Activity Based Travel Demand Analysis and Modeling: Progress and Prospects

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Second Oregon Symposium on Integrating Land Use and Transport Models

July 18-20, 2000

Presentation Outline

- Introduction
- Principles and Approaches to Travel Demand Analysis
- Progress in Activity Modeling
- Analysis of Activity Participation
- Modeling Advances
- Future Directions
- Summary and conclusions

Modeling Principle

- Develop the least complex representation of a real-world phenomenon which retains the most important elements of behavior required to enhance understanding and support decision-making.
- The essence of travel behavior is its derivation from the needs/desires of individuals and households to satisfy activity participation needs.

Basis for Enhancements in Activity Based Travel Demand Modeling

- Advances in
  - Modeling
  - Computational and data management capabilities
  - Behavioral understanding
- Enable the development of enhanced activity based models.

Trip-based Approaches to Travel Demand Analysis

- Focuses on independent trips and individuals
- Does not consider relationship between activities and trips
- Does not consider time-use or time of day context in which activity/travel decisions are made

Activity-Based Approaches to Travel Demand Analysis

- Views travel as a “derived” demand
- Framework recognizes complex space-time interactions and time-use context
- Focuses on sequences of activity behavior, with day (or longer) as the unit of analysis
- Treats time as a continuous entity including individual time-use decisions

Activity Based Study Approaches

- Time allocation to activity types
- Time and duration of activity episodes
- **Activity pattern analysis**

Conceptual Origins of Activity Analysis

- Motivation framework - Chapin
- Space-time prism – Hagerstrand
- Incorporation of varying degrees of rigidity of constraints – Cullen and Godson
- Consideration of individual's perception of action space and "bounded" mental capabilities – Heideman

Theoretical Bases for Activity Analysis

- Motivational theories (psychology and anthropology) - behavior is dictated by felt needs
- Sociological and Planning theories - influence of household structure, roles and relationships
- Economic theories - optimal time allocation based on market and non-market constraints
- Geographical and urban planning theory

Develop a Comprehensive Theory of Activity Pattern Analysis

- Integrated theory for time, activity and resource allocation among individuals in a household
  - Time Allocation to Activity Types
  - Scheduling
  - Tours and Stop Assignment
  - Activity and Resource Allocation
  - Mode(s) for each tour
  - Joint Activities

Accommodate Inter-Individual and Time Interactions in Activity Analysis

- Some models treat time as a continuous entity but exclude inter-individual interactions
  - (*e.g.*, Bhat and Singh, 1998; Kitamura and Fujii, 1996)
- Others include inter-individual interactions but treat time as non-continuous
  - (*e.g.*, Wen and Koppelman, 1999; Gliebe and Koppelman, 2000]
- Need to integrate inter-individual interactions within a continuos time domain

Travel Complexity, Prevalence of Multi-Stop Tours

Number of daily stops	Number of home-based tours: *1*	*2*	*3+*
1	43.5%		
2	20.2%	35.7%	
3	15.6%	21.1%	22.3%
4+	20.7%	43.2%	77.7%
Total	100.0%	100.0%	100.0%

Work and Non-work Tours by Gender

Non-work tours	Work tours: *None*	*Female Only*	*Male Only*	*Female & Male*
None	9.1%	12.4%	14.3%	44.2%
Female Only	9.5%	2.8%	48.4%	19.4%
Male Only	12.7%	45.5%	5.3%	16.5%
Female & Male	68.8%	39.3%	32.0%	19.9%
Total	100.0%	100.0%	100.0%	100.0%

Work and Non-work Tours by Gender: No Children

	Work tours			
Non-work tours	*None*	*Female Only*	*Male Only*	*Female & Male*
None	9.8%	8.7%	14.9%	43.8%
Female Only	9.8%	4.3%	49.2%	17.5%
Male Only	14.2%	44.3%	7.0%	19.3%
Female & Male	66.2%	42.6%	28.9%	19.3%
Total	100.0%	100.0%	100.0%	100.0%

Work and Non-work Tours by Gender: Children in Household

	Work tours			
Non-work tours	*None*	*Female Only*	*Male Only*	*Female & Male*
None	7.6%	19.0%	13.2%	44.9%
Female Only	8.8%	0.0%	47.1%	23.2%
Male Only	9.9%	47.6%	2.2%	10.9%
Female & Male	73.7%	33.3%	37.5%	21.0%
Total	100.0%	100.0%	100.0%	100.0%

Activity Pattern Travel Modeling

- Activity generation models
  - Tours, stops, auto and stop allocation
- Activity scheduling models
  - Computerized production systems
- Generation and Scheduling Models
  - Daily activity schedule analysis

The Activity Episode Generation and Scheduling Process

- Information acquisition
- Use of information/perception in activity participation and location decisions?
- Decision structure relationships for attributes of activity episodes
- Role of planning vs. spontaneous decision making in revealed activity patterns.
- Challenge: to understand internal mechanism leading to revealed patterns

Joint vs. Individual Activity Participation

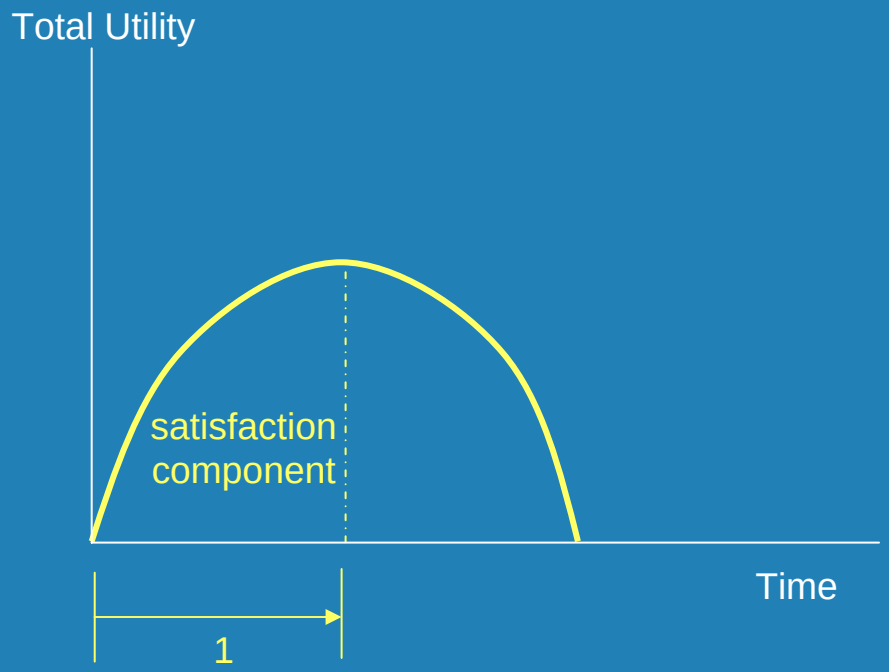
- Motivation
  - Efficiency - task synergy
  - Companionship -- activity is partly or primarily social
  - Altruism -- provide ride or support
- Influencing Attributes
  - Employment
  - Children in household
  - Auto ownership

Patterns of Joint Tours

Start of Joint Sequence	End of joint sequence: *Return home together*	End of joint sequence: *Depart separately*
Leave home together	75.2%	7.5%
Meet out-of-home	11.2%	6.1%

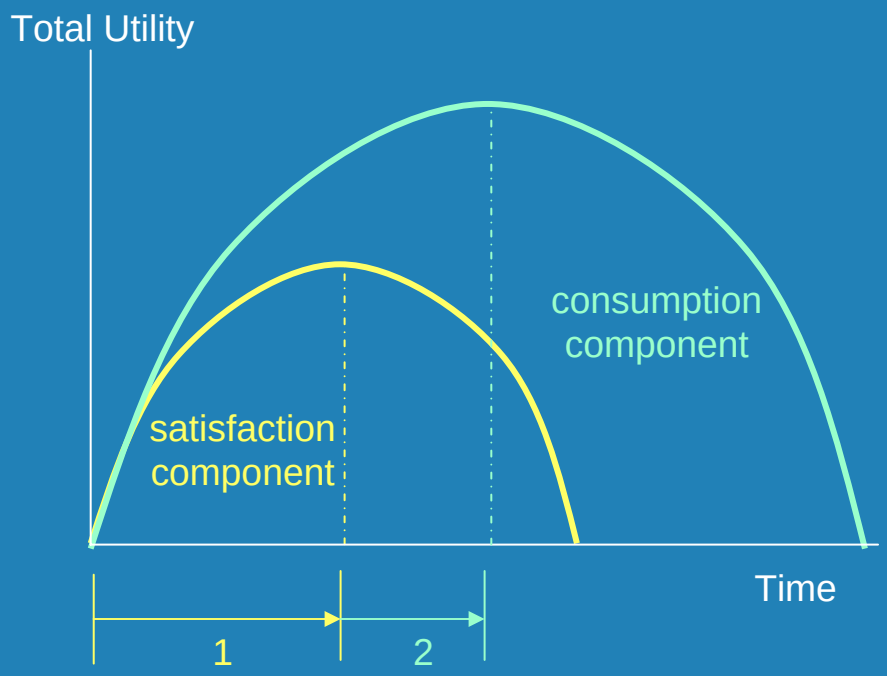
15.2% of all person tours include one or more activity stops

Household / Individual Utility Components



1. Utility associated with value of activity participation

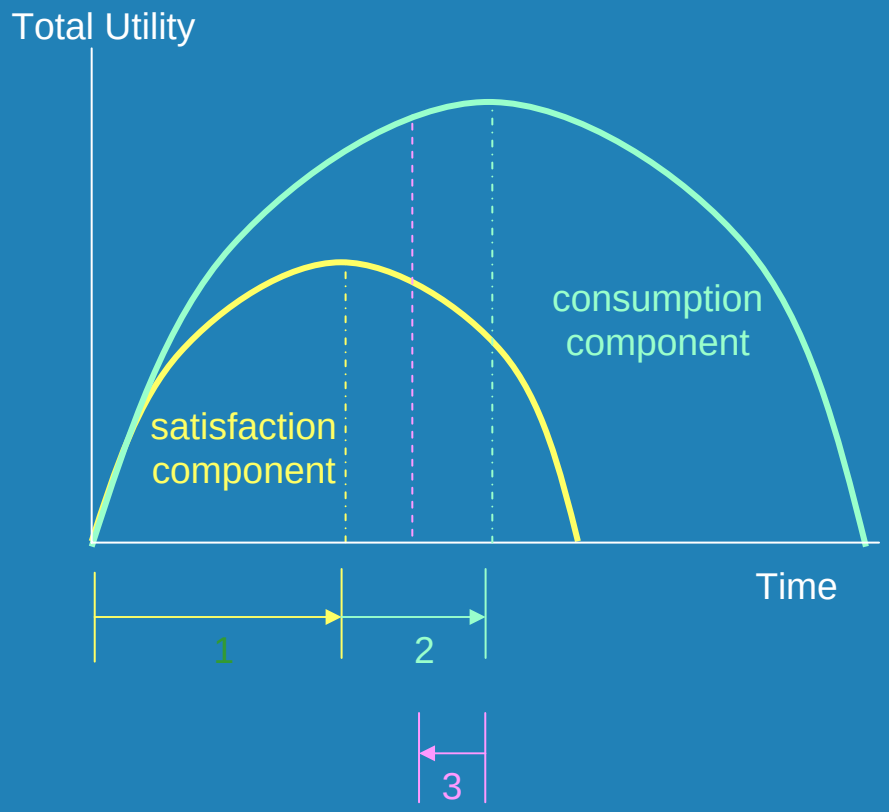
Household / Individual Utility Components



1. Utility associated with value of activity participation

2. Total utility due to activity participation and household consumption effect

Household / Individual Utility Components

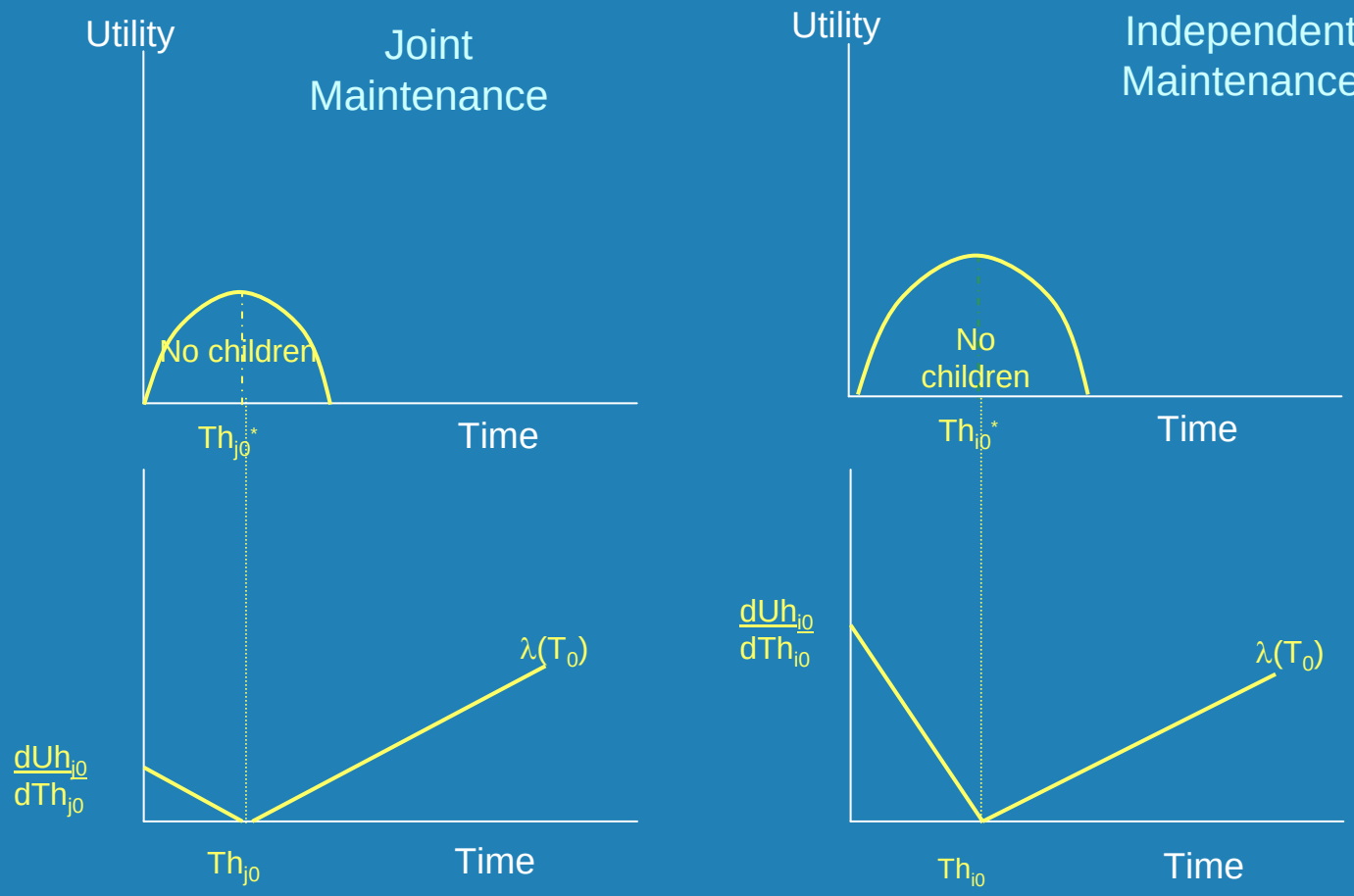


1. Utility associated with value of activity participation

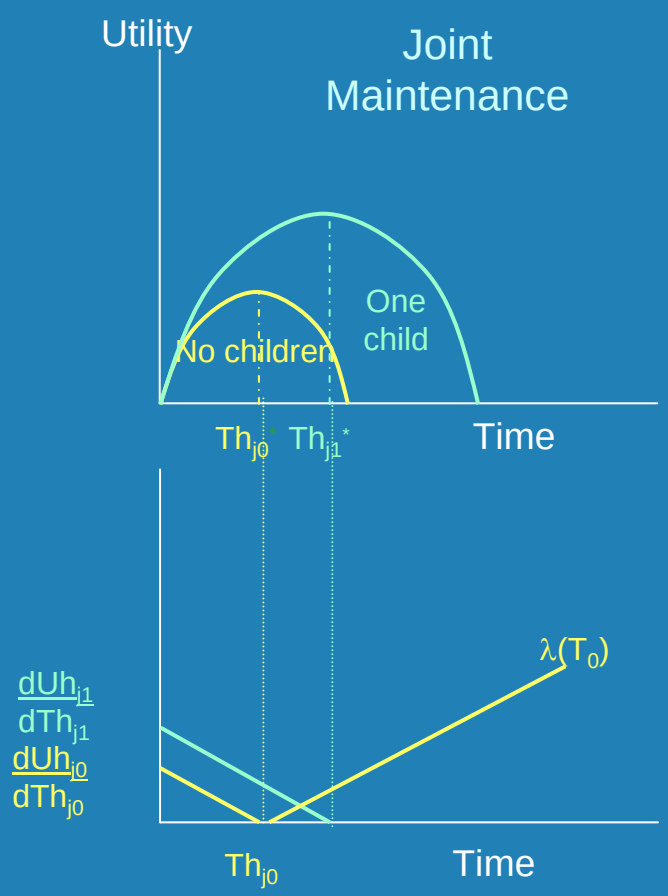
2. Total utility due to activity participation and household consumption effect

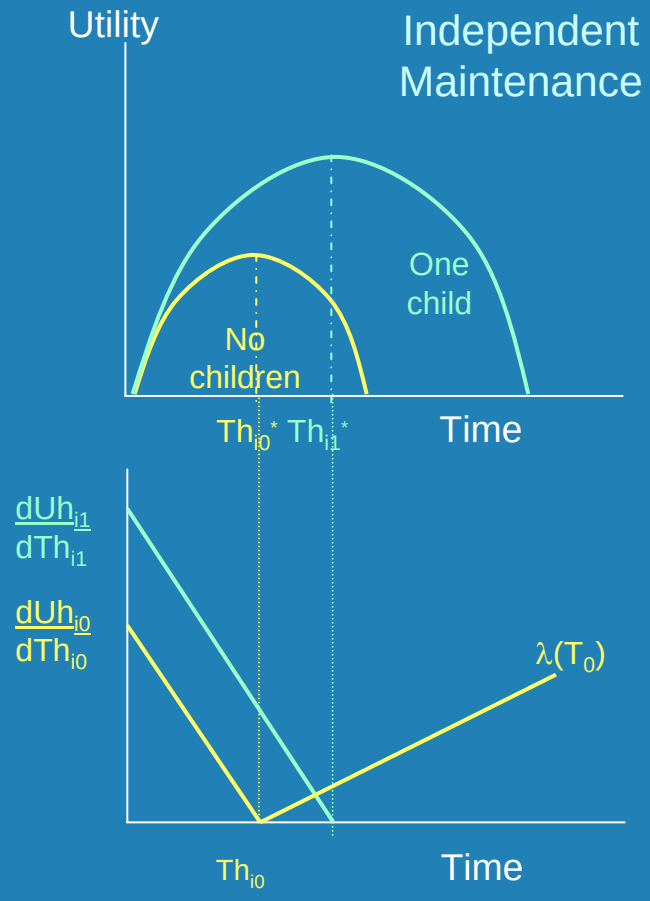
3. Effect of opportunity cost of time

Example: Impact of Young Children



Example: Impact of Young Child





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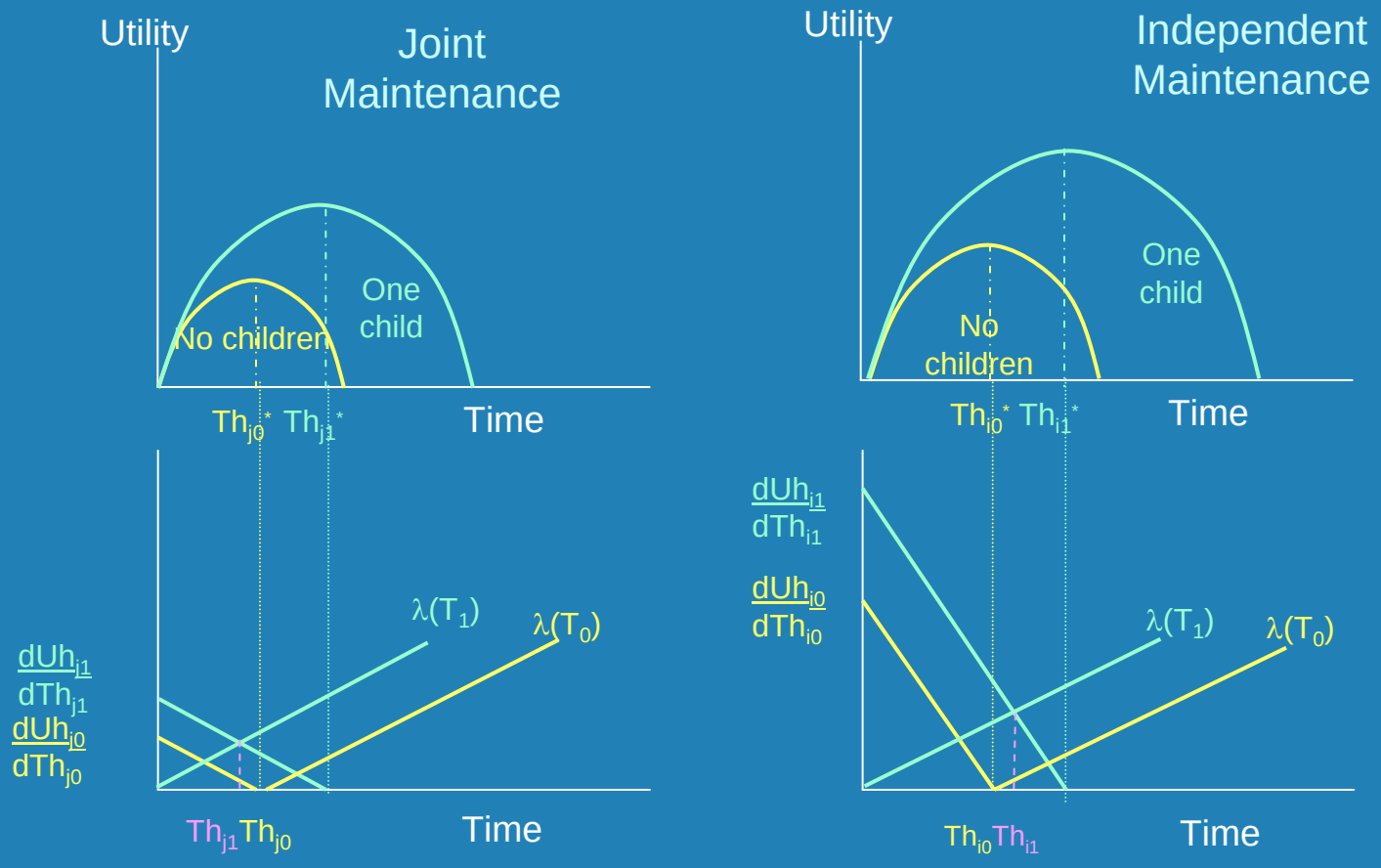


Pattern Analysis Results: Better Specification of Trip-Based Models

- Stop-making effect on mode choice
- Accommodating lifecycle, descriptors; temporal and spatial constraints
- Inter-relationships between home-based and non home-based trips

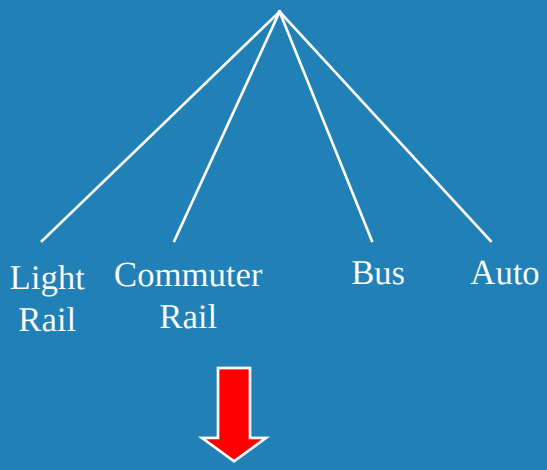
Pattern Analysis Results: Emergence of Comprehensive Activity Models

- Analyze entire daily activity-travel pattern within the context of a continuous time domain
- Enable consideration of substitution in
  - Time
  - Mode
  - Person
  - Location

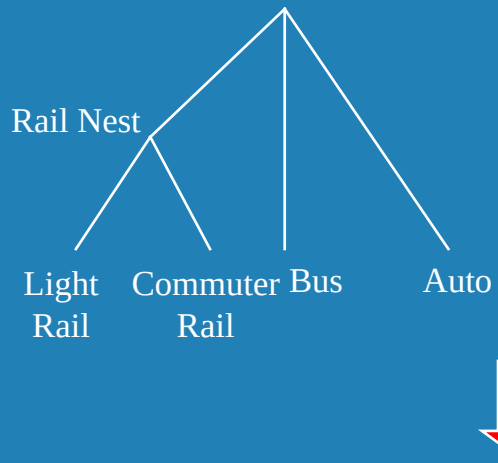
Modeling Substitution

Mode Choice Example

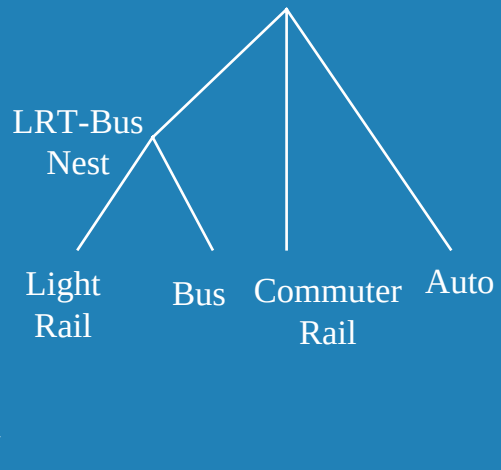
MNL



NL Model 1



NL Model 2



IIA Problem -> Equal Substitution

1. Alleviates IIA problem, but only in part
2. Nesting structure imposes restrictions on substitution relationships between pairs of alternatives

Modeling Substitution (continued)

Generalized Nested Logit (GNL) Model

- Allows alternatives to be assigned to multiple nests in portions to be estimated
- Provides high degree of flexibility in modeling substitution patterns
- Reduces to MNL (and other GEV models) under appropriate restrictions

Modeling Substitution (continued)

GNL Probability Equations

$$P_i = \sum_m \left[\frac{\text{Probability of alternative } i}{\text{Given nest } m \text{ chosen}} \times \text{Probability of nest } m \right]$$

Modeling Substitution (continued)

GNL Probability Equations

$$P_i = \sum_m \left[\frac{(\alpha_{im} e^{V_i})^{\frac{1}{\theta_m}}}{\sum_{j \in N_m} (\alpha_{jm} e^{V_j})^{\frac{1}{\theta_m}}} \times \frac{\left(\sum_{j \in N_m} (\alpha_{jm} e^{V_j})^{\frac{1}{\theta_m}} \right)^{\theta_m}}{\sum_m \left(\sum_{j \in N_m} (\alpha_{jm} e^{V_j})^{\frac{1}{\theta_m}} \right)^{\theta_m}} \right]$$

V_i is the systematic component of the utility for alternative i

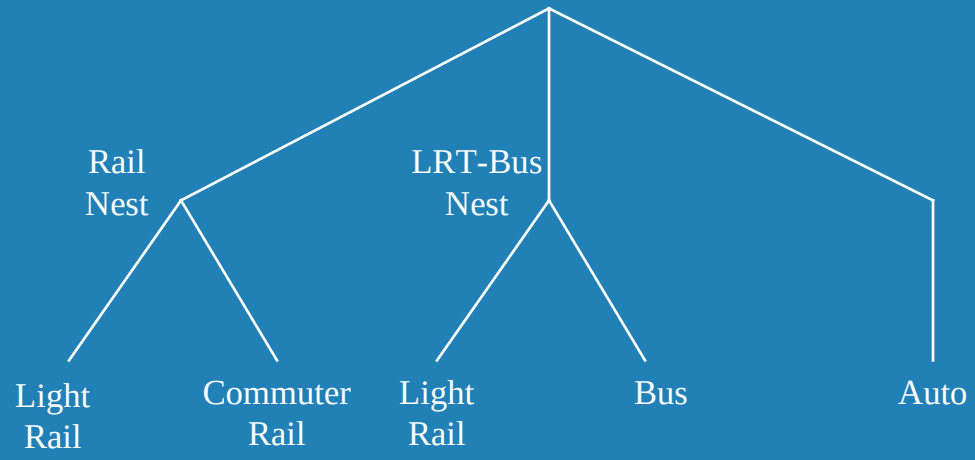
N_m is the set of all alternatives included in nest m

θ_m is the similarity parameter for nest m

α_{im} is the portion of alternative i allocated to nest m

Modeling Substitution (continued)

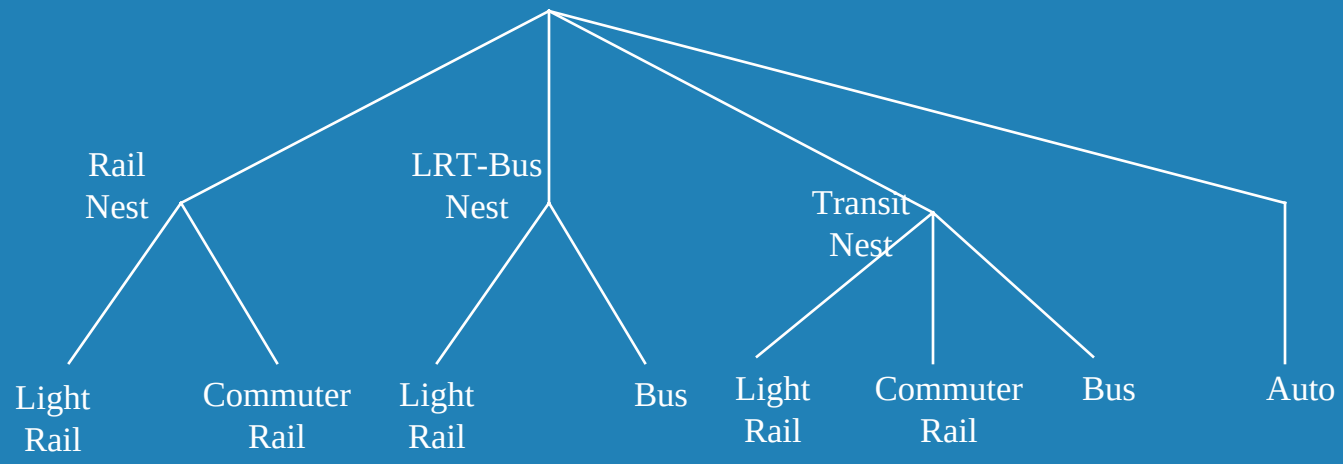
GNL Model 1



- Allows differential substitution between Light Rail-Commuter Rail and Light Rail-Bus

Modeling Substitution (continued)

GNL Model 2



- Provides increased flexibility over GNL1 by adding nest for all transit alternatives

Implication for Regional and Statewide Activity Modeling

- Enhancement of policy analysis (policies which influence individual/household activity patterns)
  - Urban development and location patterns
  - Transportation service improvements
- Improved quality of life analysis
- Improved linkage between state and metropolitan area studies

Future Directions

- Inter-individual interactions
- Time-space interactions
- In-home and out-of-home activity substitution
- Household as unit of analysis
- The decision mechanism

Summary

- Substantial progress in empirical research in recent years
- Activity based travel paradigm is increasingly accepted as the basis for demand analysis
- Important theoretical and methodological advances still to be made
- Limited knowledge of the fundamental mechanism underlying activity pattern decisions