Flexible Public Transport Modelling for Large Urban Areas

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Introduction

- Public transport makes travel demand models complex
  - PT enables many potential combination of transportation modes
  - Constructing a good choice model is cumbersome
- How to create a model that, contrary to currently existing models, is
  - Flexible w.r.t. how modes are valued and used
  - Consistent in the choice process
- Focus on mode and route choice, static modelling

Presentation contents

- Problem description

- Ideal model
  - Interface mode/route choice
  - Route set generation
  - Choice model

- Case study
  - Introduction
  - Route generation
  - Choice model

- Conclusions and recommendations

Problem description (1)

Aggregation of modes

- Different modes are modelled as one joint mode
  - Differences within the group are neglected

Example: GroeiModel

Bus and tram equivalent?

Real modes	Modes in model
Train	Train
Bus	Bus/tram/metro
Tram	
Metro	

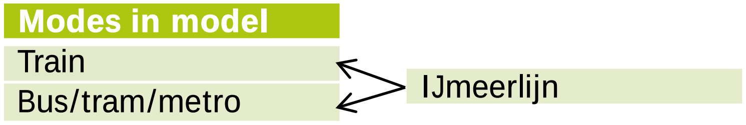
Problem description (2)

Addition of new modes

- Aggregate new mode with an existing mode?

- Add a real new mode?
  - Interaction with existing modes?

Example: IJmeerlijn in GroeiModel
- Possible future rail connection Amsterdam-Almere
- Is it train or metro?
  - Determines valuation of the mode
  - Determines possible combinations with other modes



Problem description (3)

Consistency of the choice process

- Logit models based on utility maximisation
- In terms of expectation, a group of options is more attractive than the options on themselves
  - Due to differences in preferences
    - among travellers
    - between travellers and researcher
  - Look out for mutual dependencies between options within the group (positive correlations of utilities)

Example: GroeiModel

- Ignores diversity in possible bus/tram/metro routes
- Ignores route overlap for train routes

Interface mode/route choice (1)

Classification

- Models can be classified according to two dimensions:
  - How are networks combined in a route?
  - How many modes are contained in a network?

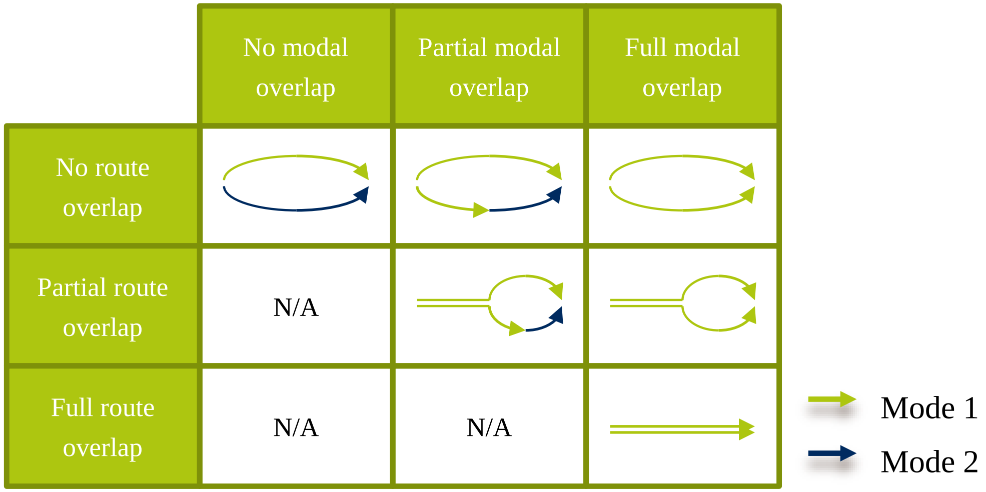
- The traveller has two choices in a model:
  - What networks will I use?
  - What route do I choose within these networks?

- Interface needs to be determined...

Interface mode/route choice (2)

Flexibility and consistency

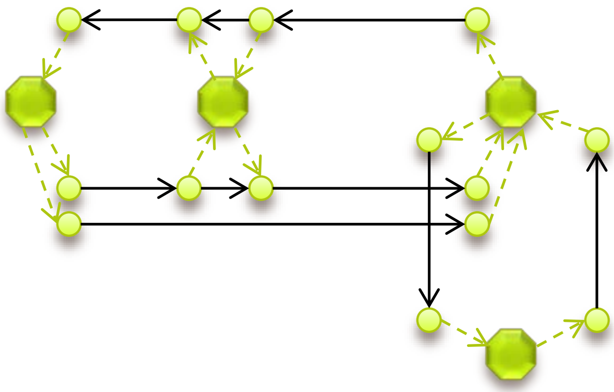
- Three types of positive correlations between utilities of route alternatives
  - Route overlap
  - Modal overlap
  - Mode similarities



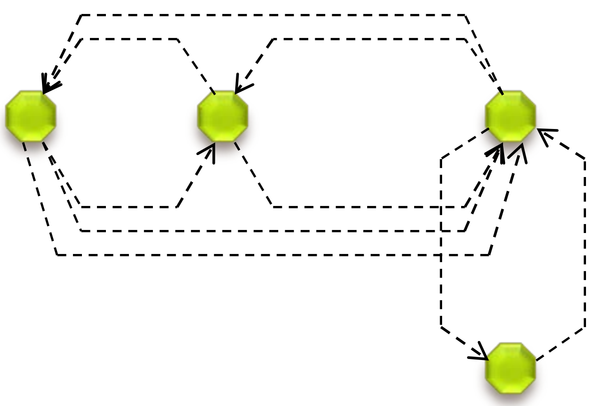
- Supernetwork required for flexibility and consistency
  - All modes should form a single network

Route set generation (1)

Public transport network structure



Stop
Departure/arrival
In-vehicle
Boarding/alighting

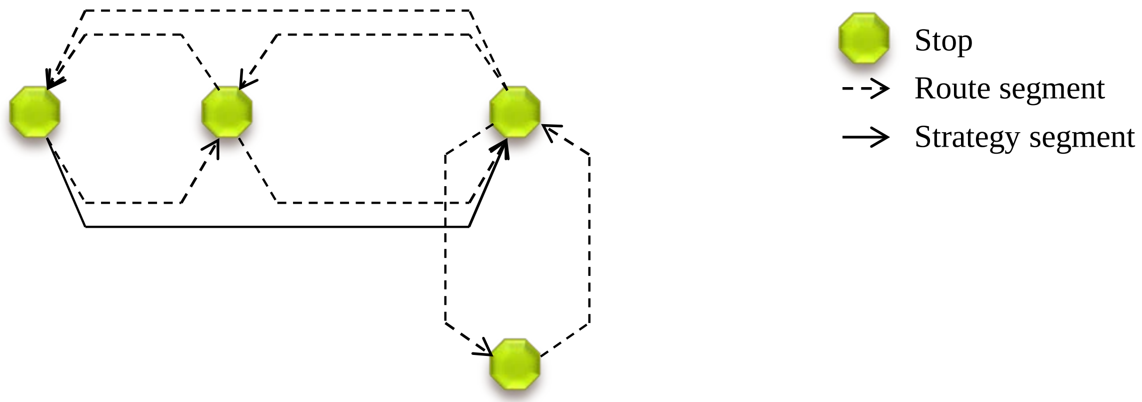


Stop
Route segment

Route set generation (2)

Common lines problem

- Common lines can now be merged
  - Simplifies network
  - Reduces the choice set size
  - More realistic from behavioural perspective (if same mode)



Route set generation (3)

Algorithm

- Branch-and-bound algorithm suitable for public transport network
  - Systematically iterate all possible routes within boundaries using the branch-and-bound algorithm
  - Choice set contents explicitly defined by search constraints
    - Tolerance constraint
      - With trade-off between number of legs and travel time
    - Logical constraints
    - Dominance constraint
  - Efficient for this public transport network with merged common lines
    - Number of segments in the network is large
    - Number of segments in a route is small

Route set generation (4)

Completing the supernetwork

- Adding private modes to complete the supernetwork should not increase the number of links per route too much
  - Otherwise, branch-and-bound algorithm will become very inefficient (search tree depth)
- Therefore, find access/direct/egress sub-routes in private mode network using Dijkstra and add these as segments to the supernetwork
  - For uni-modal route choice for private modes, you could use an additional route set generator

Choice model

Network GEV path size logit

Nested logit:

mode similarities

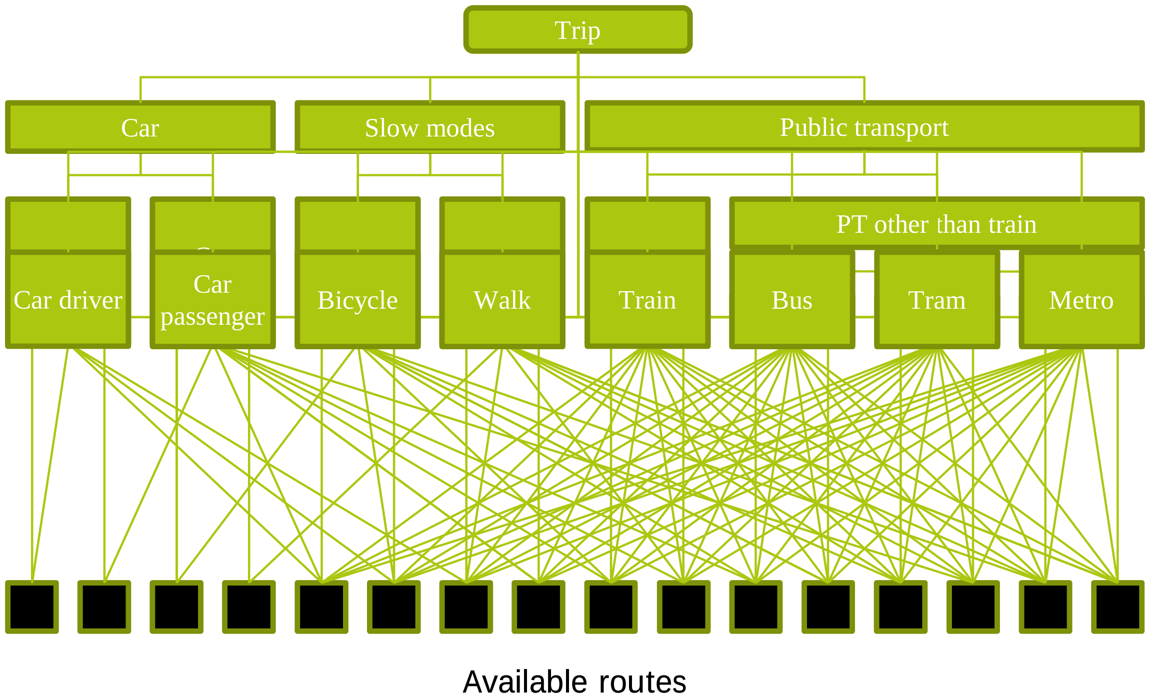
Cross-nested logit:

modal overlap

Path size factors

Path size logit:

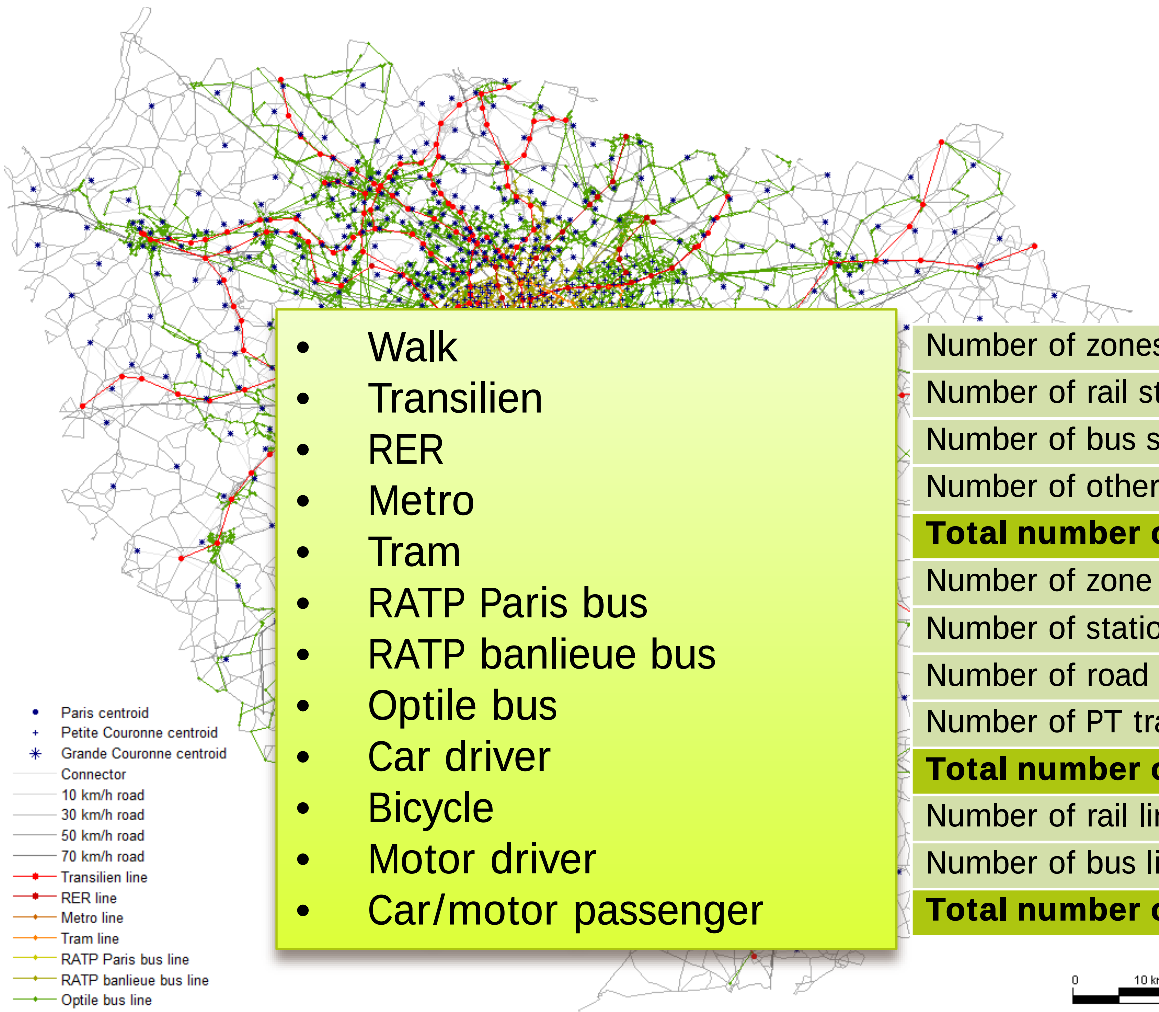
route overlap



Case study: introduction

Île-de-France

Morning peak



- Walk
- Transilien
- RER
- Metro
- Tram
- RATP Paris bus
- RATP banlieue bus
- Optile bus
- Car driver
- Bicycle
- Motor driver
- Car/motor passenger

Number of zones	1.342
Number of rail stations	936
Number of bus stops	10.978
Number of other road nodes	56.407
Total number of nodes	**69.663**
Number of zone connectors	21.336
Number of station connectors	10.546
Number of road links	261.518
Number of PT transfer links	15.054
Total number of links	**308.454**
Number of rail lines	198
Number of bus lines	2.494
Total number of PT lines	**2.692**

Case study: route generation (2)

Mapping observed routes to the supernetwork

Model is estimated based on household survey Enquête Globale Transport

- Home-work trips in morning peak
- Origins/destinations in Grande Couronne excluded

Route observations need to be mapped to the supernetwork:

What route did you take?

Car to node #2001
Metro to node #2034
Walk to node #10293
Bus to node #11839
Walk to destination

Car to (102,201)
Metro line 12 to (153,241)

Bus to node (211,294)

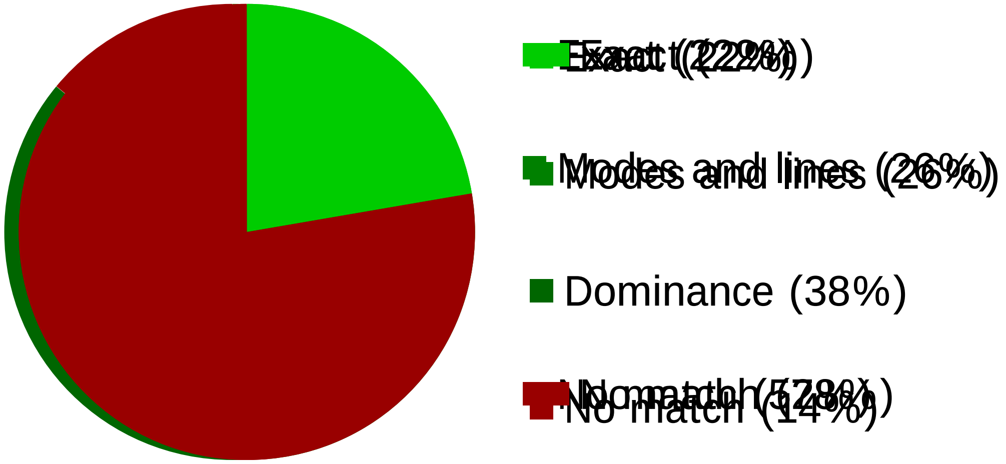
Case study: route generation (3)

Coverage of observed routes

Observed routes can now be compared with generated routes

For model estimation, the coverage of the route generation process is important

- Are routes observed in the survey also generated?
- Otherwise, one cannot choose them in the model



Case study: choice model (1)

Attributes mode and route choice model

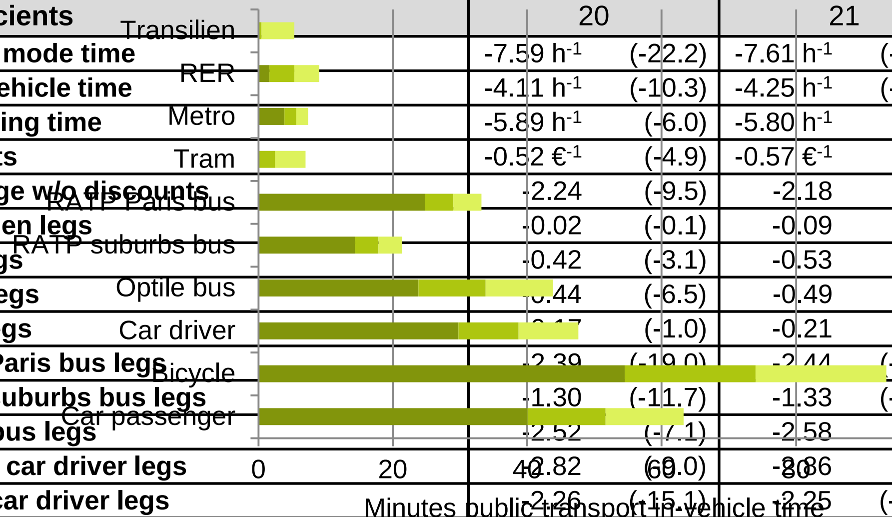
- Time in private modes (own vehicle or walk)
- Time in PT modes
- Waiting time (max. 7.5 minutes per boarding)
- PT costs
  - Taking personal discounts into account
- Dummy for using PT without discounts
- Number of legs ("boarding penalties")
  - For each mode separately
  - Separately with/without PT usage
- "Domination size" $\ln(1+n)$

- Vehicle and driving licence ownership taken into account through availability of alternatives

Case study: choice model (2)

Best estimated logit models

		MNL		PSL		NL		NPSL	
Log-likelihood		-2857.6		-2853.5		-2835.8		-2837.6	
ρ²		0.437		0.438		0.442		0.441	
Observations		2523		2523		2523		2523	
Free coefficients		20		21		22		22	
β	**Private mode time**	-7.59 h^{-1}	(-22.2)	-7.61 h^{-1}	(-22.3)	-6.90 h^{-1}	(-12.1)	-6.84 h^{-1}	(-15.4)
	PT in-vehicle time	-4.11 h^{-1}	(-10.3)	-4.25 h^{-1}	(-10.5)	-3.59 h^{-1}	(-8.5)	-3.60 h^{-1}	(-9.7)
	PT waiting time	-5.89 h^{-1}	(-6.0)	-5.80 h^{-1}	(-5.9)	-6.19 h^{-1}	(-6.4)	-6.15 h^{-1}	(-6.9)
	PT costs	-0.52 €$^{-1}$	(-4.9)	-0.57 €$^{-1}$	(-5.3)	-0.39 €$^{-1}$	(-4.1)	-0.41 €$^{-1}$	(-4.5)
	PT usage w/o discounts	-2.24	(-9.5)	-2.18	(-9.2)	-2.28	(-7.9)	-2.25	(-8.3)
	Transilien legs	-0.02	(-0.1)	-0.09	(-0.5)	-0.03	(-0.2)	-0.03	(-0.2)
	RER legs	-0.42	(-3.1)	-0.53	(-3.7)	-0.32	(-2.8)	-0.32	(-3.0)
	Metro legs	-0.44	(-6.5)	-0.49	(-7.0)	-0.34	(-6.3)	-0.40	(-7.3)
	Tram legs	-0.17	(-1.0)	-0.21	(-1.2)	-0.15	(-1.1)	-0.21	(-1.5)
	RATP Paris bus legs	-2.39	(-19.0)	-2.44	(-19.2)	-1.74	(-13.5)	-1.75	(-18.5)
	RATP suburbs bus legs	-1.30	(-11.7)	-1.33	(-11.9)	-1.07	(-10.0)	-1.07	(-11.8)
	Optile bus legs	-2.52	(-7.1)	-2.58	(-7.2)	-2.03	(-6.6)	-2.03	(-7.4)
	Access car driver legs	-2.82	(-9.0)	-2.86	(-9.1)	-2.32	(-8.5)	-2.30	(-9.8)
	Direct car driver legs	-2.26	(-15.1)	-2.25	(-15.1)	-2.17	(-9.9)	-2.13	(-11.5)
	Direct motor driver legs	-1.89	(-9.1)	-1.90	(-9.2)	-1.89	(-7.5)	-1.87	(-8.1)
	Acc./egr. bicycle legs	-5.83	(-8.1)	-5.87	(-8.2)	-4.43	(-7.5)	-4.32	(-8.6)
	Direct bicycle legs	-3.83	(-23.8)	-3.80	(-23.6)	-3.67	(-11.2)	-3.61	(-13.7)
	Access passenger legs	-3.90	(-9.7)	-3.92	(-9.7)	-3.09	(-8.7)	-3.02	(-10.5)
	Direct passenger legs	-5.48	(-25.9)	-5.48	(-25.9)	-5.37	(-11.0)	-5.33	(-13.4)
	Domination size	0.16	(5.6)	0.15	(5.1)	0.11	(4.7)	0.10	(4.1)
γ	**Path size**			-0.34	(-2.8)			-0.28	(-3.1)
θ	**PT nest**					0.74	(-4.8)	0.68	(-6.9)
	Metro/tram nest					0.57	(-4.1)		



Case study: choice model (3)

Aggregation of modes

In ANTONIN:	Train		Metro		Bus		
	Transilien	RER	Metro	Tram	RATP Paris bus	RATP banlieue bus	Optile bus
Transilien		+2.1	+2.1	+0.7	+9.9	+7.1	+6.5
RER	-2.1		+0.2	-1.0	+11.3	+7.1	+6.0
Metro	-	-0.2		-1.4	+12.7	+7.7	+5.7
Tram	-0.7	+1.0	+1.4		+9.1	+6.0	+5.9
RATP Paris bus	-9.9	-11.3	-12.7	-9.1		-6.4	+1.0
RATP banlieue bus	-7.1	-7.1	-7.7	-6.0	+6.4		+3.5
Optile bus	-6.5	-6.0	-5.7	-5.9	-1.0	-3.5	

- Significant differences in boarding penalties within buses and within trains
- Aggregation of modes hence is indeed problematic

Case study: choice model (4)

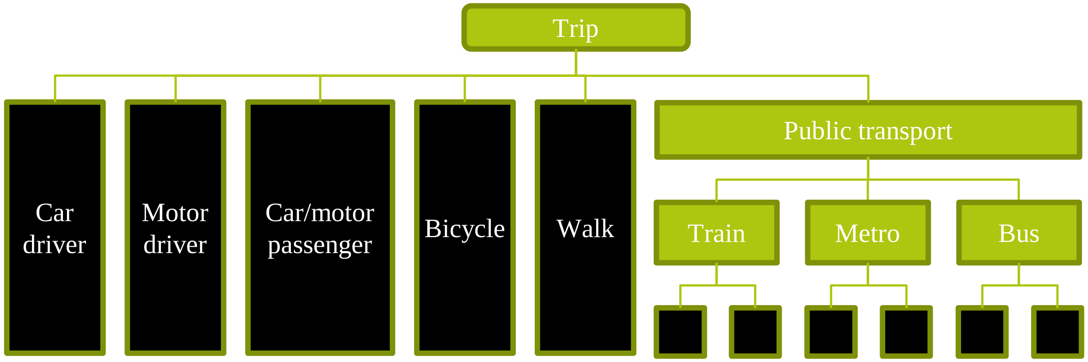
Consistency in choice process: positive correlations

- Route overlap: no positive correlation
  - On the contrary: overlapping routes seem more attractive, possibly due to ad hoc choice behaviour
    - Path size coefficient is significant with the wrong sign
  - However, a negative path size coefficient is no correct model of ad hoc route choice options

Case study: choice model (5)

Consistency in choice process: positive correlations

- Nested path size logit model
  - Necessary simplification due to software limitations



- Modal overlap: significant positive correlation among routes with main mode metro
- Mode similarities: significant positive correlation among routes with PT
- Modal overlap for private modes (different nesting): significant negative correlation among routes with PT where PT part is identical

Conclusions and recommendations

- Theoretical framework developed for flexible PT modelling
- Case study shows feasibility in practice
- Case study supports expected advantages compared to currently existing model structures

- Recommended subjects for further research include:
  - Network loading results
  - Ad hoc route choice behaviour
  - Branch and bound algorithm optimisation
  - Network GEV model usage
  - Timetable information usage
  - Robustness of adding new modes