Travel Demand Modeling

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Transportation Systems Analysis: Demand & Economics

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Review

- Discrete Choice Framework
  - A decision maker *n* selects one and only one alternative *i* from a choice set C_n={1,…,J_n}
  - Random Utility Model where

$$U_{in} = V_{in}(\text{attributes of } i, \text{ characteristics of } n, \beta) + \varepsilon_{in}$$

- Discrete Choice Models
  - Multinomial Logit
  - Nested Logit
    - Correlated Alternatives
    - Multidimensional Choice

Next… Travel Demand Modeling

Outline

- Introduction
- Approaches
  - Trip
  - Tour
  - Activity
- Emerging Approaches

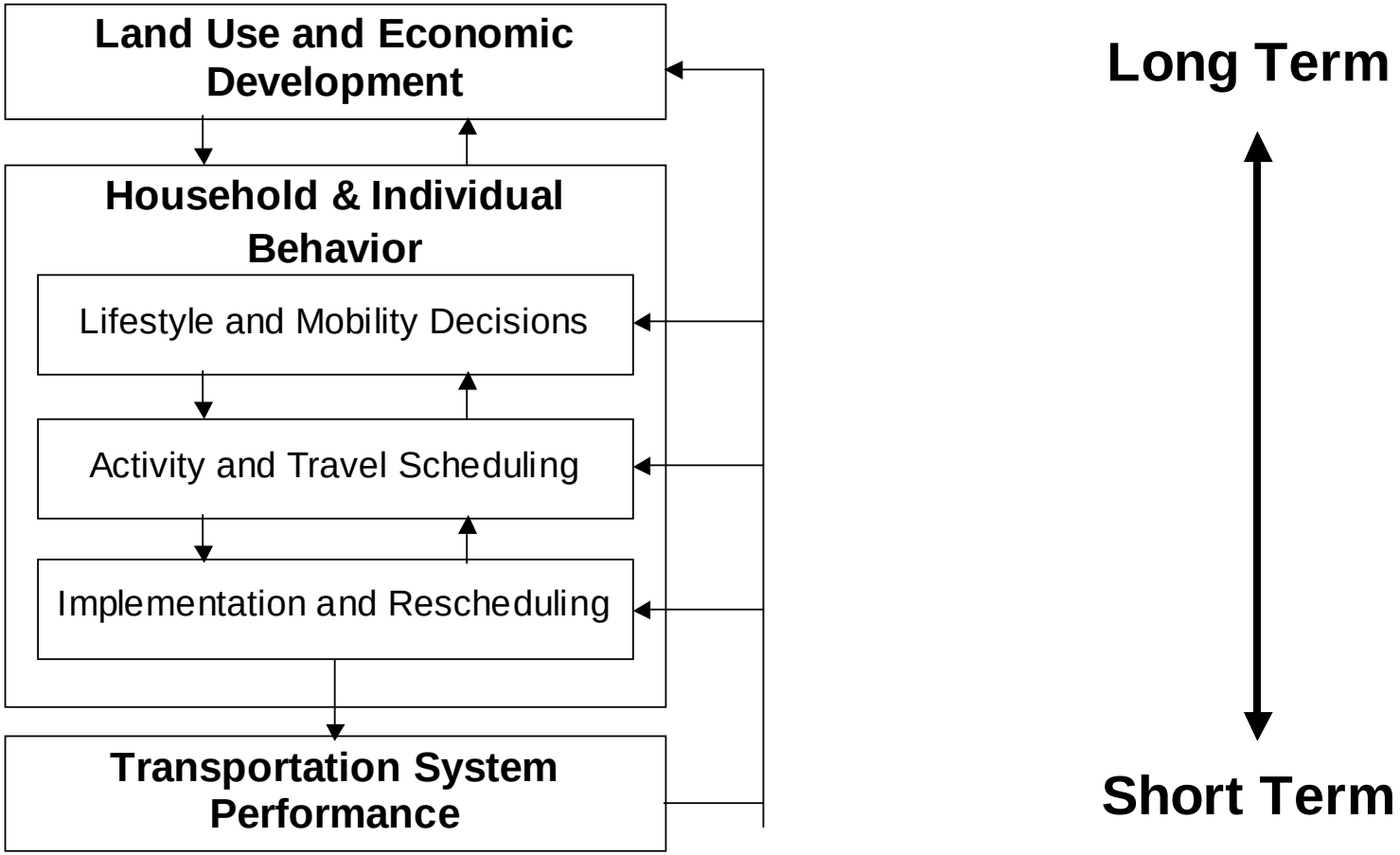
Long Term Choices

- Urban Development
  - Firm location and relocation decisions
  - Firm investment in information technology
- Mobility and Lifestyle Decisions
  - Labor force participation
  - Workplace location
  - Housing
  - Automobile ownership
  - Information technology ownership and access
  - Activity program

Activity and Travel Pattern Choices

- Activity sequence and duration
- Priorities for activities
- Tour formation
- Telecommunications options
- Access travel information
  - Traffic conditions
  - Route guidance
  - Parking availability
  - Public transportation schedules
- Reschedule activities
- Revise travel plans

Modeling Framework



The Fundamental Modeling Problem

- Adequately represent a decision process that has an inordinate number of feasible outcomes in many dimensions
- Example - *Activity Schedule*

Number of activities	10	10
Sequence		10!
Timing	10 per activity	100
Location	1000 per activity	10,000
Mode	5 per activity	50
Route	10 per activity	100
Total Number of Activity Schedule Alternatives		**10^{17}**

- Simplify
- Achieve valid results

Simplifying the Problem

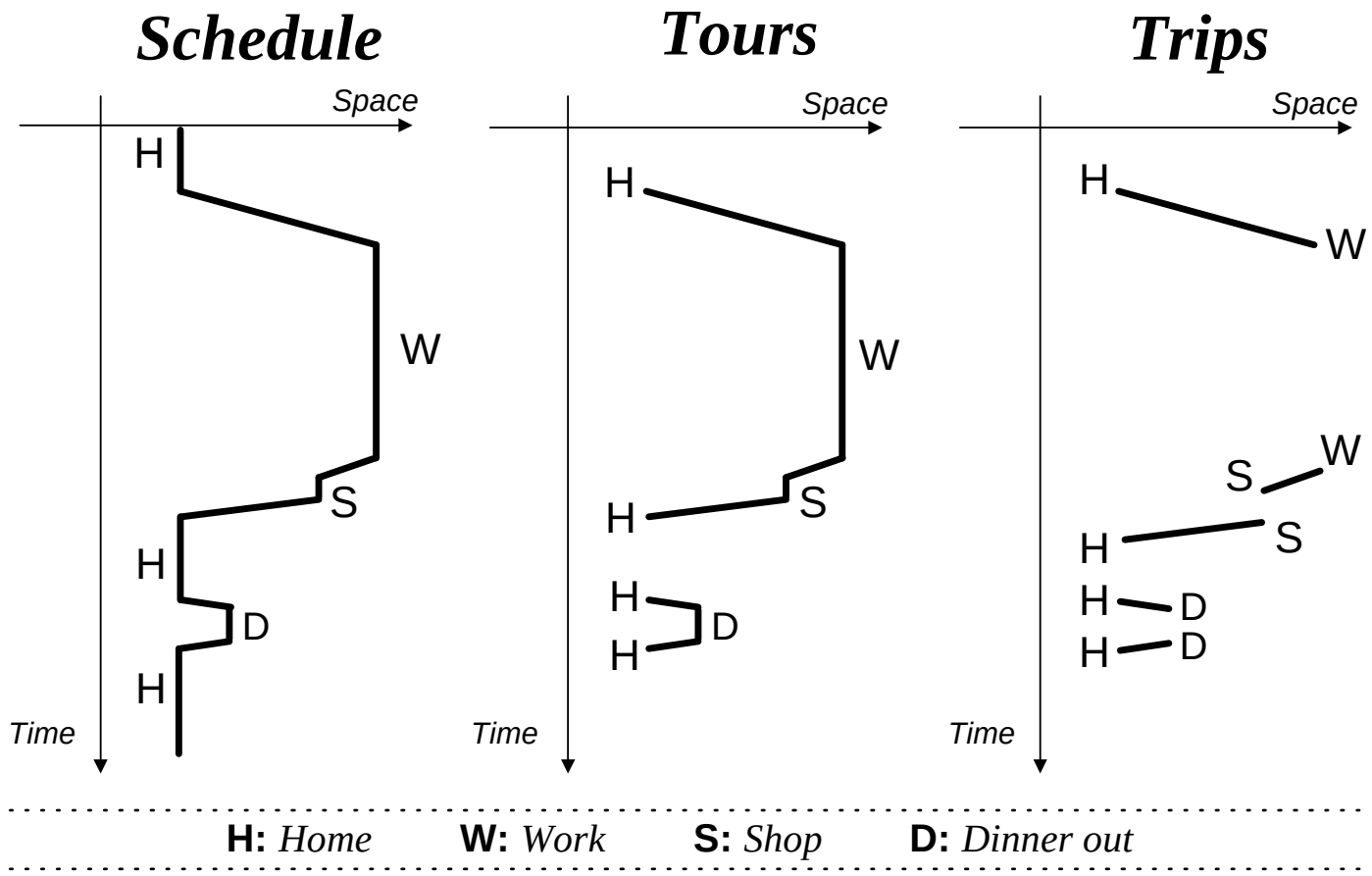
- Discrete time intervals
- Individuals defined by socioeconomic variables
- Divide space into zones
- Categories of activities
- Depiction of travel patterns

  → trips, tours, activity schedules

Approaches to Modeling Travel

- Trip-based
- Integrated trip-based
- Tour-based
- Activity schedule

Representing Activity/Travel Behavior



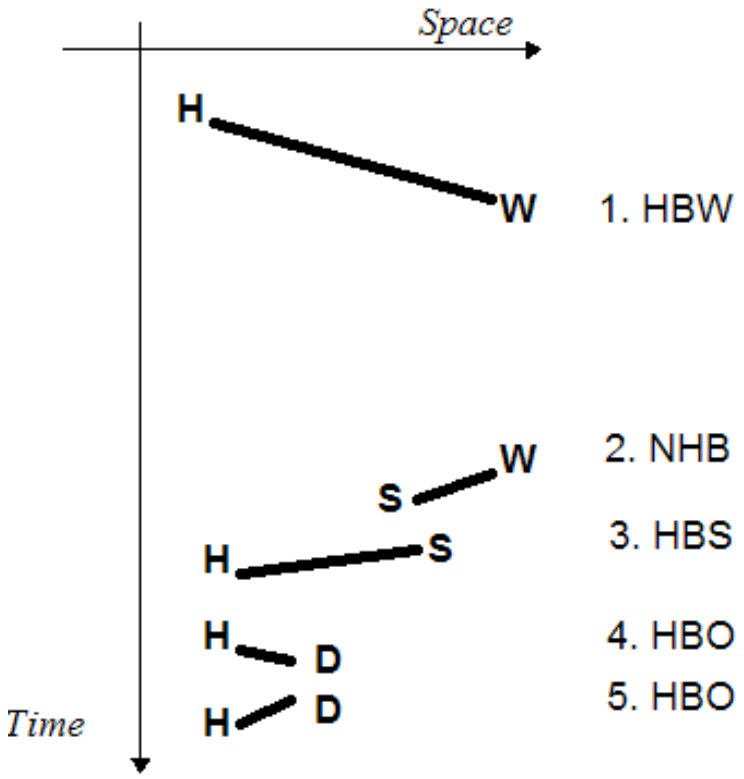
Trip-Based: The 4-Step Model

Trip Purpose

- Home-based work (HBW)
- Home-based shop (HBS)
- Home-based other (HBO)
- Non-home-based (NHB)

Behavioral Steps

1. Trip Generation (Frequency)
2. Trip Distribution (Destination)
3. Modal Split (Mode)
4. Assignment (Route)



The 4-Step Model: Trip Generation

- Trip Production
  - Household Size, Household Structure, Income, Car Ownership, Residential Density, Accessibility
- Trip Attractions
  - Land-use and Employment by Category (e.g. Industrial, Commercial, Services), Accessibility
- Cross Classification, Regression, Growth Factor

The 4-Step Model: Trip Distribution

- Trip matrix

Generations	Attractions							
	1	2	3	…	j	…	J	$\sum_j T_{ij}$
1	T_{11}	T_{12}	T_{13}	…	T_{1j}	…	T_{1J}	O_1
2	T_{21}	T_{22}	T_{23}	…	T_{2j}	…	T_{2J}	O_2
3	T_{31}	T_{32}	T_{33}	…	T_{3j}	…	T_{3J}	O_3
:	:	:	:		:		:	:
i	T_{i1}	T_{i2}	T_{i3}	…	T_{ij}	…	T_{iJ}	O_i
:	:	:	:		:		:	:
I	T_{I1}	T_{I2}	T_{I3}	…	T_{Ij}	…	T_{IJ}	O_I
$\sum_i T_{ij}$	D_1	D_2	D_3	…	D_j	…	D_J	$\sum_i \sum_j T_{ij} = T$

The 4-Step Model: Trip Distribution

- Gravity Model

$$T_{ij} = \alpha_i O_i \beta_j D_j f(C_{ij}),\ i = 1.....I \text{ and } j = 1.....J$$

$$\sum_j T_{ij} = O_i, \qquad i = 1.....I$$

$$\sum_i T_{ij} = D_j, \qquad j = 1.....J$$

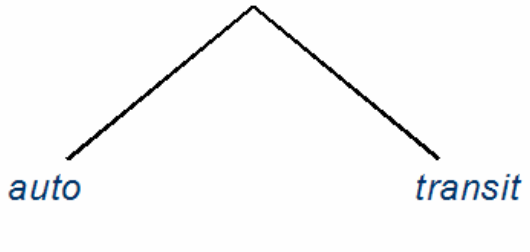
  - Where,
  - $f(C_{ij}) =$ Function of the generalized cost of travel from *i* to *j* and
  - α_i and β_j are balancing factors

Solve iteratively for T_{ij}, α_i and β_j

The 4-Step Model: Modal Split

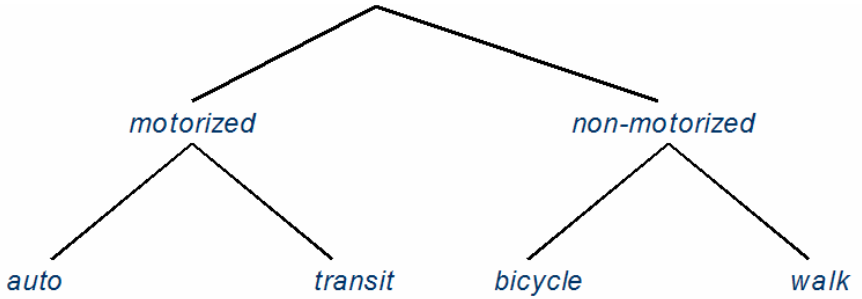
- Logit

$$\mathrm{P}(auto) = \frac{e^{V_{auto}}}{e^{V_{auto}} + e^{V_{transit}}}$$



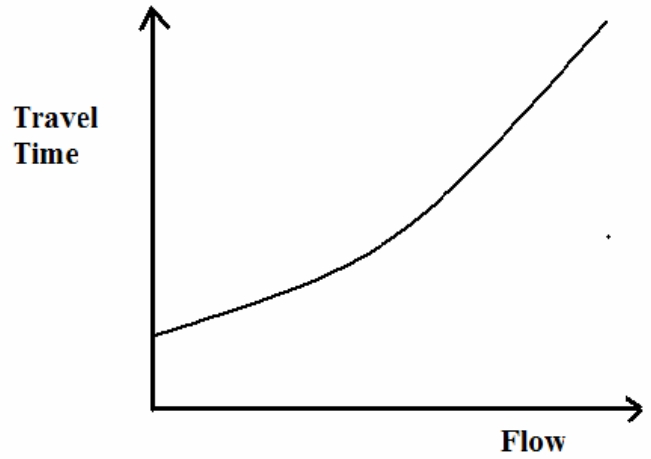
- Nested Logit

$$\mathrm{P}(NM) = \frac{e^{\mu I_{NM}}}{e^{\mu I_{NM}} + e^{\mu I_{M}}}$$



The 4-Step Model: Assignment

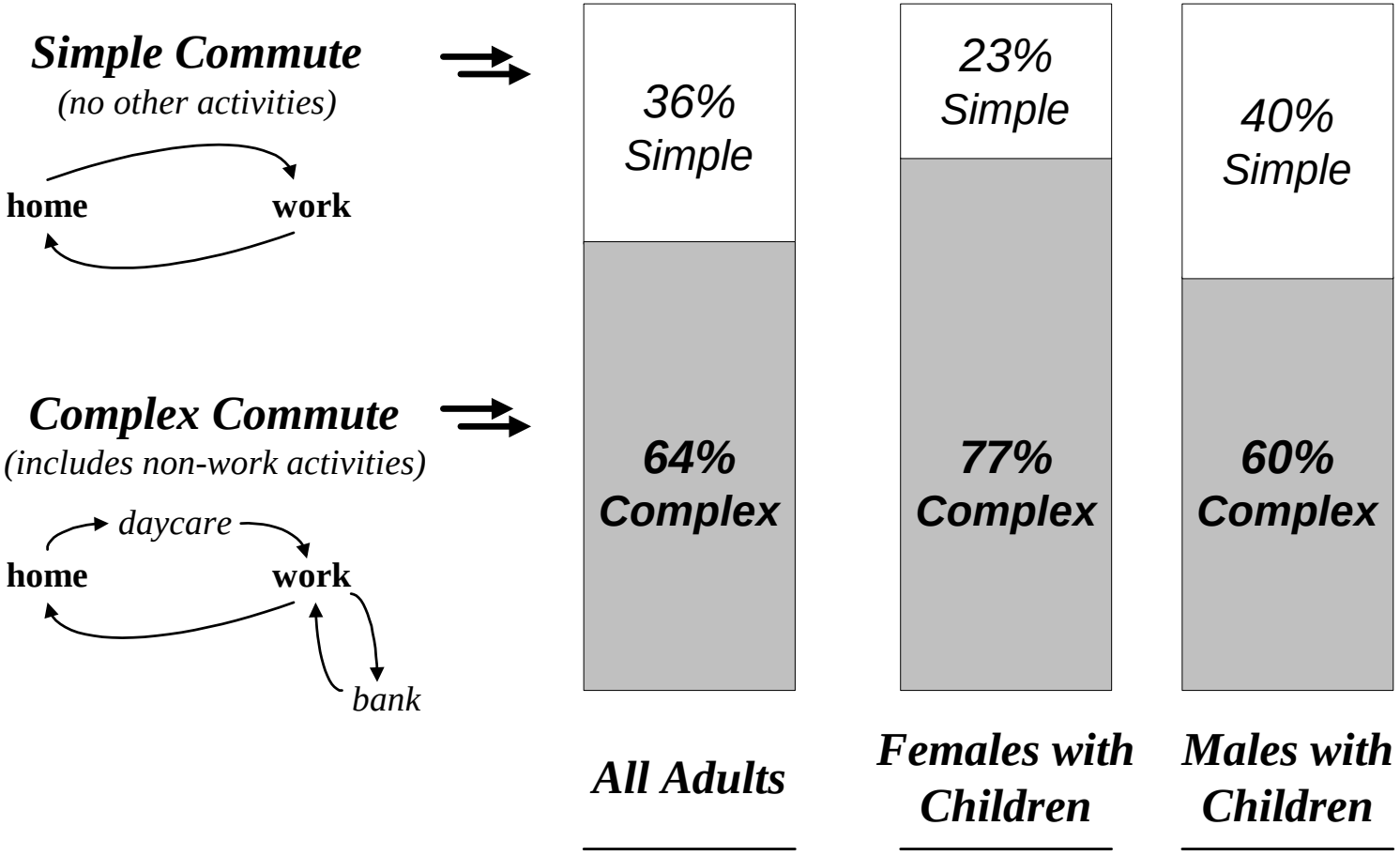
- Route Choice
  - Deterministic: Shortest Path, Minimum Generalized Cost
  - Stochastic: Discrete Choice (e.g. Logit)
- Equilibrium
  - Supply Side
  - User Equilibrium vs. System Optimal



Limitations of the Trip-Based Method

- Demand for trip making rather than for activities
- Person-trips as the unit of analysis
- Aggregation errors:
  - Spatial aggregation
  - Demographic aggregation
  - Temporal aggregation
- Sequential nature of the four-step process
- Behavior modeled in earlier steps unaffected by choices modeled in later steps (e.g. no induced travel)
- Limited types of policies that can be analyzed

Complexity of Work Commute (Boston)



Source: *Ben-Akiva and Bowman, 1998, "Activity Based Travel Demand Model Systems," in Equilibrium and Advanced Transportation Modeling, Kluwer Academic.*

Complex Responses to Policies
Example: Peak-Period Toll

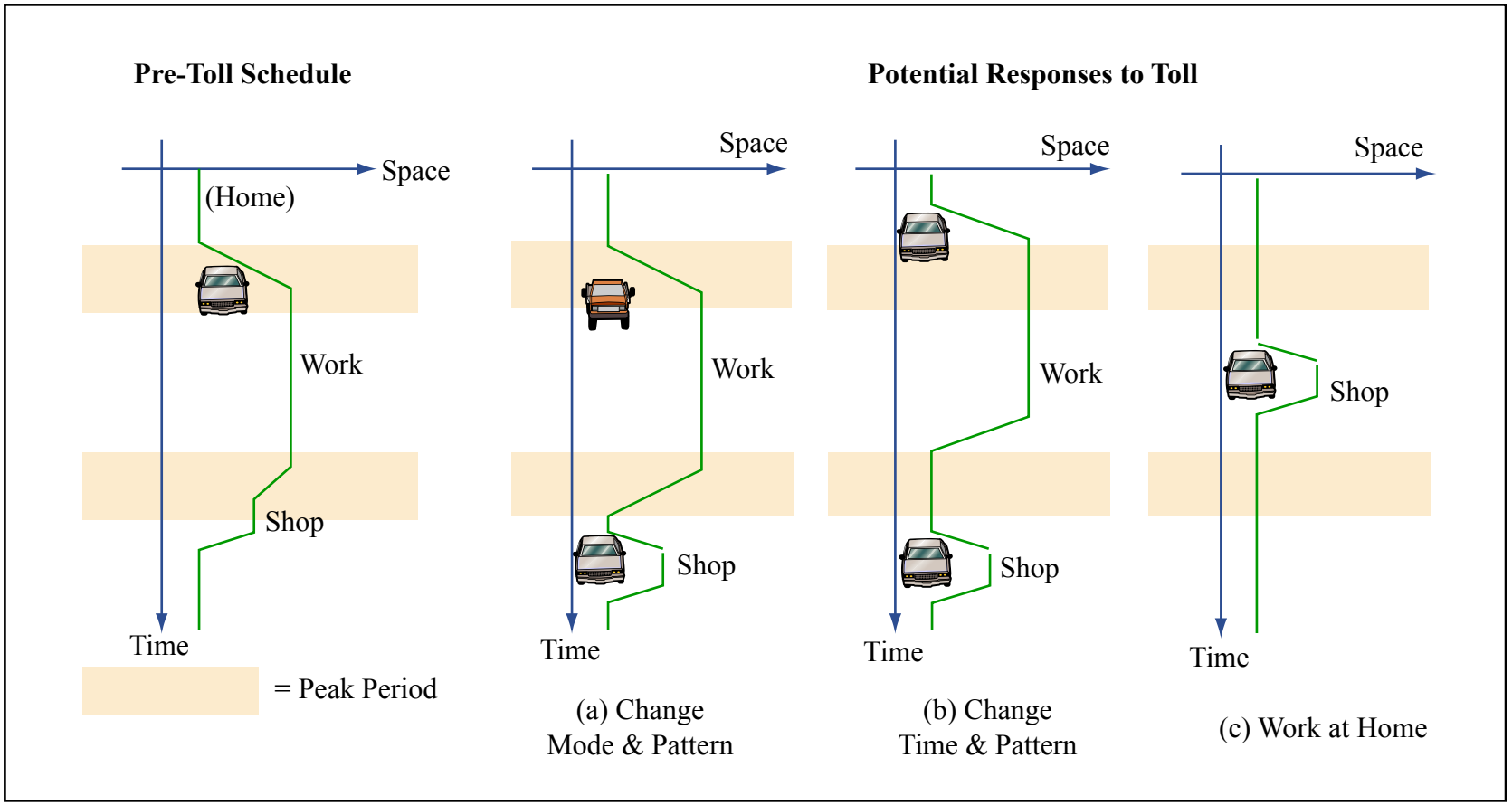


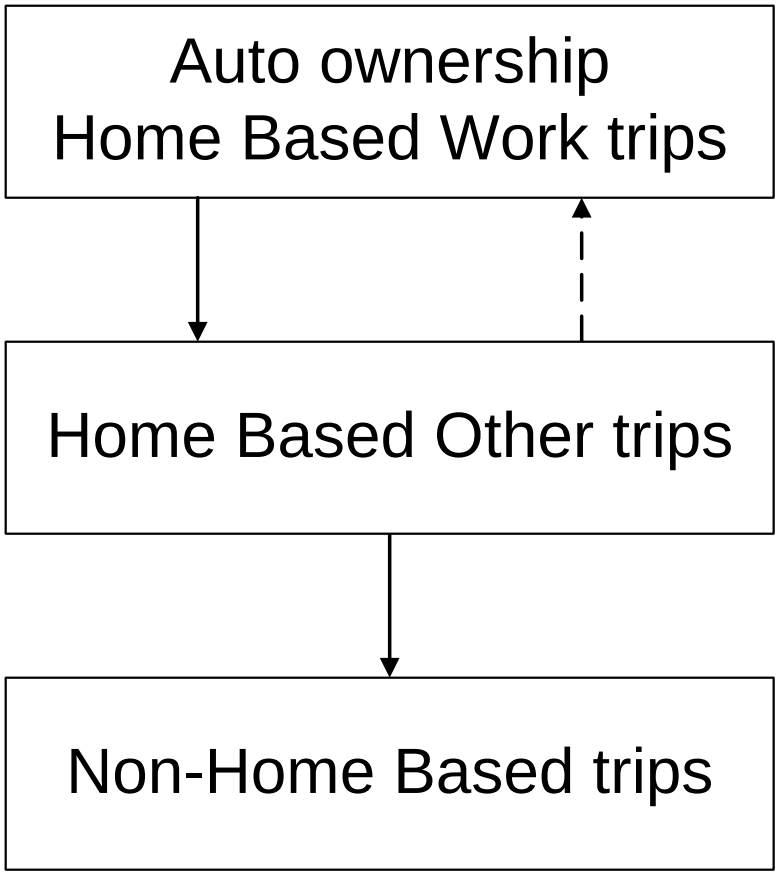
Figure by MIT OpenCourseWare.

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Modeling Travel at the Level of the Individual

- Classic 4-step
  - Trip Frequency
  - Destination Choice
  - Mode Choice
  - Route Choice
- Beyond 4-step
  - Time of Day
  - Integrated Trips
  - Tours

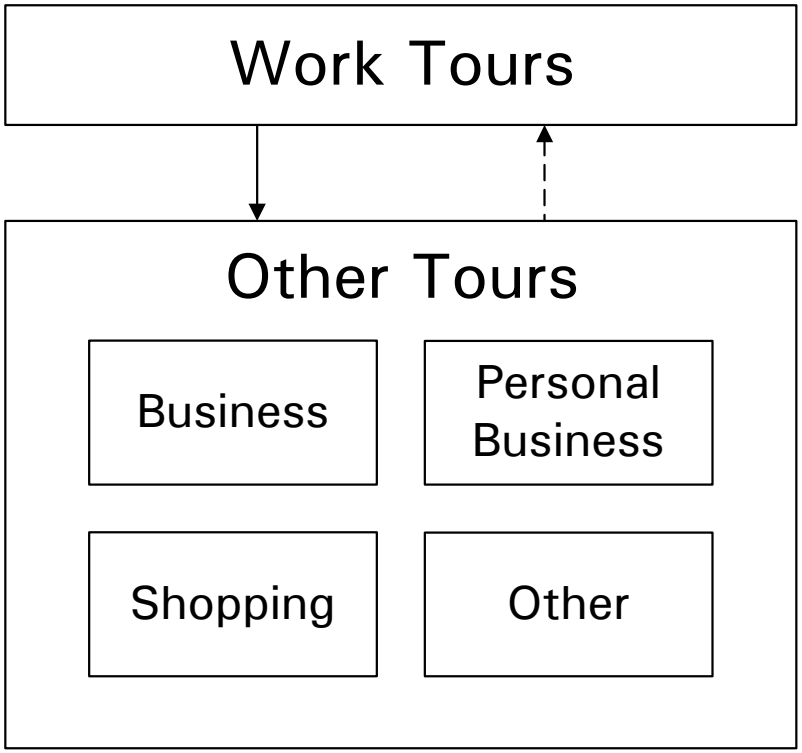
Integrated Trip-Based Framework (e.g., MTC, STEP)



Highlights of Integrated Trip-Based System

- Key features
  - Disaggregate choice models
  - Models are integrated, via conditionality and measures of inclusive value, according to the decision framework
- Key weakness
  - Modeling of trips rather than explicit tours

Tour-Based Framework (e.g. Stockholm)



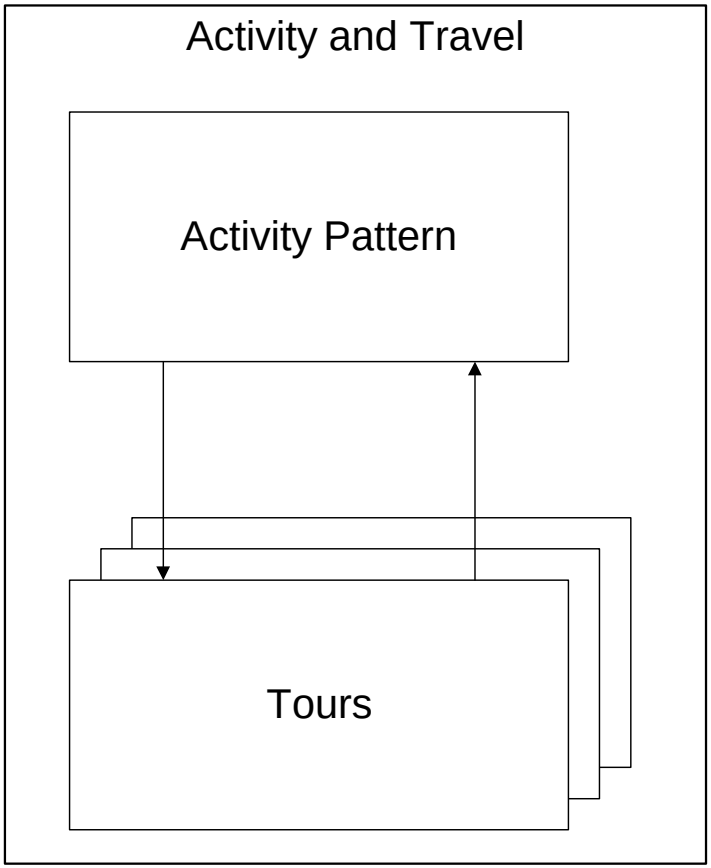
Highlights of Tour-Based System

- Key features
  - Explicitly chains trips in tours
  - Validated and widely applied
- Key weaknesses
  - Lacks an integrated schedule pattern
  - Doesn't integrate well the time dimension
- Data requirements
  - Same as for trip-based models

Basics of Activity-Based Travel Theory

- Travel demand is derived from demand for activities
- Tours are interdependent
- People face time and space constraints that limit their activity schedule choice
- Activity and travel scheduling decisions are made in the context of a broader framework
  - Conditioned by outcomes of longer term processes
  - Interacts with the transportation system
  - Influenced by intra-household interactions
  - Occurs dynamically with influence from past and anticipated future events

Activity Schedule System



Activity Pattern

- Replaces trip and tour generation steps of trip and tour-based models
- Models number, purpose and sequence of tours
  - Tours are interdependent

Table removed due to copyright restrictions.

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Example of Activity Patterns

Portland, OR

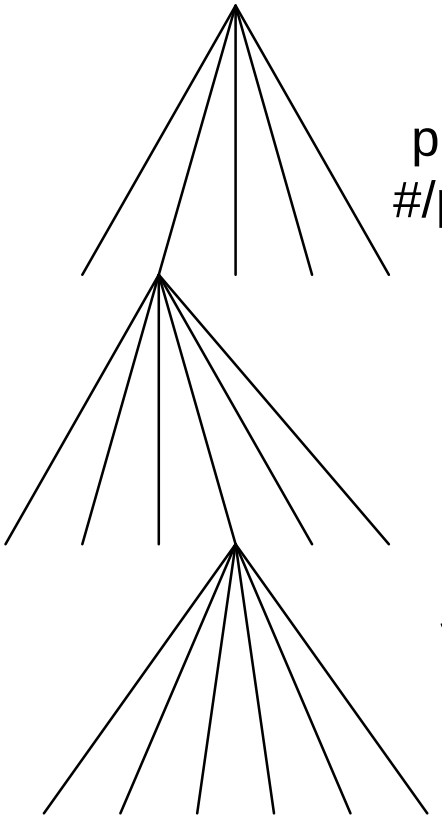
Table removed due to copyright restrictions.

Source: *Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT*

Tours

- Primary Tour
  - Primary and secondary destinations
  - Timing
  - Modes
- Secondary Tours
  - Primary and secondary destinations
  - Timing
  - Modes

Model Structure



Activity Pattern
primary activity/tour type,
#/purpose secondary tours

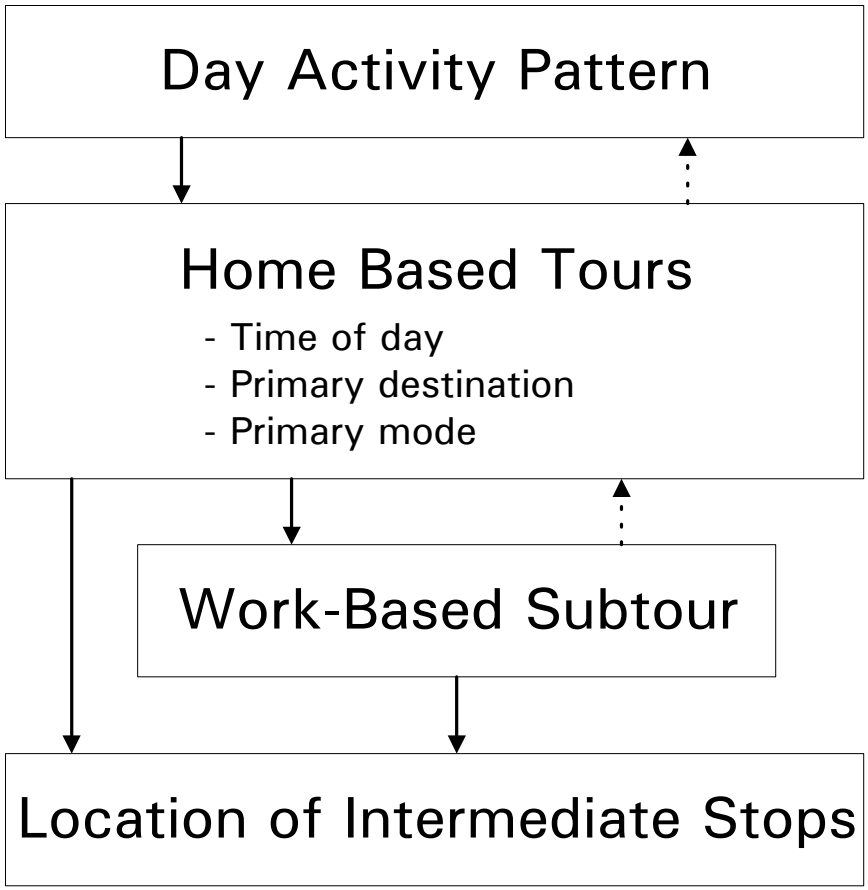
Primary Tours
timing, destination
and mode

Secondary Tours
timing, destination
and mode

Highlights of Activity Schedule System

- Key feature
  - Integrated schedule
- Key weaknesses
  - Larger choice set
    - Unrealistic behaviorally
    - Computationally burdensome
  - Incomplete representation
    - Coarse representation of schedule
    - Coupling constraints

Portland Activity-Based Model [570 Pattern Alternatives]



Preliminary Application Results

$0.50/mile Peak Period Toll

- Shift in patterns

Type of Pattern by primary activity	% before	% change
Work	62.2%	-2.0%
Maintenance	25.0%	3.4%
Leisure	12.8%	3.3%
All patterns	100.0%	

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Preliminary Application Results

$0.50/mile Peak Period Toll

- Shift in work patterns

Type of Work Pattern	% before	% change
At home		
0 sec tours	1.3%	11.5%
1+sec tours	4.0%	6.2%
Simple work tour		
0 sec tours	30.7%	-1.2%
1+sec tours	17.0%	-3.6%
Complex work tour		
0 sec tours	32.6%	-2.3%
1+sec tours	14.3%	-4.7%
Total work patterns	100.0%	-2.0%

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Preliminary Application Results

$0.50/mile Peak Period Toll

- Shift in work tour mode and chaining

Type of work tour	% before	% change
Drive alone simple	36.6%	-20.3%
Drive alone chained	39.2%	-17.3%
Other simple	13.6%	47.4%
Other chained	10.6%	54.9%
Total work tours	100.0%	

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Preliminary Application Results

$0.50/mile Peak Period Toll

- Tour purpose and time-of-day effects

	Percent change in total number of *home-based* tours		
	Work	**Maint.**	**Leisure**
A.M. Peak	-7.10%	-8.40%	-6.20%
P.M. Peak	-7.40%	-7.70%	-1.50%
Midday	3.10%	3.60%	2.80%
Outside Peak	6.80%	2.30%	2.70%
Total	-2.60%	-0.30%	1.00%

Source: Bowman, 1998, "The Day Activity Schedule Approach to Travel Demand Analysis," PhD Thesis, MIT

Trends in Transportation Demand Modeling

- ***DATA:***
  Massive OD Surveys → Small-Scale Detailed Surveys
- ***MODELING METHODS:***
  Aggregate Models → Disaggregate Models
  Static → Dynamic
  Canned Statistical Procedures → Flexible Estimation of Models
- ***APPLICATION/FORECASTING:***
  Mainframe → User-friendly GIS, powerful PC Systems
  Aggregate Forecasting → Disaggregate Forecasting (microsimulation)
- ***BEHAVIORAL REPRESENTATION:***
  Homogeneous → Heterogeneous (including demographics, attitudes and perceptions)
  Trips → Activity Schedules

Emerging Travel Modeling Approaches

- Activity and Trip-Chaining Models
  - Activity time allocation
  - Life cycle, household structure and role
  - Temporal variation of feasible activities over the day
  - Distribution of travel levels of service during the day
- Increased Travel and Information Choices
  - “No travel” options (tele-commuting, tele-shopping, etc.)
  - Information causes changes in departure time, mode and route choice
  - Choice set formation

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