Activity-Based Travel Demand Modeling

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Presentation Structure

- Background
- Need for activity-based travel analysis
- Fundamental concepts and structural framework
- Possible modeling framework
- Recent methodological advances
- Summary and conclusions

Background

- Travel demand models are used to analyze travel characteristics
- Travel forecasts are important determinants of capital decisions
- Improved models can enhance quality of decisions

Evolution of Travel Demand Forecasting Techniques

Zones do not move,
people do

People do not move to travel,
they move to
participate in activities

Aggregate trip-based approach ⇨  ⇨ Disaggregate trip-based approach ⇨  ⇨ Activity-based approach

1960's

1980's

Practical Need for Activity-Based Travel Analysis

- Tour mode ⇔ number of stops ▶
- Substitution effects ▶
- Time of day
  - TCM analysis
  - Link volumes
    - Number of trip starts
    - Travel time duration
  - Cold and hot starts ▶

⇨ Activity-travel patterns along a continuous time domain

- Time-space interactions

Fundamental Concepts

- Travel is a derived demand
- Complex interactions necessitate analyzing sequences or patterns of activity behavior
- Unit of analysis: whole day or longer time period
- Time is a continuous entity
- Interactions exist among individuals

Activity-Travel (AT) Analysis: Structural Framework

Inputs

HH/Individual demographics
AT environment
Medium-range AT decisions

↓

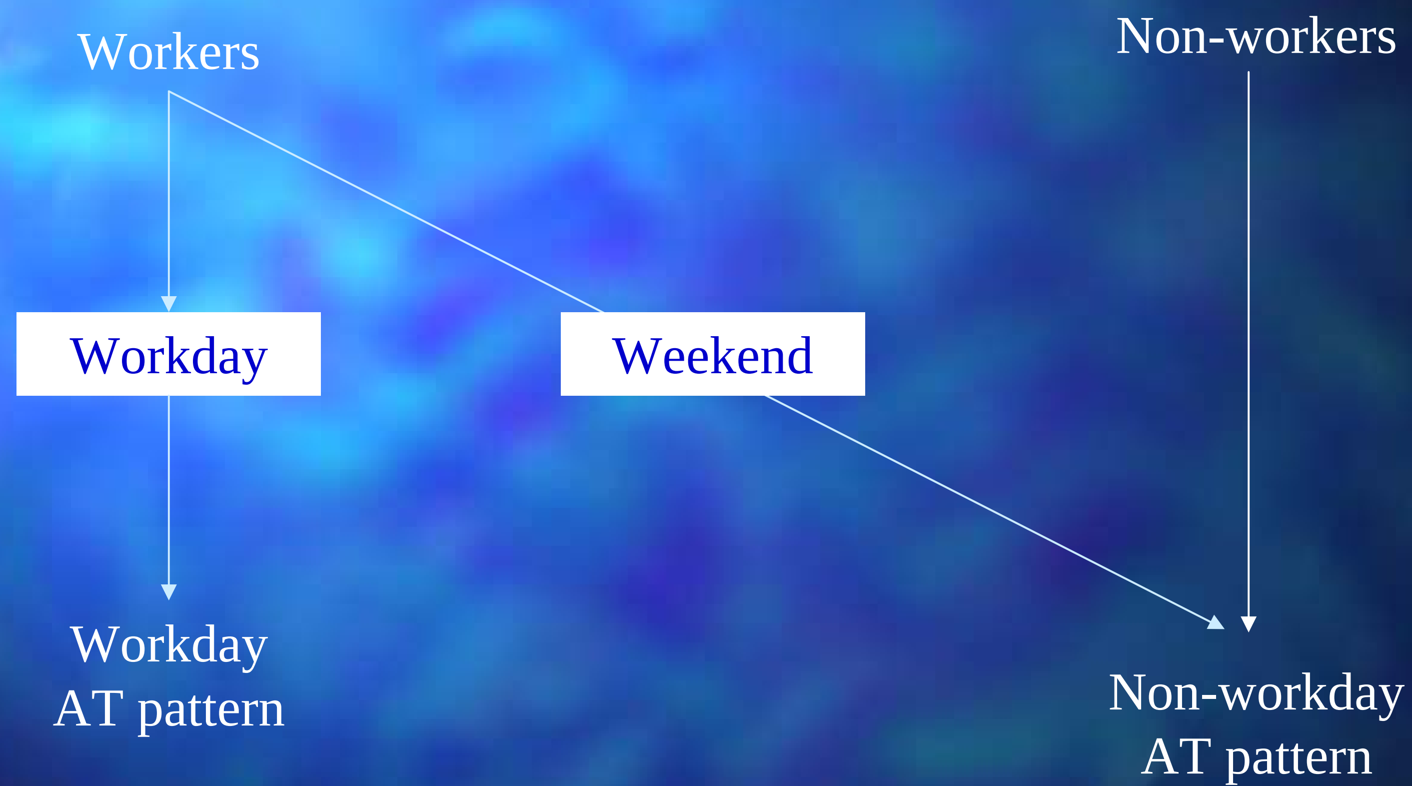
Activity-based travel model

↓

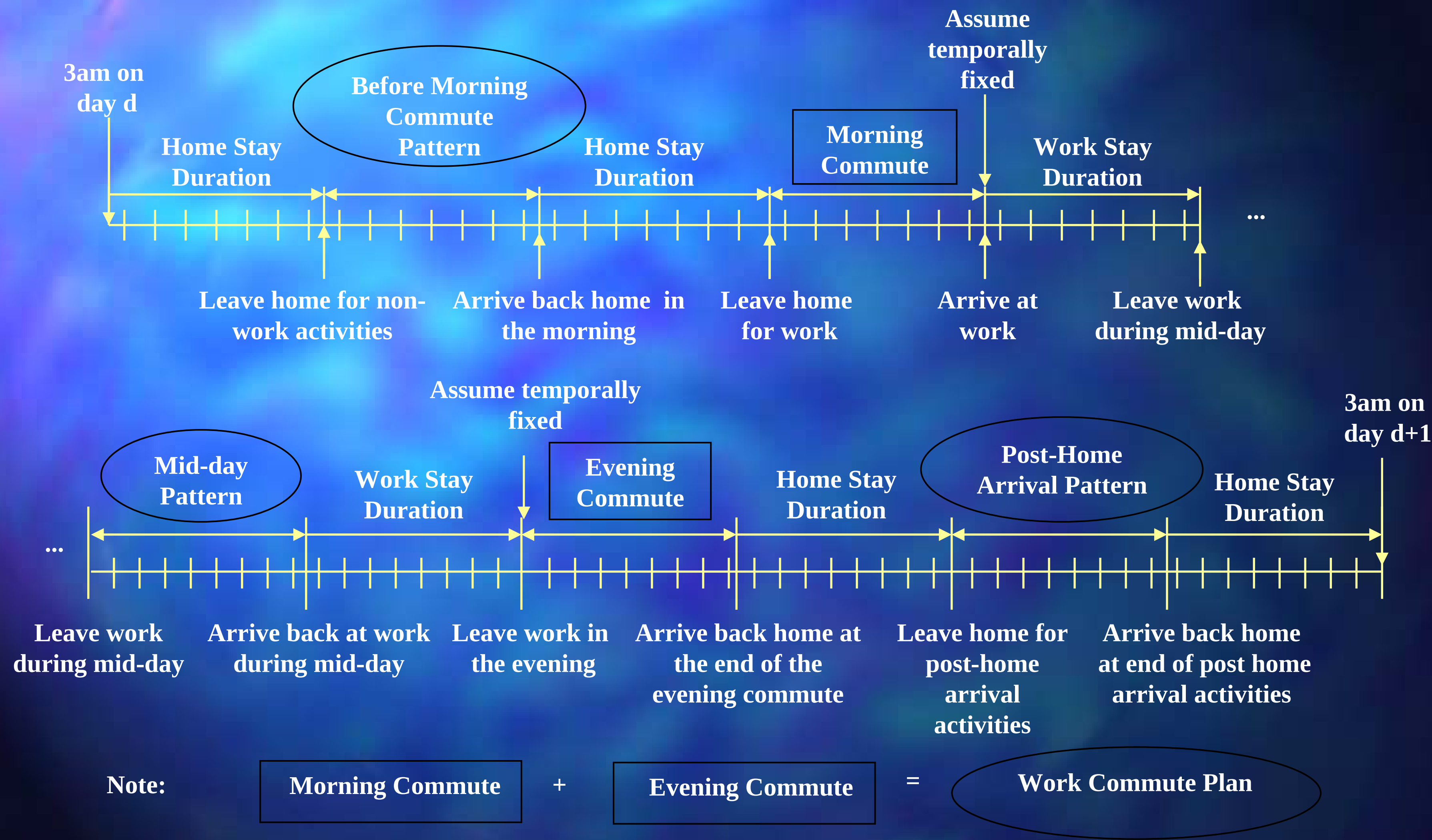
Output

Daily AT pattern

Daily AT Pattern



Worker's Daily Activity Travel Pattern



Attributes of Workday AT Pattern (1)

- Pattern-level attributes
  - Number of tours (before morning commute pattern, midday pattern, post home-arrival pattern)
  - Home-stay duration before morning commute

Attributes of Workday AT Pattern (2)

- Tour-level attributes
  - Travel mode
  - Number of stops
  - Home-stay duration before each tour in the before morning commute and post home-arrival patterns
  - Work stay duration before each tour in midday pattern
  - Sequence of tour in pattern

Attributes of Workday AT Pattern (3)

- Stop-level attributes
  - Activity type
  - Travel time to stop from previous stop
  - Location of stop
  - Sequence of stop in tour

Distribution of Number of Tours

Boston data | Bay Area data

# of tours	Percentage of each number of tours in ...					
	Before work pattern		Mid-day pattern		Post-home arrival pattern	
0	96.9	96.9	65.6	74.0	67.6	79.7
1	3.0	2.9	29.2	22.5	28.5	18.2
2	0.1	0.2	4.0	2.8	3.4	1.9
≥ 3	0.0	0.0	1.2	0.7	0.5	0.3

- Focus on presence/absence of a first tour in each pattern and then model presence/absence of second tour
- Consider interactions in first tour only across different periods of the day

Distribution of Number of Stops

# of stops	Percentage of each number of stops in ...									
	Before work pattern		Morning Commute		Mid-day pattern		Evening Commute		Post-home arrival pattern	
0	96.9	96.9	85.3	85.2	65.6	74.0	64.8	74.0	67.6	79.7
1	2.3	2.2	11.3	11.5	24.6	17.8	24.1	17.8	23.1	14.2
2	0.5	0.5	2.8	2.5	6.4	4.4	7.9	5.1	6.8	3.9
3	0.2	0.3	0.5	0.6	2.4	2.0	2.4	1.9	2.0	1.4
4	0.1	0.1	0.1	0.2	0.5	0.9	0.7	0.9	0.5	0.5
≥5	0.0	0.0	0.0	0.0	0.5	0.9	0.1	0.3	0.0	0.3

- Midday, evening commute, post-home arrival stops ⇨ morning commute stops ⇨ before work stops
- First stop in each period ⇨ second stop ⇨ …

Interaction in Stop-Making Across Different Times of Day

Control Variable	Value Label	Percentage of individuals making a stop during ...					
		Mid-day		Evening commute		Post-home arrival period	
Made a mid-day stop?	Yes No	- -	- -	36.7 34.4	28.0 25.3	32.8 32.2	23.2 20.5
Made an evening commute stop?	Yes No	35.9 33.6	27.6 25.4	- -	- -	25.3 36.3	13.2 22.8
Made a post-home arrival stop?	Yes No	34.8 34.2	27.4 25.6	27.5 38.9	18.1 28.0	- -	- -

Distribution of Activity Type of Stops

Activity type	Percentage of stops for each activity type during ...					
	Mid-day		Evening commute		Post-home arrival period	
Home	11.6	8.9	0.0	0.0	0.0	0.0
Pick-up/drop off	1.5	2.8	10.9	14.4	11.7	11.0
Work-related	18.4	19.3	2.6	10.1	1.8	2.8
School	1.5	0.3	1.6	2.3	1.8	4.2
Shopping	9.6	5.5	30.1	27.2	25.2	24.3
Social/recreational	2.9	3.7	16.5	15.6	32.8	27.3
Eat-out	39.1	41.9	7.0	4.8	11.0	12.4
Personal Business	15.4	13.5	31.3	25.6	15.7	15.7

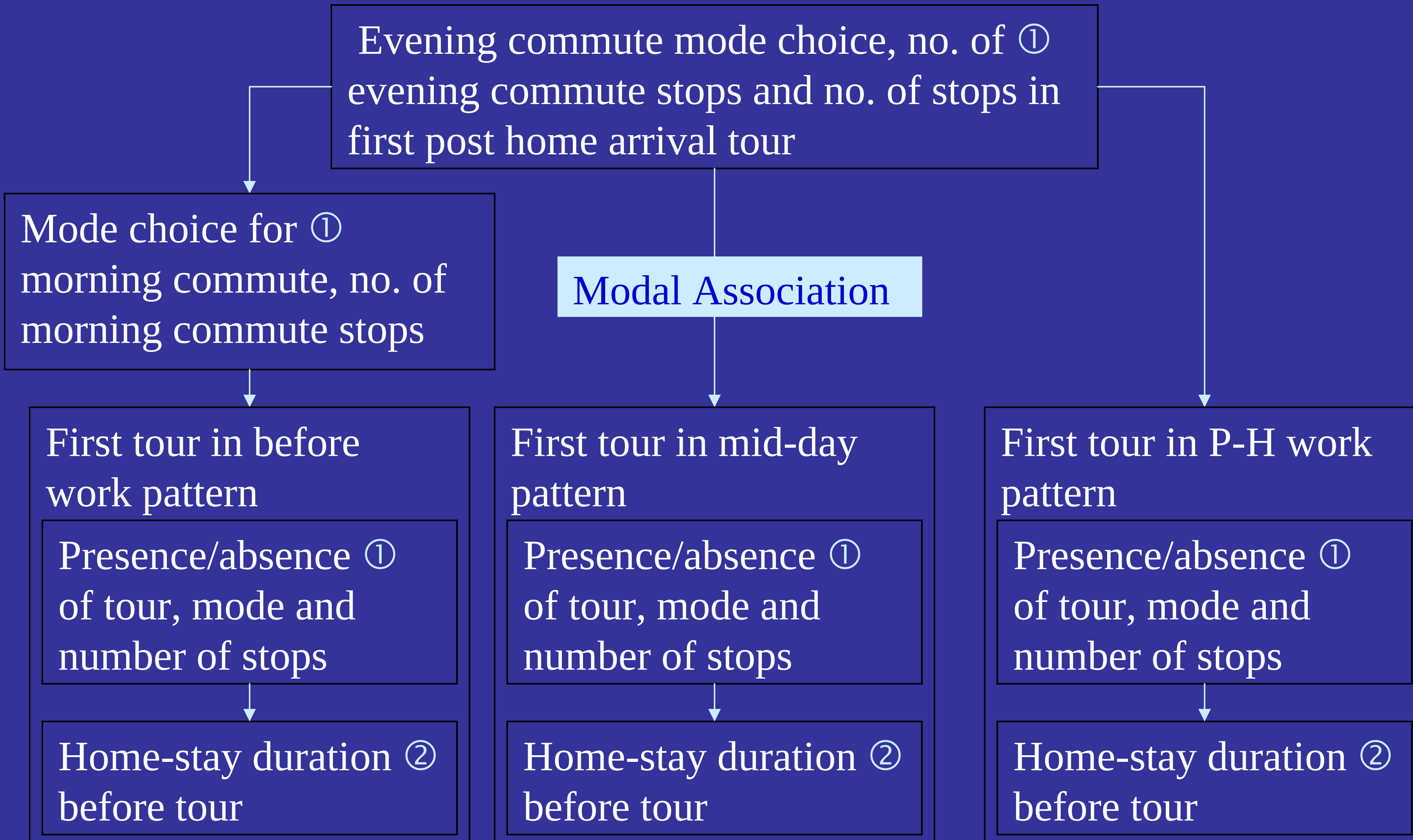
- Model number of stops in evening commute and first post home arrival tour jointly
- Model midday stop making independently

Evening Commute Mode Choice and Number of Stops

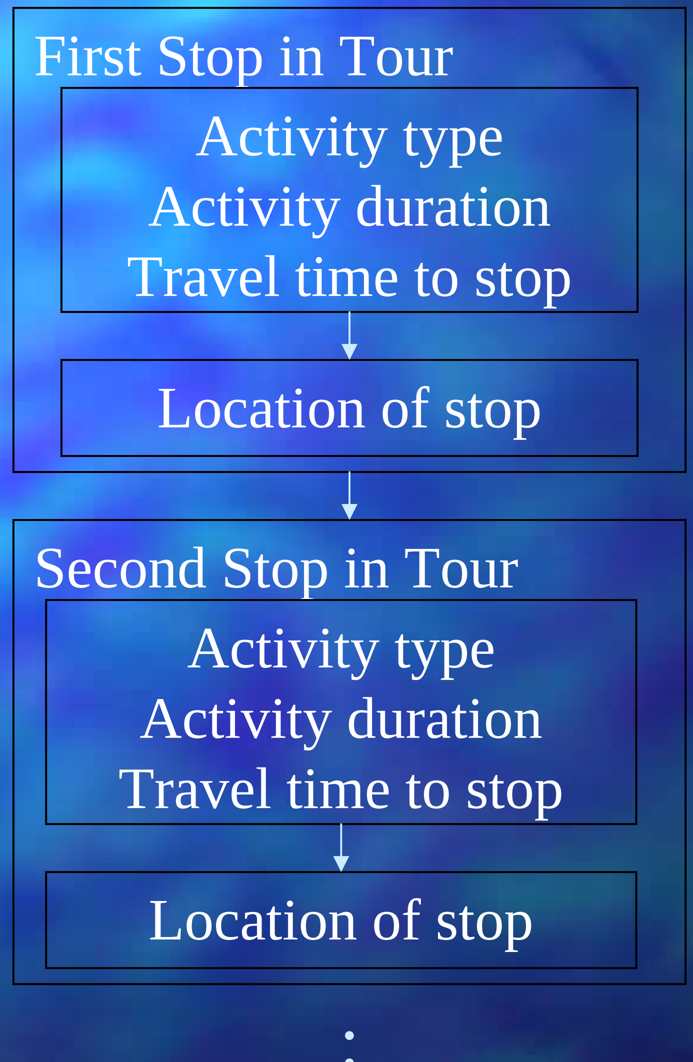
Category	Drive alone	Non-Drive Alone
% making commute stops	37.8	11.7
% making post-home arrival stops	38.6	36.7

- Model evening commute mode choice, number of evening commute stops and number of stops in first post-home arrival tour jointly
- Model travel mode for first post-home arrival tour conditional on number of stops in the tour

Modeling Framework for Pattern/Tour Level Attributes



Modeling Framework for Stop-Level Attributes



Recent Methodological Advances (1)

Motivated by:

- Refinements in discrete choice modeling
- Increasing realization of the need to model travel as part of a more holistic activity-travel pattern

Topics discussed

- Discrete choice models
- Duration modeling
- Limited-dependent variable models

Recent Methodological Advances (2)

Topics not discussed

- Detailed information on model structure/estimation
- Developments in survey data collection or imputation
- Advances in joint estimation from RP-SP data
- Panel data methods
- Computational process models

Discrete Choice Modeling

- Multinomial logit (MNL) model has been most widely used
- MNL model assumptions include:
  - IID type I extreme-value error structure across alternatives
  - Homogeneity in responsiveness to attributes of alternatives
  - Identical error variance-covariance matrix across individuals

Relaxing IID (Across Alternatives)

- Identical, but non-independent random components
- Non-identical, but independent random components
- Non-identical, non-independent random components

Identical, but Non-Independent Random Components

- Normal or type I extreme-value
- Type I extreme-value preferred
- GEV class
  - NL
  - PCL (Chu, Koppelman & Wen)
  - CNL (Vovsha, 1996)
  - OGEV (Small, 1987)
  - MNL-OGEV (Bhat, 1997)

- Advantage: closed-form
- Limitation: restrictions on dissimilarity parameters

Non-Identical, but Independent Random Components

- NE (Daganzo, 1979)
- Oddball model (Recker, 1995)
- HEV (Bhat, 1995)

Non-Identical, Non-Independent Random Components

- Error-components logit or probit (Train, 1995; Ben-Akiva & Bolduc, 1996; Bhat, 1997)

$$
\begin{aligned}
U_i &= V_i + \zeta_i \\
&= V_i + \mu' z_i + \varepsilon_i
\end{aligned}
$$

- MNP (Bunch & Kitamura, 1993; Mahmassani, 1996; marketing)

Relaxing Homogeneity in Responsiveness

Variation in coefficients

- Random coefficients with no systematic coefficient variation (Fischer & Nagin, 1985; Revelt & Train, 1996; Mehndiratti, 1996)
- Random coefficients with systematic variation (Bhat, 1996)

$$U_{qi} = \alpha_i + \delta_i' z_q + \varepsilon_{qi} + \eta_q' x_{qi}$$

$$\eta_{qk} = \pm \exp\left(\gamma_k + \nu_{qk}\right)$$

$$\eta_{qk} = \pm \exp\left(\gamma_k + \beta_k' \omega_{qk} + \nu_{qk}\right)$$

Segmentation Approaches

- Exogenous segmentation
  - Identify mutually-exclusive segments
- Endogenous segmentation (Swait, 1994; Gopinath & Ben-Akiva, 1995; Bhat, 1997; marketing)
  - Probabilistic assignment

Relaxing Error Variance-Covariance Structure Homogeneity Across Individuals

- Variance relaxation (Swait & Adamowicz, 1996; McMillen, 1995; Steckel & Vanhonacker, 1988)
- Covariance relaxation (Bhat, 1997; Kamakura et al., 1996)
- Variance and covariance relaxation

Hazard Duration Models (1)

- Modeling activity duration
- Focus on end-of-duration given that duration has lasted to some specified time
- Two specification issues
  - Distributional assumption regarding duration
  - Assumptions about unobserved heterogeneity

Hazard Duration Models (2)

Baseline hazard distribution

- Parametric (exponential, weibull, log-logistic, gamma, log-normal)
- Nonparametric

Unobserved heterogeneity

- Parametric (gamma, normal)
- Nonparametric
- Mostly ignored in transportation field (but see Bhat, 1996 and Hensher, 1994)

Multiple Duration Process

- More interesting and realistic
- Independence among risks (Gilbert, 1992)
- Competing risks model (Han and Hausman, 1991; Hensher, 1994)
- Generalized multiple-durations model (Bhat, 1996)

Limited-Dependent Variable Models

- Discrete/Continuous (Barnard and Hensher, 1992; Bhat, 1996)
- Discrete/Ordinal (Bhat, 1997)

Summary and Conclusions

The substantial progress can be traced to:

- Need for realistic representation
- Ability to provide micro-level demographic inputs
- Better tools for data storage/processing
- Advent of simulation techniques to approximate multi-dimensional integrals