Integrated Land Use, Transportation, Environment Modelling

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Presentation Outline

- What is ILUTE?
- Recent research results
  - Household auto transactions model (Mohammadian, 2001 PhD)
  - Single family housing starts modelling (Haider, 2003 PhD)
  - The Operational Prototype (Salvini, 2003 PhD)*
  - Toronto Area Scheduler of Household Activities (TASHA)*
  - Panel Activity/Travel Survey*

* Discussed further in this presentation
What is ILUTE?

- ILUTE is a research program whose objective is to develop “next generation” models of urban land use, travel & environmental impacts.
- It is being undertaken by a consortium of Canadian universities under the leadership of the University of Toronto.
- Key themes:
  - Integrated
  - Comprehensive
  - Microsimulation
  - Policy-sensitive

The ILUTE Consortium

Canadian universities involved:
- University of Toronto*
- University of Calgary*
- Université Laval
- McGill University
- McMaster University
- Wilfrid Laurier University

* Primary ILUTE modeling sites.
ILUTE Consortium, cont’d

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 and various public sector agencies (e.g., City of Calgary, City of Toronto and the Quebec Ministry of Transportation)

ILUTE Current Status

Primary model development work at Calgary & Toronto.

“Regional lab” concept.
- Different approaches/components in different locations
- Structured “conversations” between groups

Software system as “laboratory”
- Building very generalized, flexible software
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

ILUTE Status, cont’d

“ILUTE East” (Toronto)
• Activity-based modeling
• Residential location
• Housing supply
• Auto ownership
• Energy/emissions
• Overall ILUTE architecture/software
• Population synthesis
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
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
ILUTE

Relationship Between Persons & Household

- Household
- Person 1
- Person 2

Requests for resources, availability for tasks ➔ Allocation of resources, assignment of tasks

Example, Vehicle Allocation
One-Car Household

- Time
- Person 1
- Person 2
- Car 1

Request for car ➔ Allocation of the car to a given person
Software Status

- Development of the initial operational model is complete
  - 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

Microsimulating Market Interactions
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

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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
TASHA Research Objectives

- Long Term Objectives
  - Create a fully dynamic, integrated microsimulation model of household activity scheduling with interactive household agents
  - Integrated with ILUTE
- Short Term Objectives
  - Operational 24-hour activity scheduling model based on 1996 TTS trip data
  - Provide inputs for EMME/2 network assignment and provide estimates of future CO₂ emissions to the City of Toronto based on these results

Theoretical Model - Major Components

- Household agents
  - Person
  - Household
- Household resources
  - Time, Money, Vehicles
- The “episode”
  - Activity episodes, Travel episodes
- The “project”
- The “project agenda”
- The “person schedule”
Features of the Theoretical Model

- Long Term Schedule
- Dynamic Schedule
- Interactive Agents
- Detailed Project Types
- Fully Microsimulated
- Integrated with Other Household Decisions

Features of the Operational Model

- 24-hour schedule
- Semi-dynamic schedule
- Semi-interactive agents
- Broad project and episode types
- Microsimulation of 5% sample
- Sequential household decisions
  - Residential location, work location, auto ownership are inputs
  - Determine the schedule based on auto-drive travel times
  - Mode choice is done after the schedules are complete
TASHA Class Structure

- World
  - Households
    - Persons
      - Person Projects
      - Person Schedule
      - Individual & Joint Activity Episodes
    - Travel Episodes
  - Episode Distributions
  - Spatial Representation
    - Zones
      - Distance Matrix
      - Travel Time Matrices

Project Types

Person-Level Projects
  - Work Project
  - School Project
  - Shopping Project
  - Other Project

Household-Level Projects
  - Joint Shopping Project
  - Joint Other Project
  - Serve Dependent Project
Construction of Schedules - Methodology

- Randomly generate activity episodes
  - Frequency, start time, duration, location
- Insert episodes into project agendas
- Construct person schedules
  - Insert episodes in order of priority
  - Joint episodes added simultaneously
  - Travel episodes added (assuming auto drive)
  - Trip chains emerge naturally
- Clean up the schedule
- Identify trip chains
- Run chain-based mode choice model

Inserting an Episode into a Schedule – Example 1
Splitting a primary work episode with a work-business episode

Prior Case

Becomes

Episode 1

New Episode

New Episode

Episode 1a

Episode 1b

Travel Episode

Gross duration to be inserted

Extension to episode 1b’s duration to maintain total primary work event time, given the need to travel to/from the work-business location.

Time
Inserting an Episode into a Schedule - Example 2
Inserting a new episode between two episodes, overlapping both

Prior Case

Becomes

Episode 1
New Episode
Episode 2

“prior episode”

“posterior episode”

Travel Episode

Time

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Mode Choice Model

- Applied sequentially, based on the trip chains from the activity schedule model
- Chain-based
- Nested decision-tree formulation
Mode Choice Model Structure

Chain c
Trips 1, ..., T_c

Auto-Drive Chain
All trips made by auto-drive mode

Non-Drive Chain
Trip T_c Mode
Trip 2 Mode
Trip 1 Mode

Mode Choice Decision Tree with Sub-Chain

Drive Option for Chain c

m1 = drive

Sub-Chain s:
2. Work-Lunch
3. Lunch-Meeting
4. Meeting-Work

Drive for Sub-chain s
m2 = drive
m3 = drive
m4 = drive

Non-drive for Sub-chain s

Non-drive option for Chain c

m1
m2
m3
m4
m5

mN = mode chosen for trip N

mN = mode chosen for trip N
Current Status

- Operational model running and has been used in an emissions study for the City of Toronto
- Takes in the order of 10 minutes to simulate 100,000 households on a PIII-750MHz computer

Next Steps

- Operational Model
  - Model Validation
  - Experiment with current model

- Theoretical Model
  - Revise model to handle the "serve dependent" project
  - Integrated vehicle allocation/ mode choice model
  - Improved handling of episode location choice

- Narrow gap between operational and theoretical models
Panel Survey

In March 2002 launched a 3-year panel survey in Toronto and Quebec City to gather detailed information about household activity scheduling behavior.

Toronto:
- 270 households
- Wave 1 will be completed in April ’03
- CHASE survey method:
  - 1 week activities per person 16+ years old
  - Able to observe the scheduling process
- Wave 2 currently under design & pilot testing:
  - Update Wave 1 results
  - 2-day paper diary/telephone retrieval
  - “Stated response” experiments