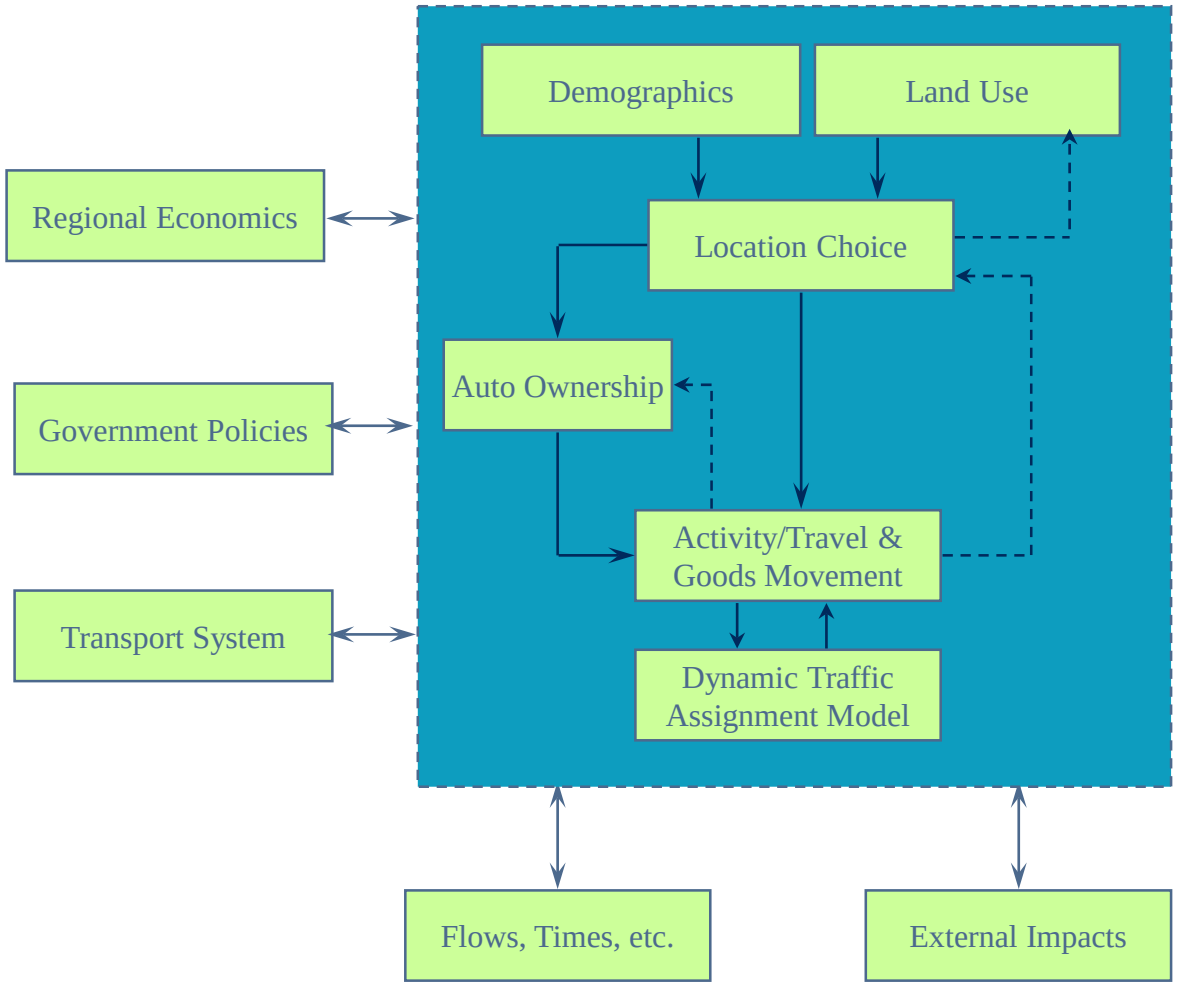


Source: Manheim, M.L. (1978) *Fundamentals of Transportation Systems Analysis Volume 1: Basic Concepts*, MIT Press

Key System Elements
T – transport system
A – activity system
F – flows & transport system performance

System Interactions/Feedbacks
I Market demand-supply interactions determine flows & system performance
II System performance (accessibility) influences activity system markets
III Gov't, public & private service providers respond system demand & performance

What is an integrated model?

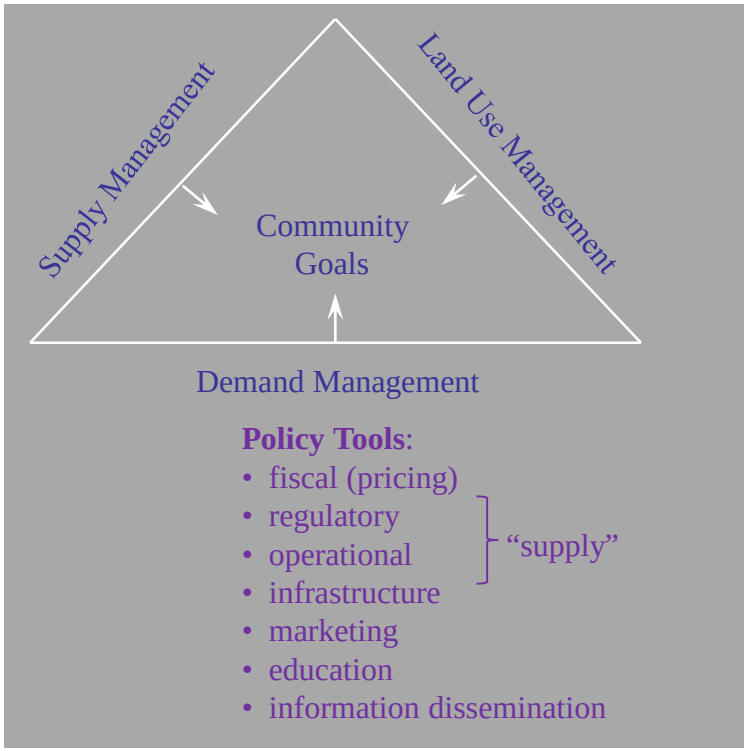


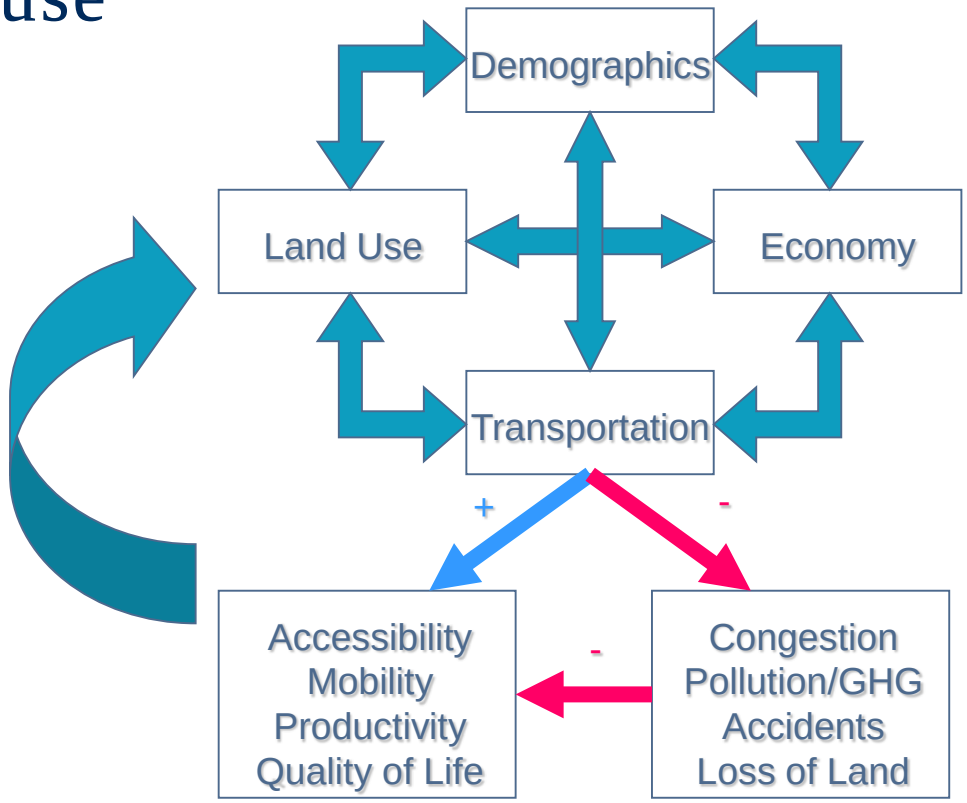
An integrated urban model is intended to represent the spatial evolution of a given study region system state over time as a function of various socio-economic, demographic and political processes. Key words:

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

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.

The need for integrated models: the transportation – land use connection





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

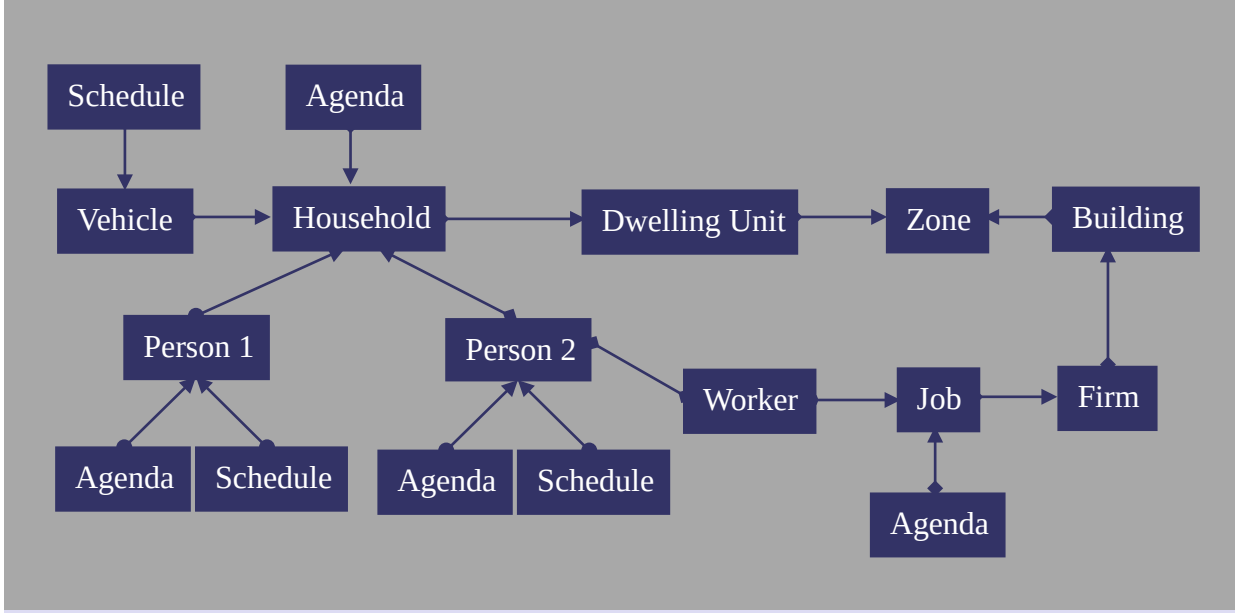
Many "transportation" issues (especially with respect to sustainability) have their origins (and perhaps their solutions as well) in land use design.

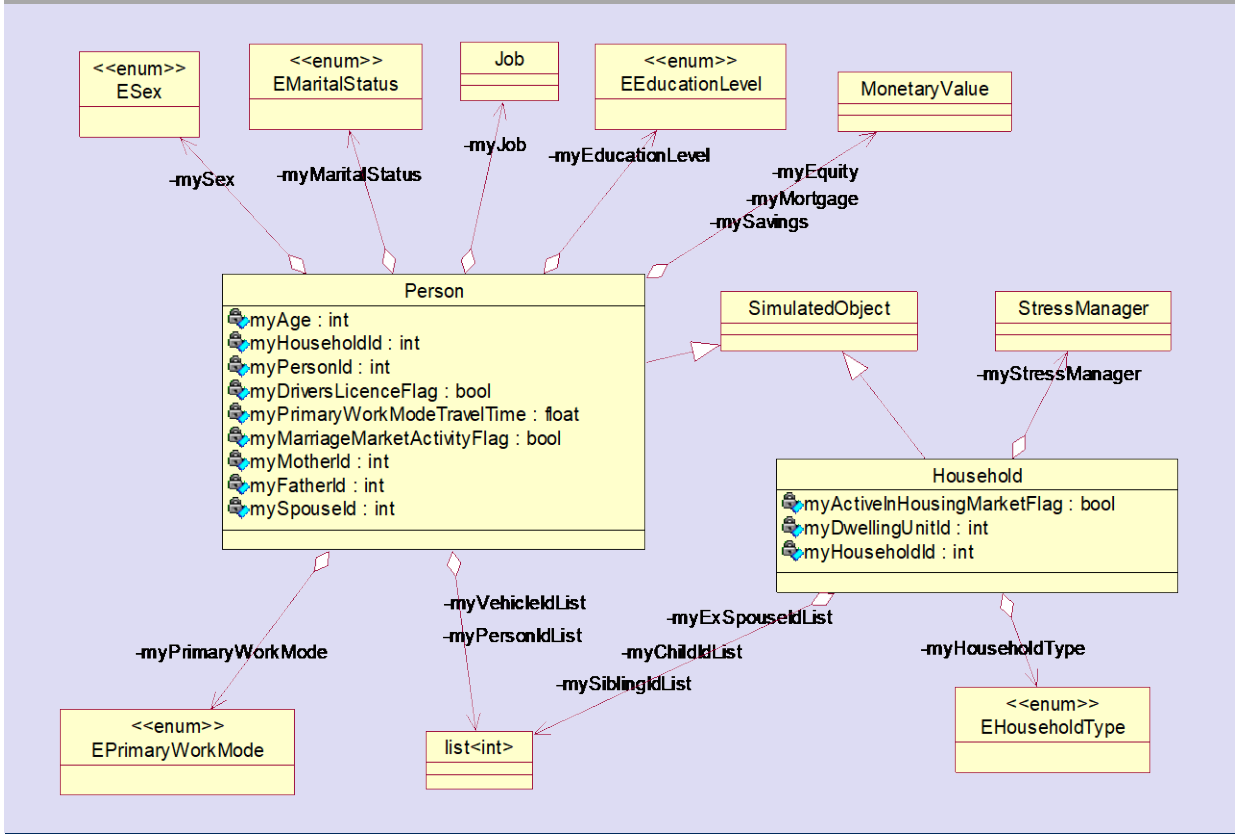
Agent-Based Modelling

An intelligent object is an *agent*. ("an object with attitude" – Paul Waddell). Agents:

- perceive the world around them
- make autonomous decisions
- act into the world

Agents provide an efficient, highly extensible framework for modelling human socio-economic activity.





Microsimulation

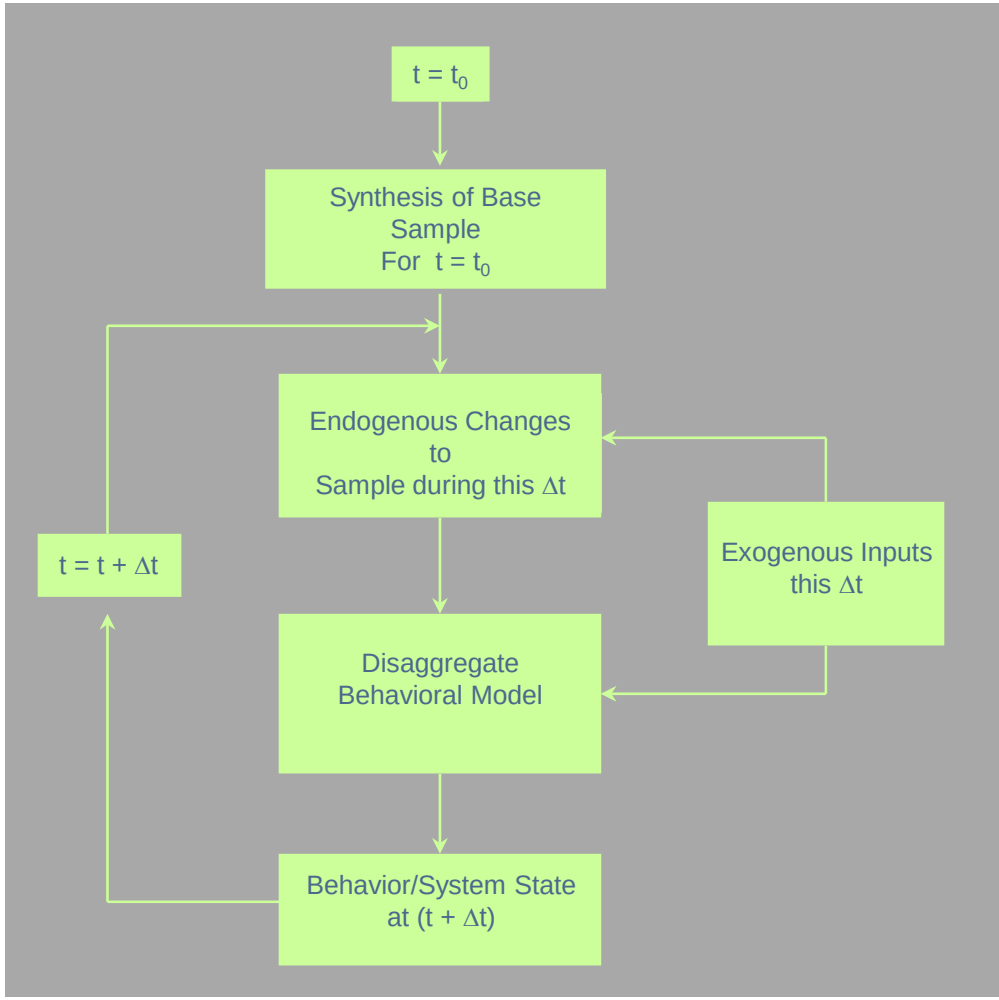
"Micro" implies a highly disaggregated model:

- spatially
- socio-economically (representation of actors)
- representation of processes

"Simulation" implies:

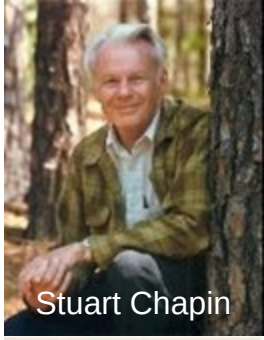
- numerical
- dynamic (time dimension explicit)
- stochastic
- end state is "evolved" rather than "solved for"

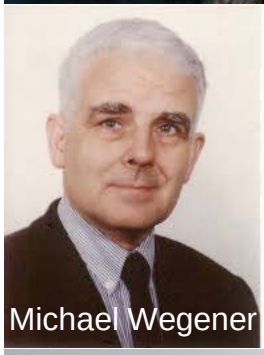
Microsimulation is the computational approach for implementing agent-based models.



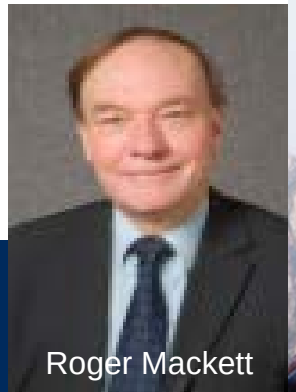
Land Use Microsimulation Models

- Pioneers: Stuart Chapin (UNC, Chapel Hill), George Orcutt (Brookings), David Birch (MIT), …
- The "Dortmund School": Michael Wegener, Klaus Spiekermann,(& later, Rolf Moeckel)
- The "UCL School: Roger Mackett; Michael Batty
- The "Toronto School":
  - TORUS (mid-1980s! Written in FORTRAN!)
  - ILUTE
- …


Stuart Chapin


Michael Wegener

Rolf Moeckel

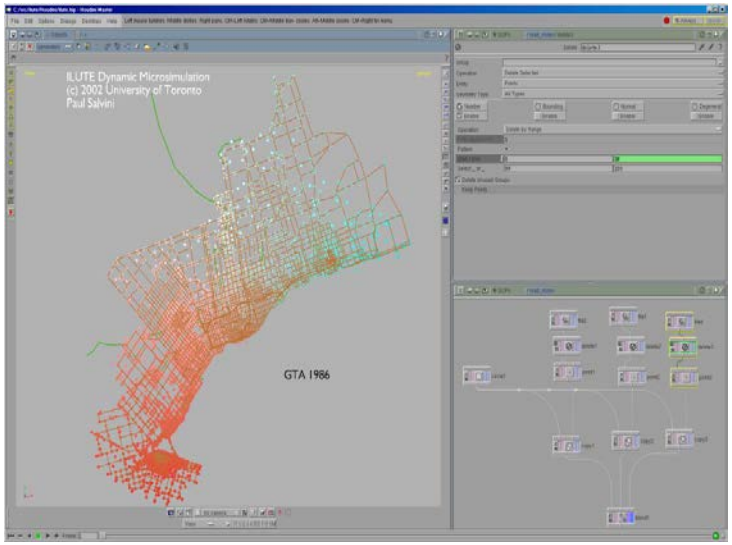

Roger Mackett

Michael Batty

The ILUTE Modeling Project

The Integrated Land Use, Transportation, Environment (ILUTE) Modelling Project design principles:

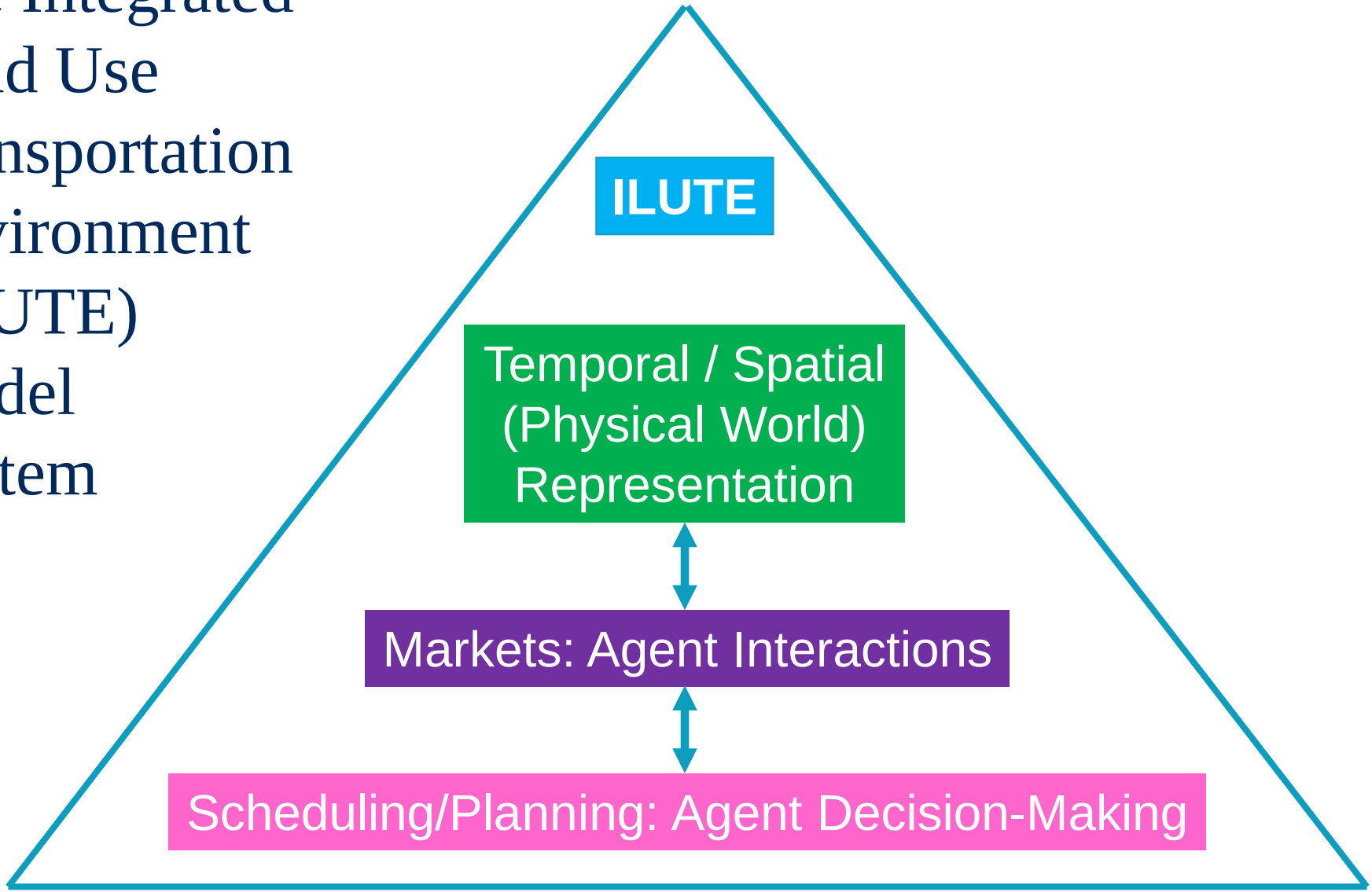
- Fully microsimulation-based
- Fully object-oriented/agent-based in design & implementation
- Full population synthesis
- Household & firm based
- Comprehensive:
  - land use
  - activity/travel
  - urban economics
  - auto ownership
  - demographics
  - emissions/energy use



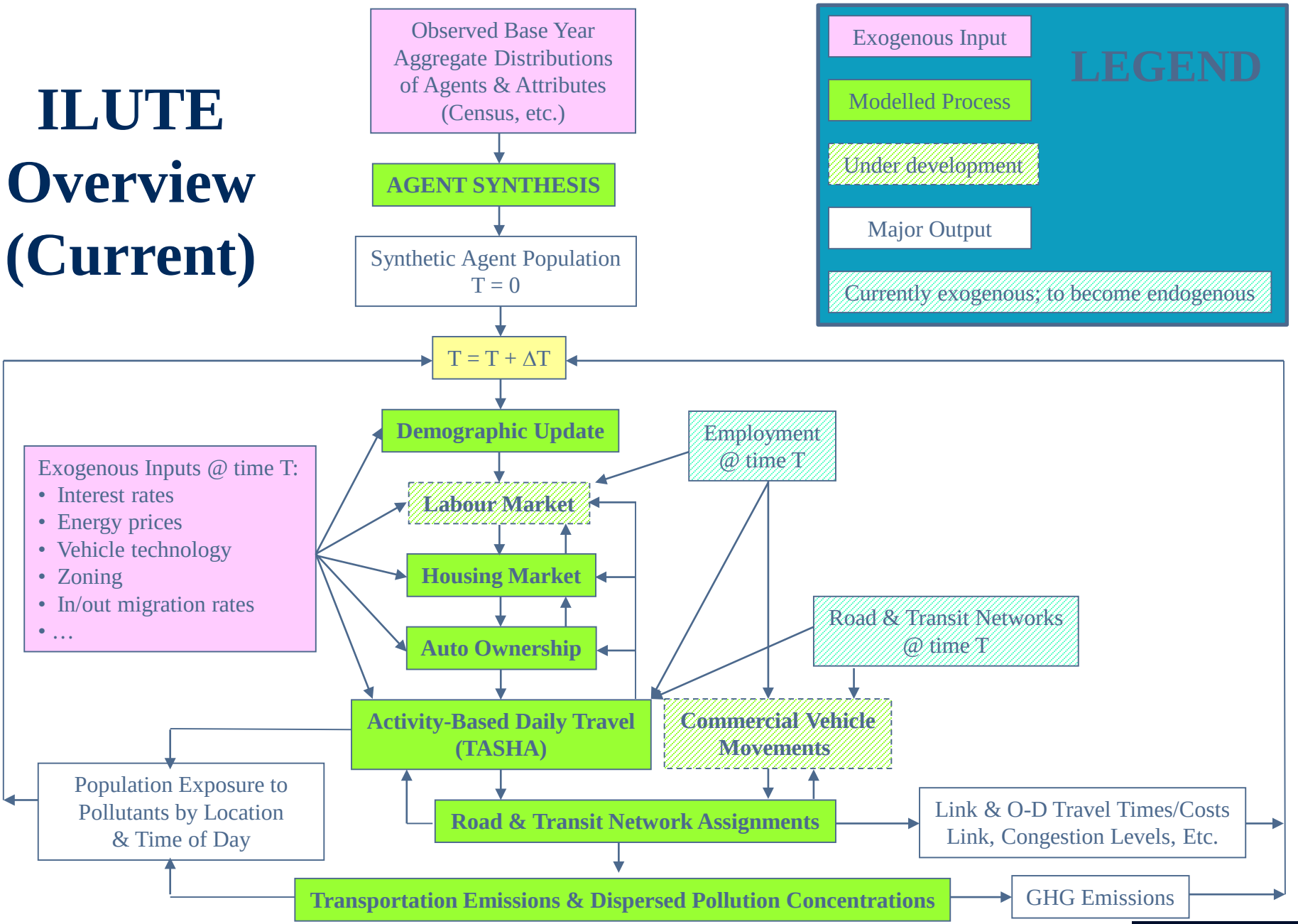
- A **framework** for model development in addition to a model *per se*.

Salvini, P.A. and E.J. Miller, "ILUTE: An Operational Prototype of a Comprehensive Microsimulation Model of Urban Systems", *Networks and Spatial Economics*, Vol. 5, 2005, pp. 217-234.

The Integrated Land Use Transportation Environment (ILUTE) Model System



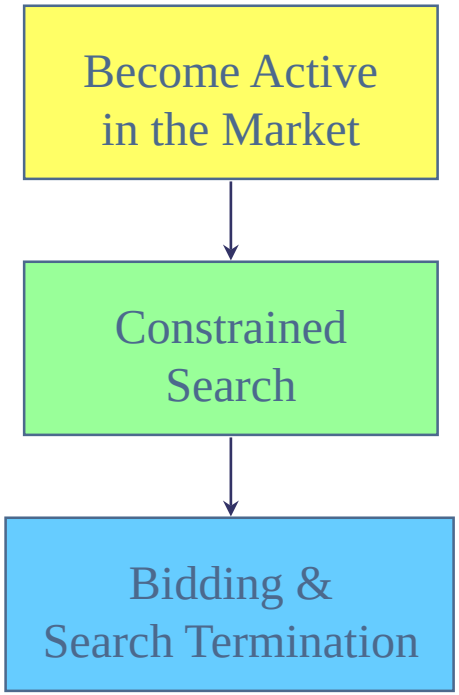
ILUTE Overview (Current)

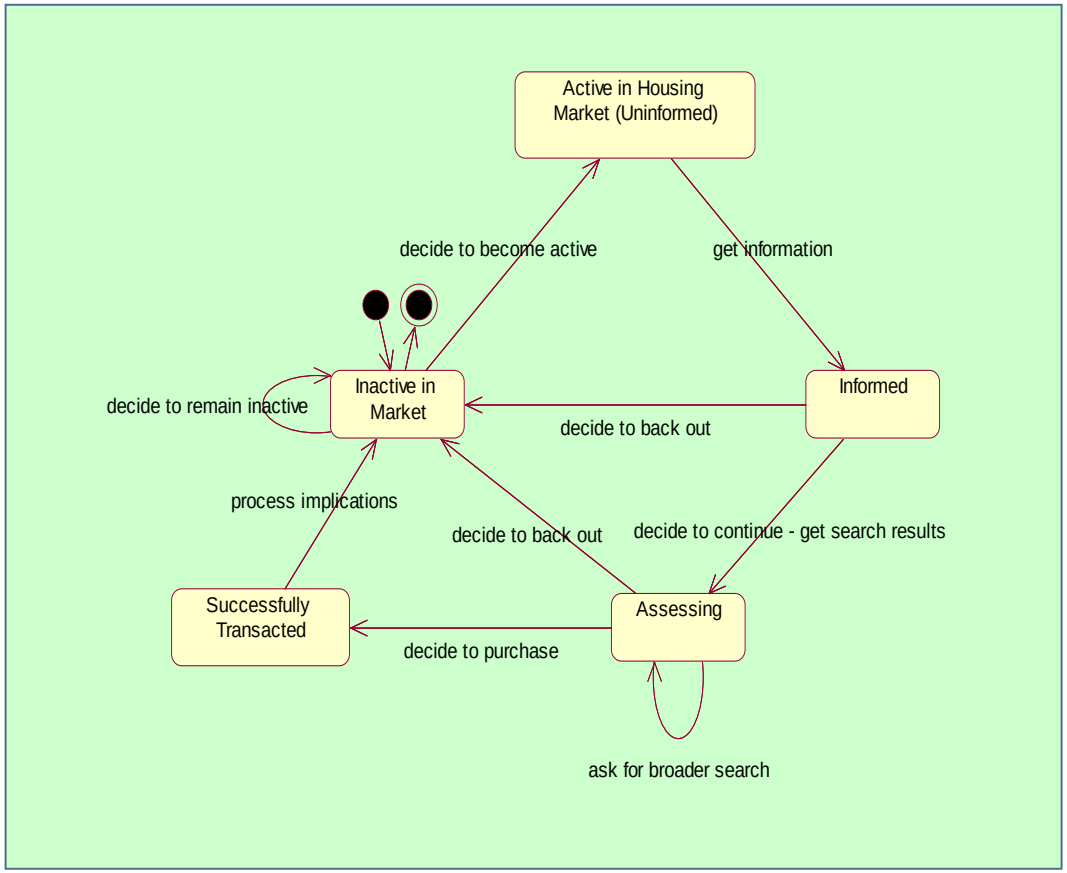


ILUTE

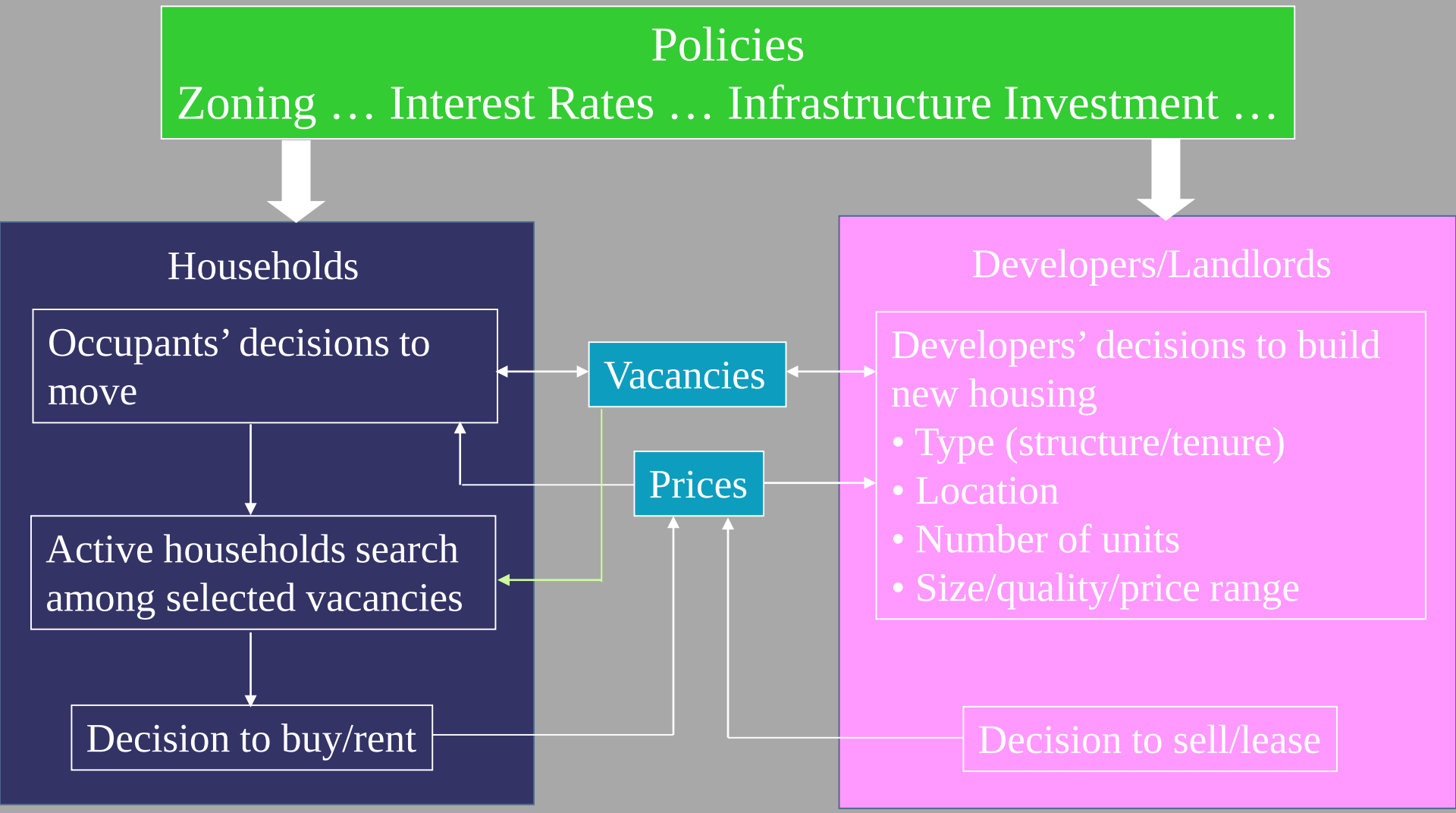
Microsimulating Markets

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

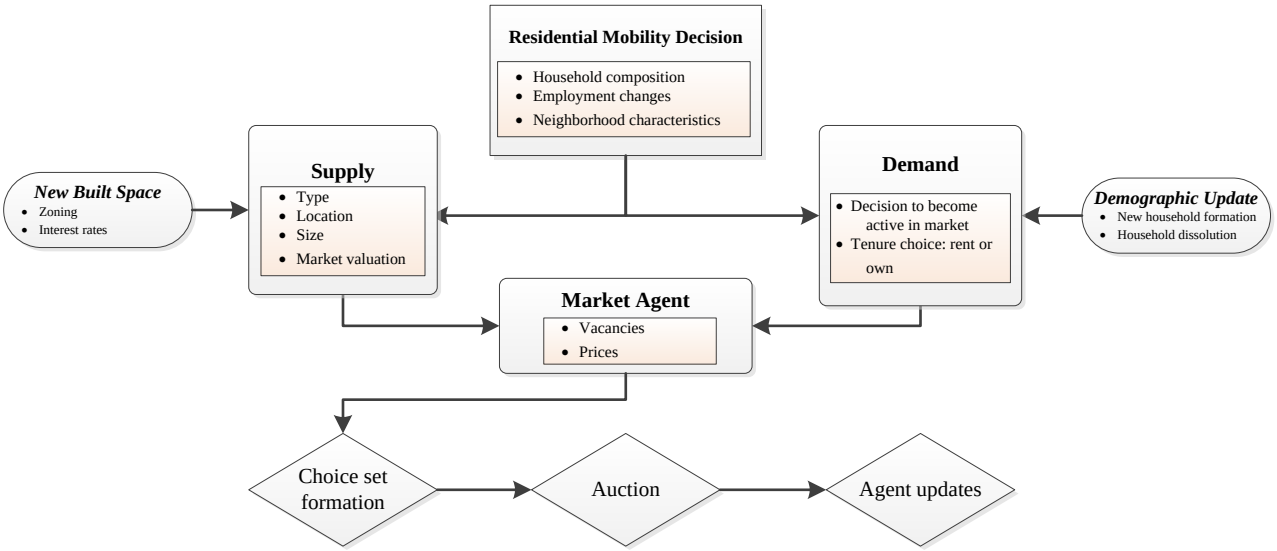


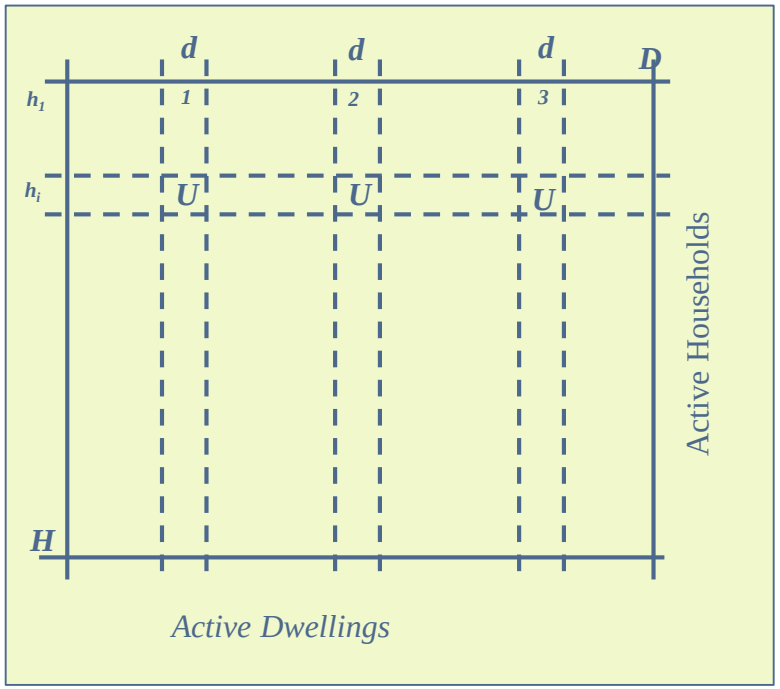


Simulating the Housing Market



Modeling Markets



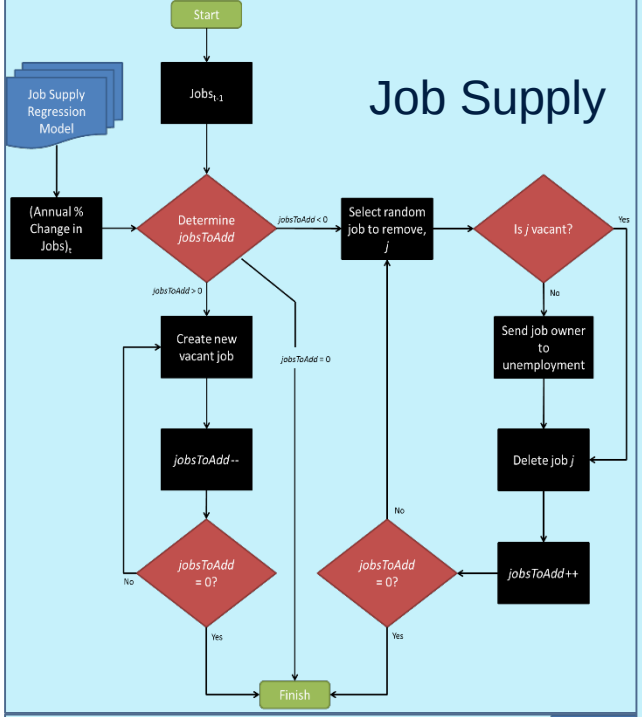


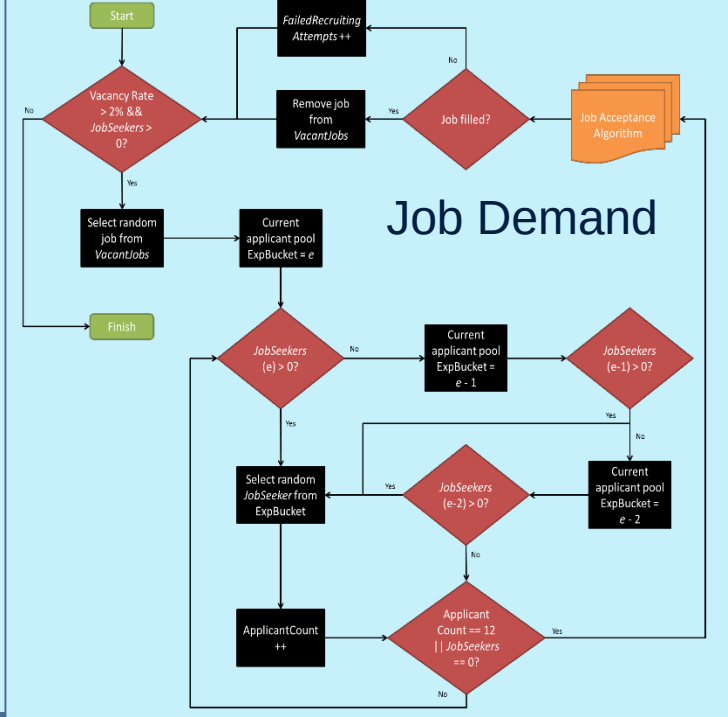
In ILUTE houses are auctioned off one at a time to interested bidders one dwelling at a time in a disaggregate implementation of Martinez' Bid Choice theory.

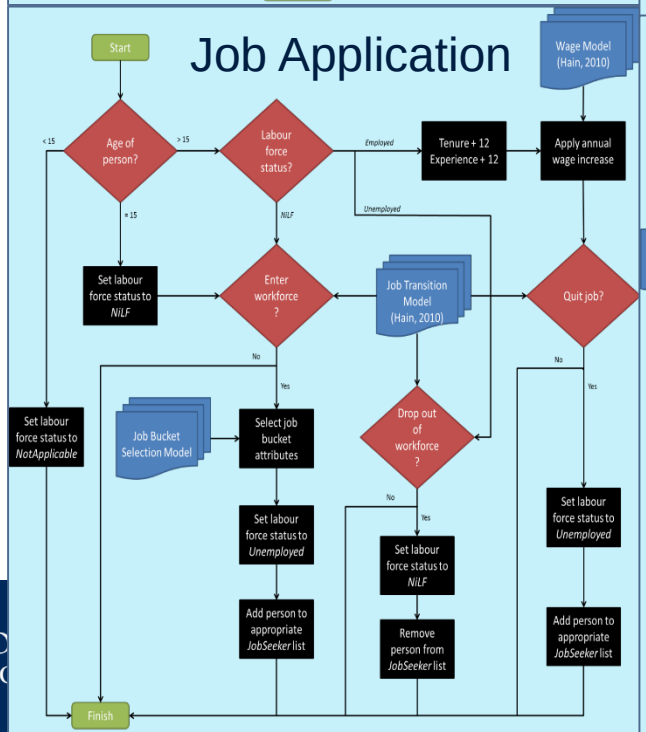
This one example of several market microsimulations within ILUTE.

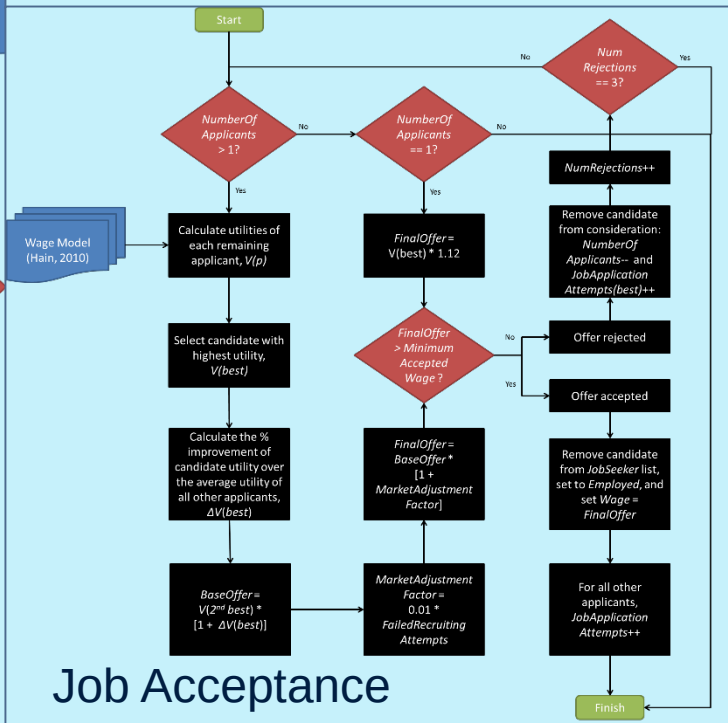
Labour Market Model

- Matching workers to jobs.
- Patterned after the housing market model.

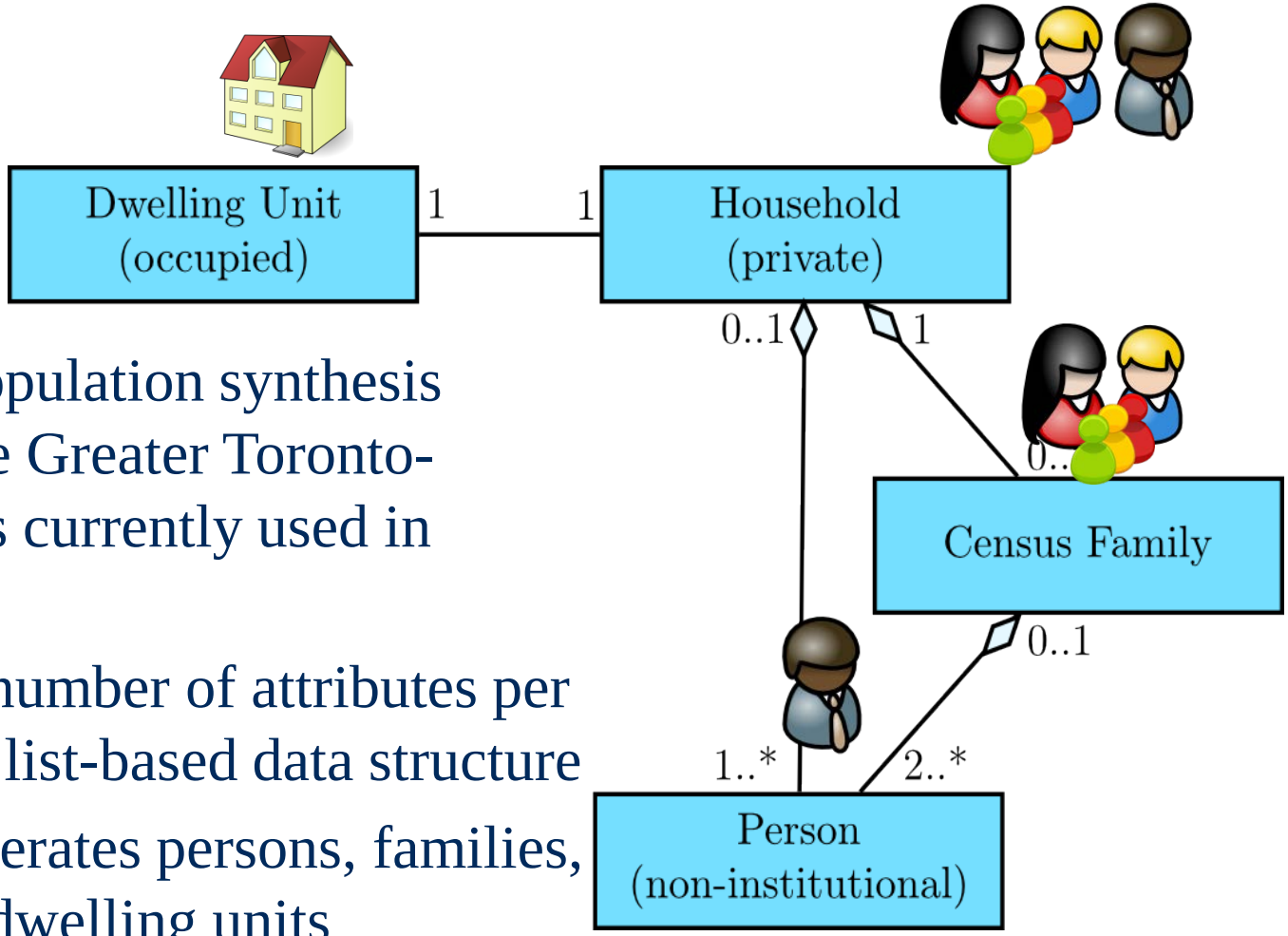








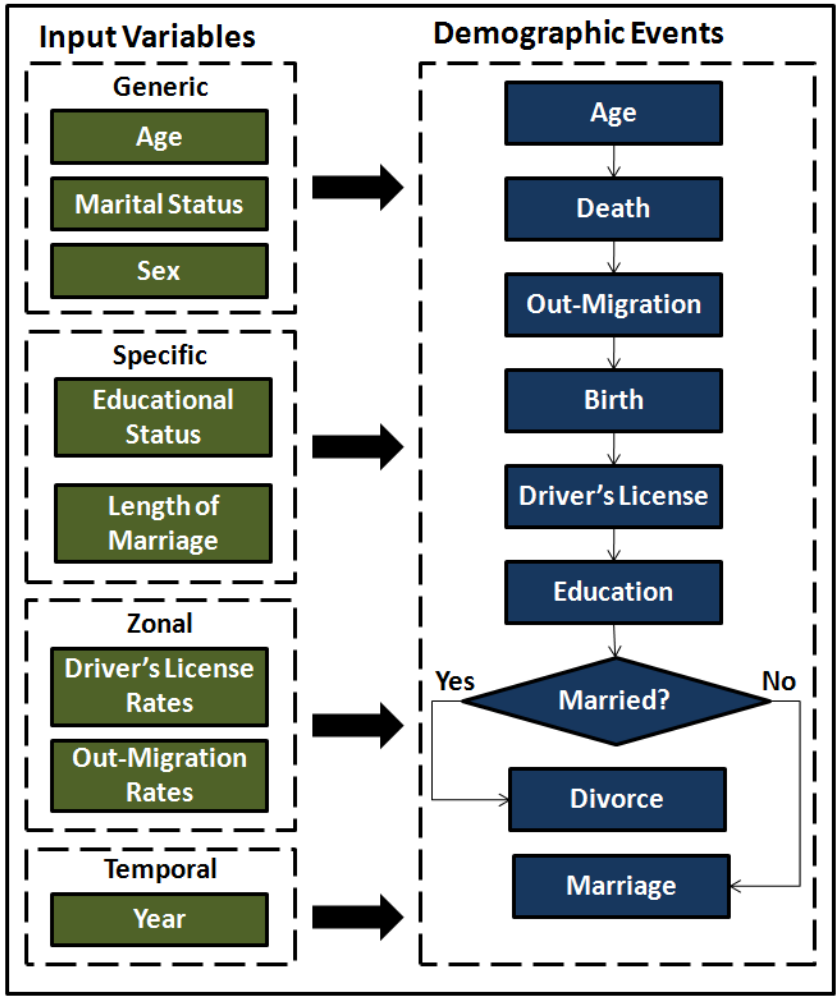
Population Synthesis



- An IPF-based population synthesis procedure for the Greater Toronto-Hamilton Area is currently used in ILUTE
- Handles a large number of attributes per agent by using a list-based data structure
- Consistently generates persons, families, households and dwelling units

Pritchard, D. and E.J. Miller, "Advances in Population Synthesis: Fitting Many Attributes Per Agent and Fitting to Household and Person Margins Simultaneously", *Transportation* 39(3), May 2012, pp. 685-704.

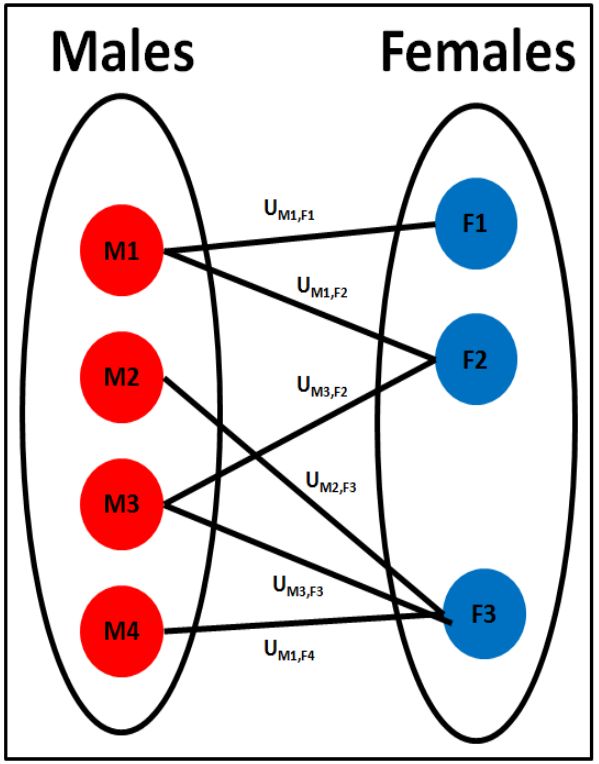
Demographic Updating



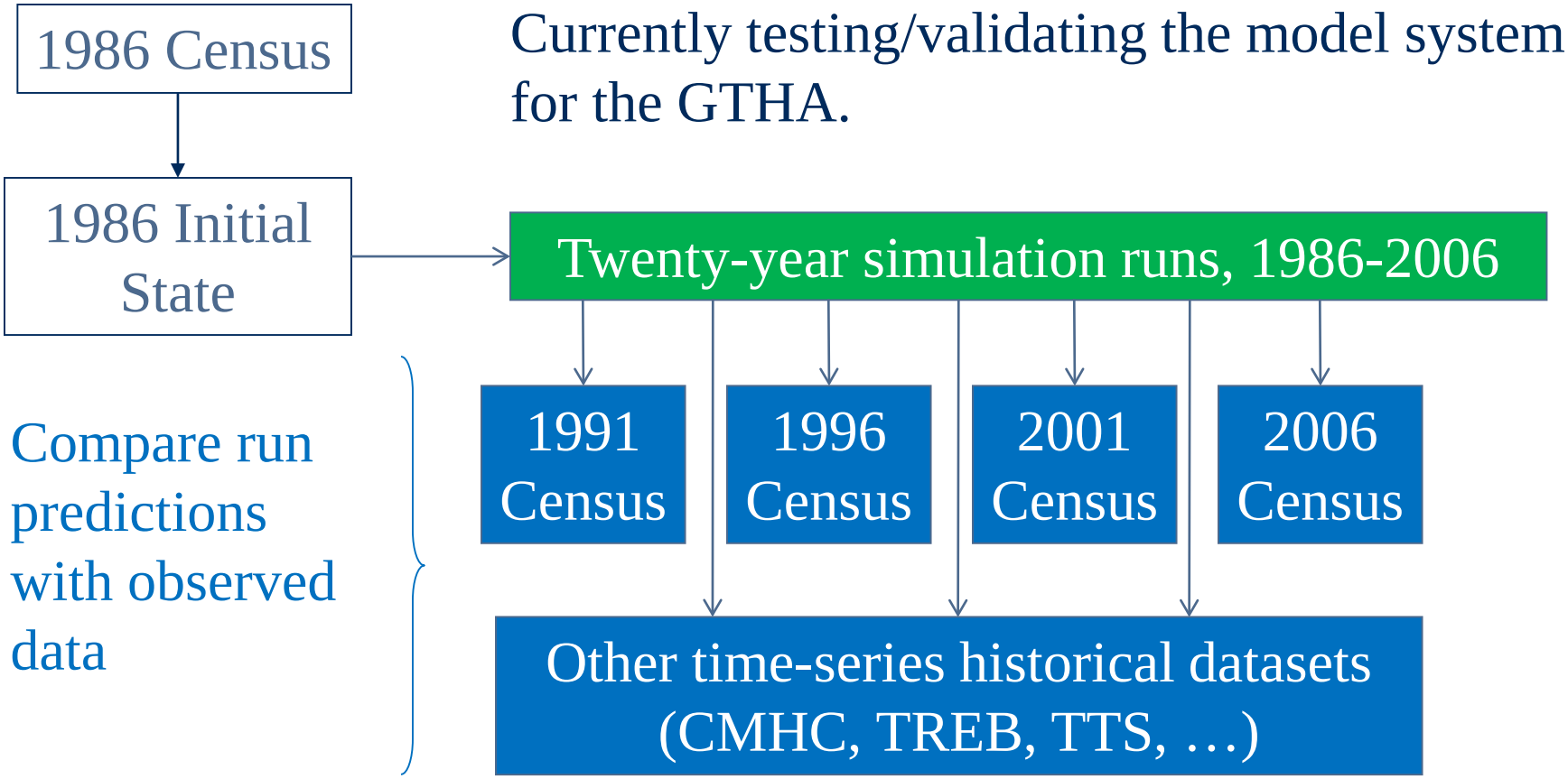
Socioeconomic Variables	Events							
	Age	Death	Out-Migration	Birth	Driver's License	Education	Marriage	Divorce
Age	X	X		X	X	X	X	
Marital Status		X		X			X	X
Sex		X			X		X	
Driver's License Status					X			
Educational Status						X		
Length of Marriage								X
Driver's License Possession Rate					X			
Out-Migration Rates			X					
Year		X	X	X	X	X		

Modelling Marriages

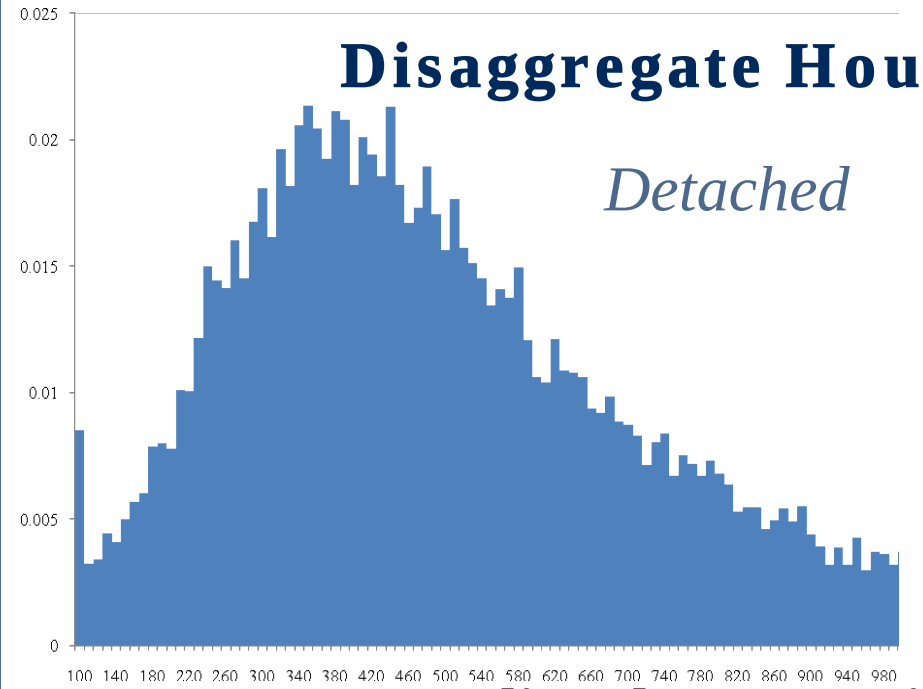
- Marriages can be modelled as a "fixed-price" (=0) "market" in which males and females are matched on a utility maximizing basis.
- The basic algorithm is being applied to other "fixed-price" markets (labour, rental housing, …)

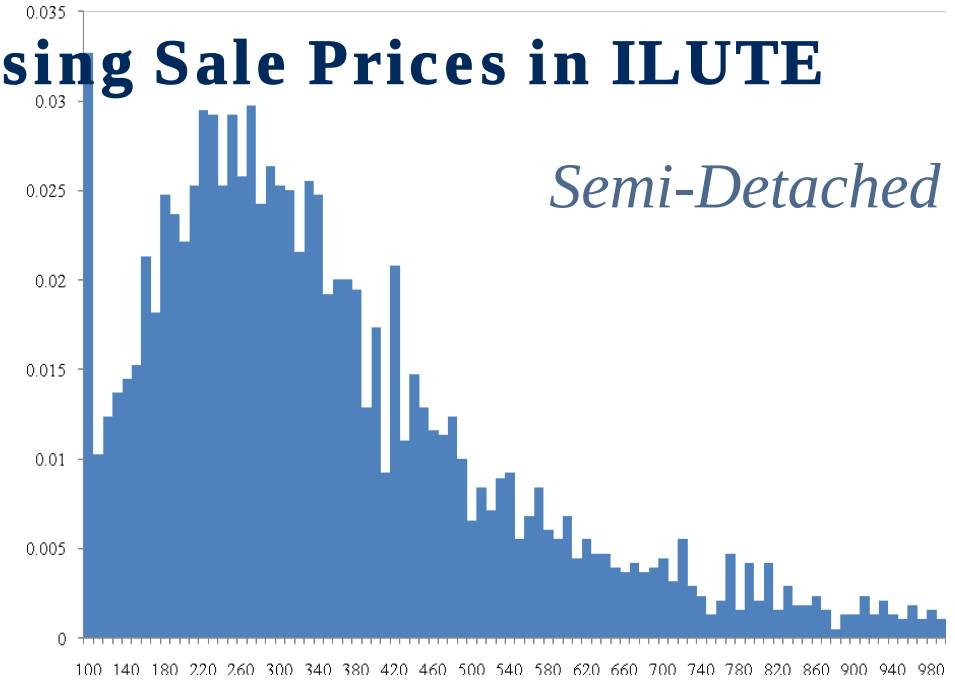


Historical Test Runs, 1986-2006

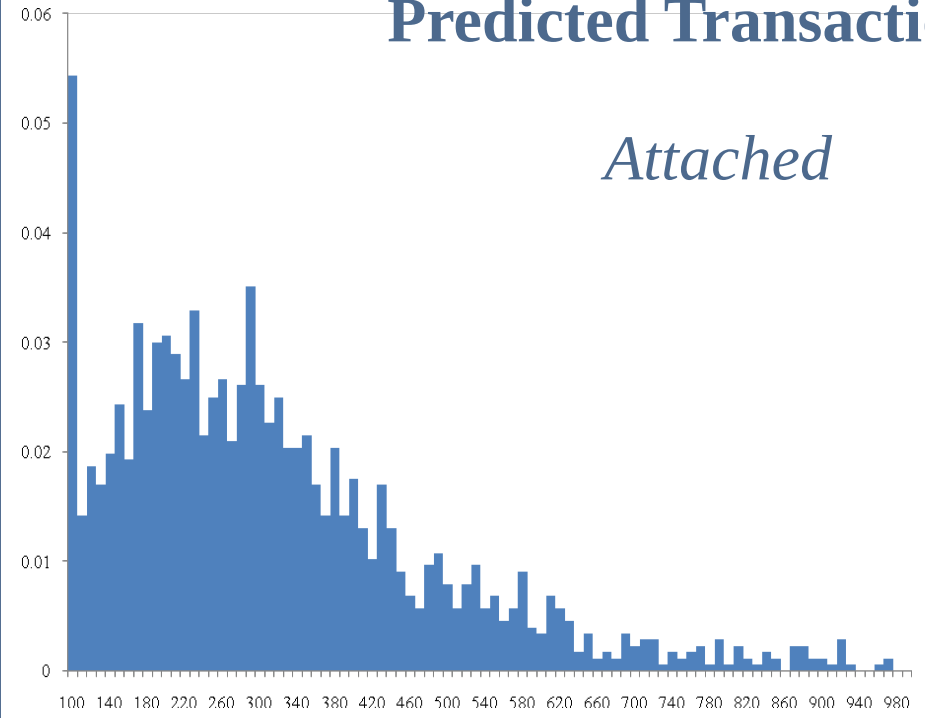


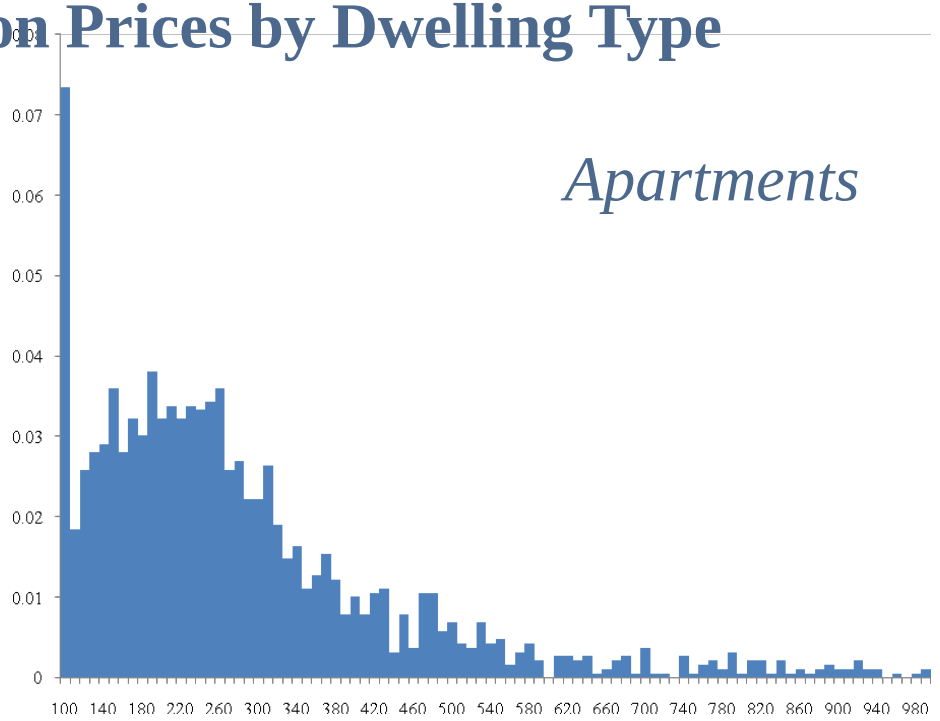
Disaggregate Housing Sale Prices in ILUTE





Predicted Transaction Prices by Dwelling Type





Selected example housing market results

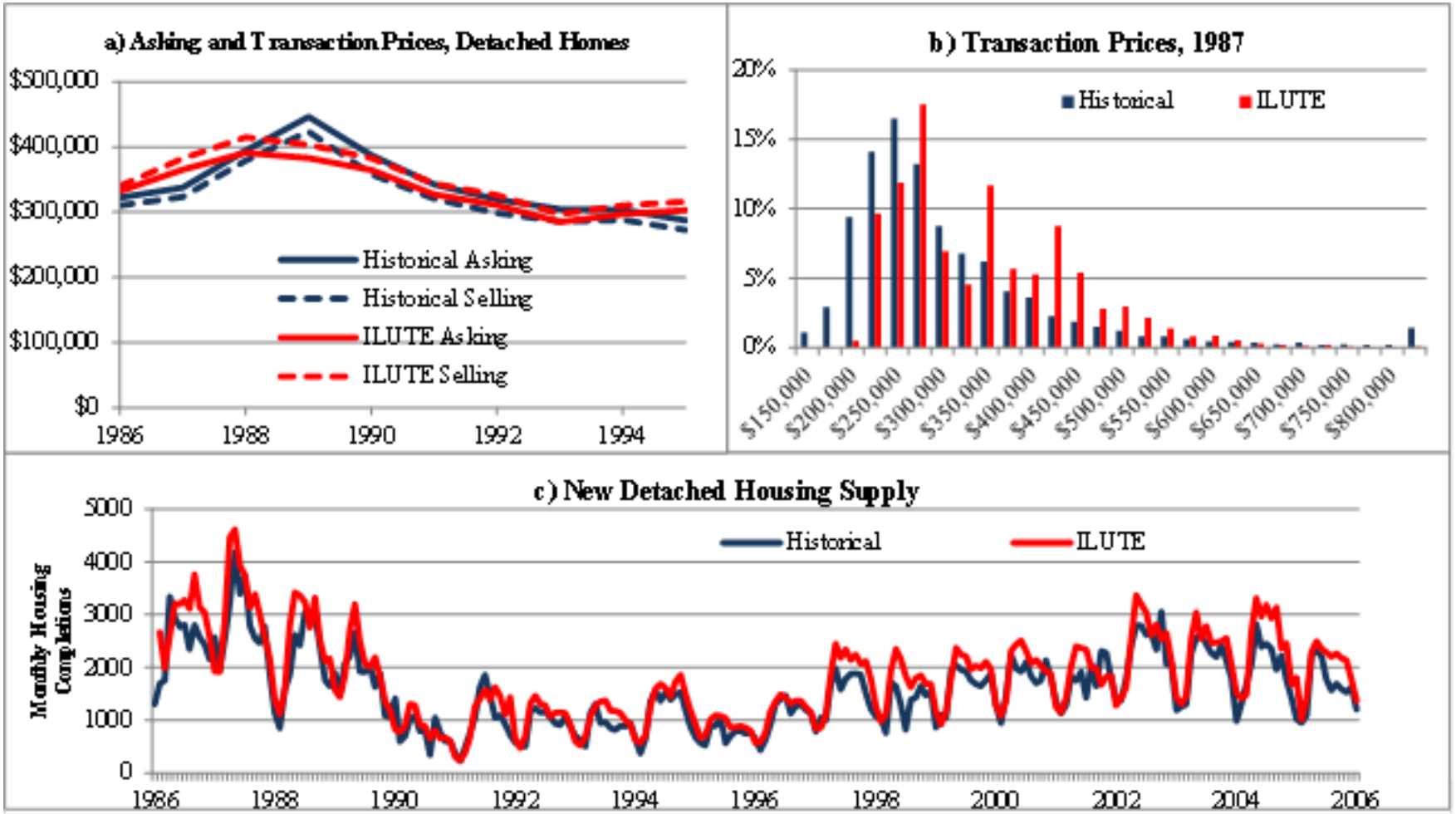
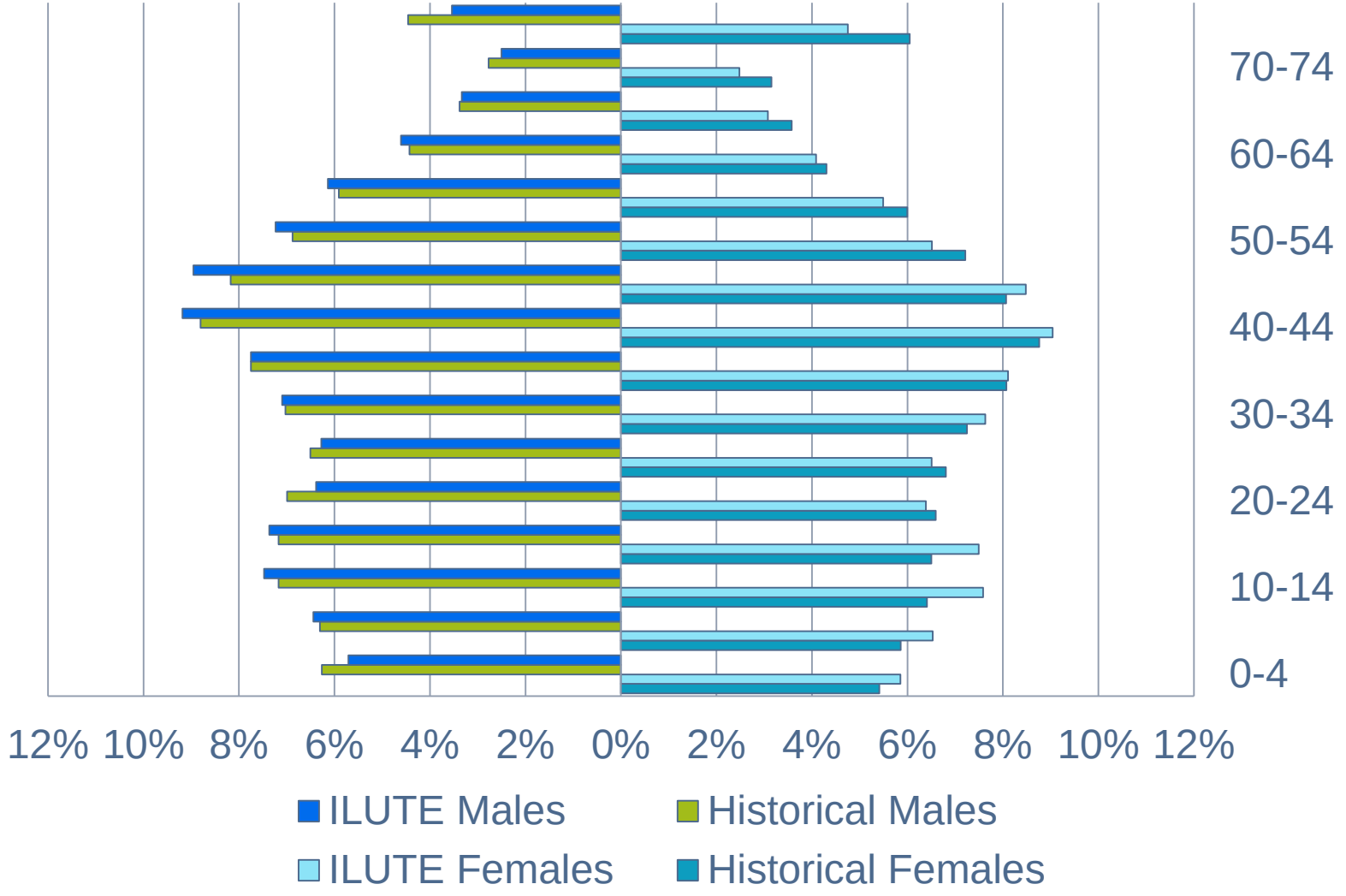


Figure 2. HoMES validation against TREB and CMHC data.

2006 Age Distribution



ILUTE vs. historical household type distributions

		Single Indiv	Multi Indiv	Single Fam	Single Fam Indivs	Multi Fam
StatsCan	1986	20.8%	2.8%	74.0%	2.2%	0.1%
	1991	21.4%	3.7%	71.6%	3.1%	0.2%
	1996	22.0%	3.0%	72.5%	2.2%	0.2%
	2001	22.2%	2.9%	72.6%	2.1%	0.2%
ILUTE	1986	21.1%	3.3%	74.1%	1.0%	0.5%
	1991	23.3%	2.8%	71.9%	1.8%	0.4%
	1996	25.3%	2.4%	70.4%	1.7%	0.3%
	2001	27.3%	2.2%	68.7%	1.5%	0.3%

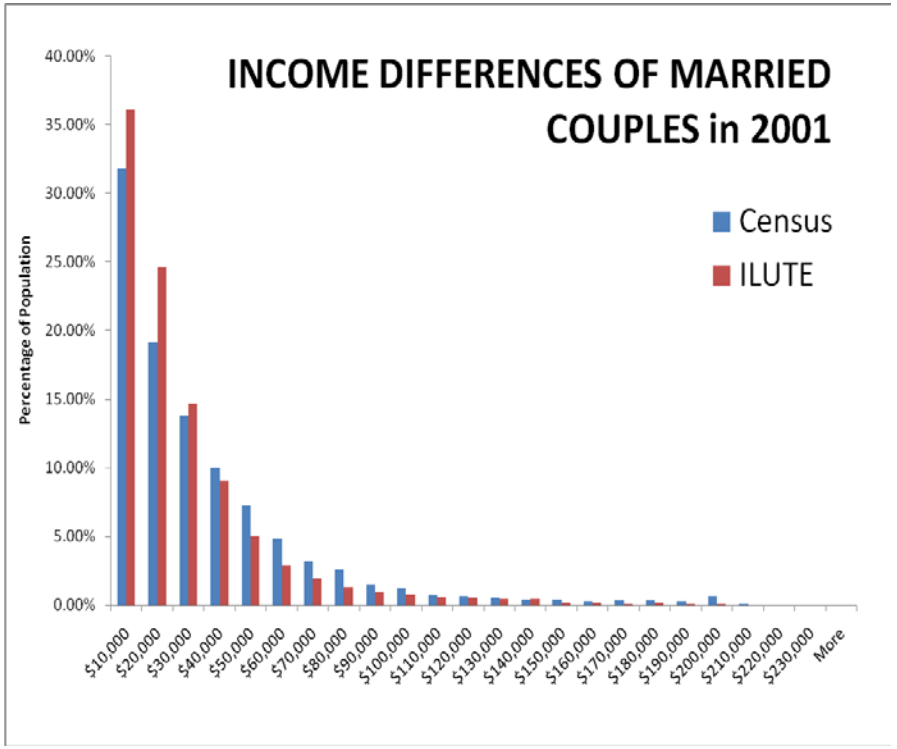
Predicted and Observed Married Couple Attributes

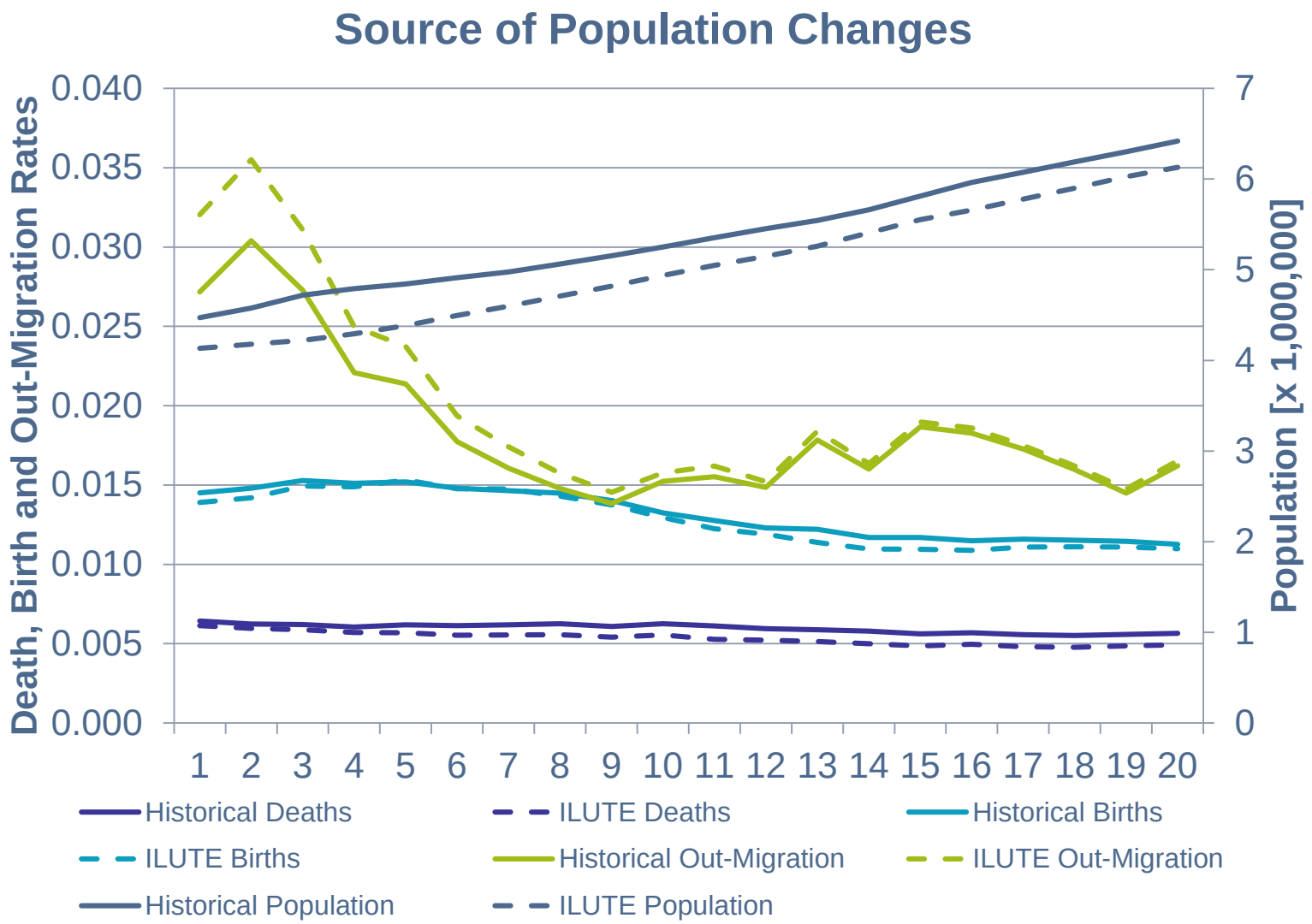
Ages

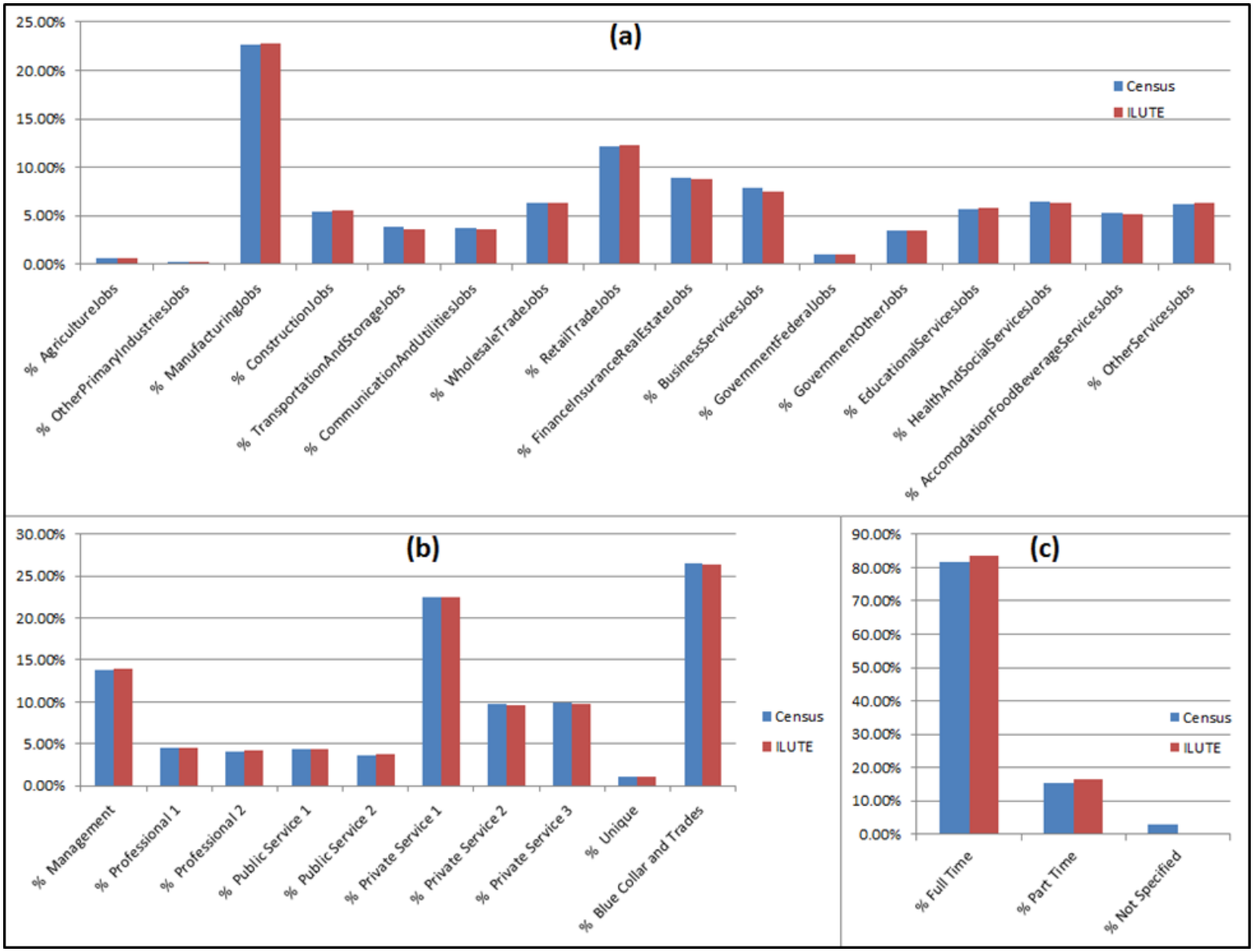
CENSUS 2001 MARRIED COUPLES		Age Male							
		18 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 - 74	75 - 84	85 & over
Age Female	18 - 24	0.28%	1.00%	0.14%	0.03%	0.00%	0.00%	0.00%	0.00%
	25 - 34	0.18%	10.94%	7.10%	0.39%	0.06%	0.00%	0.00%	0.00%
	35 - 44	0.02%	1.57%	19.11%	7.84%	0.55%	0.08%	0.00%	0.00%
	45 - 54	0.01%	0.08%	1.59%	15.21%	6.19%	0.46%	0.03%	0.00%
	55 - 64	0.00%	0.01%	0.05%	0.95%	8.58%	4.40%	0.24%	0.02%
	65 - 74	0.00%	0.00%	0.01%	0.04%	0.51%	5.98%	2.39%	0.08%
	75 - 84	0.00%	0.00%	0.00%	0.00%	0.03%	0.43%	2.56%	0.51%
	85 & over	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.11%	0.24%

ILUTE 2001 MARRIED COUPLES		Age Male							
		18 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 - 74	75 - 84	85 & over
Age Female	18 - 24	1.21%	0.71%	0.17%	0.00%	0.00%	0.01%	0.00%	0.00%
	25 - 34	0.05%	11.40%	3.78%	1.00%	0.03%	0.03%	0.00%	0.00%
	35 - 44	0.02%	0.97%	18.74%	8.73%	2.38%	0.12%	0.03%	0.00%
	45 - 54	0.00%	0.40%	4.62%	12.28%	6.32%	1.69%	0.07%	0.00%
	55 - 64	0.00%	0.01%	0.72%	3.44%	5.96%	3.33%	0.61%	0.02%
	65 - 74	0.00%	0.01%	0.02%	0.40%	1.83%	3.60%	1.54%	0.23%
	75 - 84	0.00%	0.00%	0.00%	0.01%	0.10%	1.02%	1.25%	0.47%
	85 & over	0.00%	0.00%	0.00%	0.00%	0.01%	0.05%	0.28%	0.32%

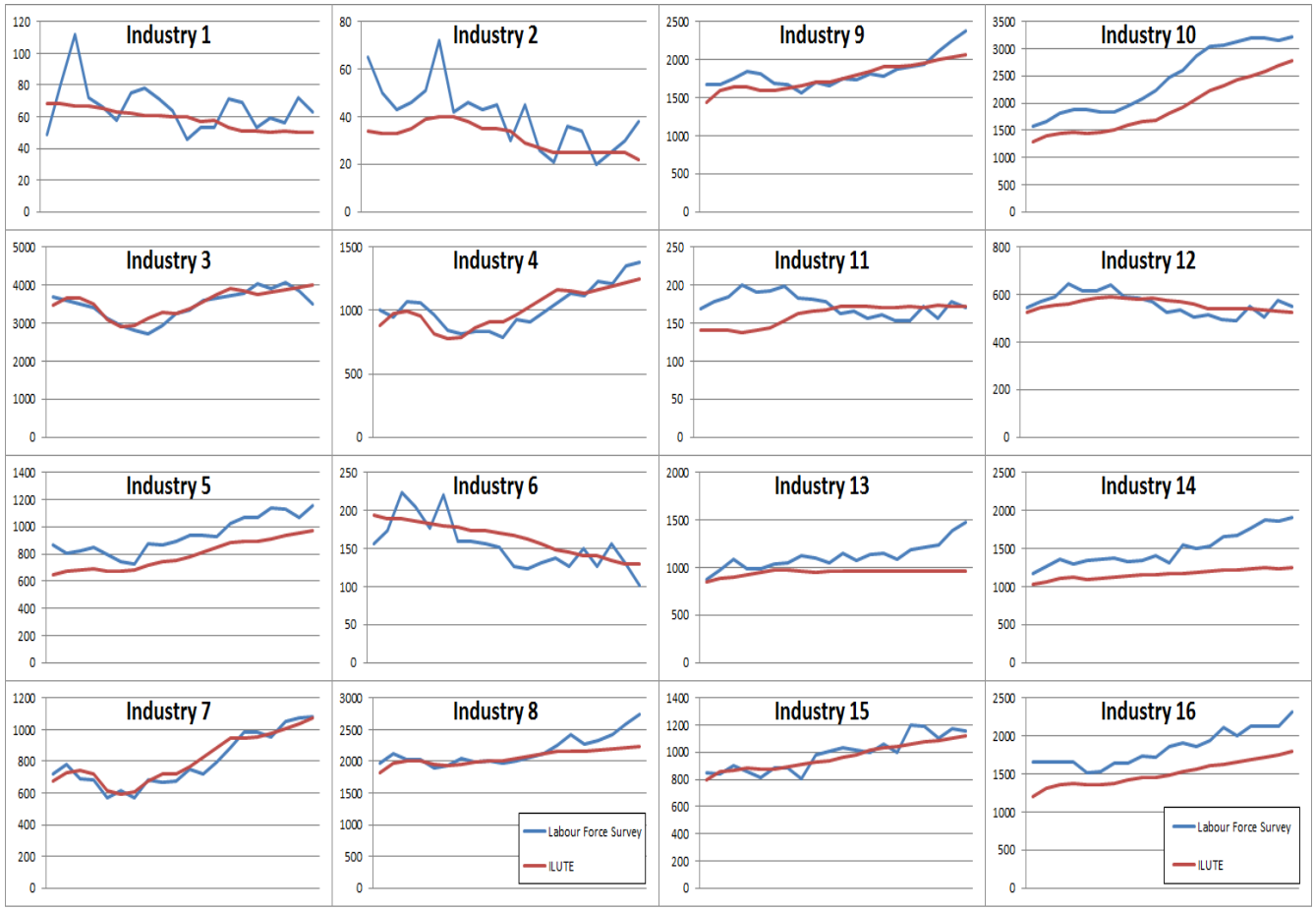
Income




Source of Population Changes
Death, Birth and Out-Migration Rates
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Population [x 1,000,000]
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Historical Deaths
ILUTE Deaths
Historical Births
ILUTE Births
Historical Out-Migration
ILUTE Out-Migration
Historical Population
ILUTE Population



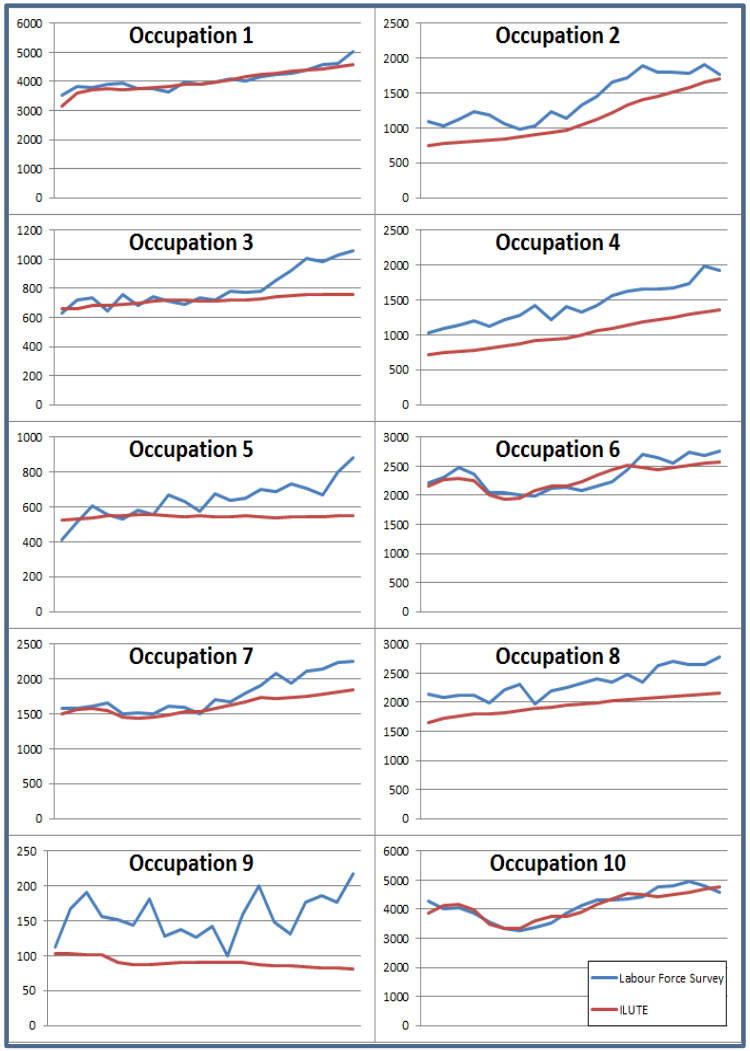
1986 Seeded ILUTE jobs versus observed Census microdata by (a) industry, (b) occupation and (c) job type



SIC (Census and ILUTE)	
Code	Description
1	Agriculture
2	Other primary industries
3	Manufacturing
4	Construction
5	Transportation and storage
6	Communication and other utilities
7	Wholesale trade
8	Retail trade
9	Finance, insurance, and real estate
10	Business services
11	Government services — federal
12	Government services — other
13	Educational services
14	Health and social services
15	Accommodation, food, and beverage services
16	Other services

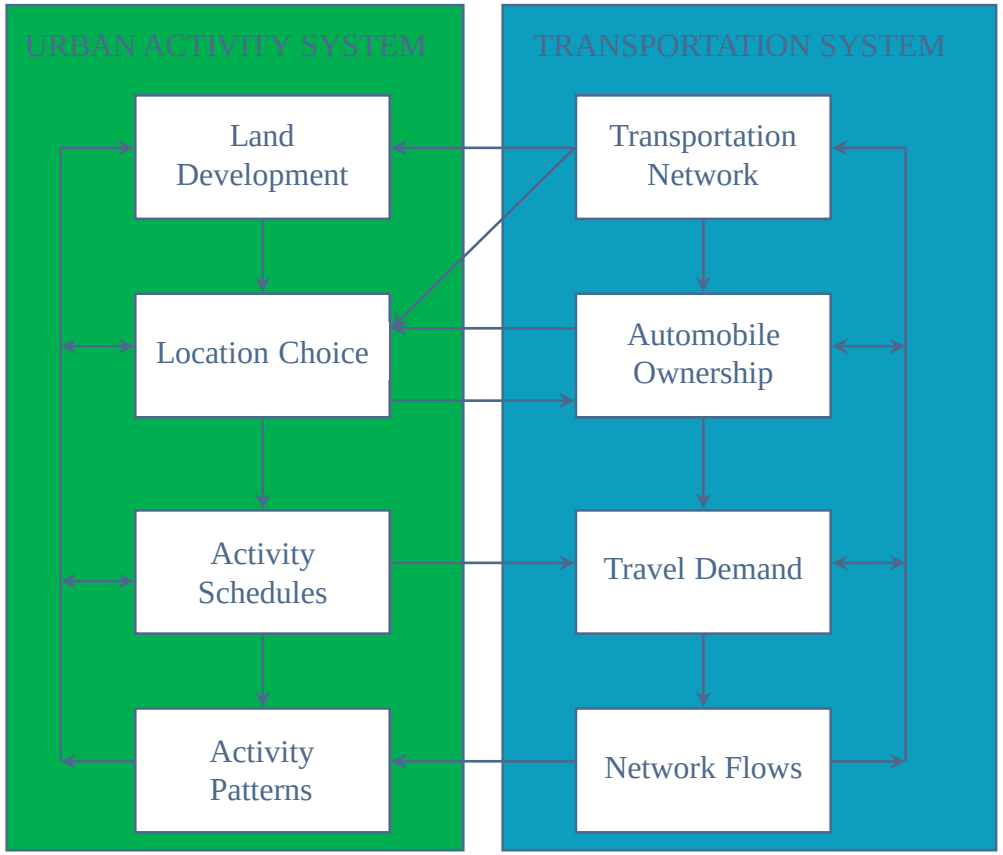
ILUTE simulated employment by industry vs. observed Labour Force Survey counts, 1987-2006

ILUTE simulated employment by occupation vs. observed Labour Force Survey counts, 1987-2006



ILUTE Occupation Category		Description of Included Occupations
Code	Name	
1	Management	Senior management, project management, financial and administrative
2	Professional 1	Science, engineering and technical professions
3	Professional 2	Doctors, nurses and health technologists
4	Public Service 1	Social science, religion, government service, culture and public recreation
5	Public Service 2	Teachers, professors and other academia
6	Private Service 1	Clerical and supervisors
7	Private Service 2	Sales, retail and trade
8	Private Service 3	Chefs, security, childcare, travel and private recreation
9	Unique	Farming, agriculture and jobs unique to industry
10	Blue Collar and Trades	Machine operators, general labour, contractors, trades and transport

ILUTE Reboot (1)



- Completely rewriting the software in XTMF.
- Improving connections with the travel model (TASHA).
- Integrated conceptual framework for consistent modelling of short- and long-run run spatial processes.
- Possibly a more event-driven framework.

ILUTE Reboot (2)

- Updating the housing market models
  - Re-estimating demand models.
  - Improving/extending the supply models.
  - Teranet (& other new) data
- Improved labour market & firmographic models.
- General updating of other model components.
  - Auto ownership (transactions) model.
  - Extension to “mobility tools”.
- Improved population synthesis.

ILUTE Reboot (3)

- In parallel, “TASHA/2” (“GTAModel 5.0”) is under design.
  - Explicit modelling of MaaS.
  - “Getting ready for AVs”.
  - General improvements to the TASHA/GTAModel components:
    - Activity episode generation.
    - Activity scheduling.
    - NWS activity location choice.
    - …

ILUTE Reboot(4)

- iCity-ORF objectives:
  - Explore transportation accessibility impacts on land value & location choices of households & firms.
  - & hence, better assessment of the benefits of transportation (largely transit) infrastructure investments.

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THANK YOU!
LET'S DISCUSS!