CIE4801 Transportation and spatial modelling
Mode choice

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• What’s it about
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• Trip distribution revisited
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1.

Mode choice: what’s it about?
Introduction to modal split

- Zonal data
  - Trip production / Trip attraction
    - Trip frequency choice
      - Destination choice
        - Mode choice
          - Time choice
            - Route choice

- Transport networks
  - Trip distribution
  - Modal split
    - Assignment
      - Travel times
        - network loads
          - etc.
What do we want to know?
Introduction to modal split

**Given:** The number of trips of each OD pair

**Determine:**
- The number of trips of each OD pair for each mode

Diagram:
- All modes
- Car
- Train
- Bike
Selection of modes
trips and trip kilometres

- car driver
- car passenger
- train
- bus/tram/metro
- moped
- bicycle
- walking
- rest
2.1

Method 1: Descriptive
Travel time ratio (VF)

- Ratio between travel time by public transport and travel time by car

- Data used: observed trips where PT might be attractive
  - i.e. train service or ‘express’ service available
  - Public transport: Access and egress time to main PT mode, waiting time first stop, in-vehicle time of main PT mode, waiting time transfer
  - Car: travel time based on fixed speeds per area and period of day, parking

- Basic version: \( P_{pt} = e^{-0.45VF^2} + 0.02 \)

- Elaborate model: \( P_{pt} = e^{-0.36VF^2-0.17N_t\cdot\frac{1.35}{F}+0.23} + 0.03 \quad N_t=\text{transfers}, \; F=\text{frequency} \)
Travel time ratio (basic version)

![Graph showing the relationship between travel time ratio and percentage PT. The x-axis represents travel time ratio ranging from 0.5 to 3.5, while the y-axis represents percentage PT ranging from 0% to 100%. The graph points decrease as the travel time ratio increases.]
2.2

*Method 2: Choice modelling*
Mode choice model

\[ \beta_{ijv} = \frac{\exp(\mu V_{ijv})}{\sum_{w} \exp(\mu V_{ijw})} \]

\[ V_{ijv} = \alpha_{0} + \alpha_{1} X_{ij1} + \alpha_{2} X_{ij2} + \alpha_{3} X_{ij3} \]
Mode choice model

\[
\beta_{ijv} = \frac{\exp(\mu V_{ijv})}{\sum_{w} \exp(\mu V_{ijw})}
\]

\[
V_{ijv} = \alpha_0^v + \alpha_1^v X_{ij1} + \alpha_2^v X_{ij2} + \alpha_3^v X_{ij3} + K
\]

- variables (e.g. distance, travel time of each mode, etc.)
- mode-specific constant (includes comfort, status, safety, etc.)
Mode choice model

\[ V_{ca}^{car} = -0.6 \cdot c_{CA}^{car} \]

\[ V_{ca}^{train} = -0.5 - 0.8 \cdot c_{CA}^{train} \]

\[ \beta_{ijv} = \frac{\exp(V_{ijv})}{\sum_{w} \exp(V_{ijw})} \]

\[ \beta_{CA}^{car} = \frac{\exp(-0.6 \cdot 4)}{\exp(-0.6 \cdot 4) + \exp(-0.5 - 0.8 \cdot 3)} \]

\[ = 62\% \]
3.

Trip distribution revisited
Gravity model and distribution functions

- Using distribution functions per mode
  \[ T_{ij} = \rho Q_i X_j F_{ij} \quad \text{with} \quad F_{ij} = \sum_v f_v(c_{ijv}) \]

- Note that this formula also holds per mode
  \[ T_{ij} = \rho Q_i X_j F_{ij} = \rho Q_i X_j \sum_v f_v(c_{ijv}) = \sum_v \rho Q_i X_j f_v(c_{ijv}) = \sum_v T_{ijv} \]
Distribution functions per mode

![Graph showing distribution functions for different modes: Car, PT, Bike. The x-axis represents travel time in minutes, ranging from 0 to 60. The y-axis represents distribution function values, ranging from 0 to 16. The graph compares the distribution of travel times for each mode.]
## Example mode choice

### Zoetermeer - TU Delft

- Car: 30 min
- PT: 50 min
- Bike: 45 min

### Function values

- Car: 1.12
- PT: 0.40
- Bike: 0.04

### Result

- Car: 71%
- PT: 27%
- Bike: 2%

Total: 1.59
Doubly constrained simultaneous distribution/modal split model

\[ T_{ijv} = a_i b_j P_i A_j F_{ijv} \quad \text{with} \quad F_{ijv} = f_v(c_{ijv}) \]

\[ \sum_j \sum_v T_{ijv} = P_i \quad \text{and} \quad \sum_i \sum_v T_{ijv} = A_j \]

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Can be solved in a similar way as the standard doubly constrained model
Alternative approach: aggregate costs

General gravity model for trip distribution:

\[ T_{ij} = \rho Q_i X_j F_{ij} \quad \text{with} \quad F_{ij} = f(c_{ij}) \]

Which travel costs \( c_{ij} \) do we use?
Every mode may have different travel costs \( c_{ijv} \).

Example

A trip from Rotterdam to Delft takes 20 minutes by car and 35 minutes by bus.
What is the travel cost between Rotterdam and Delft?
Which costs should be applied?

1. Minimum cost
   \[ c_{ij} = \min_v \{c_{ijv}\} \]  
   \[ c_{ij} = 20 \]

2. Logit analogy
   \[ c_{ij} = -\frac{1}{\mu} \ln \left( \sum_v \exp(-\mu c_{ijv}) \right) \]  
   \[ c_{ij} = 18 \ (\mu = 0.1) \]  
   \[ c_{ij} = 20 \ (\mu = 1) \]

3. Electric circuit analogy
   \[ c_{ij} = \frac{1}{\sum_v (1/c_{ijv})} \]  
   \[ c_{ij} = 12.7 \]

4. Average costs
   \[ c_{ij} = \frac{1}{V} \sum_v c_{ijv} \]  
   \[ c_{ij} = 27.5 \]
Derivation of logit analogy

Probability of choosing alternative $j$?
Let’s first look at the mode choice for $j$

\[
P_{ijv_i} = \frac{\exp(-\mu c_{ijv_i})}{\sum_v \exp(-\mu c_{ijv})}
\]

Translate attractiveness of all alternatives into costs

\[
c_{ij} = -\frac{1}{\mu} \ln \sum_v \exp(-\mu c_{ijv})
\]
Derivation of logit analogy

Probability of choosing alternative $j$:

$$p_j = \frac{\exp(\mu_d V\left(w_a, X_{ja}, c_{ij}\right))}{\exp(\mu_d V\left(w_a, X_{ja}, c_{ij}\right)) + \sum_{k \neq j} \exp(\mu_d V\left(w_a, X_{ka}, c_{ik}\right))}$$

$$c_{ij} = -\frac{1}{\mu} \ln \sum_v \exp(-\mu c_{ijv})$$
Simultaneous distribution/modal split model

Most of the time, destination choice and mode choice are made *simultaneously* instead of *sequentially*.

Combined choices (e.g. for going shopping):
- Take the train to the center of Amsterdam
- Take the bike to the center of Delft
- Take the car to the center of Rotterdam

General gravity model for simultaneous trip distribution/modal split:

\[ T_{ij} = \rho Q_i X_j F_{ij} \text{ with } F_{ij} = f(c_{ij}) \text{ or } F_{ij} = \sum_v f(c_{ijv}) \]
4.

Special topics
Special topics

- Role of constraints: Car ownership
- Car passenger
- Parking
- What comes first: destination choice or mode choice?
Car ownership

• How is that accounted for so far?

• Implicit
  • Mode specific constant
  • Distribution functions

• Explicit approach
  • Split demand matrix in matrix for people having a car and people not having a car available and apply appropriate functions
Car passenger

• Why is this relevant?

• Simple approach
  • Exogenous car occupancy rate per trip purpose

• Comprehensive approach
  • Car passenger and car driver as separate modes

• Problem in both cases?
  No guarantee for consistency in trip patterns car driver and car passenger
Parking

- Would you include it, and if so, how?
- How would you do it in case of tours?
- How would you do it in case of trips?
- What about morning and evening peak?
  Assign half of parking costs to a trip (origin and destination)?
What comes first: trip distribution or mode choice?

- What is the order we discussed so far?

Swiss model:

- Mode preferences appear to be pretty strong