

Activity-Based Models: Too Many Choices to Handle

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Outline

Activity-based models

Choice modeling

Combinatorial choices

Introduction



Why do people travel?

Most of the time, not for the sake of it.

They perform activities spread in space and time.

Activities

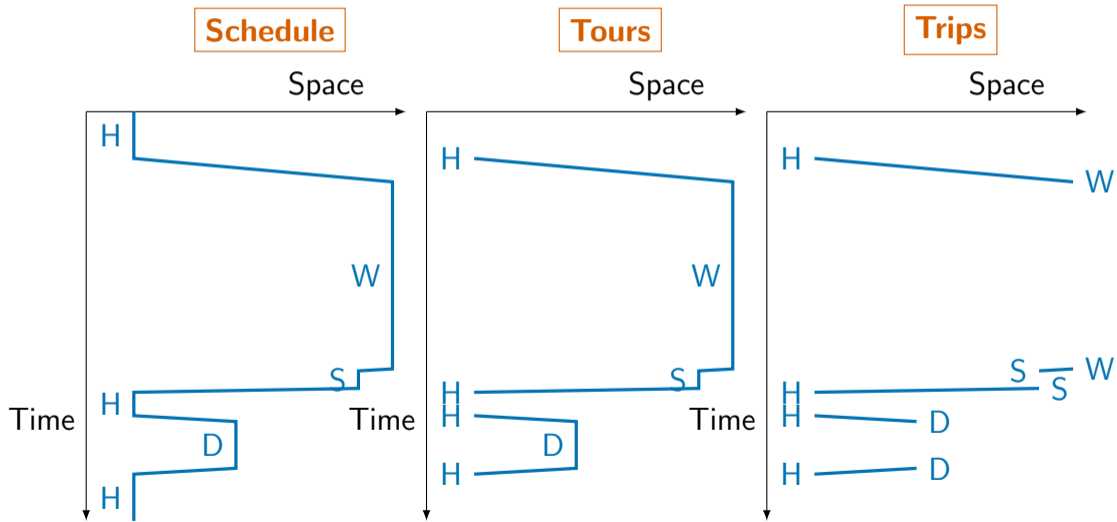
Primary

- ▶ home-based,
- ▶ work,
- ▶ education.

Secondary

- ▶ leisure,
- ▶ shopping,
- ▶ escort,
- ▶ business,
- ▶ etc.

Travel demand models



H: Home, W: Work, S: Shop, D: Dining out [Source: M. Ben-Akiva]

Combination of many choices

- ▶ Activity participation
- ▶ Activity type
- ▶ Activity location
- ▶ Activity timing
- ▶ Activity duration
- ▶ Activity scheduling
- ▶ Activity frequency
- ▶ Travel mode choice
- ▶ Route choice
- ▶ Departure time choice
- ▶ Trip chaining / Tour formation
- ▶ Vehicle usage
- ▶ Parking choice
- ▶ Joint activity participation
- ▶ Ride-sharing / Carpooling decision
- ▶ Household resource allocation
- ▶ Teleworking decision
- ▶ Trip cancellation or rescheduling
- ▶ Use of on-demand mobility services
- ▶ ... and many more

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Predicting choice behavior



Decision rule

Homo economicus

Rational and narrowly self-interested economic actor who is optimizing her outcome

Behavioral assumptions

- ▶ The decision maker solves an optimization problem.
- ▶ The analyst needs to define
 - ▶ the decision variables,
 - ▶ the objective function,
 - ▶ the constraints.

Continuous case: classical microeconomics

Optimization problem

$$\max_q \tilde{U}(q; \theta)$$

subject to

$$p^T q \leq I, q \geq 0.$$

Demand function

- ▶ Solution of the optimization problem.
- ▶ KKT optimality conditions:

$$q^* = f(I, p; \theta)$$

Discrete choices



How does it work for discrete choices?

Utility maximization

Optimization problem

$$\max_{q,w} \tilde{U}(q, w; \theta)$$

subject to

$$\begin{aligned} p^T q + c^T w &\leq I \\ \sum_j w_j &= 1 \\ w_j &\in \{0, 1\}, \forall j. \end{aligned}$$

where $c^T = (c_1, \dots, c_j, \dots, c_J)$ contains the cost of each alternative.

Derivation of demand functions

- ▶ Mixed integer optimization problem
- ▶ No optimality condition
- ▶ Impossible to derive demand functions directly

Derivation of the demand functions

Step 1: condition on the choice of the discrete good

- ▶ Fix the discrete good(s), that is select a feasible w .
- ▶ Derive the conditional demand functions from KKT.

Step 2: enumerate all alternatives

- ▶ Enumerate all alternatives.
- ▶ Compute the conditional indirect utility function U_i .
- ▶ Select the alternative with the highest U_i .



Enumerate all alternatives ???????

- ▶ Activity participation
- ▶ Activity type
- ▶ Activity location
- ▶ Activity timing
- ▶ Activity duration
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Also relevant in non transportation contexts



Starbucks has 383 billion unique latte combinations, [Merritt, 2023]

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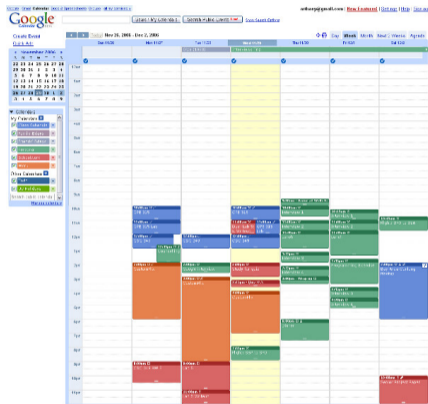
Combinatorial choices

Mathematical optimization

- ▶ Each individual is solving a combinatorial optimization problem.
- ▶ Decisions: see the long list before...
- ▶ Objective function: utility (to be maximized).
- ▶ Constraints: complex rules.

[Pougala et al., 2022]

Example: activity schedule



The context

- ▶ Given a list of potential activities,
- ▶ with preferred starting time and duration,
- ▶ identify a feasible schedule,
- ▶ that maximizes utility.

Combinatorial choice model

Decision variables

$$\phi \in \{0, 1\}^K$$

Total: 2^K combinations.

Choice set: defined by constraints

$$\mathcal{C}_n = \{\phi \mid g_n(\phi) \leq 0, h_n(\phi) = 0\}.$$

Combinatorial choice model

Utility

$$U_{\phi,n} = V_n(\phi, x_n, \xi_n; \theta) + \nu_{\phi,n},$$

where

- ▶ $\nu_{\phi,n}$ are i.i.d. extreme value,
- ▶ ξ_n is a random vector, capturing
 - ▶ correlation among alternatives,
 - ▶ taste heterogeneity,
 - ▶ etc.
- ▶ θ is a vector of unknown parameters, to be estimated from data.

Combinatorial choice model

Mixture of logit models

$$P_n(\phi|x_n, \xi_n; \theta) = \frac{e^{U_{\phi,n}}}{\sum_{\ell \in \mathcal{C}_n} e^{U_{\ell,n}}},$$

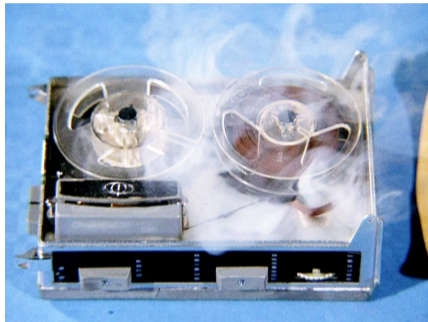
$$P_n(\phi|x_n; \theta) = \int_{\xi} P_n(\phi|x_n, \xi_n; \theta) d\xi.$$

Main challenge

- ▶ Enumeration of \mathcal{C}_n is impossible.
- ▶ Calculating the probability is impossible.

MISSION: IMPOSSIBLE

Challenges



Your mission, should you choose to accept it

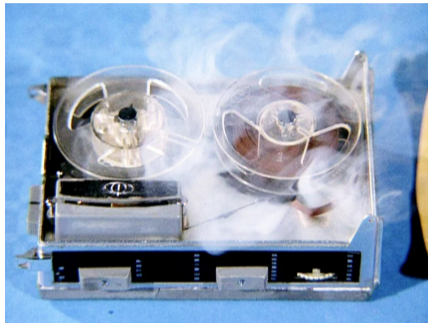
- Use the model for prediction.
- Estimate its parameters from data.



Anne-Valérie Preto

- ▶ Started May 2025.
- ▶ Bayesian methodology: Markov chain Monte-Carlo methods.
- ▶ New method: adaptive sampling.
- ▶ Current achievement: $22\times$ faster for a model with 500 alternatives (54.5 min \rightarrow 2.4 min).

Anne-Valérie's challenges





Your mission, should you choose to accept it...

- Methodology for complex models (mixture models).
- Use real data from SBB.
- Activity-based models.
- Route choice models.

This presentation will self-destruct in 5 seconds.

Bibliography I

-  Merritt, M. (2023). Starbucks has 383 billion drink combinations and wants to make them faster. <https://www.morningbrew.com/daily/stories/starbucks-has-383-billion-drink-combinations>. Accessed: 2025-06-09.
-  Pougala, J., Hillel, T., and Bierlaire, M. (2022). Capturing trade-offs between daily scheduling choices. [Journal of Choice Modelling](#), 43(100354). Accepted on Mar 19, 2022.