CIE4801 Transportation and spatial modelling

What for, what, and how?

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17/4/13
Topic of this course

- Transportation and spatial modelling
  - Theory
  - Concepts
  - Algorithms
  - Application

- Focus on HOW it is done today
  - Don’t let that stop you from being critical

- Focus on how it is might be done tomorrow:
  - CIE5802-09 Advanced transportation modelling
Course material

Course material:
Lecture notes Transportation Modeling

Recommended material:

Recommended articles on spatial modelling:
Wegener M., F. Furst (1999), Land-use transport Interaction: State of the art, Berichte aus dem Institut für Raumplanung 46, Universität Dortmund
Zondag B, G. de Jong (2011), The development of the TIGRIS XL model: a bottom-up approach to transport, land-use and the economy, Research in transportation economics 31, pp. 55-62
Exercises in Omnitrans 6.0

For more information on Omnitrans and its tutorial see: http://www.omnitrans-international.com
Content

- What for?
- What?
- How?
- How? Modelling choices
- Resumé
1.

What for?
Similarity between travelling and transportation modelling?

• You don’t travel just for fun, but to perform an activity somewhere
  • Note that travelling can be fun as well!

• You don’t model the transport system just for fun, but for a purpose
  • Note that modelling transport systems can be fun as well!
What would you like to know?
Possible answers

- Traffic flows on links and/or line occupancy
  - For design purposes
    - Traffic engineering, Business case
  - For assessment purposes
    - Economic, Environmental, Safety
  - For traffic management studies

- Network/system performance
  - Vehicle kilometres (per road type)
  - Modal split (per trip type)
Why would you like to know this?

- Because you’re considering a measure
  - To build a road
  - To add a lane
  - To change a public transport network
  - To develop a residential/industrial area
  - To change a one-way street system
  - To introduce a pricing policy

- Because you want to understand a situation or a problem
  - Congestion
  - Pollution
  - Noise
  - Accessibility

- Because of legislation
  - Air quality
Main goal of transportation and spatial models

- To provide quantitative information of the transportation and spatial system for the analysis of possible future situations

- Key tool for decision making processes for the transportation and spatial system
Transportation planning process

1. Problem
2. Objectives
3. Assessment criteria
4. Design of solutions, plans
5. Analysis of solutions = Prediction of solutions
6. Evaluation of solutions
7. Decision

- Congestion Environment
- Accessibility
- Congestion standards
- Environmental standards
- Model
- CBA
- MCA
Evaluation of transportation plans

Current situation

Future situation
Zero alternative

Planning alternatives

Environmental alternative

Public transport alternative

Infrastructure alternative

Alternative A

Alternative B

Alternative C
2.

What?
What should be in the black box?

Or when would you say that the black box is OK?
Possible answers

• Proper representation of the transportation system or
  Capture the key mechanisms of the system

• Theoretically underpinned

• Empirically validated

• As simple as possible, but not simpler

How?
Proper representation?

- Decomposition in relevant components
- Model mechanisms within components
- Model relationships between components
- Note that these relationships are most likely
  - Non-trivial
  - Non-linear
  - Imply many feedback mechanisms
Main mechanism for the transportation and spatial system

- **Transport system** (transport and traffic services)
- **Activities** (living, work, recreation)
- **Accessibility** (ease to reach a location)
- **Land use** (spatial planning)
What are the components of the transportation system?
What are the components of the spatial system?
Mechanism in more detail: Wegener’s circle
Travel choice model system

- 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
3.

How?
Previously mentioned topics

- Theoretically underpinned
- Empirically validated
- As simple as possible, but not simpler
Theoretically underpinned?

- Descriptive models
  - Mathematical relationship between input and output
    - Statistics
    - Analogy

- Models based on Choice Theory
  - Utility maximisation
  - Logit modelling

- Equilibrium concept
  - E.g. route choice: 10 minutes versus 15 minutes.......
Development process of a model

- Observations
- Phenomenon
  - Hypotheses
  - Theory
  - Conceptual model
  - Empirical model
  - Validated model
- Decision problem
- Model application
  - Estimation/calibration
  - Testing/verification
Empirically underpinned?

- What kind of data are you thinking of?
- Data to build a model
- Data to validate a model
What is the input you need?

Input → Model → Output
Typical types of input

- Transport system
  - Road network
  - Public transport services
  - Transport policy

- Spatial system
  - Inhabitants, jobs, facilities

- Environment
  - Economic system
When is a model valid?

Current practice:
- State of the art techniques
- Well established software
- Based on available data

Bottom line in practice:
- When the model reproduces observed flows
How to simplify the system?

- 16.7 million inhabitants (plus $x$ visitors from abroad)
- 7.5 million households
- 7.2 million houses
- 750 thousand companies

- $x$ reasons for travelling
- 365 $\frac{1}{4}$ days per year
- 24 hours per day

- 7.9 million cars
- 10.6 million vehicles

- 138 thousand kilometre road
- 3 thousand kilometre rail
Possible simplifications

- Aggregation to groups
  - Persons, trip type, geographical

- Selection of a period and/or day
  - Average pattern!

- Selection of trip purposes

- Selection of modes

- Selection of network detail

- Selection of processes/components
Example zoning system
Travel choice model system

- Zonal data
- Transport networks
- Travel resistances

- Trip production / Trip attraction
- Trip distribution
- Modal split
- Period of day
- Assignment

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

Travel times network loads etc.
4

How?: Modelling choices
Theory choice behaviour

Beach: $U_k$

Leisure park: $U_m$

Home

IKEA: $U_l$

$Z_{ik}$

$Z_{im}$

$Z_{il}$
Utility maximisation

\[ U_i = 0 \]

\[ U_k - Z_{ik} \]

\[ U_l - Z_{il} \]

\[ U_m - Z_{im} \]

Beach

IKEA

Leisure park
Choice theory: Utility maximisation

- Main assumptions
  - People make choices
  - They maximise their personal utility (within their constraints)

- Thus not just minimisation of travel times!

- People have set of (feasible) alternatives having utility (and disutility)
  - People opt for alternative having the highest net utility

- NB. What happens when the net utility is negative?
Travel choice theory

Travel behaviour is not always logical at first sight
- large detours just to avoid parking costs
- waiting times are usually over-estimated:
  - waiting at the train station
  - waiting in front of a traffic light
  - waiting in a congestion queue
- costs for driving a car may seem less expensive than a train ticket

It is all about the perceptions that travelers have
Discrete choice theory

Definitions:

Each alternative $i$ has an objective/observable utility $V_i$.

Each individual faces a subjective non-observed utility $\varepsilon_i$ for each alternative $i$.

Utility of alternative $i$ for each individual:  
$$U_i = V_i + \varepsilon_i$$

Behavior:

An individual will choose alternative $i$ if this alternative has the highest utility, i.e. if

$$U_i \geq U_j \quad \text{for all } j$$
Discrete choice theory

\[ p_i = P(U_i \geq U_j \text{ for all } j) \]
\[ = P(V_i + \varepsilon_i \geq V_j + \varepsilon_j \text{ for all } j) \]
\[ = P(\varepsilon_j - \varepsilon_i \leq V_i - V_j \text{ for all } j) \]

If \( \varepsilon_i \)'s are all Gumbel distributed (independent, with scale parameter \( \mu \)),

Logit-model

\[ p_i = \frac{e^{\mu V_i}}{\sum_j e^{\mu V_j}} \]

Probit-model

\[ p_i = K \].

If \( \varepsilon_i \)'s are all normally distributed (independent),
Logit model

Alternatives to choose: \( i = 1, 2, 3, \ldots \)

What is the probability to choose alternative \( i \)?

or:

Which share of travellers chooses alternative \( i \)?
Logit model: main principle

- Each alternative has measurable attributes ($A_{xi}$)
- These attributes have their own perception ($c_x$)
- Not everything is measured or objective ($\varepsilon$)

For each alternative the '(dis-)utility' is the weighted sum of the attributes plus an error term

$$U_i = V_i + \varepsilon = \sum_x c_x \cdot A_{xi} + \varepsilon$$
Utility and disutility: Weighted sum of attributes

- Route choice car:
  \[ c_1 \times \text{time} + c_2 \times \text{costs} \Rightarrow \text{time} \times \frac{c_1}{c_2} + \text{costs} = \text{time} \times \text{VOT} + \text{costs} \]

- Route choice urban PT:
  \[ 2.2 \times T_a + 1.5 \times T_w + T_i + 2.3 \times T_{wt} + 5.9 \times N_t + 1.1 \times T_e \]

- Mode choice:
  additional attribute for preference for specific modes

- Destination choice:
  additional attributes describing attractiveness location
## Value of time (€/h)

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<th>Commuting</th>
<th>Business</th>
<th>Rest</th>
<th>Total</th>
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<td>27.56</td>
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Price level 2006
Logit model: Formula

\[ p_i = \frac{e^{\mu V_i}}{\sum_j e^{\mu V_j}} \]

- Logit formulation assumes independent alternatives
- Parameter \( \mu \) represents the sensitivity for differences in utility
  - High value: crisp choice; Low value: uniformly distributed
Shape of logit function

\[ p_i = \text{probability for choosing alternative } i \]
Impact of the scale parameter

The lower the scale parameter $\mu$, the higher the variance or ‘spread’ in the choice proportions.
Scale parameter and distribution

\[ P(U_1 = U) \]

\[ P(U_2 = U) \]

\[ \frac{1}{\mu} \]

\[ V_1 \]

\[ V_2 \]

\[ \mu = 10 \]

\[ \mu = 1 \]

\[ \mu = 0.1 \]
Example: toll

Extension A4

Schiedam - Den Haag
route A: 20 min. + € 2
route B: 35 min.

(dis)utility function:
\[ V_i = -[\text{time} + 5 \times \text{toll}] \]
\[ \mu = 0.1/\text{min} \]
\[ P_A = 62\% \]
Effect of constraints

PT share

100%

Car captives

PT captives

Travel time

Car travel time

PT travel time
Some comments on logit

- Logit is commonly used, but isn’t perfect

- Logit is sensitive for differences between utilities, independent of the absolute value of the utility

- Logit assumes independent alternatives
  - Route overlap
  - Red/Blue bus problem
5.

Resumé
Resumé

• Modelling is a tool in a decision process
  • Decision process sets requirements

• Modelling focuses on transport system
  • When relevant spatial system is included as well

• Modelling is simplifying the system
  • Zones, specific period(s), specific trip purposes, selection of networks

• Most of all selection of processes
Travel choice model system

- zonal data
- transport networks
- travel resistances

- trip production / trip attraction
- trip distribution
- modal split
- period of day
- assignment

- trip frequency choice
- destination choice
- mode choice
- time choice
- route choice

travel times
network loads
etc.
## Course schedule

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<th>Lecture 11</th>
<th>Case study Delft Exam questions</th>
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