

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.

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: Amanda Stathopoulos, Labs: Anna Fernández Antolín

- Part 2: Operational models on the supply side:

- Methodology: operations research;
- Applications: scheduling for airlines, ports, railways.

Lectures: Jiang Hang Chen, Labs: Iliya Markov, Tomáš Robenek.

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.
 - 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.

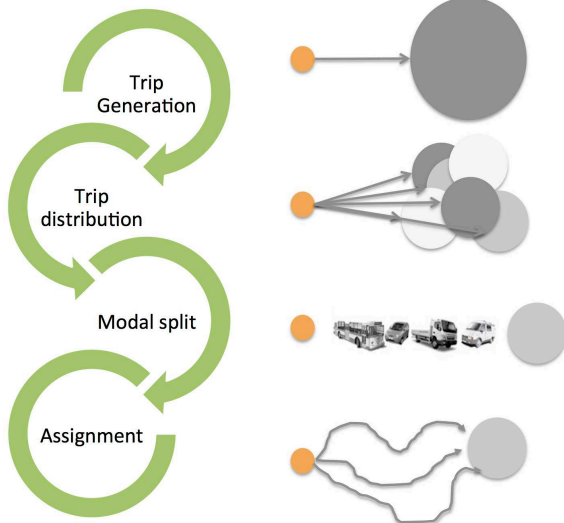
Representations of the supply

- 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 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

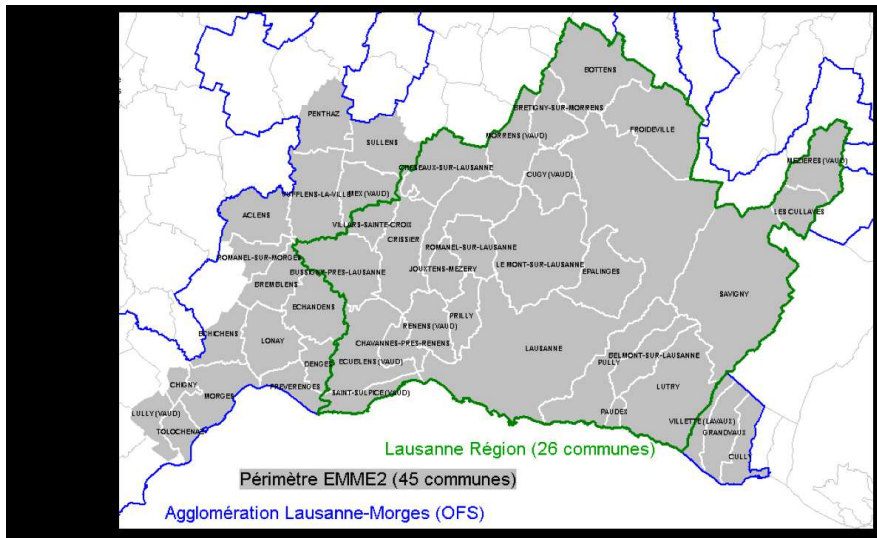
Spatial scope:

- 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.

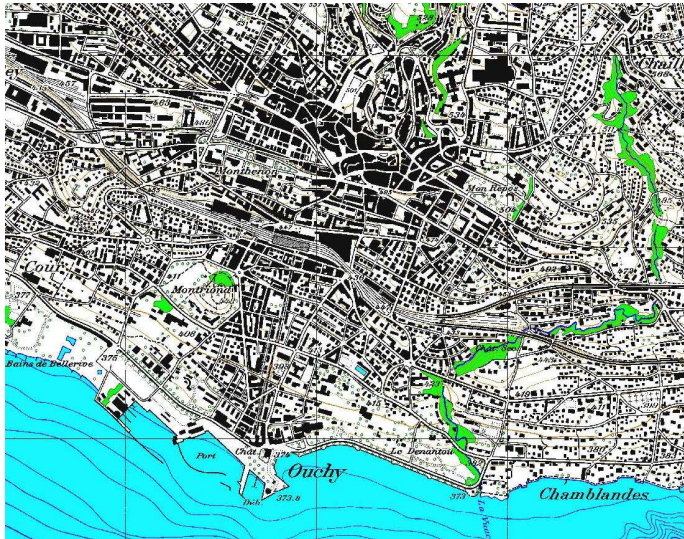
Temporal scope:

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

Perimeter



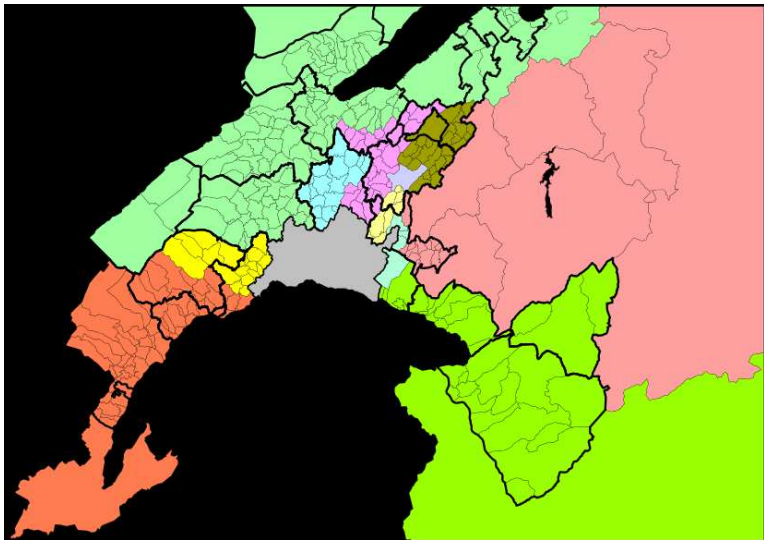
Zoning



Zoning



Zoning

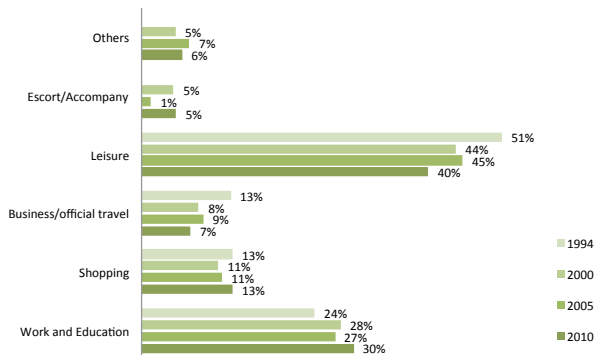


Step 1: Trip generation

Is a trip performed or not?

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

Travel purposes (contribution to daily travel distances) 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;
 - the number of trips ending in the zone.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.)

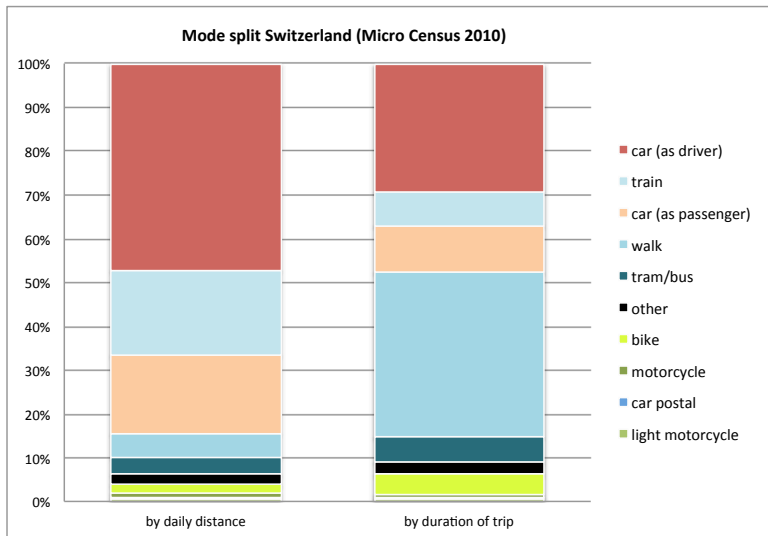
OD matrix

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

- 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 this course:

Introduction to choice models: theory and case studies.