CIE4801 Transportation and spatial modelling
Trip generation and networks

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17/4/13
Content

- Trip generation
  - Definitions
  - 3 methods
  - Special issues

- Networks
  - Defining a network
  - Shortest path
1.

Trip generation
Definitions
Introduction to trip generation

- Zonal data
- Trip production / Trip attraction
- Trip distribution
- Modal split
- Period of day
- Assignment
- Travel times, network loads, etc.

- Trip frequency choice
- Destination choice
- Mode choice
- Time choice
- Route choice

- Transport networks
- Travel resistances
What do we want to know?
Ambiguous definitions?

• Definition 1
  • Production: person related
  • Attraction: activity related

• Definition 2
  • Production: departures
  • Attraction: arrivals
Introduction to trip generation
Trips or tours?

- **Trip**

  Origin ➔ Destination ➔ Origin

- **Tour**

  Home ➔ Activity 1 ➔ Activity 2 ➔ Home ➔ Activity
Travel characteristics Netherlands (MON)

- **Trips per person per day**
  - 1978: 3.0 trips/day
  - 1983: 3.2 trips/day
  - 1988: 3.4 trips/day
  - 1993: 3.6 trips/day
  - 1998: 3.8 trips/day
  - 2003: 4.0 trips/day
  - 2008: 4.2 trips/day

- **Distance travelled per person per day**
  - 1978: 25 km/day
  - 1983: 28 km/day
  - 1988: 30 km/day
  - 1993: 32 km/day
  - 1998: 34 km/day
  - 2003: 36 km/day
  - 2008: 38 km/day

- **Time travelled per person per day**
  - 1978: 60 min/day
  - 1983: 62 min/day
  - 1988: 64 min/day
  - 1993: 66 min/day
  - 1998: 68 min/day
  - 2003: 70 min/day
  - 2008: 72 min/day

- **Average speed**
  - 1978: 20 km/hour
  - 1983: 22 km/hour
  - 1988: 24 km/hour
  - 1993: 26 km/hour
  - 1998: 28 km/hour
  - 2003: 30 km/hour
  - 2008: 32 km/hour
Key figures passenger transportation Netherlands (MON)

- Number of trips per person per day: 2.9
- Travel time per person per day: 70 minutes (1 a 1.5 hour)
  
  **Travel time budget!**

- Average trip length: 11 km
- 50% of trips is shorter than 3 km
- 1.5% of trips is longer than 100 km
Trip purpose (Netherlands) Trips and tripkilometres

- commuting
- business
- personal care
- shopping
- education
- visiting
- touring
- social/recreation
- other
Dominant definition in this course

Given: A map with zones and zonal data

Determine:
- The number of trips departing at each zone (production)
- The number of trip arriving at each zone (attraction)

<table>
<thead>
<tr>
<th>From:</th>
<th>zone 1</th>
<th>⋮</th>
<th>zone i</th>
<th>⋮</th>
<th>⋮</th>
<th>total attraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>zone 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⋮</td>
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<td>zone i</td>
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<td>⋮</td>
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</tr>
</tbody>
</table>

To:
Possible factors traveller production

Factors affecting the production:

- income
- car ownership
- household structure
- family size
- value of land
- residential density

Which definition for production is used?
Possible factors traveler attraction

Factors affecting the attraction:
• office space
• retail space (shops)
• employment levels

And which for attraction?
Possible classifications

Trip purpose
• compulsory / mandatory trips
  – working trips
  – education trips
• discretionary / optional trips
  – shopping trips
  – social / recreational trips

Time of day
• peak period
• off-peak period

Person type
• income level
• car ownership
• household size
2.1

Trip generation
Method 1
Regression models

\[ Y = \sum_{k} \beta_k X_k \]  
(linear regression)

\( Y \)  Endogenous (explained) variable  
e.g. number of trips produced by a zone or household

\( X_k \)  Exogenous (explanatory) variables  
e.g. number of inhabitants, household size, education

\( \beta_k \)  Parameters

\[ Y = 0.91 + 1.44 X_1 + 1.07 X_2 \]  
number of trips       number of workers       number of cars
Regression models

Least squares: minimize \( \sum_i \varepsilon_i^2 = \sum_i \left( Y_i - \hat{Y}_i \right)^2 \)

\[
\hat{Y}_i = \alpha + \beta X_i
\]
Regression models

Linear regression:

\[ Y = 0.91 + 1.41X_1 + 1.07X_2 \]

Nonlinearity problem:
The parameter for \( X_2 \) is not constant.

Regression with dummy variables:

\[ Y = 0.84 + 1.41X_1 + 0.75D_1 + 3.14D_2 \]

\( D_1 = 1 \) if 1 car, 0 otherwise
\( D_2 = 1 \) if 2 or more cars, 0 otherwise

\( Y = 1.41X_1 + \begin{cases} 0.84 & \text{if } X_2 = 0 \\ 1.59 & \text{if } X_2 = 1 \\ 3.98 & \text{if } X_2 \geq 2 \end{cases} \)
Example for 24-hour model

<table>
<thead>
<tr>
<th>Trip purpose</th>
<th>Regression formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>0.9 * working population + 0.9 * jobs</td>
</tr>
<tr>
<td>Business</td>
<td>0.5 * working population</td>
</tr>
<tr>
<td>Education</td>
<td>0.2 * households + 1.9 * students</td>
</tr>
<tr>
<td>Shopping</td>
<td>1.0 * households + 15.6 * retail jobs</td>
</tr>
<tr>
<td>Other</td>
<td>3.5 * households</td>
</tr>
<tr>
<td>Total</td>
<td>6.5 * households + 2.9 * jobs</td>
</tr>
</tbody>
</table>

Note that in this case it is assumed that production equals attraction.
2.2

Trip generation
Method 2
Cross-classification models

Classify households in homogenous groups
e.g. number of people in household, number of cars, and combinations

[Graph showing trip rate distribution for all households and four distinct groups]
Cross-classification models

Advantages:
- groupings are independent of zone system
- relationships do not need to be linear
- each group can have a different form of relationship

Disadvantages:
- no extrapolation beyond the calibrated groups
- large samples are required (at least 50 obs. per group)
- what is the best grouping?
## Cross-classification models

<table>
<thead>
<tr>
<th>household size</th>
<th>0 cars</th>
<th>1 car</th>
<th>≥2 cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 person</td>
<td>$n = 20, \mu = 0.2$</td>
<td>$n = 10, \mu = 0.5$</td>
<td>$n = 0, \mu = ?$</td>
</tr>
<tr>
<td>2 persons</td>
<td>$n = 85, \mu = 0.5$</td>
<td>$n = 150, \mu = 0.9$</td>
<td>$n = 20, \mu = 1.5$</td>
</tr>
<tr>
<td>3 persons</td>
<td>$n = 25, \mu = 0.7$</td>
<td>$n = 40, \mu = 1.2$</td>
<td>$n = 30, \mu = 2.0$</td>
</tr>
<tr>
<td></td>
<td>$n = 130, \mu = 0.5$</td>
<td>$n = 200, \mu = 0.9$</td>
<td>$n = 50, \mu = 1.8$</td>
</tr>
</tbody>
</table>
Cross-classification models

Multiple Class Analysis (MCA)

<table>
<thead>
<tr>
<th>household size</th>
<th>0 cars</th>
<th>1 car</th>
<th>≥2 cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 person</td>
<td>0.0</td>
<td>0.3</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.5</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 persons</td>
<td>0.4</td>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥3 persons</td>
<td>0.9</td>
<td>1.3</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>−0.4</td>
<td>0.0</td>
<td>+0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\mu = 0.9$
Cross-classification models

Zone $i$ having 253 households yields

<table>
<thead>
<tr>
<th>Household size</th>
<th>0 cars</th>
<th>1 car</th>
<th>$\geq 2$ cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 person</td>
<td>50</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.3</td>
<td>1.2</td>
</tr>
<tr>
<td>2 persons</td>
<td>25</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td>$\geq 3$ persons</td>
<td>10</td>
<td>44</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>1.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Trip production of zone $i$: 188
2.3

Trip generation
Method 3
Discrete choice models

Binary logit

Alternative 0: do not make a trip \( V_0 = 0 \)
Alternative 1: make one or more trips \( V_1 = \ldots \)

Probability of making at least one trip:

\[
P_{1+} = \frac{\exp(\mu V_1)}{\exp(\mu V_0) + \exp(\mu V_1)} = \frac{1}{1 + \exp(-\mu V_1)}
\]

How many trips on average does a person make?
Discrete choice models

Stop/repeat-model

- Person
  - 0 trips: \( p_0 \)
  - ≥1 trips: \( p_1 \)
  - ≥2 trips: \( p_2 \)
  - ≥3 trips: \( p_3 \)

Possible attributes:
- Household characteristics
- Driving license
- Car ownership
- Gender
- Age
- Education
- Income

\[ p_0 + p_1 + p_2 + p_3 = 1 \]

binary logit

etc…
3.

Trip generation
Special issues
Special issues

• What about external zones?

• Modelling all trips or a single mode?

• Segmentation?

• Role of accessibility?

• Does total of departures equal total of attractions?
Which area do you model?

<table>
<thead>
<tr>
<th></th>
<th>Study area</th>
<th>Cordon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study area</strong></td>
<td>Internal</td>
<td>Out</td>
</tr>
<tr>
<td><strong>Cordon</strong></td>
<td>In</td>
<td>Through</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Study area</th>
<th>Influence area</th>
<th>External area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study area</strong></td>
<td>Internal</td>
<td>Out</td>
<td>Out</td>
</tr>
<tr>
<td><strong>Influence area</strong></td>
<td>In</td>
<td>Through and....</td>
<td>Through and....</td>
</tr>
<tr>
<td><strong>External area</strong></td>
<td>In</td>
<td>Through and....</td>
<td>Through and....</td>
</tr>
</tbody>
</table>
Swiss model
Segementation by trip purpose
Trips and trip kilometres
Role of accessibility?

- MON: ‘fixed’ trip rate per person per day
- Recent model estimations: small effect for some trip types
- In case of unimodal models?

  Substantial impact, especially for public transport
Does trip production equal trip attraction?

- We have determined the trip production
- We have determined the trip attraction

What to do?

Trip balancing: your choice to decide which of the two is the constraint
4.

Networks
Defining a network
Networks

- zonal data
  - trip production / trip attraction
    - trip frequency choice
  - trip distribution
    - destination choice
    - mode choice
    - time choice
    - route choice
  - modal split
  - period of day
    - time choice
  - assignment
    - route choice
- transport networks
- travel resistances
- travel times
  - network loads
  - etc.
Constructing a transport network

Given a map of the study area, how to represent the infrastructure and the travel demand in a model?
Network attributes

- node
  - x-coordinate
  - y-coordinate
- centroid node
  - zonal data
  - origin/destination
- link
  - node-from
  - node-to
  - length
  - maximum speed
  - number of lanes
  - capacity
Links and junctions

Junction with all turns allowed

Junction with no left turns allowed
Define zones and select roads
Define zones

How do we determine zones?

- base zone definitions on official spatial systems (e.g. municipalities, postal districts)
- try keeping compact convex forms
- more zones needed for modal split than for assignment
Select links

How many zones / nodes / links?

- depends on the application
- rule of thumb:
  include 75% of the network capacity
  (note: 20% of the network accounts for 80% of the travelled kilometers)

modelling

= the art of leaving things out
Which roads should be included?
Urban or regional model?

Regional

Urban
Example car network regional model
Important issues

- Connecting the zones to the network:

- Single connector or multiple connectors?

- Connecting to which type of node/link?

- Choices have major consequences for the assignment to the network!
Public transport network

• Car or bike:
  • Roads defined using links

• PT: Network of services
  • Space accessibility
    • Stops, stations
    • Lines
  • Time accessibility
    • Frequencies
    • Operating hours
  • Defined using access links, transfer links, in-vehicle links, ...
5.

Networks
Shortest path
Shortest Path algorithms

• “Oldies”
  • Moore (1959)
  • Dijkstra (1959)
  • Floyd-Warschall (1962)

• Still a topic for research
Main concept for ‘tree algorithms’
(Moore and Dijkstra)

- For all nodes
  - Set travel time \( tt(x) \) to \( \infty \) and set the back node \( bn(x) \) to 0
- For the origin \( i \) set time to 0 and back node to -1
- Node \( i \) is the first active node \( a \)
- Select all links \( (a,j) \) and check travel times
  - If \( tt(a) + \text{time}(a,j) < tt(j) \)
    \( tt(j) = tt(a) + \text{time}(a,j) \) and \( bn(j) = a \) and node \( j \) becomes an active node
  - Node \( a \) is no longer active
- Select a new active node from the stack and repeat previous step until there are no active nodes left

- For Dijkstra: select the link having the lowest travel time and select the active node having the lowest travel time
Main concept for matrix algorithm
(Floyd-Warschall)

- Create two matrices from all nodes to all nodes
  - \( tt(i,j) = t(i,j) \) for all links \((i,j)\) or \( tt(i,j) = \infty \)
  - \( bn(i,j) = i \) for all links \((i,j)\)

- For every node \( k \) check travel times
  - If \( tt(i,k) + tt(k,j) < tt(i,j) \)
    \( tt(i,j) = tt(i,k) + tt(k,j) \) and \( bn(i,j) = bn(k,j) \)

- Repeat previous step until no changes are made
Shortest paths
Shortest paths
Shortest paths
Shortest paths
Shortest paths
Shortest paths
Shortest paths
Shortest paths
Shortest paths

Contains shortest paths to all nodes from a certain origin
Representation of shortest paths

Shortest route from node 7 to node 5:

node 7 → node 4 → node 1 → node 2 → node 5

or

link 8 → link 3 → link 1 → link 4
Representation of shortest paths

Very compact, less practical:
Back node representation

route “7 → x” (4 1 6 7 2 9 -1 7 8)

Number for elements for storing all shortest routes in the network:
\[ N \times N = 9 \times 9 = 81 \]
Representation of shortest paths

Less compact, very practical: Assignment map

Number for elements for storing all shortest routes in the network:

\[ A \times N \times (N - 1) = 12 \cdot 9 \cdot 8 = 864 \]