Decision-aid methodologies in transportation

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Transport and Mobility Laboratory

Introduction

Roles of transportation systems:

- move people and goods
- from one place (origin) to another (destination)
- safely
- efficiently
- with minimum negative impacts.

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Roles of mathematical models

- Transportation systems are complex
  - the elements are complex
  - their interactions are complex
- Need to simplify in order to
  - describe
  - design
  - predict
  - optimize

Decision aid system

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In this course...

- Part 1: operational models on the demand side
  - Methodology: choice models
  - Applications: transportation mode choice
  - Lecturer: Michel Bierlaire
  - TA: Jingmin Chen
- Part 2: operational models on the supply side
  - Methodology: operations research
  - Applications: airline scheduling
  - Lecturer: Prem Kumar
  - TA: Nitish Umang

Transportation Demand Analysis

- Demand in transportation is a **derived** demand.
- A derived demand occurs as a result of demand for something else.
- Direct demand:
  - for people: activities
  - for goods: consumption
- Demand / supply interactions
  - The level of service influences travel decisions
  - Travel decisions influence the level of service

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 (= max. flow)
- Static (average state) or dynamic (varies with time)

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.

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Modeling framework

- We focus on the transportation of people
- Four step model
- Decompose 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

Step 0: preparing the scope of the analysis

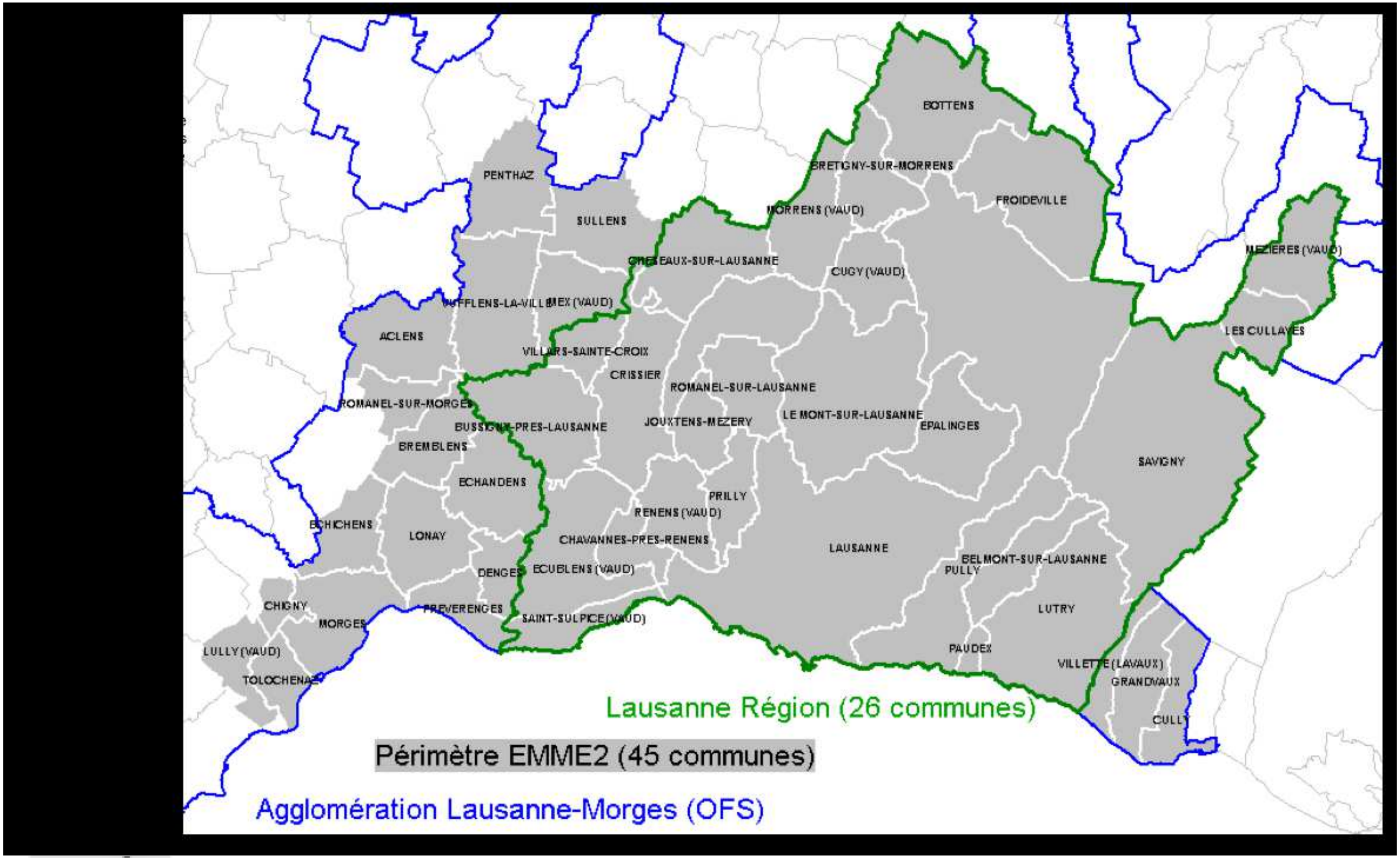
Spatial scope

- The perimeter relevant for the analysis is identified.
- It is partitioned into geographical zones (e.g. Lausanne: 500 zones)
- Assumption: travels within a zone are ignored

Temporal scope

- Identification of the period of the analysis
- For instance, the morning peak-hour, or the evening peak-hour.

Perimeter



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

Zoning

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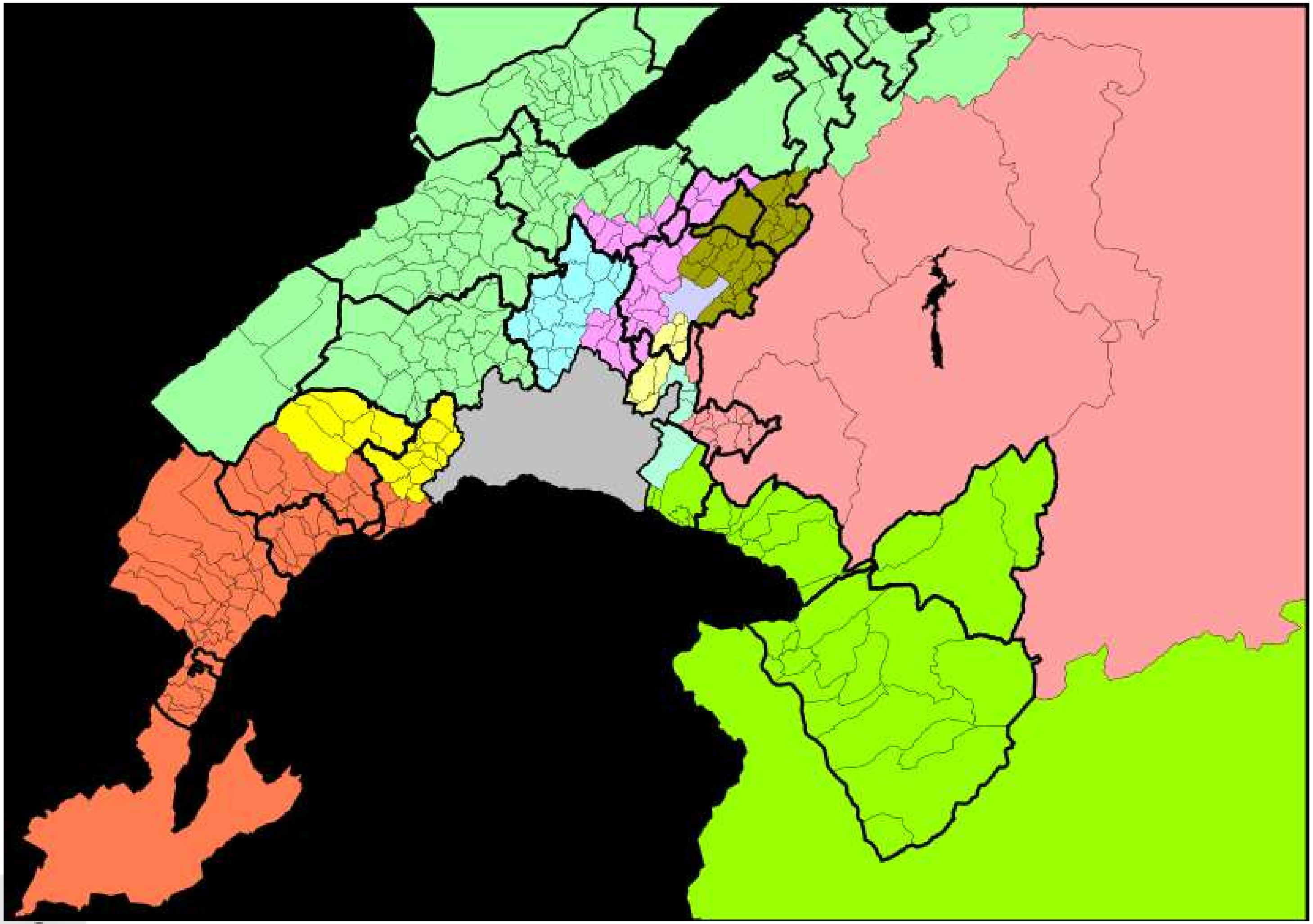
Zoning

Zoning



Step 1: trip generation

Is a trip performed or not?

- derived demand
- travel is required when two successive activities are not located at the same place
- Travel purposes (Swiss Micro-census 2000)

Leisure	41743	40.4%
Work	23420	22.7%
Shopping	20297	19.6%
Education	7912	7.7%
Service	3352	3.2%
Business activity	3006	2.9%
Escorting	1732	1.7%
Other	1017	1.0%
Business trip	837	0.8%
Change mode	60	0.1%

Step 1: trip generation

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

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Step 1: trip generation

Aggregate representation

- For each zone, determine
  - the number of trips originating from the zone
  - the number of trips reaching the zone

  during the analysis period
- Modeling tool: linear regression

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

  with, for instance, $Y =$nbr of trips, $X =$population

Disaggregate representation

- Activity choice models
- Location choice models

Step 2: distribution

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

- Aggregate representation: origin-destination matrix
- Disaggregate representation: destination choice models

Step 2: distribution

Origin-destination 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?

- 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

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

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Step 3: modal split

- In practice, one 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 this course

Step 4: 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”

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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.

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