Activity-Based Travel Demand Models

Baltimore Metropolitan Council
Realizing a Vision
Understanding Travel Behavior

- Derived nature of travel demand (Jones, 1979)
  - Travel generally undertaken to fulfill activity needs and desires
  - Activities distributed in time and space necessitating travel

- Desire travel demand models that reflect this fundamental notion
Roots of Activity Based Paradigm

- Microsimulation of individual activity-travel patterns
- Bring together two schools of thought
  - Hägerstrand’s Constraints School (1969)
  - Chapin’s Activity-pull (Needs and Desires) School (1971 and 1974)
The Perfect Storm

- Why is vision being realized now?
  - Disaggregate modeling of travel behavior
  - Advances in statistical and econometric estimation methods
  - Quantum leaps in computational power
  - Policy questions with complex behavioral implications
  - Availability of databases (land use, travel behavior, GPS, networks)
An Evolutionary Stream of Research

- Chapin (1971 and 1974) studied human activity patterns in urban contexts
- Hägerstrand (1969) examined activity patterns in the time-space domain (continuum) and identified series of constraints
- Activity-based analysis traces its roots to these schools of thought
Hägerstrand’s Constraints

- Three primary types of constraints identified
  - Authoritative: Time-space constraints
  - Capability: Biological needs and resources (sleep, income)
  - Coupling: Inter-agent interactions (children)
Activity-Based Paradigm in Transportation

- Jones (1979) explicitly identified relationships among activities, travel, time, and space
  - Travel demand is a derived demand
- Followed with a conference in 1981 on *Travel Demand Analysis: Activity-Based and Other New Approaches*
Activity-Based Paradigm in Transportation

- Impetus grew in late 1980s and into 1990s
  - Key legislative acts such as ISTEA (1991), CAAA (1990), and TEA-21 (1998)
  - Major lawsuit filed by Sierra Club against San Francisco Bay Area MTC
  - Federal Travel Model Improvement Program (TMIP)
Activity-Based Paradigm in Transportation

- Early research efforts under TMIP
  - Development of TRANSIMS at Los Alamos National Laboratory
  - Activity-based model development research (AMOS)
- Four key papers published in *Transportation* (1996) offered frameworks for activity models
Activity-Based Paradigm in Transportation

- Four papers in *Transportation*
  - Late Kitamura/Pas
  - Ben-Akiva/Bowman
  - Stopher/Hartgen
  - Slavin

- Other key publications
Activity-Based Paradigm in Transportation

- Other key events
  - 1996 Activity Based Modeling Conference (New Orleans) organized by TMIP – everybody from Missouri?
  - 1995 and 2004 Netherlands Conferences in Progress in Activity-Based Analysis
  - TRB Task Force on Moving Activity-Based Approaches to Practice (2003-2008) – chaired by Prof. Kostas Goulias
A Daily Activity Itinerary

- **Home**: 7:15 am
- **Kid’s School**: 7:30 am
- **Work**: 7:35 am
- **Restaurant**: 12:30 pm
- **Shop**: 5:00 pm

**Transport Methods**:
- Drive
- Walk

**Timeline**:
- 6:30 pm: Home
- 6:00 pm: Shop
- 5:30 pm: Shop
- 5:05 pm: Work
- 1:05 pm: Work
- 12:35 pm: Restaurant
- 1:00 pm: Restaurant
- 6:00 pm: Shop
- 5:30 pm: Shop
- 5:00 pm: Shop
- 12:30 pm: Restaurant
- 8:00 am: Work
- 7:30 am: Kid’s School
- 7:35 am: Work

*Illustrations by Ira A. Fulton School of Engineering, Arizona State University*
Interactions and Constraints

- How does a four-step trip-based model view this itinerary?

**Two Home-based trips**

- O1: Drive (Peak) → D1
- O2: Drive (Peak) → D2

**Four Non home-based trips**

- O3: Drive (Peak) → D3
- O4: Drive (Peak) → D4
- O5: Walk (Off Peak) → D5
- O6: Walk (Off Peak) → D6
Influence of Trip Chaining

Consider a transit enhancement

Drive alone

Enhanced Transit Service

Drive alone

Home

Shopping

Work
Influence of Trip Chaining

- How can a switch to transit be accommodated?

Diagram showing travel patterns:
- From Home, drive alone to Shopping, return drive alone.
- Transition to transit from Home to Work.

Logos:
- ASU
- Ira A. Fulton School of Engineering
- Baltimore Metropolitan Council
Activity-Travel Inter-relationships

- Note series of inter-related behavioral responses
  - Shift in mode choice to work
  - Shift in destination choice for shopping
  - Shift in timing of shopping activity
  - Impact on trip generation (4 trips instead of 3 trips)
Limits of Four-Step Trip-Based Models

- Consider a change in system conditions
  - Increase in capacity
  - Increase in congestion (travel time)
  - Change in fuel price
Limits of Four-Step Trip-Based Models

- What do people do?
  - According to USA Today/Gallop Poll in June 2008, >80% consolidate errands → Direct impact on trip generation
  - However, activity participation remained largely unaltered

- Trip generation models in practice
  - Largely insensitive to system conditions
Limits of Four-Step Trip-Based Models

- Insensitivity of trip generation to system conditions
  - Inability to model suppressed demand or induced demand
- Could incorporate accessibility measures in trip generation models, but...
  - Still very limited in ability to reflect interactions and constraints
Social Equity and Quality of Life Issues

- Quality of life tightly connected to human activity patterns and how people spend “time”
- Activity-based paradigm offers ability to construct utility measures that directly address these issues
Planning Issues

- Traditional/novel multimodal capacity additions/subtractions
- Transit/Pedestrian Oriented Development
- Bicycle facility enhancements
- HOV/HOT lanes, Congestion Pricing, Variable Pricing, Parking Pricing
- Telecommuting (Telecommunications), Flexible Work Schedules
- ITS deployments
- Equity, Social Exclusion, Environmental Justice
- Energy (Fuel Prices) and Environment (Air Quality)
- Homeland security and disaster management
Basis for Model Design

- Policy issues and questions of interest
- Realistic behavioral paradigm/representation
- Computationally feasible and tractable
  - Estimation
  - Implementation
- Data availability (present and future)
A Focus on Behavioral Considerations

- Multitude of choices define activity-travel behavior
  - Activity type/purpose
  - Activity timing (time-of-day)
  - Travel mode and destination
  - Activity duration
  - Activity linkage (trip chaining)
  - Accompanying persons
  - Network-level choices
Behavioral Decision Processes

- Multitude of decision hierarchies possible
  - What is the sequence in which choices are made?
  - Virtually all model systems imply a certain decision hierarchy
- To what extent are choices made sequentially versus simultaneously/jointly?
Decision Hierarchies

- Large variety of decision hierarchies possible
  - Heterogeneity in the population
  - Careful market segmentation based on decision processes
- Growing evidence of simultaneity in choice decisions
  - People choose an activity-travel (lifestyle) package
- If choice process is sequential, more constrained choice precedes less constrained choice
  - In household with vehicle ownership constraints, would mode choice precede destination choice?
The Role of Time

- The notion of time and time use is central to the activity-based modeling paradigm
  - Time is not just a “cost” to be minimized
  - Rather, it is a finite resource whose “use” people strive to “optimize”
  - Time is an all-encompassing entity in activity-based models
The Role of Time

- Time appears in activity-travel agendas in numerous ways
  - Daily time allocation to activities and travel
  - The duration of single activity and travel episodes
  - The timing (time-of-day) of activities/trips
  - Multi-day (weekly) activity scheduling
The Role of Time

- Consideration of relationships between in-home and out-of-home activity time use
- Evidence of increased availability of leisure time
- Evidence of increase in travel time expenditures
  - Productivity efficiencies brought about by specialized services and technology deployment
The Role of Time

- Do people treat time as a continuous entity or a discrete entity?
  - Discrete time-of-day choice models (break the day into discrete periods)
  - Continuous duration models where activity timing is modeled along the continuous time axis

- Scheduling may be discrete while time allocation may be continuous
Agent Interactions

- Task allocation and joint activity-travel engagement
  - With whom and for whom?
- Activity dependency (children)
- Household vehicle allocation
- Residential and workplace location choices
- Real-time activity scheduling
  - Influence of mobile technologies
  - Generate activities on-the-fly in model?
Time-Space Interactions

- Gain realism by incorporating time-space prism constraints
- Constraints on modal transition, public transit availability, and destination choices
- Generate work/school schedules and tours first (define anchor points)
  - Discretionary activities simulated along the time axis recognizing constraints imposed by work and school
Time-Space Interactions

- **Prism Constrained Activity-Travel Simulator (PCATS) of Kitamura** – now embedded in *OpenAMOS*
- Divides a day into open periods and blocked periods
- Defines a Hägerstrand’s prism for each open period and simulates activities and travel within it
Time-Space Interactions

- Activity 1 (Fixed)
- Activity 2 (Fixed)
- Home Activity
- Activity 1
- Activity 2
- Activity at Location A
- Time
- Urban Space
- Home
- Work
Time-Space Interactions

- **Sequential structure**
  - The attributes of an activity and trip to it are simulated activity by activity, conditional on past activity engagement
  - Operational hierarchy: activity type $\rightarrow$ mode-destination $\rightarrow$ activity duration

- **Representation of prism constraints**
  - Activity type choice/generation $\leftarrow$ remaining time in prism
  - Mode-destination choice $\leftarrow$ constrained choice set
  - Duration choice $\leftarrow$ remaining time in prism
Decision Time Points for Discretionary Activities

Decision Point 1  |  Decision Point 2  |  Decision Point 3

- Trave
- Activity 1
- Activity 2
- Fixed Activity

Open Period  |  Blocked Period

Time
PCATS Model Components

- **Prism vertex models**
  - Stochastic frontier models to determine unobserved prism vertices

- **Activity type choice models**
  - Multinomial logit models that determine activity engagement in each open period
PCATS Model Components

- **Destination-Mode choice models**
  - Nested logit models that assign a destination-mode pair to each activity within a prism

- **Activity duration models**
  - Split-population survival models that determine length of each activity while considering the prism size
Representing Prism Constraints

A prism configured assuming the fastest travel mode in the choice set

Travel mode availability by time of day and mode continuity checked within and across prisms

Prism vertices generated by stochastic frontier models
Integrate with Dynamic Traffic Simulator

- Maximize use of information from activity-based model system
  - Activities and trips generated along the continuous time axis
  - Load trips on the network as they are generated (at one-minute resolution)
  - Dynamic interface and concurrent execution, along the time axis, of the activity simulator and a network simulator
  - No post-processing of model outputs
Integration with Traffic Simulator

**Decision Processor**
- Decision to engage in some activity
- Determine destination and mode
- Given arrival time, determine activity duration
- Decision to engage in some activity

**Event Manager**
- Scanning Interval (1")
- Agent on Process Waiting List
- Activity duration
- Agent on Actor List

**Traffic Simulator**
- Travel
- Agent on Traveler List
Enhancing Behavioral Realism

- Exact trip durations not known until trips are completed
- Need to consider issues of unmet mobility
  - An agent may be late for work, cannot finish errand, cannot return home, etc.
  - Prism constraints may not always be satisfied
  - Prism constraints increasingly fuzzy? (technology effects)
Activity-Based Model Systems

- Numerous activity-based model systems developed in research arena
- Models have matured to varying degrees
  - Attempt to incorporate aspects of behavior highlighted in presentation
Activity-Mobility Simulator (AMOS, FAMOS)

- Household Attributes Generation System
  - Network Level-of-Service Data
  - Census Socio-Economic Data
- Synthetic Population (Households and Persons)
- Prism-Constrained Activity-Travel Simulator
  - O-D Flows by Purpose and Time-of-Day
  - Output Reports
- Activity-Travel Records for Each Person
  - GIS Visualization
  - Output Processor
Model Design: SimTRAVEL
Model Design

Start simulation for Base Year

Synthetic Population Generator

Work/School/Preschool Location Choices

Vehicle Ownership Model

MALTA: Skims for the whole day from previous years run; Access to underlying travel skims structure for generating location choice sets???

UrbanSim: Location Choices

Longer term choices simulated for the base year
Model Design

Fixed Activity Prism Generator

Child Daily Status and Allocation Model

Adult Daily Status

Activity Skeleton Reconciliation

MALTA: Skims for the whole day from previous iteration (day). Access the underlying travel skims structure for generating location choice sets???

Simulated for the whole day
SimTRAVEL: Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land

Funded by FHWA through Exploratory Advanced Research Program

See: http://simtravel.wikispaces.asu.edu
Integrated Model: Supply and Demand

OpenAMOS

Origin, Destination, Vehicle Info for Vehicle Trip 1

t = 0 t = 1 min

DynusT/MALTA

Vehicle is loaded and the trip is Simulated

6 sec. interval

O-D Travel Times for Destination and Mode Choice Modeling

Arrival Time

Person(s) reach destination and pursue activity

Origin, Destination, Vehicle Info for Vehicle Trip 2

24 hr duration

Update Set of Time-Dependent Shortest Paths – 1440 paths per O-D Pair

New link travel times
CEMDAP (Bhat)

Input

Data Coordinator

LOS & Zonal data queries

Internal Data Entities

Household

Person

Pattern

Tour

Stop

Simulation Coordinator

Model Modules

Decision to work

Work duration

Work start time

HH activity generation

Activity stop location

Comprehensive Econometric Microsimulator of Daily Activity-travel Patterns
CEMDAP: Model Components

**Application of the Generation-Allocation Model System**

- Work and school activity participation and timing decisions
- Children’s travel needs and allocation of escort responsibilities to parents
- Independent activity participation decisions

**Application of the Scheduling Model System**

- Work-to-home and home-to-work commute characteristics
- Drop-off tour of the nonworker escorting children to school
- Pick-up tour of the nonworker escorting children from school
- School-to-home and home-to-school commutes
- Joint tour of the adult pursuing discretionary activity with children
- Independent home-based and work-based tours for each worker
- Independent home-based tours for each non-worker
- Independent discretionary activity tour for each child
CEMDAP: Parent-Child Interaction

Children's Pattern
- Go to School?
- School Timing

Go to Work?
- Work Timing

Parent(s)’ pattern

Mode to/from School
- Drive by parent

Allocate to Parent(s)

Adjust Work Timing of Parent(s)
Integrated Activity-Travel Demand and Dynamic Traffic Assignment Model System (CEMDAP-VISTA: Bhat/Waller)

**VISTA**

- **Traffic Simulation**
  - Find 6 sec. traffic flows
  - Accounts for ramp metering, information provision, traffic incidents, etc
  - Output: Travel times per interval and road segment

- **Optimal routing**
  - Finds optimal route for all OD pairs and departure times
  - Solve time-dependent shortest path
  - Accounts for non-travel time costs (tolls, stochasticity)
  - Output: Optimal route per OD pair and departure time

- **Path Assignment**
  - Assign paths to each individual vehicle on the network
  - Output: Vehicle path

- **Convergence Check**

**CEMDAP**

- Activity-travel simulator
- Activity-travel environment (LOS)

**CEMSELTS**

- Interface: Convert Person-Tours to O-D Trip Tables by Time of Day

**SPG**

- Synthetic population generator and Input generation

**Aggregate socio-demographics**

**Interface: Link Volumes and Speeds**

**Update LOS**

**Link Volumes and Speeds**

**O-D Trip Tables by Time of Day**

**Link Volumes and Speeds**

**Convergence**

**After Convergence**
SimAGENT
Simulator of Activities, Greenhouse Emissions, Networks, and Travel

- Address provisions/mandates of SB375
  - Requires metropolitan planning organizations (MPOs) to include sustainable communities strategies (SCS) for the purpose of reducing greenhouse gas emissions

- Address wide range of policies, e.g.:
  - Economic analysis: location-based welfare, wages, and exports
  - Equity analysis: change in welfare by household income class
  - Evaluate the energy use and GHGs produced by households and workers in building space
  - Comprehensively evaluate economic development impacts
  - Evaluate time-of-day roadway tolls
## SimAGENT Phased Implementation Plan for SCAG

<table>
<thead>
<tr>
<th>Phase</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Model Development Plan and Strategy</td>
<td>Work closely with SCAG staff to finalize model development plan, model structure, model implementation path, and software and data requirements and specifications</td>
</tr>
<tr>
<td>2</td>
<td>Development and Implementation of SimAGENT Version 1</td>
<td>Adapt CEMDAP to SCAG region Add Synthetic Population Generator Compare to 2003 Trip-Based Model Extensive Validation and Sensitivity Testing Conduct Hands-on Staff Training Sessions Estimate GHG using EMFAC</td>
</tr>
<tr>
<td>4</td>
<td>Training and Reports</td>
<td>Submission of Final Deliverables Conduct Hands-on Staff Training Sessions</td>
</tr>
</tbody>
</table>
6:00 AM-7:00 AM

taz2kv3 Charts

Legend:
- AM7Home
- AM7School
- AM7Shopping
- AM7Social
- AM7OtherServePassenger
- AM7Pickup
- AM7IndependentAct
- AM7Work
- AM7Workrelated
- AM7Household
- AM7Eatout
- AM7Dropoff
- AM7JointAct

Distance Scale:
0 15 30 45 Miles
11:00 AM- Noon
Noon-1:00PM
The diagram illustrates the components of the Opus Framework, which includes the Transport Planning and UrbanSim systems. The Transport Planning system consists of Transport Networks, Parcel Attributes (Transport Development), and a Trip Aggregator. The UrbanSim system includes Parcel Attributes (Land Development), Synthetic Population, and Accessibility. The AB Household Travel Demand Simulator connects these components with Special Generators (e.g., airport), External trips, Trip Aggregator, Commercial movements, OD Matrices, Network traffic assignment, and Network performance (skims). The Reporting and Query Subsystem is depicted as a separate component that interacts with the main system.
Activity-Based Model System - DASH(Gliebe)

- MetroScope Land Use Data
  - Population Synthesis
    - Workplace Location Choice
      - School/College Location Choice
        - Auto Ownership Choice
          - Initial Conditions (Day)
            - Day Activity Pattern/Role Choice
              - Starting Time Choice
    - Dynamic Activity Pattern Generation
      - Tour Mode Choice
        - Tour First Stop Purpose Choice
          - Next Stop Location Choice
            - Next Stop Mode Choice
              - Next Stop Purpose Choice
                - Post Processor
                  - Trip Lists
                    - Trip Tables
                      - Assignment
ADAPTS (Mohammadian)

Agent-based Dynamic Activity Planning and Travel Scheduling

Information Flow

Simulation Flow

For each timestep

Initialize Simulation
- Initialize World
- Synthesize Population
- Generate routine activities

Household Schedule

Household Memory

Individual Schedules

Individual Memory

Social Network

Household Planning

Individual Planning

Write Trip Vector

Traffic Assignment

Land Use

Institutional Constraints

Network LOS
ADAPTS (Mohammadian)

At timestep $t$

Plan new activities

Update existing activity(s)

Attribute Planning Order model

Set Plan Flags: $(T_{time}, T_{with}, T_{loc}, T_{mode})$

Time-of-Day model

Party composition model

Destination choice model

Mode Choice model

Mode Choice model

Resolved Activity Schedule

Resolve Conflicts

Conflict Resolution Model

Execute activity

Executed Schedule

Activity Generation

Activity Planning

Activity Scheduling
ALBATROSS  (Timmermans/Arentze)

➢ A learning-based activity-based travel model system
➢ Employs theories of choice heuristics to represent behavioral processes
➢ Decision tree approaches used to formalize heuristics and predict choice behavior
➢ Explicit consideration of multitude of constraints
**ALBATROSS** (Timmermans/Arentze)

- *Albatross* assumes that choice behavior is based on rules that are formed and **continuously adapted** through learning.
- Individual interacts with the environment (reinforcement learning) or communicates with others (social learning).
- *Albatross* is based on a learning theory which implies that rules governing choice behavior are:
  - heuristic
  - context-dependent
  - adaptive in nature
Components:
- a model of the sequential decision making process
- models to compute dynamic constraints on choice options

A set of decision trees representing choice behavior of individuals related to each step in the process model
ALBATROSS (Timmermans/Arentze)

Rule-base

Decision Trees

Dynamic constraints

Schedule engine

Schedules

Data-base

Agents
- Day of week
- Household attributes
- Individual attributes

Study area
- Land-use data
- Transport data
- Opening hours
- Parking data

START

Scheduling work activity

Scheduling other fixed activities

Generating flexible activities

Timing of flexible activities

Trip-Chaining decisions

Location of flexible activities

Transport mode of non-work Tours

STOP
ALBATROSS (Timmermans/Arentze)

Schedule skeleton
- Next activity
  - Select
    - yes: Travel party
    - no: Duration
      - Add to Program
  - no: Schedule+activities

Skeleton+activities
- Next activity
  - Time of day
  - Next activity
  - Trip link
    - yes: Location1
    - no: Location2
  - Schedule+Tours
    - Next tour
      - Mode
      - Next activity
    - Schedule+Tours+Mode+Location
Rule-Based Heuristics

Let $L$ be the choice set for the given activity defined by Eqs. (1)–(4), $L^+ \subseteq L$ be the subset of non-inferior locations, $t'_l$ be the travel time to location $l$, $r_1 < r_2 < r_3 < \cdots < r_m$ be pre-defined critical travel times of increasing lengths, $R_r \subseteq L$ be the subset of locations reachable within travel time $r$. Then, the heuristics can be written as

- $h_1$: choose location $l$ if $l \in L^+ \land t'_l = \min_{l' \in L}(t'_l)$
- $h_2$: choose location $l$ if $l \in L^+ \land o_l = \max_{l' \in L}(o_{l'})$
- $h_{3,1}$: choose location $l$ if $l \in L^+ \land l \in R_1 \land o_l = \max_{l' \in R_1}(o_{l'})$
- $h_{3,2}$: choose location $l$ if $l \in L^+ \land l \in R_2 \land o_l = \max_{l' \in R_2}(o_{l'})$
- \ldots
- $h_{3,m}$: choose location $l$ if $l \in L^+ \land l \in R_m \land o_l = \max_{l' \in R_m}(o_{l'})$
- $h_4$: use some other heuristic
# Classification of Activities

<table>
<thead>
<tr>
<th>Fixed activities</th>
<th>Flexible activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work/school</td>
<td>Daily shopping</td>
</tr>
<tr>
<td>Bring or get persons or goods</td>
<td>Service related activities (post office, bank etc.)</td>
</tr>
<tr>
<td>Medical visits</td>
<td>Non-daily shopping</td>
</tr>
<tr>
<td>Personal business (a rest category)</td>
<td>Social activities (visiting friends, relatives etc.)</td>
</tr>
<tr>
<td>Sleep and eat</td>
<td>Leisure activities (sports, concert, library, restaurant etc.)</td>
</tr>
<tr>
<td></td>
<td>Home-based activities (other than sleep and eat)</td>
</tr>
</tbody>
</table>
TRANSIMS (FHWA/LANL)

- Transportation Analysis and Simulation System
- Generates and simulates activity/travel patterns for individuals in a region over a 24 hour period
- Supports highly detailed road and transit networks
- Time dependent link delays are considered for routing trips through the network
TRANSIMS: Framework

- Population Synthesis
- Activity Patterns
- Mode Preference
- Router
- Microsimulator

Attraction Balancing

Route Attributes

Stabilization

Refine Modes

Change Activity Times or Patterns

Attraction Balancing

Textual Content:

TRANSIMS: Framework

Population Synthesis → Activity Patterns → Mode Preference → Router → Microsimulator

- Attraction Balancing
- Route Attributes
- Stabilization
- Refine Modes
- Change Activity Times or Patterns
TRANSIMS: Activity Generator

- Generates activity engagement patterns for each member of a household over a 24-hour period
- Out-of-home activity locations determined using a destination choice model
- Activity engagement patterns generated by sampling from activity patterns of individuals in a travel survey
  - In the current implementation, Classification and Regression Trees are used
TRANSIMS: Activity Generator (continued)
TRANSIMS: Application

Network Preparation
- Highway Network Conversion
- Transit Network Conversion
- Network Editing

Trip-based model
- Trip Table Conversion

Tour-based model
- Census Data Conversion
- Population Synthesis
- Activity Generation

Hybrid model
- Trip Table Conversion
- Census Data Conversion
- Population Synthesis
- Activity Generation

Router and Router Feedback
Microsimulator
TRANSIMS: Feedback Processes

Router Stabilization
- Router
- PlanPrep (Merge)
- PlanSum
- PlanSelect
  - Done? (No)
  - Done? (Yes)

Microsimulator Stabilization
- Router
- PlanPrep (Merge/Sort)
- Microsimulator
- PlanSelect/ProblemSelect
  - Done? (No)
  - Done? (Yes)

User Equilibrium
- Microsimulator
- Router
- PlanCompare
  - Done? (No)
  - PlanPrep (Merge/Sort)
    - Stop
  - Done? (Yes)
MATSIM-T (Axhausen/Nagel)

- Multi-Agent Transport Simulation Toolkit
- Iterative agent-based traffic simulation framework
- Only autos are simulated
- Involves two main components
  - Agent generation (grouped as households)
  - Activity Scheduling
## MATSim-T: Scheduling Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Frequency per run</th>
<th>Model type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number, sequence and type of activities</td>
<td>Once</td>
<td>Conditional probability</td>
</tr>
<tr>
<td>Start and duration of activities</td>
<td>Per iteration</td>
<td>Best response model (GA-based optimizer)</td>
</tr>
<tr>
<td>Composition of the group undertaking the activity</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Expenditure and its allocation among the participants</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Secondary location choice</td>
<td>Once</td>
<td>Imputed (Proportional to size and distance)</td>
</tr>
<tr>
<td>Mode/vehicle choice</td>
<td>Per iteration</td>
<td>Imputed (Chain based MNL)</td>
</tr>
</tbody>
</table>
MATSim-T: Framework

- Travel demand \( q \) is generated and microsimulated
- Resulting generalized costs \( k \) are used to adjust schedules, capacities and prices of facilities
- Route \( (r) \) adaptation process also extends towards time choice \( (t) \), mode choice, location choice \( (j) \), etc
ILUTE (Miller)

- Integrated Land Use, Transportation, Environment (ILUTE) model system
- ILUTE mainly tries to model the “spatial markets and the persons’ daily decision-making within a household-based context”
- Simulates the evolution of agents and objects over time
  - Agents and objects include individuals, transportation networks, the built environment, the economy, and the job market
ILUTE: Framework

- Regional Economics
- Government Policies
- Transport System
- Demographics
- Land Use
- Location Choice
- Vehicle Ownership
- Activity/Travel & Goods Movement
- Dynamic Traffic Assignment
- Flows, Times, etc.
- External Impacts

[Diagram showing the interconnections between the different components of the ILUTE framework]
ILUTE: Structure and Current Implementation

- Observed Base Year Aggregate Distributions of Agents and Attributes
  - Synthetic Agent Population $T = 0$

- $T = T + \Delta T$

- Exogenous Inputs @ time $T$:  
  - Interest Rates
  - Energy Rates
  - Vehicle technology
  - Zoning
  - In/out migration rates
  - ...

- Demographic Update
- Labour Market
- Housing Market
- Auto Ownership

- Activity-Based Daily Travel (TASHA)

- Employment @ time $T$

- Road & Transit Networks @ Time $T$

- Commercial Vehicle Movements

- Road and Transit Network Assignments

- Transportation Emissions & Dispersed Pollution Concentrations

- Link & O-D Travel Times/Costs Link, Congestion Levels, Etc.

- GHG Emissions

Population Exposure to Pollutants by Location and Time of Day
ILUTE: Evolutionary Engine

Base Year Census Data, Other Aggregate Data

Synthesize Base Year Population, Employment, Dwellings, etc.

T0 = Base time point
T = Current time point being simulated
NT = Number of simulation time steps

ILUTE Evolutionary Engine
For T = T0+1, T0+NT do:
- Demographic Update
  - Demographics
  - Family/household composition update
  - School participation update
- Building Stock Update
  - Residential Housing
  - Commercial Floorspace
- Firm/Job Location Update
- Work Participation & Location Update
- Residential Location Update
- Auto Ownership Update
- Commercial Vehicle Movement Update
- Activity/Travel Update (TASHA)

Exogenous Inputs, Time T
- In-migration
- Policy Changes
- ...

EMME/2 Transportation Network Model (Compute travel times/costs by mode)
TASHA (Miller/Roorda)

- Travel/Activity Scheduler for Household Agents
- Simulates out-of-home activity and travel patterns for individuals recognizing household-level interactions and constraints
- TASHA uses the concept of project introduced by Axhausen (1998)

- TASHA comprises of:
  - An activity episode generator
  - An activity scheduler
  - A random utility tour-based mode choice model
TASHA: Activity Generation, Scheduling and Mode Choice

Activity Episode Frequency, Start Time and Duration Generation

- Draw activity frequency from marginal PDF
- Draw activity start time from feasible region in joint PDF
- Draw activity duration from feasible region in joint PDF

Trip-Chain (Tour) Based Mode Choice

- 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

Scheduling Activity Episodes into a Daily Schedule

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

- “Gap” in Project Agenda
- Activity Episode
- Travel Episode
Time Use Utility Measures

- Time use allocation is central to the activity-based modeling paradigm
- Offers strong framework for analyzing measures of welfare that people derive from their activity-travel patterns
- Address social equity and quality of life issues
Formulation of Time Use Utility Measure

- **Utility formulation**

\[ U_q = [x_q \beta + \gamma \ln(S_q + 1) + \varepsilon_q ] \ln(T_q + 1) \]

- \( U_q \) is utility derived from activity of type \( q \)
- \( T_q \) is cumulative daily time expenditure on activity of type \( q \)
- \( S_q \) is cumulative daily time expenditure on travel for activity of type \( q \)
- \( x_q \) is a vector of covariates affecting utility \( U_q \)
- \( \gamma \) is a scalar coefficient associated with \( \ln(S_q + 1) \)
- \( \beta \) is a vector of coefficients associated with \( x_q \)
- \( \varepsilon_q \) is an i.i.d. random error term in \( U_q \).
Formulation of Time Use Utility Measure

Utility formulation

\[ U_S = \ln(T_S + 1) \]

Maximize

\[ U = \sum_q U_q + U_S \]

Subject to

\[ \sum_q T_q + \sum_q S_q + T_s = T_f \]

\( U_s \) is the utility derived from sleep
\( U \) is the total utility derived from the time use pattern
\( T_s \) is cumulative daily time expenditure on sleep
\( T_f \) is the total time available in a day.
## Baseline Activity Pattern

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Daily Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td>472</td>
</tr>
<tr>
<td>In-home maintenance</td>
<td>202</td>
</tr>
<tr>
<td>Out-of-home maintenance</td>
<td>53</td>
</tr>
<tr>
<td>Travel for out-of-home maintenance</td>
<td>37</td>
</tr>
<tr>
<td>In-home discretionary</td>
<td>166</td>
</tr>
<tr>
<td>Out-of-home discretionary</td>
<td>76</td>
</tr>
<tr>
<td>Travel for out-of-home discretionary</td>
<td>16</td>
</tr>
<tr>
<td>Commute time (round trip)</td>
<td>60</td>
</tr>
</tbody>
</table>
## Modified Activity Pattern: After Telecommuting

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Daily Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td>492 (+20)</td>
</tr>
<tr>
<td>In-home maintenance</td>
<td>202</td>
</tr>
<tr>
<td>Out-of-home maintenance</td>
<td>53</td>
</tr>
<tr>
<td>Travel for out-of-home maintenance</td>
<td>37</td>
</tr>
<tr>
<td>In-home discretionary</td>
<td>186 (+20)</td>
</tr>
<tr>
<td>Out-of-home discretionary</td>
<td>90 (+14)</td>
</tr>
<tr>
<td>Travel for out-of-home discretionary</td>
<td>22 (+6)</td>
</tr>
<tr>
<td>Commute time (round trip)</td>
<td>0</td>
</tr>
</tbody>
</table>
Example

- Time use utility measure formulated as a function of:
  - Socio-economic and demographic characteristics
  - Travel durations to and from activities
  - Activity durations for different activity types/episodes

- Time Use Utility before capacity enhancement = 25.570
- Time Use Utility after capacity enhancement = 27.531
- Could translate into monetary benefits
- Also examine equity across market segments
## Example

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Utility Value Before Telecommuting</th>
<th>Utility Value After Telecommuting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td>6.159</td>
<td>6.201</td>
</tr>
<tr>
<td>In-home maintenance</td>
<td>2.939</td>
<td>2.939</td>
</tr>
<tr>
<td>Out-of-home maintenance</td>
<td>0.777</td>
<td>0.777</td>
</tr>
<tr>
<td>In-home discretionary</td>
<td>2.882</td>
<td>2.946</td>
</tr>
<tr>
<td>Out-of-home discretionary</td>
<td>12.813</td>
<td>14.669</td>
</tr>
<tr>
<td>Total</td>
<td>25.570</td>
<td>27.531</td>
</tr>
</tbody>
</table>
Key Considerations

- Representation of fuzzy time-space prism constraints, inter-agent interactions, and time use behavior
- Greater level of simultaneity in choice processes to reflect choice of lifestyle package
- Recognition of heterogeneity in population – behavioral structure, decision hierarchy, parameters/coefficients
  - Careful market segmentation, trip purpose definition, representation of time, space, and networks
Key Considerations

- **Central role of time and space**
  - Disaggregate representation of time-space domain
  - Continuous representation of time
  - Disaggregate spatial representation

- **Maximize use of information from activity-based travel model**
Things to Think About

- Feedback processes
  - Feedback within activity-travel simulator from destination/mode choice to time-of-day choice to activity type/generation
  - Feedback from network assignment to activity type/generation (tour stops), and mode and destination choice
  - Criteria for convergence and equilibrium conditions
Things to Think About

- **Stochastic simulation**
  - One run represents one realization of stochastic process
  - How many runs are required to achieve stable results?
  - Impacts on computation time and hardware/software requirements

- **Data requirements**
  - Travel survey data
  - Multimodal network data by time of day
  - Detailed land use data
  - Greater level of disaggregation for activity microsimulation
Things to Think About

- In-house resources
  - Staff training and expertise
  - Computational resources
  - Phased development plan
    - Comprehensive model design upfront with staged development and implementation schedule