PhD Program in Transportation

Simulation of Land Use-Transportation Systems

Bruno F. Santos

Lecture 4
Land-use and Transportation Models
LUT Models

- Transport and land-use interaction
- Operational land-use transport (LUT) models
- Integrated LUT models:
  - Heuristic models
    - Lowry and Lowry-type models
  - Simulation models
  - Operational models
  - Microsimulation models
- LUT and environmental modeling
- LUT and decision-making
Transportation and Land-use Systems

How do they work?

Operational LUT Models

"Essentially, all models are wrong but some are useful."
George Box

- Formal models which capture the interaction between land-use and transportation

Why land-use transportation models?
- Decision-support systems
- Forecast future urban patterns based on a set of economic assumptions
- Test application of policy measures to scenarios for urban futures

Existed since the early 1960’s – era of scientific and technological success (computers, telecommunications)
Operational LUT Models

A brief history…

- 1960’s ➔ Spatial interaction, gravity-based models
  - 1973 Lee’s “Requiem for Large-Scale Urban Models”

- 1970’s ➔ Aggregated simulation models

- 1980’s ➔ Random utility, discrete choice models

- 1990’s ➔ Microsimulation models
Operational LUT Models

Evolution

1960: Lowry: Gravity Model

1970: Spatial Interaction
   DRAM/EMPAL
   HLFM II+

1970: Spatial Input-Output
   Dynamic
   LEPLAN

1980: Equilibrium
   Dynamic
   Discrete Choice
   Land use
   Models:
   METROSIM
   MUSSA
   Miroscope

1990: Hybrid Spatial
   I/O:
   PECAS/ODOT

2000: Spatially Detailed
   Dynamic
   Dynamic
   Discrete Choice Land Use Models:
   Delta
   ILUTE
   UrbanSim

Orcutt: Micro-simulation

McFadden: Discrete Choice Models

Alonso/Mills/Muth: Urban Economic Bid-Rent Theory

Leontief: Input-Output Model

Operational LUT Models

- **Static modeling:**
  - express the state of a system at a given point in time through the classification and arithmetic manipulation of representative variables (e.g., accessibility).
  - By their very nature, cannot realistically capture urban spatial processes and their effects on the transport system.
  - Early models, not very representative to policy analysis – gravity-based models.
  - Examples:
    - DRAM/EMPAL (Putman, 1995);
    - MUSSA (Martinez, 1996).
Operational LUT Models

Dynamic modeling:

- The improved modeling methodologies, such as entropy-based interaction, random utility theory, bifurcation theory and non-linear optimization, together with significant computational advances has paved the way to the development of several dynamic LUT models.
- Fully integrated land-use and transport elements.
- General spatial equilibrium model systems are, therefore, based on random utility theory and theories of competitive markets.
- Examples:
  - MEPLAN (Hunt and Simmonds, 1993);
  - ILUTE (Miller et al, 2004);
  - UrbanSim (Waddell, 2002).
Still, these models have pros and cons:

- **Advantages.**
  - Incites a conceptualization of urban economic and spatial processes.
  - Moving from an urban concept to an urban model is simply a step forward, albeit an important one.
  - The data requirements of TLUM are often an incentive to perform surveys from which useful information about urban mobility and spatial structure can be gathered.
  - This information has the additional advantage of contributing to advances in the understanding of the dynamics of urban systems.
Operational LUT Models

Still, these models have pros and cons:

- **Drawbacks.**
  - Models are data greedy, and are usually associated with an intense work of survey, analysis and modeling.
  - Excessive reliance on static equilibrium assumptions.
  - Poor integration between short-run (travel) and long-run (location choices).
  - Models often fail to grasp significant economic, technological and social changes, falling to progress through “out of the box” models.
  - They may also give the (false) impression that a system can effectively be controlled since all its major elements have been summarized.
  - In generating forecasts for the city or metropolitan area as a whole, in several dimensions of its attributes, the models could not provide adequate richness of detail for a less-than comprehensive view.
Integrated LUT models

What is an integrated model?

- An urban region’s system state is highly multi-dimensional. It usually includes:
  - The spatial distribution of the resident population;
  - The spatial distribution of the region’s employment & other out-of-home activity locations;
  - 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.

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 modeled.
Integrated LUT models

- Can we build integrated models?
  - (Hyper)comprehensiveness vs. incomplete models
  - Complicatedness vs. complexity
  - Grossness vs. disaggregation
  - Data hungriness vs. level of detail
  - Expensiveness vs. benefits
  - Wrongheadedness & mechanicalness

- For Timmermans (@2003 IATBR conference) the theoretical foundations of our models is arguably the biggest current concern.
The Lowry Model

- Model of Metropolis Lowry (1964)
  - Used spatial interaction (gravity) models to predict:
    a) population, b) employment, c) work trip flows

- Divides employment into 2 types:
  - Basic employment: location does not depend on local market (industry), it is an exogenous input
  - Retail employment: location depends on local market it serves (endogenous)

- The third sector includes households (endogenous)

- The basic model keeps track of basic and retail employment; number of households; land area allocated to basic, retail, and households
The Lowry Model

- The basic Lowry model keeps track of 3 variables:
  - \( E_j^x \) = Employment of type \( x \) (\( x = B, R \)) in zone \( j \)
  - \( N_j \) = Number of households in zone \( j \)
  - \( A_j^x \) = Land area allocated to activity \( x \) (\( x = B, R, H \)) in zone \( j \)

- The retail sector sub-divides into a hierarchy of activities along a central place hierarchy scheme – Lower-level activities have smaller thresholds.

- Lowry models use spatial interaction models (gravity/entropy or logit models) to allocate workers to residential location and to allocate retail activities to population-serving zones.
Households = \( f(\text{workers}) \)
Retail activity = \( f(\text{households}) \)

Workers generate households \( \Rightarrow \) households generate workers to serve them \( \Rightarrow \) generates additional households

Spatial interaction models to allocate households based on place of work and retail based on residential zones

The Lowry Model

- Land Area Calculations

\[ A_j = A_j^U + A_j^B + A_j^R + A_j^H \]

- Total area of Zone \( j \); exogenous
- Basic employment Land area; exogenous
- Retail & Household land areas endogenously determined within the model
- Unusable land in zone \( j \); exogenous

\[ A_j^R = e^k E_j^k \]

- \( e^k \) = employment density parameter for retail sector \( k \)
- Retail activity cannot exceed available space

\[ A_j^H = A_j \]

- Land allocated to housing is simply whatever is left over after allocating employment activities
The Lowry Model

Population calculation

\[ N = \sum_{j} f \cdot E_j \]

\[ N_j = g \sum_{k} \frac{E_k}{T_{jk}} \]

- \( f \) = parameter = avg. no. of households per worker
- \( N \) = total number of households
- \( g \) = scale factor, chosen so that \( j N_j = N \)
- \( T_{jk} \) = “impedance function”
The Lowry Model

Retail employment calculation

\[ E^k = a^k N \]

\[ E_j^k = b^k \left( \sum_i^n \frac{c^k N_j}{T_{ij}^k} + d^k E_j \right) \]

- \( a^k = \) retail employee in sector \( k \) to household parameter
- \( E^k = \) total retail employment in sector \( k \)
- \( b^k = \) scale factor, chosen so that \( j E_j^k = E^k \)
- \( c^k, d^k = \) parameters
- \( T_{ij}^k = \) “impedance function” for retail sector \( k \)

\[ E^k \sum_i \frac{c^k N_j}{T_{ij}^k} + d^k E_j \]

\[ E_j^k = \frac{\sum_i \left( \sum_{j'} \frac{c^k N_{j'}}{T_{ij'}^k} + d^k E_{j'} \right)}{\sum_{j'} \left( \sum_i \frac{c^k N_{j'}}{T_{ij'}^k} + d^k E_{j'} \right)} \]
The Lowry Model

- Constraints

\[ E_j^k Z^k \] or \[ E_j^k = 0 \]  \( Z^k \) = min. emp. threshold for retail sector \( k \)

\[ N_j Z_j^H A_j^H \]  \( Z_j^H \) = max. residential density in zone \( j \)

\[ A_j^R \] \( A_j^T \) \( A_j^U \) \( A_j^B \)  Retail activity cannot exceed available space
The Lowry Model

Land use

\[ A_j = A_j^U + A_j^F + A_j^P + A_j^H \]

Retail sector

\[ E^k = a^k N \]

\[ E^k_j = b^k \left( \sum_{i=1}^{n} \frac{c^k_i N_i}{T_{ij}} + a^k E_j \right) \]

\[ E^k = \sum_{j=1}^{n} E^k_j \]

\[ E_j = E_j^R + \sum_{k=1}^{m} E^k_j \]

\[ A_j^R = \sum_{k=1}^{m} c^k E^k_j \]

Household sector

\[ N = \sum_{j=1}^{n} E_j \]

\[ N_j = \sum_{i=1}^{n} \frac{E_i}{T_{ij}} \]

\[ N = \sum_{j=1}^{n} N_j \]

Variables

- \( A \) = area of land (thousands of square feet)
- \( E \) = employment (number of persons)
- \( N \) = population (number of households)
- \( T \) = index of trip distribution
- \( Z \) = constraints

Superscripts and subscripts

- \( U \) = unusable land
- \( B \) = basic sector
- \( R \) = retail sector
- \( H \) = household sector
- \( k \) = class of establishments within retail sector \( (k = 1, \ldots, m) \)
- \( i, j \) = tracts or zones within region \( (i, j = 1, \ldots, n) \)

Unspecified functions and coefficients are represented by lowercase letters \( (a, b, c, d, e, f, g) \).
Lowry-type Models

- Garin (1966) reformulated the Lowry model in matrix notation. This requires dropping the constraints and retail sub-sectors.

- The same author also developed an equation to directly solve for the final employment distribution – thus, demonstrating that Lowry model is a static and deterministic model;

- Some authors have used a quasi-dynamic Lowry model by adding increments of basic employment and sensitive factors over time.

- Considerable work has occurred over the years in improving Lowry allocation submodel, based both on entropy maximization (Wilson, 1974; Batty, 1976; Putman, 1991) and random utility maximization (Ben-Akiva and Lerman, 1985) methods.
Lowry-type Models

- ITLUP (DRAM/EMPAL)
  - ITLUP: Integrated Transportation & Land Use Package
    - DRAM: Disaggregate Residential Allocation Model
    - EMPAL: Employment Allocation Model
  - Developed by Stephen Putman, University of Pennsylvania

- Logit models used to allocate households given employment locations (DRAM);

- Logit models used to allocate employment given population distribution (EMPAL);

- Multinominal logit modal split submodel, as well as a trip assignment submodel is used to integrate the travel system.

- However, in practical application, DRAM and EMPAL are “linked” with the help of existing 4-stage model (e.g., EMME/2, TRANPLAN).
Lowry-type Models

- Compared with other models, ITLUP is considered to have relatively parsimonious data requirements.

- Relatively simple and inexpensive to operate;

- However, this reflects a weakness, e.g., ignored the land market process:
  - No land development process: households and firms allocated to locations without regard to supply of building stock; and
  - Price of houses and other buildings is absent or exogenous rather than an endogenous outcome of demand-supply interactions (location decisions are based on price).

- ITLUP was the most widely used spatial allocation model in the US in the 80’s and early 90’s (Putman, 1997).
Lowry-type Models

- Other weaknesses of Lowry-type models (see also Lee 1973):
  - Static equilibrium framework;
  - Large zone sizes;
  - Very little socio-economic disaggregation;
  - No goods movements;
  - No housing supply;
  - No prices;
  - Lack of policy sensitivity;
  - Over-emphasize the role of transportation in allocation of people and jobs;
  - Lack of differentiation between land development and activity location processes.
Second generation LUT models emerged in the 70’s, with large-scale, aggregated (zonal-based, homogeneous categories of hhlds), mainframe-based simulation models.

These models simulated the changes in the urban activity system over time through a set of discrete time steps (usually 5- or 10- years steps).

They also include a more explicit behavioral theoretical foundation (typically microeconomic).

The two most successful models were:
- the National Bureau of Economic Research (NBER) Model, and
- the Community Analysis Model (CAM).
The development of the **NBER** model was an attempt to model urban housing markets explicitly based on microeconomic theory:

- demand & supply processes;
- endogenous prices;
- utility- & profit-based decision-making.

The model explicitly generated:

- household decisions to move;
- types & locations of housing chosen by new & moving hhlds;
- housing prices by type & location;  
  
  Determined by demand-supply interaction

- filtering of housing stock from quality stratum to another;
- renovation & modification of the housing stock;
- construction of new housing;
- interzonal work trip flows.

**“Demand” processes**

**“Supply” processes**
Simulation Models

The NBER model is composed by the following submodels:

- *Employment location* – changes in the employment on the various industrial groups for each zone and for each time period (exogenous in first models but in later versions an endogenous “Lowry-like” procedure is used).

- *Movers* – in- and out-migrants, newly hhlds (e.g., children moving out, divorces), dissolved hhlds, intraregional movements (usually, moving rates are used).

- *Demand allocation* – prediction of the probability that a hhld (of a certain type) with a worker employed in a given zone will wish to move.

- *Vacancies* – essentially a bookkeeping of housing units vacancy.

- *Filtering* – consists of upgrading or downgrading the quality of housing stock.

- *Supply* – generates the construction of new housing and the conversion of existing housing (e.g., by changing the housing unit type).

- *Market-clearing* – links the demand and supply sides.
The **NBER** model:

- **Demand side**:
  - Employment-location submodel
  - Exogenous job changes
  - Movers submodel
    - Moving households
  - Demand allocation submodel
    - Movers -> submarkets

- **Supply side**:
  - Vacancy submodel
    - Available units
  - Filtering submodel
    - Filters available units
  - Supply submodel
    - Conversion and construction

- **Market-clearing submodel**:
  - Households -> Available units
  - Price determination
  - Excess demanders
  - Vacant units

- Begin period $T + 1$

**Source:** [Ingram, Kain and Ginn, 1972]
Simulation Models

- The CAM model is fairly similar to the NBER model in terms of its submodels and overall structure.
- Major difference lies in the theoretical constructs used to generate the submodels.
- Developed by David Birch, professor at the MIT-Harvard Joint Center for Urban Studies
- Originally developed for New Haven, Conn (USA) and eventually was applied to 6 US cities in the 1970’s.
Simulation Models

- Inductive approach to model-building;
  - strong emphasis on model validation (the “New Haven Laboratory”).
  - identification of the key actors in the system, their roles (i.e., what decisions/actions are available to them), what information they make use of in their decision-making, and how to best characterize these actors (i.e., their attributes).

- Major emphasis on acquiring as much information about the city as possible and applying (then) state-of-the-art computer analysis/display methods to the database.

- In moving from one city to another, model parameters changed, but the model structure did not.
# Simulation Models

**Actors in the CAM model – Source: Birch (1974)**

<table>
<thead>
<tr>
<th>Actor</th>
<th>Decision</th>
<th>Stratification</th>
<th>Major Determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>To Move</td>
<td>Age</td>
<td>Life Cycle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by E/R</td>
<td>Race</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Educational Level</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Racial Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Forced Moves</td>
</tr>
<tr>
<td></td>
<td>Within Region</td>
<td>Source: Birch (1974)</td>
<td></td>
</tr>
<tr>
<td>Choice of</td>
<td>Neighborhood</td>
<td>Life Cycle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Race</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education Level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Available Units</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social Class of Neigh.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Job Access. of Neigh.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Location of Neigh.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Racial Transition of Neigh.</td>
<td></td>
</tr>
<tr>
<td>Choice of</td>
<td>Unit</td>
<td>Housing preferences</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial capability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability of mortgage credit</td>
<td></td>
</tr>
<tr>
<td>Migrate in</td>
<td>and out of Region</td>
<td>Employment opport.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unemployment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Income Levels in Reg.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Educational Mix in Reg.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>City Size</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proximity to other Areas.</td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>Have Children</td>
<td>Age</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>by E/R</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>by Educa.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obtain Education</td>
<td>Life Cycle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Race</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level of Educa.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Join Workforce</td>
<td>Ethn/Racial Background</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethnic/Racial Background</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Educational Level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth rate of Local economy</td>
<td></td>
</tr>
</tbody>
</table>

**Actor**

- **Homeowner**
  - Decision: Setting selling price of home
  - Stratification: Age, by Ethnicity by Education by Price of home
  - Major Determinants: Potential demand relative to available vacancies

- **Landlord**
  - Decision: Setting rent levels on apartments
  - Stratification: Rent level of apartments
  - Major Determinants: Potential demand relative to available vacancies

- **Builder**
  - Decision: Constructing single-family homes under contract
  - Stratification: Contract vs. Speculative Type of unit (tenure and price)
  - Major Determinants: Vacancy rate in submarket and region

- **Investing in home maintenance**
  - Decision: Investing or dis-investing in maintenance for apartments (including abandonning apartments)
  - Stratification: Characteristics of homeowners (e.g., housing preferences)
  - Major Determinants: Characteristics of housing unit (e.g., age of unit)

- **Characteristics of neighborhood (e.g., average housing condition)**

- **Investing in home maintenance**
  - Decision: Investing in home maintenance for apartments (including abandonning apartments)
  - Stratification: Characteristics of tenants (e.g., age, education, ethnicity)
  - Major Determinants: Characteristics of apartment (e.g., age of unit)

- **Characteristics of neighborhood (e.g., ethnic composition)**

- **Absorption rate in submarket**
  - Decision: Absorption rate in submarket
  - Stratification: Excess demand in submarket
  - Major Determinants: Vacancy rate in submarket and region

- **Availability restrictions**
  - Decision: Availability of suitable vacant land
  - Stratification: Availability of credit

1. E/R = Ethnic/Racial
Simulation Models

Information flowchart in CAM model – Source: Birch (1976)
Operational models

- The third generation of models began to emerge in the 80’s, building on the lessons learned in previous 2 decades and exploiting computer advances.

- A significant number of integrated (or semi-integrated) urban models have been developed around the world (Wegener 1995 identified 20 active models of this kind).

- Concerned with spatial choice
  - Started with Lerman’s (1976) application of multinomial logit model to residential location choice;
  - A household will choose the location that maximizes its (random) utility among a set of locations in a city.

- Strongly equilibrium-based;

- Generally very aggregate spatially & socio-economically;

- Generally based on sound economic theory;

- Generally derived from Lowry concepts.
Operational models

- Improved representation of land markets and endogenous prices
  - By balancing demand/supply
    - All households are assigned to vacant units;
    - The household is a decision-maker selecting a dwelling;
    - Applied in MEPLAN/TRANUS;
  - By applying Alonso’s (1964) bid rent and Martinez (1992) bid choice theories:
    - Optimal location for household maximizes the consumer surplus (CS = WP – actual price);
    - Owners will sell to highest bidder (price = MAX {WP} for all households bidding);
    - Equilibrium rent function (estimated from housing prices);
    - Applied in MUSSA and UrbanSim.
Operational Models

- **MEPLAN**
  - Developed by Marcial Echenique & Partners (MEP) in UK

- **TRANUS**
  - Similar modeling system developed by Tomas de la Barra (Modelistica) in Venezuela

- Models intra-urban spatial economy: regional/spatial Input/Output (I/O) model, subject to exogenous control totals;

- I/O model predicts flows of goods and services from producers to consumers (workers produce labor, firms consume labor);

- Land is consumed by households and businesses;

- Economic exchange of goods and services and labor $\rightarrow$ flows of goods and people.

  (e.g. workers “produce” labor, which is “consumed” by firms $\rightarrow$ the result is work trips)
Operational Models

Land use
f fixed demand coefficient
e price elastic demand coefficient
v variable household consumption demand coefficient
Incremental
d changes coded directly only
p changes proportional to previous distribution
r changes influenced by prices

Transport
m modes available to flows
s travel states comprising modes
a link types available to states, with capacity restraint
w link types available to states, without capacity restraint

Abbreviations
PUB public
PRV private
OHB other home-based
OHNB other non-home-based
FLSP floorspace
HH household
OSS other goods and services
SEG socioeconomic group

Phd in Transportation / Simulation of Land Use-Transportation Systems
Operational Models

MEPLAN

Strong Lowry elements still evident in the models:

- Logit allocation functions;
- In particular, workers allocated to residential zones, given place of work in a traditional Lowry process.

Endogenously determined prices mediated between demanders and suppliers of floor space in the land market:

- Supply decisions in time period $t$ depend of the prices in previous time period $t-1$;
- Location and travel demand decisions in time period $t$ are based on the level of (dis)utility provided by the transportation system in time period $t-1$;

The land and transportation markets interact:

- in that the spatial interaction between activities gives rise to travel demand and
- in that accessibilities defined by the transportation system influences location choice.
Operational Models

MEPLAN

Related markets

Order of model operations for simulating dynamics of interaction

MEPLAN (and TRANUS)

- **Strengths:**
  - Strong, coherent economic framework;
  - Use of I/O model to link urban spatial processes to “macro” economic processes attractive;
  - Fully integrated travel demand models;
  - Endogenous building supply;
  - Endogenous land prices;
  - Both packages have been applied in dozens of cities world-wide.

- **Weakness:**
  - Static, equilibrium framework;
  - Very large zone sizes;
  - Limited socio-economics;
  - Data hungry;
  - MEPLAN – expensive;
  - TRANUS -- problems with some sub-models.
Operational Models

- **MUSSA** (Modelo de Uso de Suelo de Santiago) developed by Martinez;
- Land-use model is driven by the output of an external regional economic model (population and employment by sector totals);
- Connected with a 4-stage model (ESTRAUS) which takes population and employment from MUSSA and feeds back accessibility measures → 5-LUT;
- Is an example of a “connected” rather than an “integrated” transport-land use modeling system.

![Diagram](image)
Operational Models

- Note that MUSSA allocates households to residential locations as a function (among other factors) of accessibility to work locations, but it does not explicitly connect household workers to specific job locations.
  → Thus, is not a Lowry-based model.

- Key features:
  - Very strong microeconomic foundation;
  - Consistent framework throughout;
  - Very strong static, equilibrium framework (both within MUSSA & ESTRAUS);
  - Traffic zone based -- quite fine level of spatial resolution.
  - Highly disaggregated socio-economically:
    - 65 household types in operational version;
    - Can be run using a large, weighted sample of households (“static microsimulation"
  - Has been used in a number of operational planning studies.
Operational Models

- **UrbanSim** – Developed by Paul Waddell, UC Berkeley (formerly from University of Washington).

- Loosely on Martinez’ Bid Choice Theory

- Like MUSSA
  - is a “connected” model, designed to interface with local area’s existing travel demand model (although flexible as to what this model needs to “look like”);
  - is highly disaggregated spatially:
    - traffic zones for travel demand & housing demand;
    - individual land parcels for housing supply;
  - is highly disaggregated socio-economically:
    - 111 household types.

- Still evolving – Recently has been redesigned within the OPUS (Open Platform for Urban Simulation) framework.
  - Microsimulation and activity-based travel demand;
UrbanSim

Operational Models

Regional Forecast

Demographic Transition

Base Year Land Use

Economic Transition

Household Move/Locate

Market Clearing

Business Move/Locate

Development/Redevelopment

Future Land Use

Public Policy/User Interface

Trip Generation

Trip Distribution

Mode Split

Assignment

Accessibility
Operational Models

- Key innovation in UrbanSim:

- Is not a static, equilibrium model, rather, a dynamic, dis-equilibrium framework is used:
  - supply based on expected revenues;
  - expected revenues = \( f(\text{last year's prices}) \);
  - new construction not available until next year;
  - demand = \( f(\text{last year's prices; current supply}) \);
  - prices = \( f(\text{current demand, supply by sub-market}) \).

- Not a static equilibrium but dynamic non-equilibrium, path-dependent → need to simulate each year’s state
Operational Models

Other operational models (not an exhaustive list):

- **DELTA**: land-use/economic modeling package by Davids Simmonds Consultancy, Cambridge, UK (Simmonds, 1999).

- **IRPUD**: model for the Dortmund region developed at the University of Dortmund (Wegener, 1983).

- **LILT**: Leeds Integrated Land-Use/Transport model developed at the University of Leeds (Mackett, 1983).

- **PECAS**: the Production, Exchange and Consumption Allocation System developed at the University of Calgary (Douglas & Hunt, 2005).

- **METROSIM**: the microeconomic land-use and transport model developed for the New York Metropolitan Area, recent extension is NYMTC-LUM (Anas, 1994).

- **IMULATE**: Developed at McMaster University for the City of Hamilton, Ontario. Applied in other Canadian Cities.
Current generation models involve microsimulation and event-based/agent-based modeling.

“Micro” implies a highly disaggregated model:
- spatially,
- socio-economically (representation of actors),
- representation of processes.

Discuss why microsimulation of location and travel decisions allows for:
- Better policy sensitivity;
- Better understanding of distributional impacts;
- Link with network microsimulators (e.g., VISIM, PARAMICS, AIMSUM);
- Generate detailed demographics required by disaggregate activity/travel models;
- To exploit the efficiency of large list-base data banks;
- Computational efficiency.
Microsimulation

- **ILUTE**, developed by Eric Miller (University of Toronto), is a microsimulation modeling within the Integrated Land Use, Transportation, Environment (ILUTE) Modeling Project.

- Topics of research concern include:
  - household-level modeling
  - activity modeling
  - demographic evolution modeling
  - auto-ownership modeling
  - microsimulating market processes
  - modeling the supply side
  - emissions/energy issues
  - temporal issues
  - spatial issues.

- It is a dynamic, full population synthesis, agent-based microsimulation model.
ILUTE modeling

- Demographics
- Regional Economics
- Government Policies
- Transport System
- Land Use
- Location Choice
- Auto Ownership
- Activity/Travel
- Flows, Times, etc.
- External Impacts
Microsimulation

- Model design focuses on definition of the objects which exist and interact within the system → an intelligent object is an agent.

- Agents:
  - perceive the world around them;
  - make autonomous decisions;
  - act into the world.
Example, relationship between household and individuals:

- Deals with many system components:
  - housing location/type choice;
  - automobile ownership;
  - demographics/household structure/lifecycle stage;
  - activity/travel scheduling.

- Households agents:
  - share resources among household members;
  - constrain member behavior;
  - condition member decision-making;
  - generate activities.
Microsimulation

- In ILUTE, the travel/activity submodel is fuelled by the TASHA (Travel/Activity Scheduler for Household Agents) model:
  - Key features include:
    - Activity-based
    - Household-based
    - Microsimulation-based, agent-based, object-oriented
    - Capable of interfacing with either conventional aggregate modeling systems or new disaggregate microsimulators at both “input” and “output” ends of the model (unique to this model).

Scheduling Activity Episodes into a Daily Schedule

<table>
<thead>
<tr>
<th>Work Project</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Project</td>
<td></td>
</tr>
<tr>
<td>Other Project</td>
<td>Other</td>
</tr>
<tr>
<td>Shopping Project</td>
<td>Shop 1 Shop 2</td>
</tr>
<tr>
<td>Person Schedule</td>
<td>At-home</td>
</tr>
</tbody>
</table>

= “Gap” in Project Agenda   = Activity Episode   = Travel Episode
- TASHA

  - Foundation: People do not travel for the sake of traveling but in order to engage in activities
  - Robust behavioral theory
  - Household interactions
  - Level of disaggregation
  - Non-work, non peak-period travel
  - Reflect scheduling of activities in time and space

Microsimulation

- ILUTE results

ILUTE Microsimulation
© 2004 University of Toronto
Miller & Salvini

GTA 1986
Visualization of PM peak travel time to CBD

Color Legend

<table>
<thead>
<tr>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>45</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>55</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>65</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>80</td>
</tr>
</tbody>
</table>
Microsimulation

- **ILUTE results**

![INCOME DIFFERENCES OF MARRIED COUPLES in 2001](chart1)

![Total New Stock in GTA](chart2)
Other microsimulation models (not an exhaustive list):

- **MatSim**: Multi-agent Transport Simulation by Kay Axhausen (ETH Zurich) and Kai Nagel (TU Berlin – Balmer, 2007).

- **Albatross**: Learning Based Transportation Oriented Simulation System by Theo Arentze and Harry Timmermans (Eindhoven Univ – Arentze and Timmermans, 2004).

- **ILUMASS**: Integrated Land-Use Modelling and Transportation System Simulation by Moeckel et al (Germany – Moeckel et al., 2003).

- **RAMBLAS**: Regional Planning Model Based on the Microsimulation of Daily Activity Travel Patterns by Veldhuisen (Eindhoven Univ – Veldhuisen et al., 2000).

- **TLUMIP**: Transportation & Land Use Model Integration Project by Weidner et al (Oregon DoT & Univ Calgary – Weidner et al., 2007).
LUT and environmental modeling

- LUT affects almost all environmental aspects
  - Environment affects land use (noise, air pollution, soil pollution affect land value/development and location decisions);
  - Environment has weak effect on travel decisions and car ownership except in extreme cases;

- Environmental impacts are quantified in some models but no feedback to land use and location decisions;

- Beyond LUT and environment \(\rightarrow\) Modeling urban ecosystems (or metabolisms);
LUT and environmental modeling

- Environmental assessment in ILUTE (Mobile6.2_C):

```
Individual Activity Schedules

Trips

Start emissions
Evaporative emissions

Network flows

Traffic Emissions

Meteorology

Ambient Air Quality

Population Exposure
```
LUT and environmental modeling

Link-based NOx emissions in the City of Toronto 16:00 LST
Zoning / land-use policies:

<table>
<thead>
<tr>
<th>Policy Category</th>
<th>Specific Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pricing</td>
<td>• Taxation: property taxes</td>
</tr>
<tr>
<td></td>
<td>• Subsidies: Business Redevelopment Zones</td>
</tr>
<tr>
<td></td>
<td>• Development charges</td>
</tr>
<tr>
<td>Infrastructure and services</td>
<td>• Public housing</td>
</tr>
<tr>
<td></td>
<td>• Servicing land (excluding transportation, e.g. sewers, waters, wired city)</td>
</tr>
<tr>
<td></td>
<td>• Government buildings/other not-for-profit institutions (i.e. location of these as ‘seeds’/cores for development)</td>
</tr>
<tr>
<td>Regulatory</td>
<td>• Zoning (uses, densities)</td>
</tr>
<tr>
<td></td>
<td>• Micro-design building/neighbourhood issues (‘shadowing’, pedestrian-scale massing, neo-traditional design, etc.)</td>
</tr>
<tr>
<td>Education/marketing</td>
<td>• Changing/how to change attitudes and sensitivities (e.g. traveller ‘value of time’ as opposed to deeply held values)</td>
</tr>
</tbody>
</table>

LUT and decision-making

- Transportation policies:

<table>
<thead>
<tr>
<th>Policy Category</th>
<th>Specific Policy</th>
</tr>
</thead>
</table>
| Pricing                          | • Road tolls/congestion pricing
• Gas taxes
• Subsidies (capital, operating)
• Transit fares
• Parking pricing                |
| Infrastructure and services      | • Build roads, high-occupancy vehicles
• Build rail/dedicated transit ways
• Operate transit services
• ITS (i.e. infrastructure technology; system optimization, transportation system management (TSM), etc.)
• Parking                        |
| Regulatory                       | • Parking provision regulations (off-street)
• Rules of the road (speed limits, on-street parking, high-occupancy vehicle lanes, traffic operations, etc.)
• Non-pricing TDM (e.g. employer trip reduction programmes, etc.)
• Vehicle/driver licensing (i.e. granting of access) |
| Education/marketing              | • Changing/how to change attitudes and sensitivities (e.g. traveller ‘value of time’ as opposed to deeply held values) |

## LUT and decision-making

- **Other policies:**

<table>
<thead>
<tr>
<th>Policy Category</th>
<th>Specific Policy</th>
</tr>
</thead>
</table>
| Pricing                         | • Car purchase tax  
• Licence charges  
• Income redistribution (e.g. progressive taxation, welfare, etc.) |
| Infrastructure and services     | n/a                                                                              |
| Regulatory                      | • Air quality standards (area wide)  
• Emissions standards (vehicle-specific)  
• Noise  
• Safety (accidents)  
• Vehicle technology standards (e.g. must have 10% electric vehicles in CA, etc.) |
| Education/marketing             | • Changing/how to change attitudes and sensitivities (e.g. traveller ‘value of time’ as opposed to deeply held values) |

Bibliography


