Decision-Aid Methodologies in Transportation

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Transport and Mobility Laboratory

Introduction

The role of transportation systems is to:

- Move people and goods;
  - From one place (origin) to another (destination);
- Safely;
- Efficiently;
- With a minimum of negative impacts (congestion, discomfort, noise, pollution, accidents,...).

The role of mathematical models

- Transportation systems are complex:
  - their elements are complex;
  - their interactions are complex.
- Need to simplify in order to be able to:
  - describe;
  - design;
  - predict;
  - optimize.

Need for Decision-aid Systems

In this course...

- Part 1: Operational models on the demand side:
  - Methodology: choice models;
  - Applications: transportation mode choice.

  `Lectures: Matthieu de Lapparent, Labs: Anna Fernández Antolín, Evanthia Kazagli`

- Part 2: Operational research problems in transportation:
  - Methodology: operations research;
  - Applications: scheduling for airlines, ports, railways.

  `Lectures: Shadi Sharif Azadeh, Labs: Yousef Maknoon, Iliya Markov.`

Learning Goal

The course will

- Introduce decision-support methods for complex transportation problems
- Give practical hands-on experience of solving problems using software and real data

Learning Assessment

4 credits = 120 hours work (26 h. lectures, 26 h. labs)
Grade consists of 3 components

- 2 graded hand-in assignments
  - One in choice models, one in operations research
  - Corresponds each to 20% of the grade
  - Based on team work (you will be assigned to a group)
  - Hand in joint report
- Final presentation
  - A problem assigned to each group in the last week of the course
  - 20 minute presentation in June (tbd)
  - Corresponds to 60% of grade

Transportation demand analysis

- Demand in transportation is a *derived* demand (an intermediate consumption).
  - A result of demand for something else.
- Travel results from a decision to *make a trip*, for a certain *purpose* (work, shopping, leisure), to a certain *place* (destination), by a certain *mode* (car, public transport, etc.), along a certain *route*, at a certain point in *time* (departure time).
- Direct demand:
  - wrt people: activities
  - wrt goods: consumption
- Demand/ supply interactions:
  - The level of service influences travel decisions
  - Travel decisions influence the level of service

Representations of the demand

- Aggregate representation:
  - Modeling element: flow
  - Flow: number of transported units (i.e. travelers, tons of freight, cars, flights, etc.) per unit of time, at a given location.
- Disaggregate representation:
  - Modeling element: the transported unit (i.e. travelers, etc.)
  - Individual behavior of the traveler, or of the actors of the logistic chain.

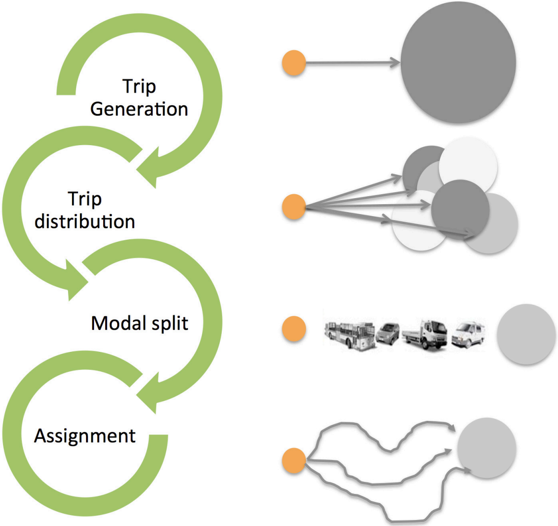
Representations of the supply

- Transportation supply = infrastructure;
- Network representation;
- Usually one network per mode (roads, railways, buses, airlines, etc.);
- Classical indicators associated with each link:
  - travel time;
  - cost;
  - flow (nbr of persons per unit of time);
  - capacity (= maximum flow);
- Static (average state) or dynamic (varies across time).

Modeling framework

- We focus on the transportation of people;
- Four step travel demand model;
- Decomposes the travel decision into 4 levels/ steps;
- Each step involves:
    - The description of a specific behavior:
        1. Is a trip performed or not?
        2. What is the destination?
        3. What is the transportation mode?
        4. What is the itinerary?
    - Data collection;
    - Modeling assumptions.

Four step model



Step 0: Preparing the scope of the analysis

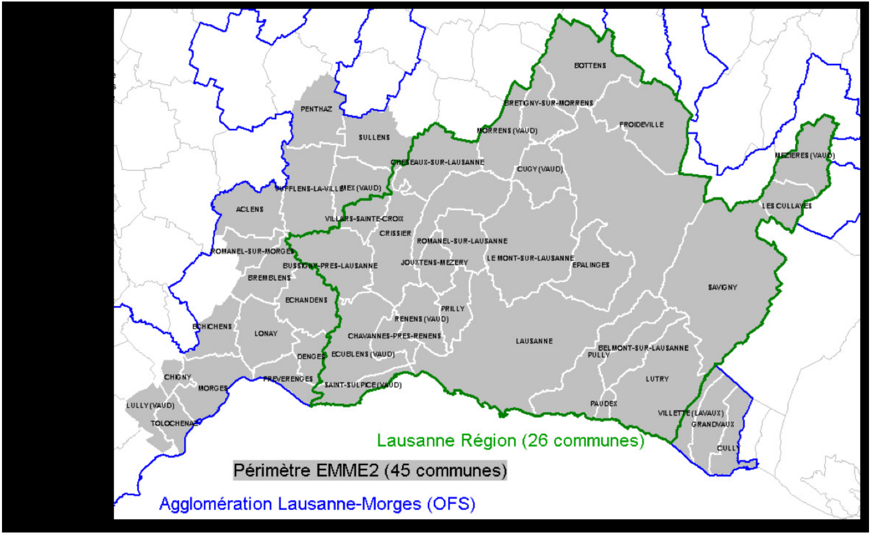
Spatial scope:

- Identification of the relevant perimeter for the analysis;
- Partition of the perimeter into geographical zones (e.g. Lausanne: 500 zones);
- Assumption: trips within a zone are ignored.

Temporal scope:

- Identification of the period of the analysis (e.g. morning peak-hour, evening peak-hour etc.).

Perimeter


BOTTENS
BRETIGNY-SUR-MORRENS
FROIDEVILLE
MORRENS (VAUD)
PENTHAZ
SULLENS
CHESEAUX-SUR-LAUSANNE
CUGY (VAUD)
MEZIERES (VAUD)
MEX (VAUD)
ACLENS
LES CULLAYES
VILLARS-SAINTE-CROIX
CRISSIER
ROMANEL-SUR-LAUSANNE
ROMANEL-SUR-MORGES
BUSSIGNY-PRES-LAUSANNE
JOUXTENS-MEZERY
LE MONT-SUR-LAUSANNE
EPALINGES
BREMBLENS
SAVIGNY
ECHANDENS
PRILLY
RENENS (VAUD)
ECHICHENS
LONAY
CHAVANNES-PRES-RENENS
LAUSANNE
BELMONT-SUR-LAUSANNE
PULLY
DENGES
ECUBLENS (VAUD)
CHIGNY
PREVERENGES
LUTRY
MORGES
SAINT-SULPICE (VAUD)
LULLY (VAUD)
PAUDEX
VILLETTE (LAVAUX)
GRANDVAUX
TOLOCHENAZ
CULLY
Lausanne Région (26 communes)
Périmètre EMME2 (45 communes)
Agglomération Lausanne-Morges (OFS)

Zoning


Montbenon
Mon Repos
Cour
Montriond
Bains de Bellerive
Port
Chât.
Ouchy
Le Denantou
Chamblandes
Chât. Sec

Zoning


Ouchy
Chamblandes
Port
Bains de Bellerive
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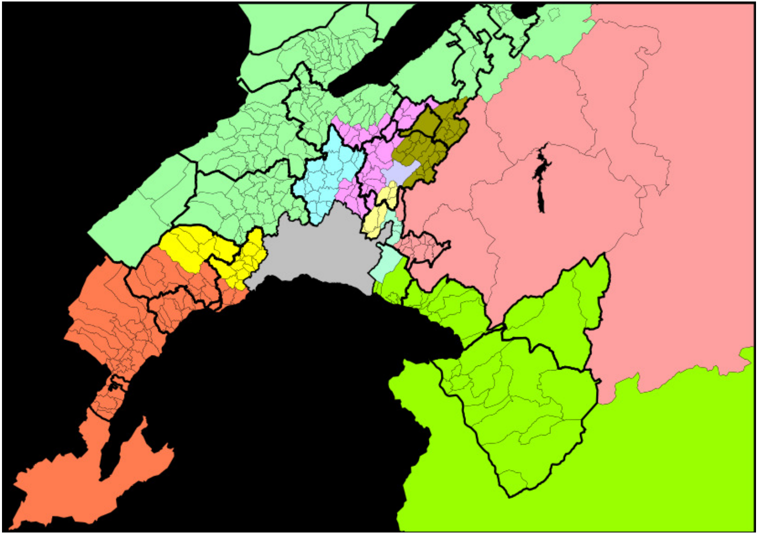
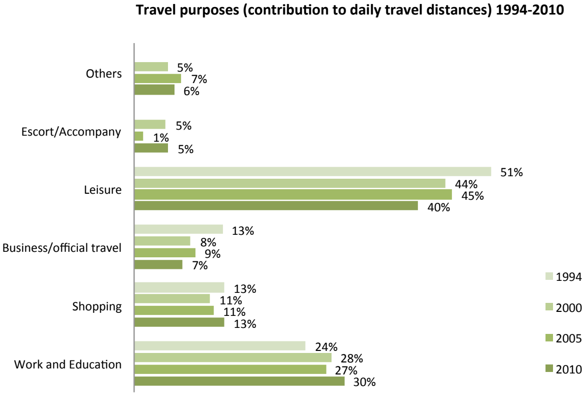
Zoning



Step 1: Trip generation

Is a trip performed or not?

- Derived demand
- Two successive activities are not proximal
- Data from Swiss Micro-census (1994-2010) →



Step 1: Trip generation (cont.)

- Land use, urban planning and transport are closely related.
- Question: where are the activities located?
- Main locations to identify in a city:
  - housing;
  - work places;
  - shops and commercial centres;
  - schools.
- Many studies focus on home-based trips.

Step 1: Trip generation (cont.)

Aggregate representation:

- For each zone, determine:
  - the number of trips originated from the zone (production);
  - the number of trips ending in the zone (attraction).

  during the analysis period

- Modeling tool: linear regression

$$Y = \beta_0 + \beta_1 X$$

  with, for instance, Y = number of trips, X = population

Disaggregate representation:

- Activity choice models;
- Location choice models.

Step 2: Trip distribution

What is the destination?

How many trips starting at a given origin are reaching a given destination?

- Aggregate representation: origin-destination (OD) matrix;
- Disaggregate representation: destination choice models.

Step 2: Trip distribution (cont.)

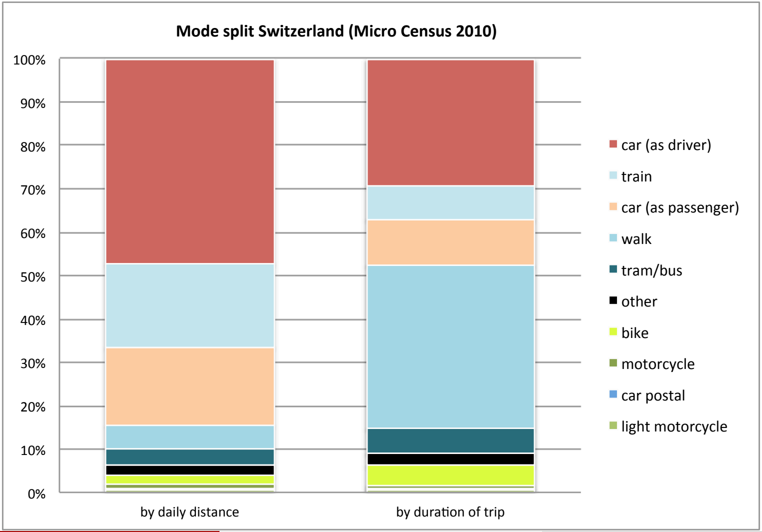
OD matrix

	D_1	D_2	D_j	
O_1	T_{11}	T_{12}	T_{1j}	$\cdots$
O_2	T_{21}	$\ddots$		
O_i	T_{i1}		T_{ij}	
	$\vdots$			$\ddots$

- T_{ij} is the flow between origin i and destination j
- For each origin i, $\sum_j T_{ij} = O_i$
- For each destination j, $\sum_i T_{ij} = D_j$

Step 3: Modal split

What is the transportation mode? (Swiss example)



Step 3: Modal split

What is the transportation mode?

- Assume K modes
  - car (as driver);
  - car (as passenger);
  - bus;
  - metro;
  - bike;
  - motorbike;
  - walk;
  - etc.
- From OD matrix T, create K matrices T^k such that

$$T = \sum_{k=1}^{K} T^k$$

Step 3: Modal split (cont.)

- In practice, generate a split function p such that:

$$0 \leq p(k|i,j) \leq 1, \ \forall i,j,$$

and

$$\sum_{k=1}^{K} p(k|i,j) = 1, \ \forall i,j$$

- Obviously, we have

$$T_{ij}^{k} = p(k|i,j) T_{ij}$$

- The split function p is derived from a mode choice model;
- This will be the main focus of part 1 of this course.

Step 4: Trip assignment

What is the itinerary?

Aggregate representation:

- Shortest path algorithm;
- Based on travel time, so "fastest path".

Disaggregate representation:

- Route choice models;
- Based on various indicators.

Note:

If many travelers use the best path, it will be congested...

...and it will not be the best anymore.

This is captured by the concept of "traffic equilibrium"

Summary

- Four step models
  1. Generation;
  2. Distribution;
  3. Modal split;
  4. Assignment.
- Each step captures a type of choice
  1. Activity location choice;
  2. Destination choice;
  3. Mode choice;
  4. Route choice.

Main objective of the first part of this course:

Introduction to choice models: theory and case studies focusing on mode choice.