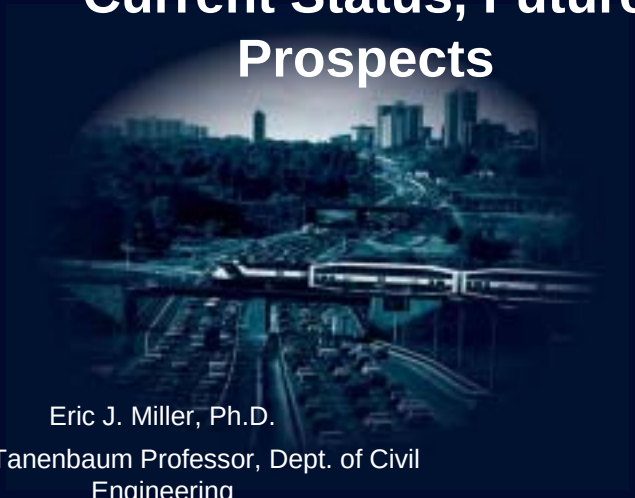
ILUTE: Historical Evolution, Current Status, Future Prospects



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University of Toronto. April 25, 2003

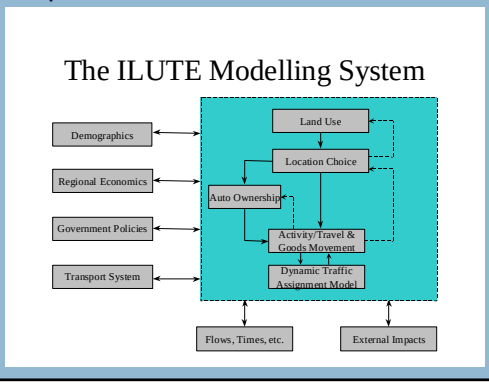
ILUTE

Presentation Outline

- What is ILUTE?
- Historical evolution
- Current status: The operational prototype (Salvini, 2003 PhD)
- Towards a unified model of household decision-making
- Recent research results not discussed in this presentation:
  - Household auto transactions model (Mohammadian, 2001 PhD)
  - Single family housing starts modelling (Haider, 2003 PhD)
  - **T**oronto **A**rea **S**cheduler of **H**ousehold **A**ctivities (TASHA)
    - activity scheduler (Roorda)
    - event-based microsimulation (Litwin)
    - social networks (Carrasco)
    - tour-based mode choice (Roorda, Carrasco)
  - Panel Activity/Travel Survey

What is ILUTE?

- ILUTE is a research program whose objective is to develop “next generation” models of urban land use, travel & environmental impacts.
- Key themes:
  - Integrated
  - Comprehensive
  - Microsimulation
  - Behavioural
  - Policy-sensitive



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The ILUTE Consortium

A consortium of Canadian universities are working on ILUTE. Universities involved involved:

- University of Toronto*
- University of Calgary*
- Université Laval
- McGill University (Murtaza Haider)
- McMaster University
- Wilfrid Laurier University (Sean Doherty)
- [Cal State Sacramento (Kouros Mohammadian)]

* Primary ILUTE modeling sites.

ILUTE Consortium, cont'd

Current primary funding is from a 5-year Social Sciences & Humanities Research Council (SSHRC) Major Collaborative Research Initiative (MCRI) grant.

- 17 individual projects
- 10 co-investigators

Some additional funding from individual research grants (e.g., NSERC) and various public sector agencies (e.g., City of Calgary, City of Toronto and the Quebec Ministry of Transportation)

Pre-ILUTE: TORUS: TORonto Urban Simulator

- Before ILUTE there was TORUS.
- Developed in the mid-1980's
- One of the first large-scale microsimulation models
- Prototype model:
  - housing market
  - labour market
  - demographics
- MASc theses:
  - Sarjeant (86); Noehammer (87); Cheah (88); Cheng (88)

Miller, Noehammer & Ross (1987) "A Micro-Simulation Model of Residential Mobility", *Proceedings of the International Symposium on Transport, Communications and Urban Form, Vol. 2: Analytical Techniques and Case Studies*, Monash University, pp. 217-234.

ILUTE History (1992-93)

- Origins in early collaboration between University of Toronto & McMaster University.
- Funded by seed money from Ontario Ministry of Energy & Environment.
- Resulted in development of a prototype integrated model (IMULATE).
- (Independently Doug Hunt at Calgary working on MEPLAN & other integrated modeling applications.)

ILUTE History (1995-98)

NSERC Collaborative Project Grant

- Added Laval & Calgary to the network
- Conceptual work (Haider MASc '99)
- Prototype architecture/proof of principle (Salvini MASc '98)
- Small sample retrospective surveys
  - residential mobility
  - residential spatial search processes (Pushkar MASc '99)
  - household auto ownership/transactions (Roorda MASc '98)
- Developed relationships among network partners

In parallel: Miller, Hunt & Kriger: TCRP Project H-12, *Integrated Transportation - Land Use Models and Their Applications to Transit Policy Analysis*

ILUTE History 1999-present

Network collaborators further expanded under MCRI/GEOIDE funding (+ other).

- GEOIDE 1999-2002
- MCRI 2000-2005

Emphasis in MCRI is on behavioural foundations underlying models.

However, ILUTE development/elaboration has continued under MCRI.

ILUTE Current Status

Primary model development work at Calgary & Toronto.

"Regional lab" concept.

- Different approaches/components in different locations
- Structured "conversations" between groups
- "ILUTE East" & "ILUTE West"

Software system as "laboratory"

- Building very generalized, flexible software

Miller, Hunt, Abraham & Salvini, "Microsimulating Urban Systems", forthcoming in *Computers, Environment and Urban Systems* special issue "Geosimulation: Object-Based Modeling of Urban Phenomena", 2002

ILUTE Status, cont'd

"ILUTE West" (Calgary):

- Building on Oregon work
- Main focus on:
  - intra-urban economic processes
  - firm location, etc.
- Calgary/Edmonton surveys
  - activity/travel
  - shipper activity
  - residential mobility

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ILUTE Status, cont'd

"ILUTE East" (Toronto)

- Activity-based modelling (Roorda, Carrasco, Litwin)
- Residential location (Poon MASc '02; Haroun)
- Housing supply (Haider PhD '03)
- Auto ownership (Mohammadian PhD '02)
- Energy/emissions (C. Lee MASc '00; A. Lee MASc '02)
- Overall ILUTE architecture/software (Salvini PhD '03)
- Population synthesis (Guan BASc '02)

ILUTE 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*.

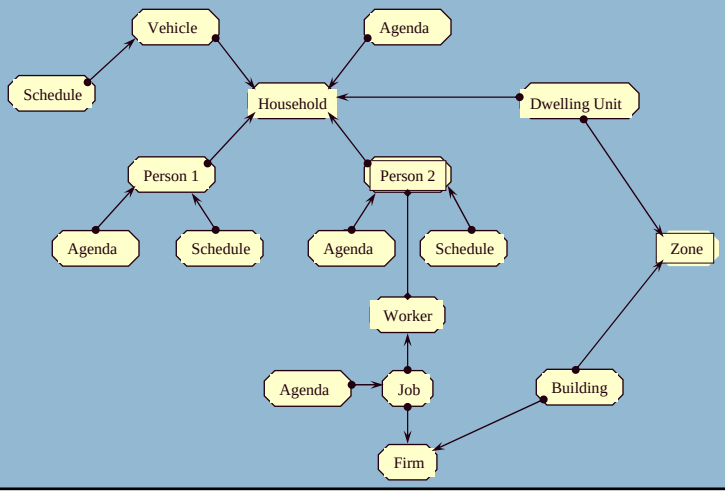
Object-Oriented Microsimulation

- Object-orientation is more than a programming method; it provides a rigorous language/conceptual framework for the development of complex behavioral models

- A major theme within ILUTE is to “start fresh” in our model design and to build “from the ground up” our modeling system explicitly within an object-based microsimulation framework

- In particular, emphasis is placed on developing a high-fidelity **class design** and **system semantics** within which many behavioral assumptions might be implemented and tested

Partial View of Relationships Among System Objects



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Household-Level Models

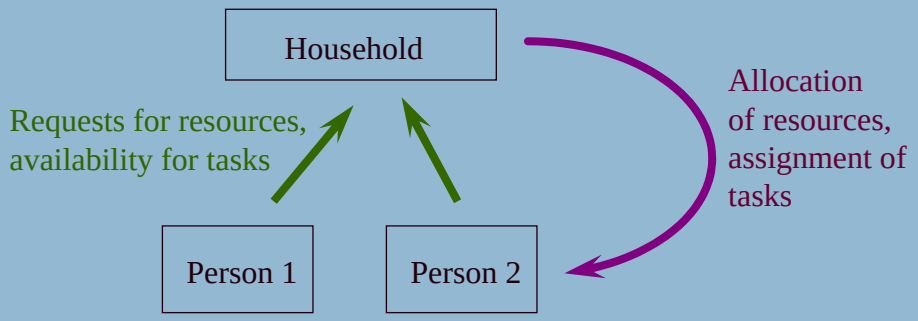
Household-level models are required to “properly” deal with many system components:

- housing location/type choice
- automobile ownership
- demographics/household structure/lifecycle stage
- activity/travel scheduling

Households:

- share **resources** among household members
- **constrain** member behavior
- **condition** member decision-making
- **generate** activities

Relationship Between Persons & Households



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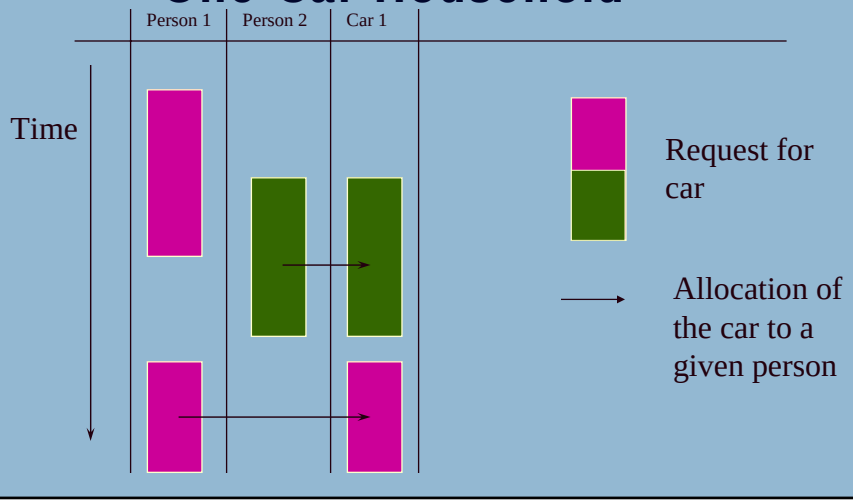
Example, Vehicle Allocation One-Car Household



Software Status

- Development of the initial operational model is complete
  - documented as part of Ph.D. thesis, "**ILUTE: An Operational Prototype of a Comprehensive Microsimulation Model Of Urban Systems**" by Paul Salvini (2003)
  - will be presented at the 10th International Conference on Travel Behaviour Research (IATBR 2003) in Lucerne
- Operational prototype running with GTA 1996 base
- Over 15,000 lines of C++ code in 60 classes
- CD includes UML diagrams and source code
- Runs on any Windows® workstation
- Ready for additional sub-models

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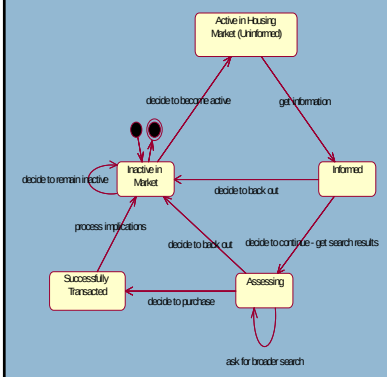
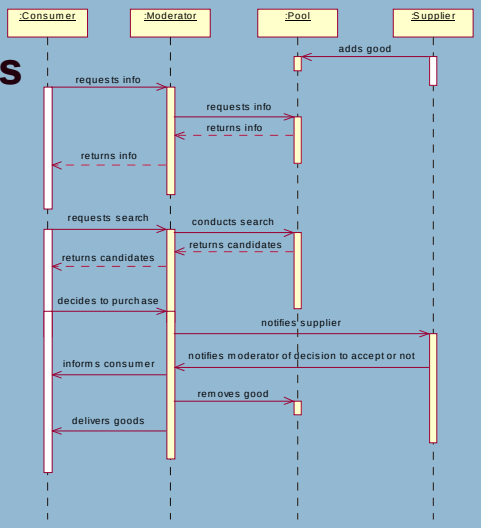
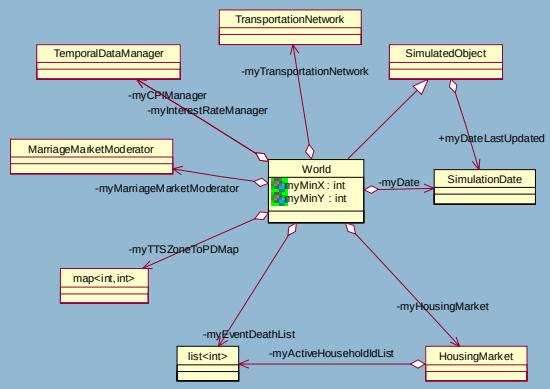
Microsimulating Market Interactions





ILUTE World Class Diagram



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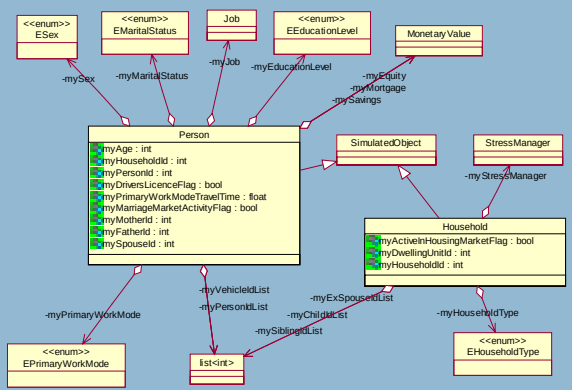
Person & Household Classes



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Current Capabilities

- Synthesizes (test purposes only) connected households, persons, jobs, dwelling units, and buildings
- Imports spatial data: Census Tracts, TTS Planning Districts, TTS Travel Zones, EMME/2 Road & Transit networks
- Imports travel time data (by mode and time of day), and economic data (e.g. interest rates and consumer price indexes)
- Evolves the system to an arbitrary date using an arbitrary time step by simulating the activities and behaviours of individual objects

continued on next page...

ILUTE

Current Capabilities

- Implements a stressor-based mechanism for handling triggered events, joint decisions, accumulated stress, and person-household interaction
- Implements two fully-elaborated sub-models for residential mobility and auto transaction decisions
- Tracks (i.e. displays) the activities and behaviours of individual objects and/or individual processes
- Simulates population in-migration and out-migration
- Exports spatiotemporal data for visualization (supporting 2D, 3D, and animated 3D formats)
- Reads and writes state information to any industry-standard relational database (e.g. MS SQL Server 7.0)

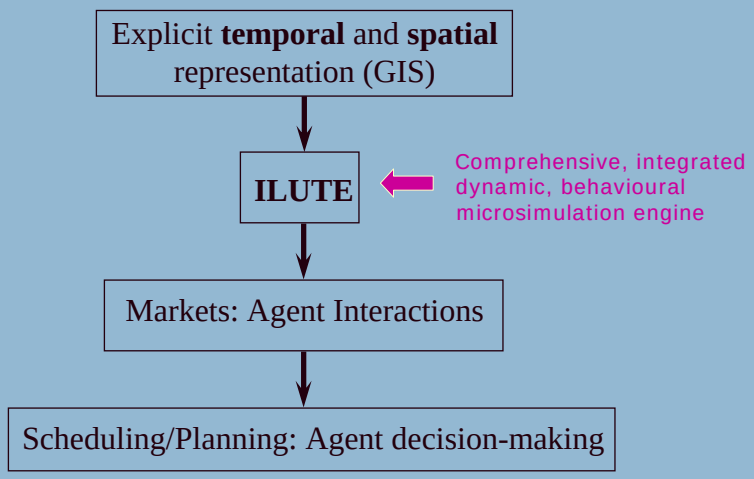
Software Advances

- Open design supports collaborative development
- Contains fully-elaborated "real-world" classes
- Microsimulates persons, households, and families
- Handles multiple spatial aggregations
- Handles (formal and ad hoc) joint decisions
- Handles events with temporal leads and lags
- Stressor-based decision-making handles triggered events, joint decisions, and accumulated stress
- Handles arbitrary time increments
- Integrates temporal data management
- Improves monetary value handling

Recommended Next Steps

- Integration of TASHA activity scheduler (Roorda)
- Integration of calibrated population synthesis (Guan)
- Put ILUTE into a CVS development environment
- Implement (Haider's) Housing Developer model
- Develop and implement a basic firm model
- Integrate calculation of travel times
- Adjust for relative price of goods over time
- Add spline interpolation to the temporal data manager
- Enable loading of temporally-variant spatial areas
- Develop a formal user interface
- Research ways to visualize urban system changes

A Hierarchy of Frameworks



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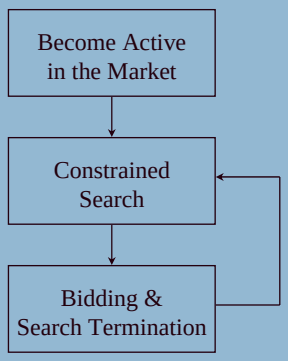
Modeling Markets

Many markets are of interest within ILUTE:

- residential housing market
- commercial real estate market
- land market
- labor market
- markets for goods & services
- personal use vehicle market
- travel markets (persons and goods)

"Generic Model" of Market-Based Decision-Making



Market Representation

Prior work in (Walrasian) market theory provides a rich paradigm for representing interactions between various suppliers and consumers

- supply-demand
- endogenous prices
- preferences/utility
- bid-rent/bid-choice

Objective is to extend classic market theory to a microsimulation framework.

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Unified Model of Household-Based Decision-Making

In ILUTE we are working towards a unified model of household-based decision-making which applies to and integrates **long-run** decisions (housing, jobs, cars, etc.) with **short-run** decisions (activity/travel within a given day or week).

The unifying theme within this model is that it must represent decision-making in both the short- and the long-run with respect to the **acquisition**, **allocation** and **usage** of tangible household and personal resources:

- time
- money
- goods & services

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Activities, Episodes & Schedules

- We live our lives through a sequence of **activities** in which we engage
- Activities are manifested in terms of individual **episodes** (which have duration, start time & location)
- Trips are **travel episodes**
- Episodes exist within a **schedule** which is a planned, feasible set of activity and travel episodes
- Decision-making concerning activity and travel is a problem in **scheduling**
- Scheduling is on-going, continuous, over multiple time periods (daily, weekly, yearly, lifetime)
- Note that this scheduling/planning/decision-making process applies to **all** activities, both in the long and the short run

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Goods & Services

- Two major types:
  - **consumables**
    - one-time acquisition cost
    - one-time "benefit"
  - **durables**
    - acquisition ("capital") cost
    - on-going costs (maintenance; debt service)
    - on-going benefits
    - "big-ticket" items/resources/"projects" for households:
      - housing
      - cars
      - ….
- Goods & services are of importance within the model for many reasons:
  - acquisition/consumption/usage of goods & services
  - major linkage to the urban economic (firm activity "side" of the modeling system
  - "shopping" a major travel generator (etc.)
  - acquisition/usage of "big ticket" durables (houses, cars) of major interest within ILUTE

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Budgets

- Households and persons are constrained in their actions by time, money and other resource **budgets**
  - In each time period, each person must spend each minute doing "something"
  - In each time period all money available to the household must be spent (includes "spending" on savings)
  - Only one driver at a time can use a car (etc.)
- In long-run, durable acquisition decisions (houses, cars), monetary budget tends to dominate
- In short-run activity/travel decisions, time budget (and car availability constraints) tend to dominate
- Both time & money constraints, however, potentially operative within all time frames

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Projects

- Axhausen [1998]defines a **project** as a coordinated set of activities tied together by a common goal or outcome.
- In this conceptual model, the project is **the** fundamental organizing principle
- It is argued that **all** activities (short- and long-run) are embedded within and generated by projects
- This approach can be tied back (at least loosely) to Maslow's **Hierarchy of Needs** as a possible philosophical/theoretical starting point

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Conceptual Potential of Projects

It is hoped that we can *encapsulate* behavior within the project class in a way that will allow us to model very complex behavior in a manageable manner.

That is, each project needs only to "know about" its own activities -- can therefore decompose the complexity of daily activities into separate, more "bite size pieces" in a theoretically defensible way.

Projects interact with one another through the scheduling process, and through competition for household (and personal) resources.

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Primary Projects

- Community service
- Education
- Family
- Health care
- Religious group
- Mobility
- Personal maintenance
- Recreation (personal/household)
- Shelter
- Socializing (with non-household members)
- Sustenance
- Vacation
- Work

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Household-Level Decision-Making

- Acquisition of durable goods
  - housing
  - vehicles
- Allocation of household resources to household members
  - money
  - vehicles
- Allocation of household activities/responsibilities to household members
  - serve-dependent
  - household “chores”
  - joint household activities

Conceptual Model Applications

The conceptual model has been applied to date to the development of a prototype activity/travel scheduling model.

Work is proceeding on extending it to auto ownership and residential location choice.

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Extensions Beyond Activity / Travel