Karlsruher Institut für Technologie

WCTR 2023 Montréal

19 July 2023

How to apply the four-step model for 150,000 travel zones: The HIPAT model

Jan Ihrig & Patrick Jochem

INSTITUTE FOR ECONOMICS (ECON), NETWORK ECONOMICS

In European transport models, travel zones are defined according to the NUTS-classification.

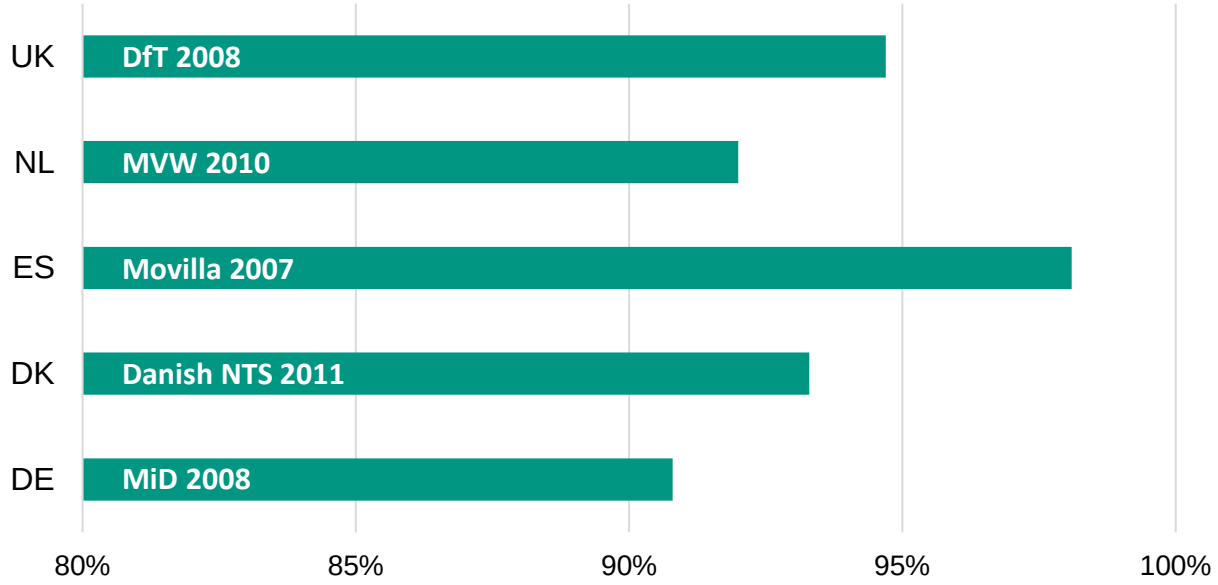
Level	Diameter	#Zones	#O/D relations
NUTS-0			
NUTS-1	250 km	100	10,000
NUTS-2			
NUTS-3	**65 km**	**1,500**	**2 million**
LAU-1			
LAU-2	7 km	150,000	20 billion

Scope: EU-28 and neighbouring countries, approximate values

- Runtime problems increase with the number of travel zones
- Trade-off between model runtime and model accuracy
  - NUTS-3 for “regional” models (e.g., TRANS-TOOLS, Vaclav, TRIMODE)
  - NUTS-2 for high-level models (e.g., HIGH-TOOL, ASTRA-EC)

Less than 10% of the motorized trip demand can be modelled by NUTS-3 based transport models.

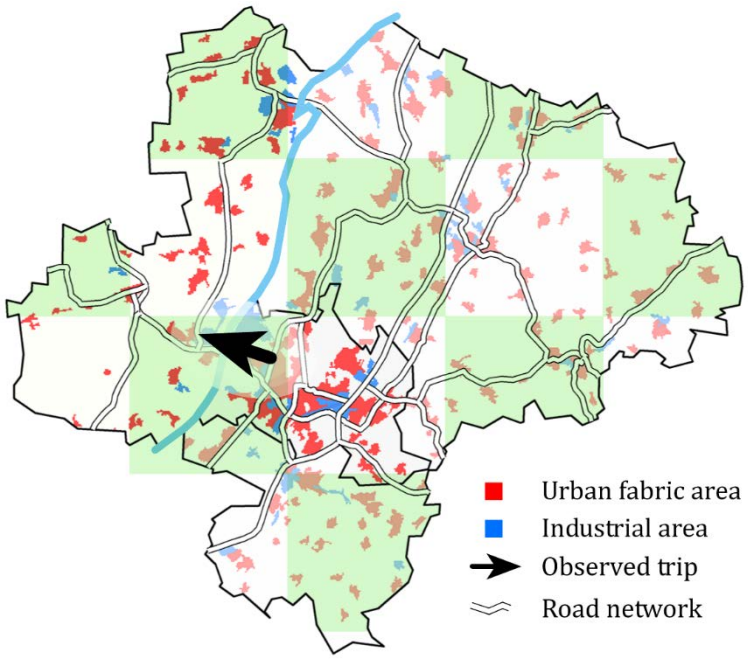
- Over 90% of the motorised trip demand is shorter than 50km.
  - ➔ Source: Travel Surveys of European countries.
  - ➔ NUTS-3 based models cannot assess impact of policies on regional trips.
  - ➔ Higher level of detail needed and more travel zones, but runtime problems.

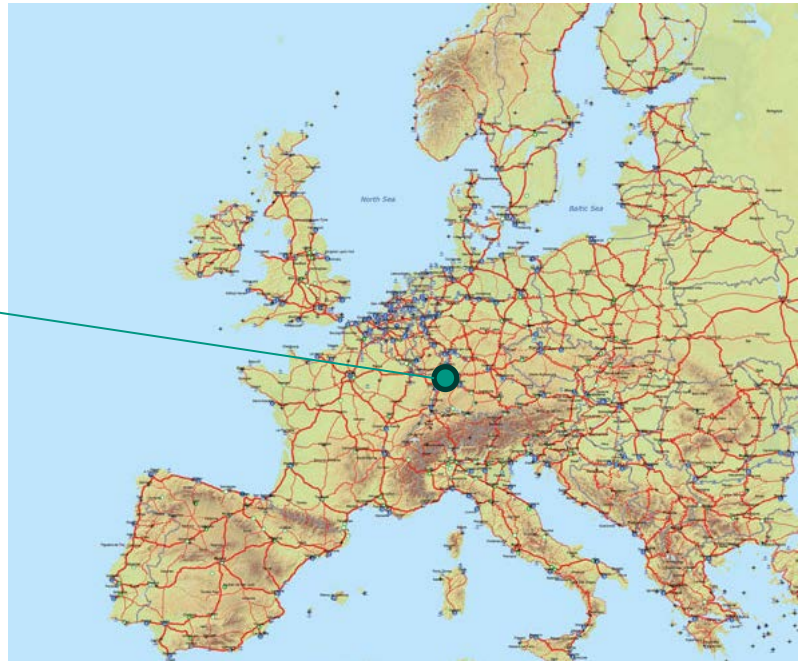


Scope: Rail, road and air passenger trips < 50km

Dilemma - Policy impact assessment: Focus on regional or on long-distance trips?

- Regional transport model (LAU-2)
- European transport model (NUTS-3)



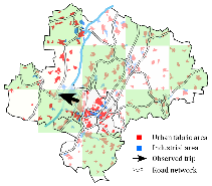


➔ <u>Not consistent</u>: Combining results from both models.

HIPAT provides insights into regional and long-distance transport for the whole of Europe.

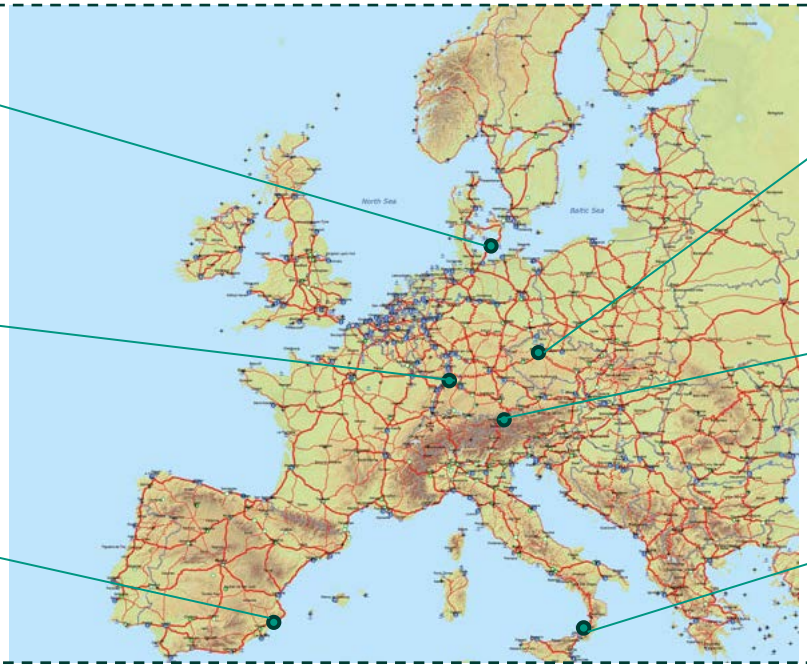
- The whole of Europe is modelled at the detailed LAU-2 level.

Fehmarn Belt fixed link



Karlsruhe Rhine Bridge

Mediterranean Corridor



HSR upgrade in CZ

Brenner Base Tunnel

Strait of Messina Bridge

➔ Consistent approach for transport planning and policy assessment.

Agenda

- Introduction
- Foundation of data and methodology
- Avoiding runtime problems
- Case study and HIPAT prototype model
- Outline of policy scenarios

HIPAT bases on ETISplus data and the EU transport policy assessment model HIGH-TOOL.

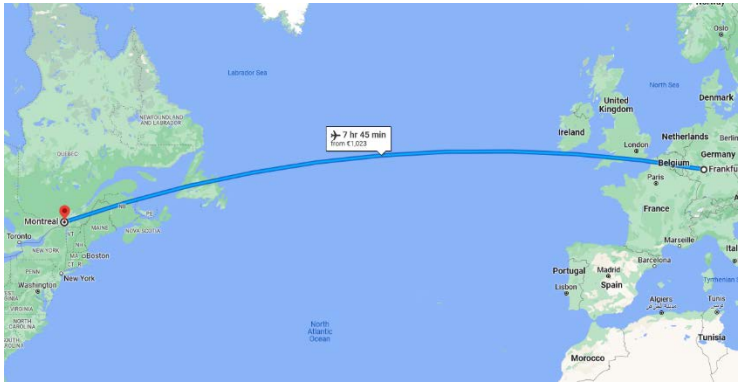
- ETISplus project
  - European transport policy information system (ETIS)
  - Socio-economic data, networks, O/D trip demand data
- HIGH-TOOL project
  - High-level tool for transport policy assessment by the European Commission
  - Transport demand module (peer-reviewed by other modelers)
- PhD thesis
  - Development of the Hipat model
  - Prototype implementation and Case study

Agenda

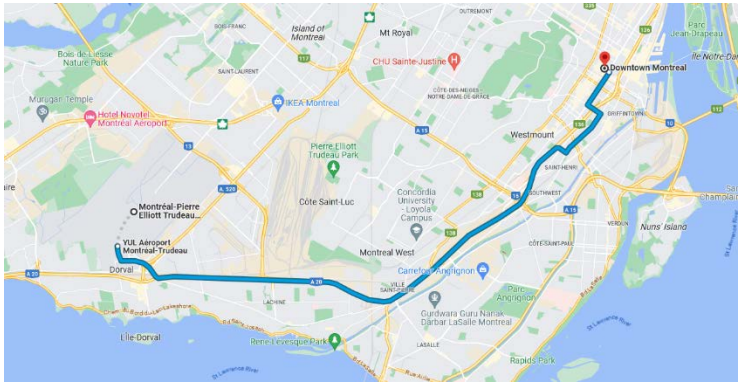
- Introduction
- Foundation of data and methodology
- Avoiding runtime problems
- Case study and HIPAT prototype model
- Outline of policy scenarios

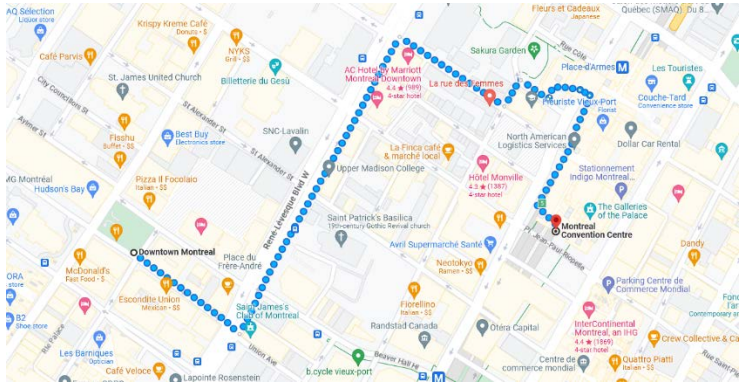
Real world trip planning problems are solved at different scales.

- My trip planning to the WCTR 2023



- Global scale
  Flight from Central Europe to North America
- Regional scale
  Trip from Montréal airport to the hotel
- Urban scale
  Walk from hotel to convention centre





Modelling long-distance and regional trips at different levels of detail reduces the complexity.

- HIPAT selects the optimal level of detail for each trip
  (i.e., number of travel zones and O/D relations)

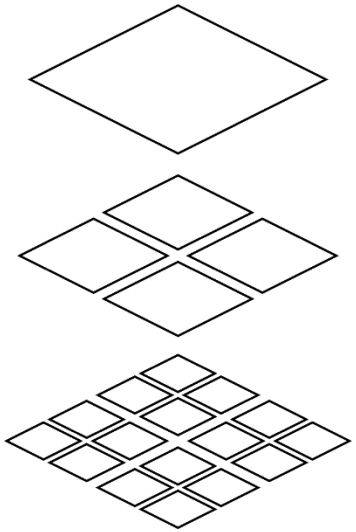
- Long-distance trips are modelled at NUTS-1 level. (e.g., Belgium to Greece, >2000 km)
  - LAU-2 : 600,000 O/D relations
  - NUTS-3 : 2,000 O/D relations
  - NUTS-1 : 12 O/D relations

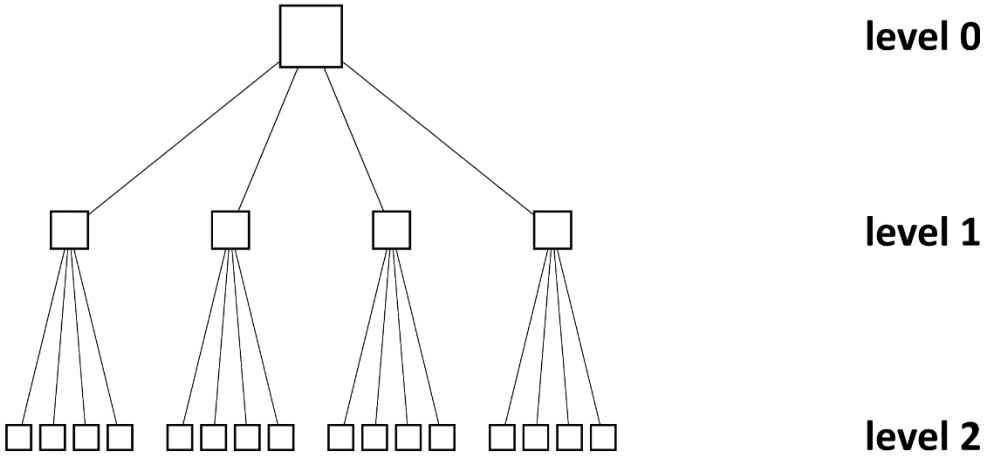
- Regional trips are modelled at LAU-2 level. (e.g., Karlsruhe to Stuttgart, 70km)
  - LAU-2 : 60,000 O/D relations
  - NUTS-3 : 156 O/D relations
  - NUTS-2 : 1 O/D relation

Backbone of the HIPAT model is a hierarchical zoning-system.

- Quad-tree
  - Efficient data structure.
  - Each zone is sub-divided into four zones.
  - Hierarchical structure follows a top-down approach.

- Structure

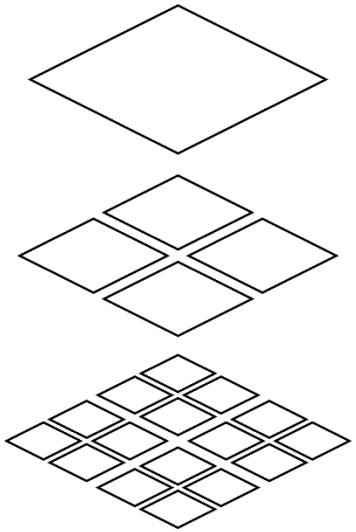


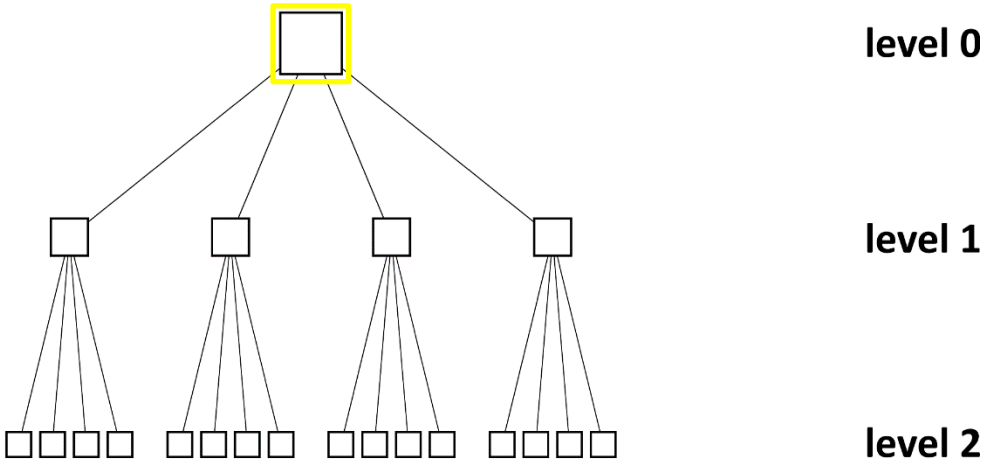


Efficient computation of indicators at different hierarchical levels.

- Computation of O/D trip matrix
  - Starts at the top level.
  - If higher accuracy is required, switch to level 1.
  - For missing parts, switch to next level (continue until bottom level is reached).

- Structure

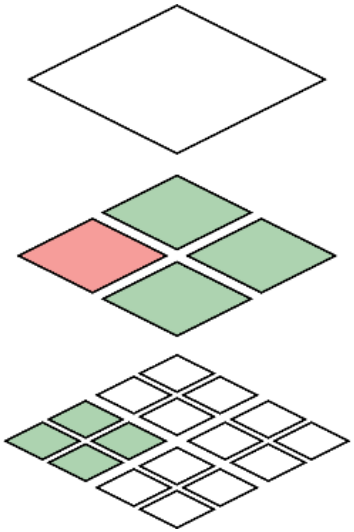


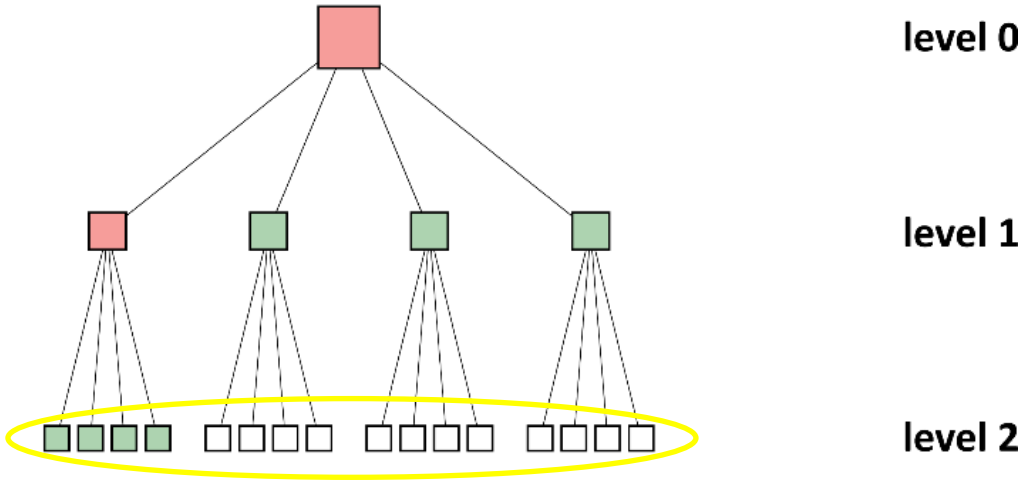


Efficient computation of indicators at different hierarchical levels.

- Computation of O/D trip matrix
  - Starts at the top level.
  - If higher accuracy is required, switch to level 1.
  - For missing parts, switch to next level (continue until bottom level is reached).

- Structure





Result: Only 7 computations instead of 16

The more hierarchical levels we add, the more calculations we can save.

- Example: Quad-trees with 3 to 8 levels
  - Trip matrix computation following quad-tree-based approach
  - Trip matrix computation following standard four-step approach
  - Quantum leap >99.9% savings

		Number of O/D relations		
Level	**Zones**	**Quad-tree**	**Standard**	**Savings**
3	64	1,756	4,096	57.1%
…	…	…	…	…
5	1,024	40,756	1 million	96.1%
…	…	…	…	…
8	65,526	2.9 million	4.3 billion	**99.9%**

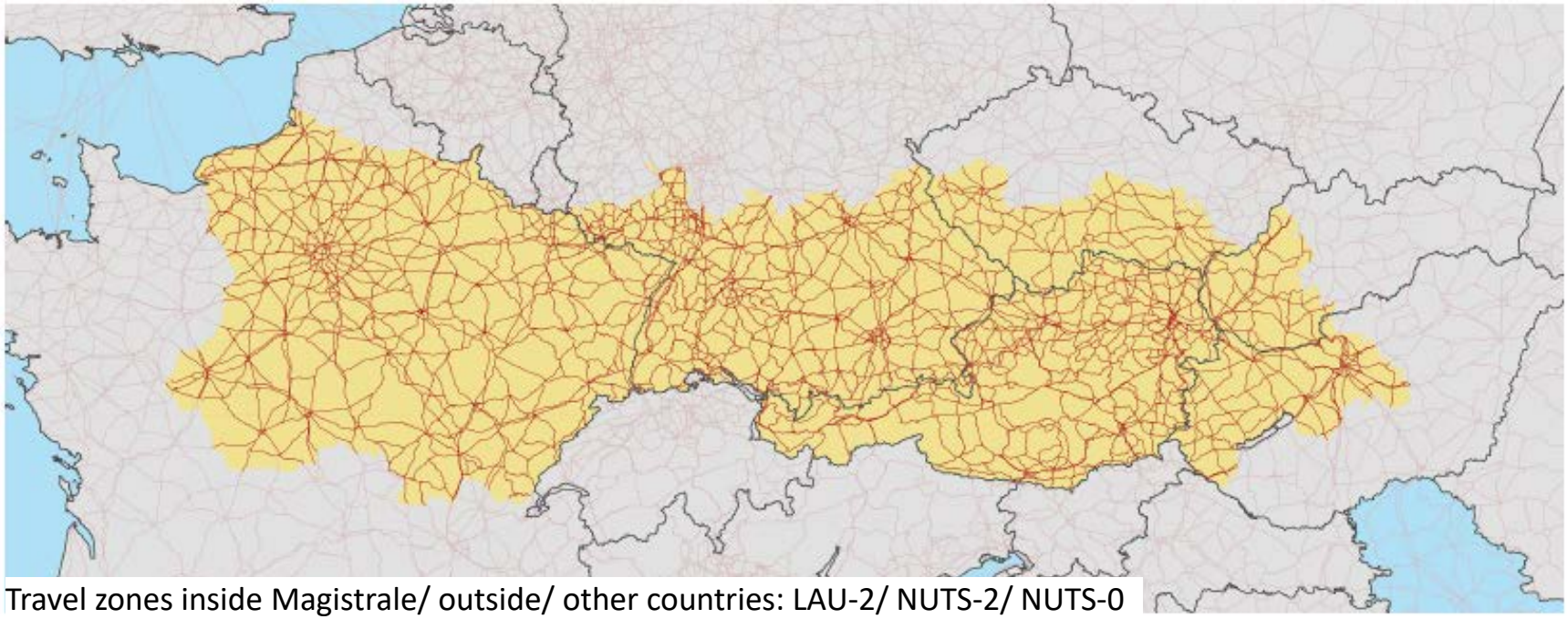
➔ Quad-tree-based approach can handle 150,000 travel zones

Agenda

- Introduction
- Foundation of data and methodology
- Avoiding runtime problems
- Case study and HIPAT prototype model
- Outline of policy scenarios

The HIPAT prototype model was realised for 33,000 travel zones.

- Key figures
  - Scope: “Magistrale” transport corridor, Road commuting trips
  - Runtime: 2 minutes



Travel zones inside Magistrale/ outside/ other countries: LAU-2/ NUTS-2/ NUTS-0

Case study investigates the impact of the travel zone size on the quality of the model output.

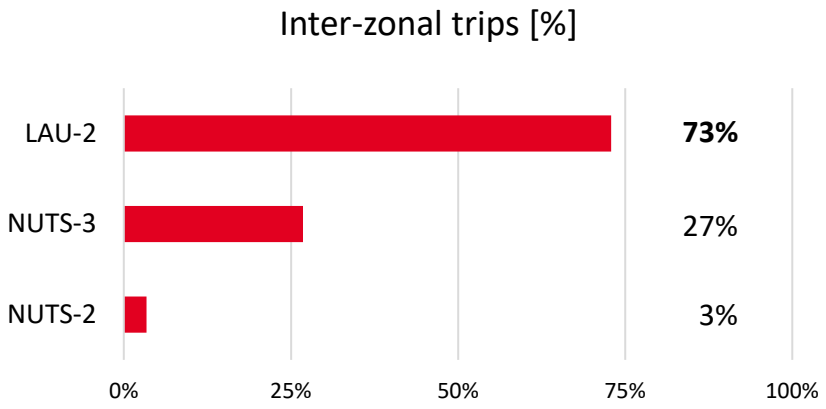
- Scenarios are restricted to different levels of detail.

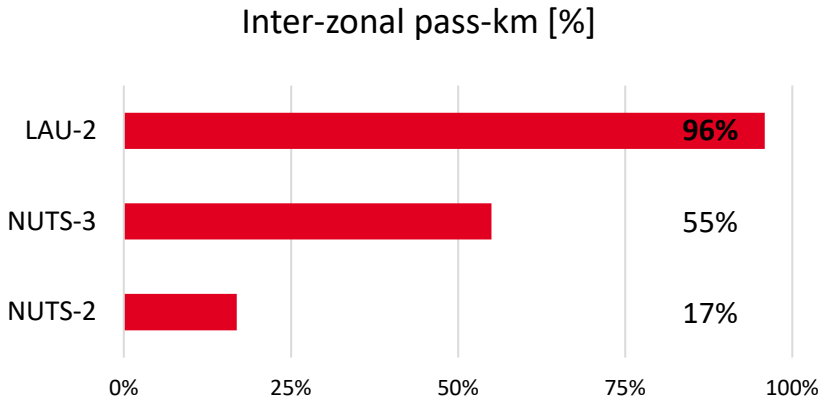
	EU	NUTS-0	NUTS-1	NUTS-2	NUTS-3	LAU-1	LAU-2
NUTS-2 scenario	✔	✔	✔	✔	-	-	-
NUTS-3 scenario	✔	✔	✔	✔	✔	-	-
LAU-2 scenario	✔	✔	✔	✔	✔	✔	✔

- Approach
  - Apply prototype model, then evaluate computed O/D trip matrices.
    (scope: only trips originating inside the Magistrale)

Results ...

The smaller the zones are, the higher the share of inter-zonal road commuting trips is.

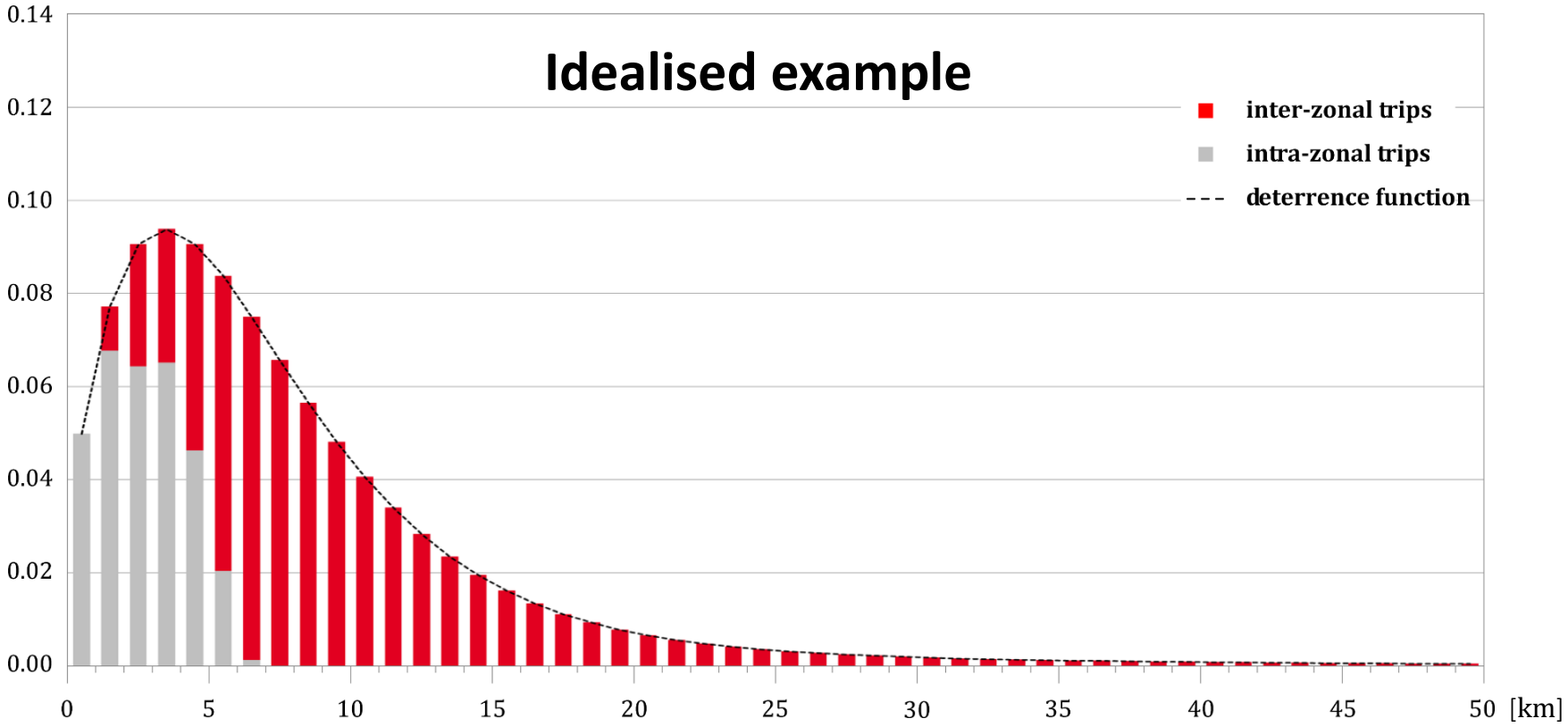




- Result is as expected
- Share of inter-zonal demand
  - LAU-2: very high share
  - NUTS-2: very low share

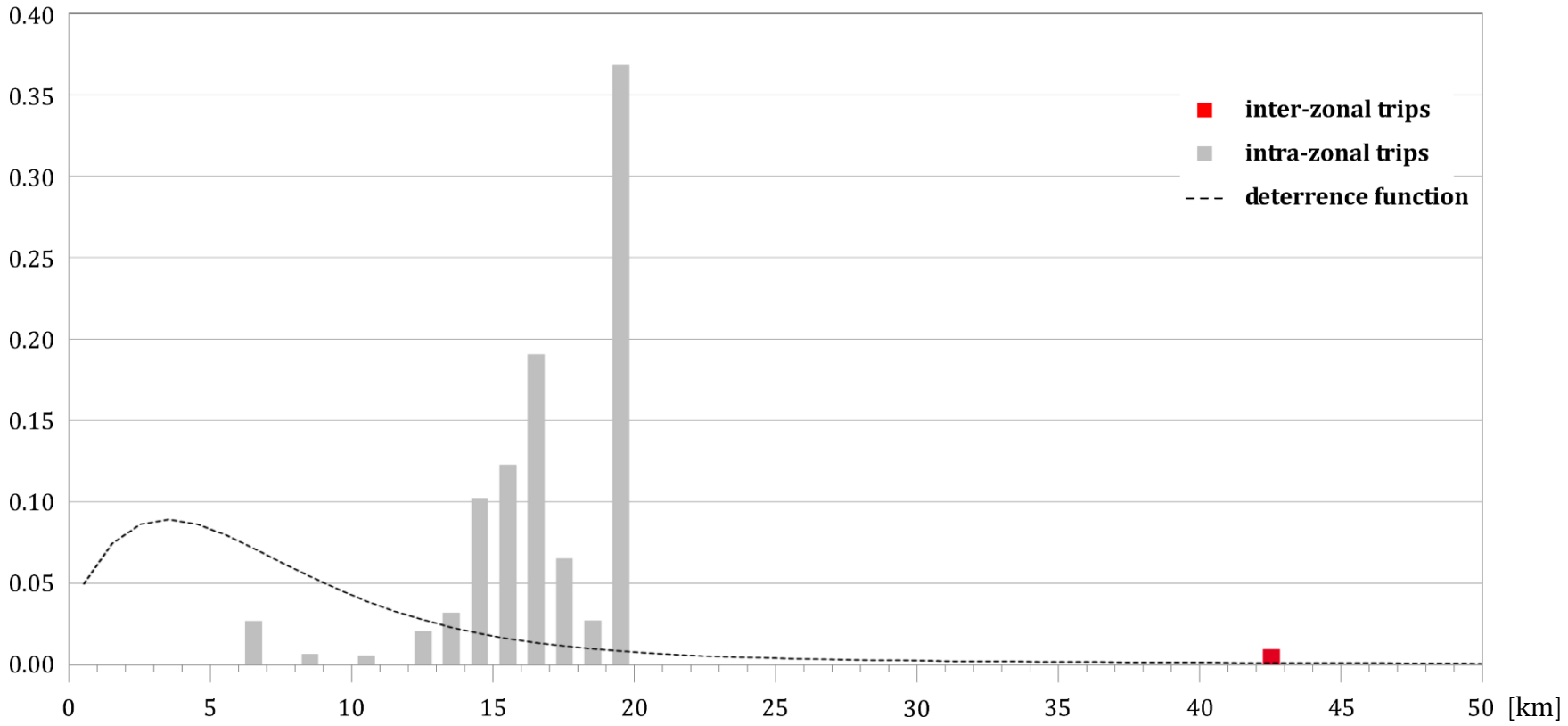
Comparison of trip length distribution to the deterrence function (trip distribution model).

- Ex.: Perfect match.



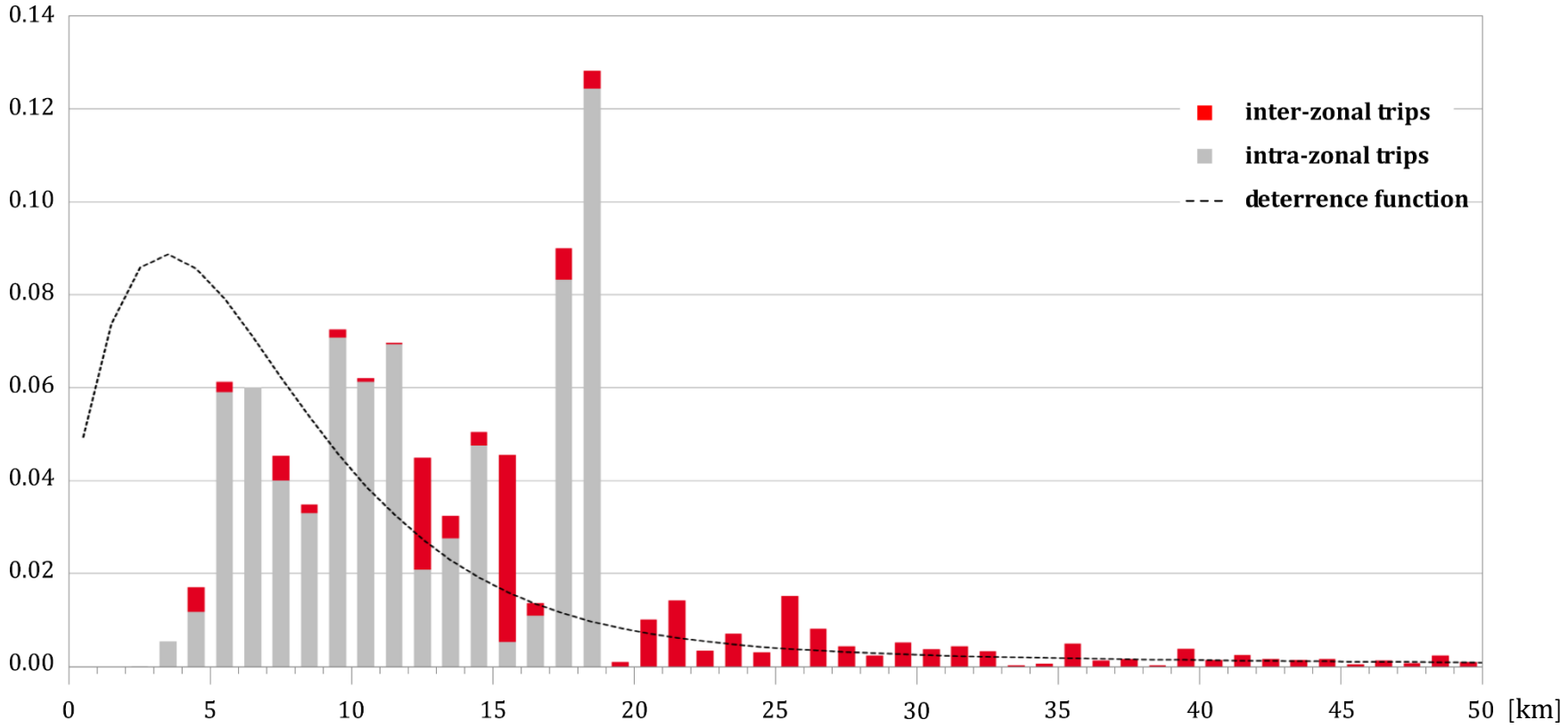
TLD cannot be computed for the NUTS-2 scenario.

- Not any matching.



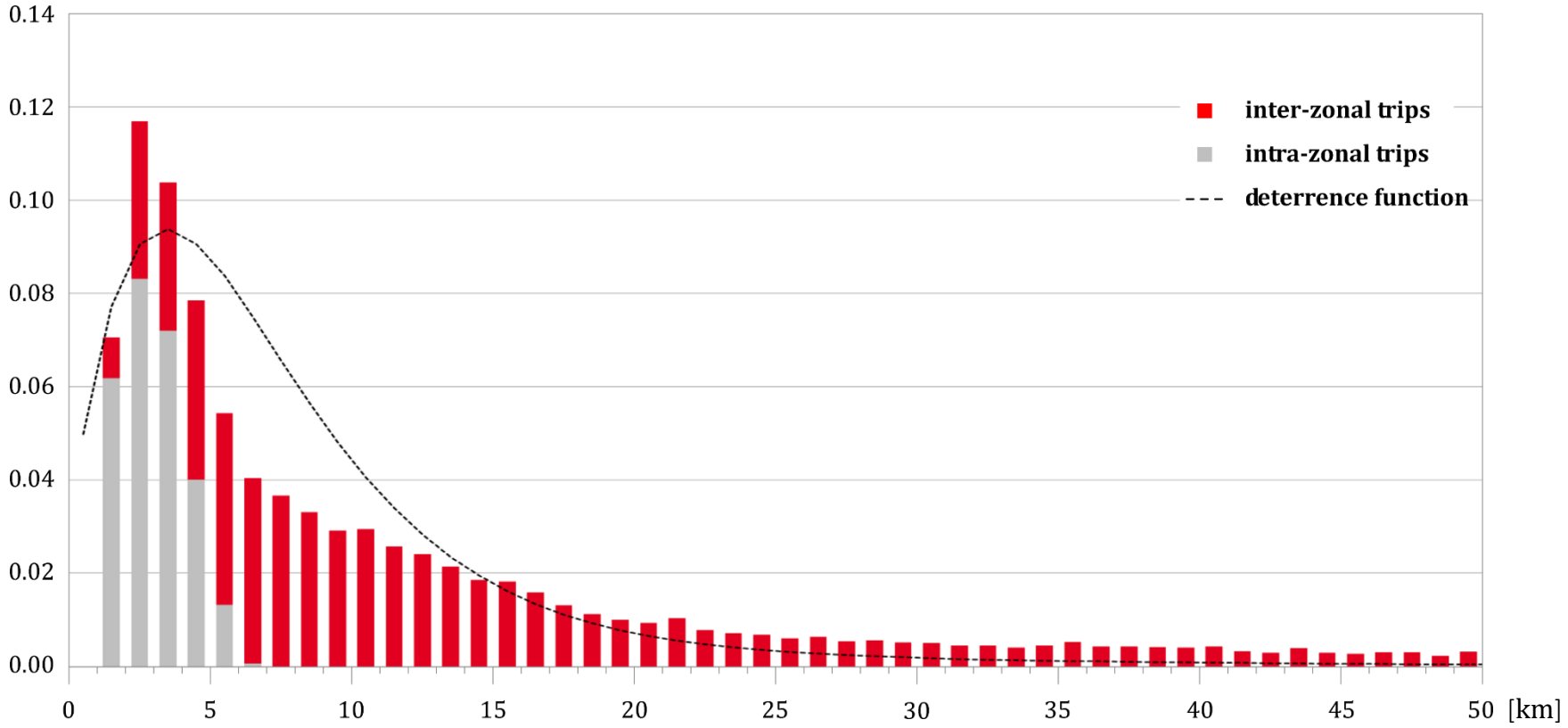
Poor matching for the distance bands 0-20km for the NUTS-3 scenario.

- Many gaps.



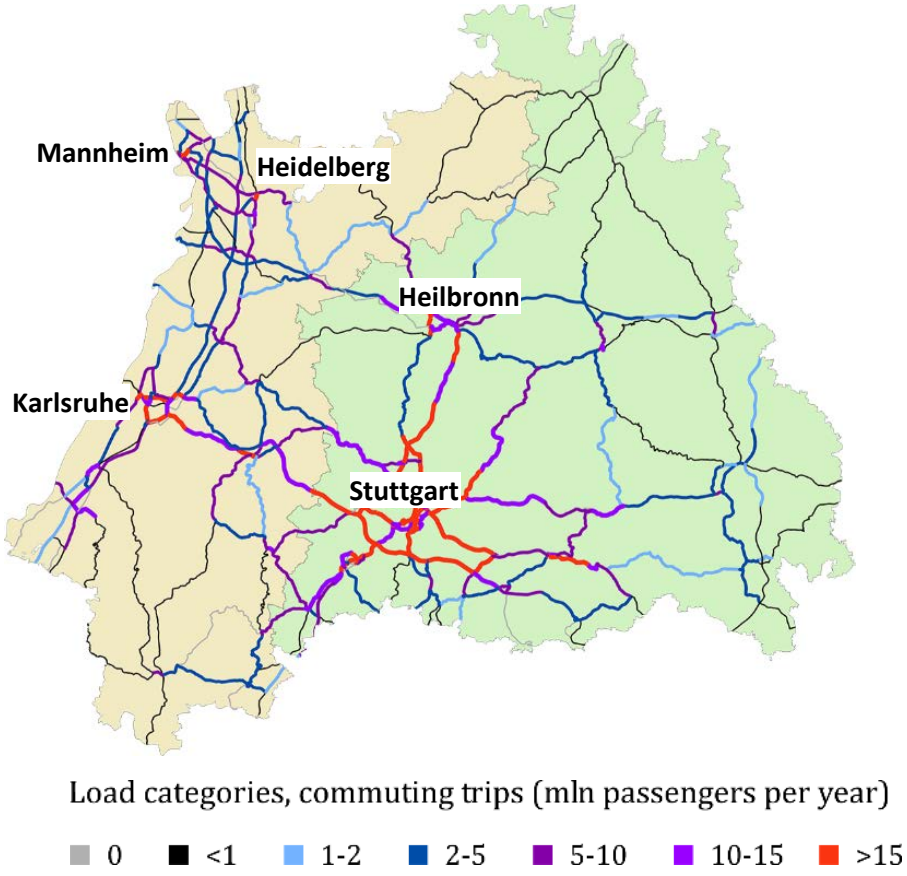
Good matching between the TLD and the deterrence function for the LAU-2 scenario.

- Almost continuous distribution.
- Not perfect, but all differences are within reasonable limits.



O/D trip matrix was allocated to the network to analyse the derived traffic load patterns.

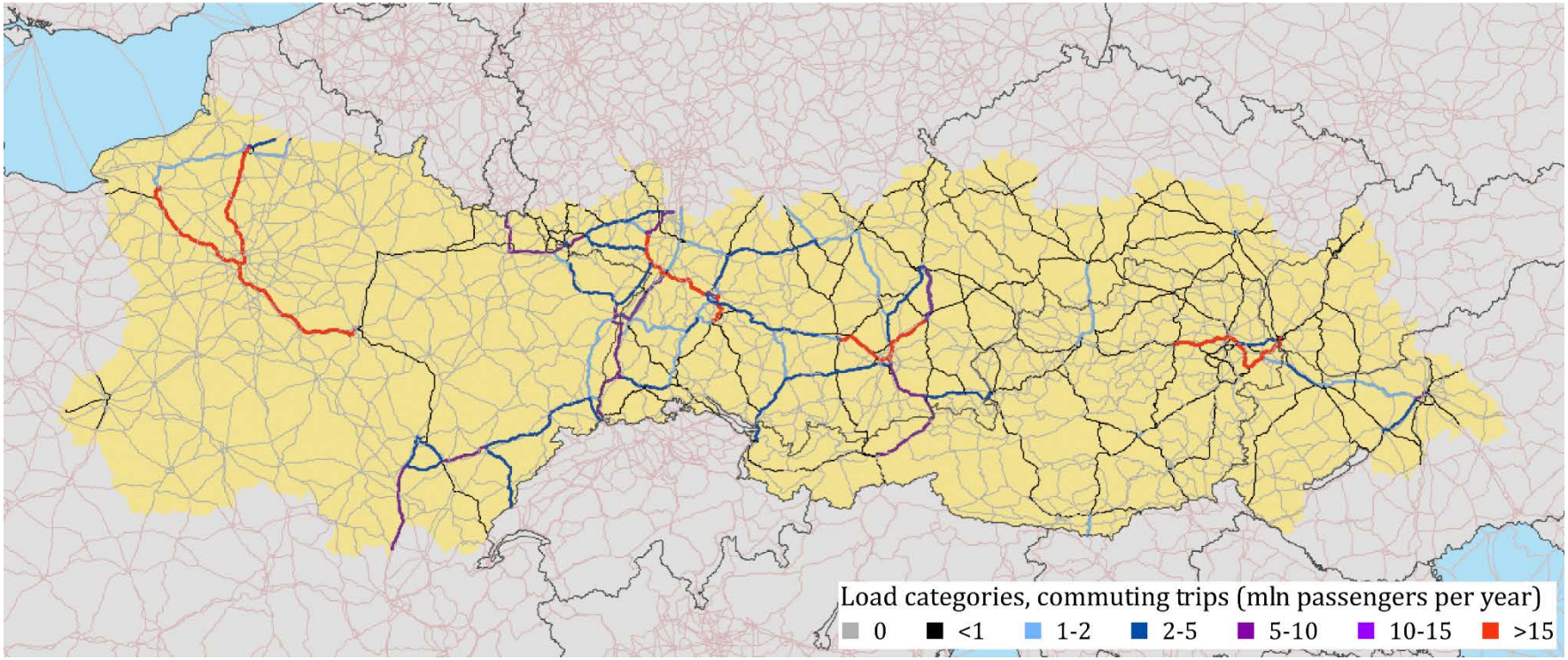
- Ex.: Network assignment with reasonable patterns
  (all or nothing assignment)



- High traffic loads around cities
- Low traffic loads in rural areas

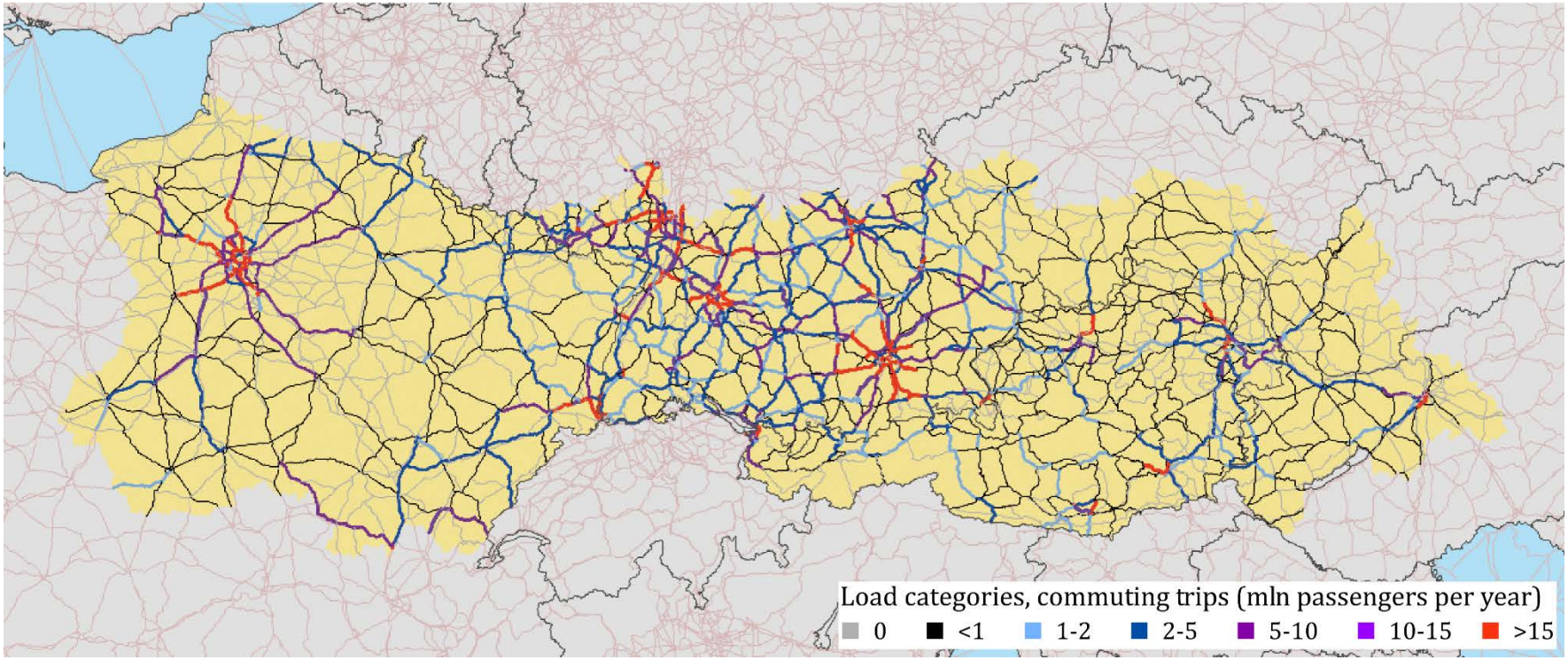
Network assignment produced for the NUTS-2 scenario provides no basis for further analyses.

- Most links are empty.



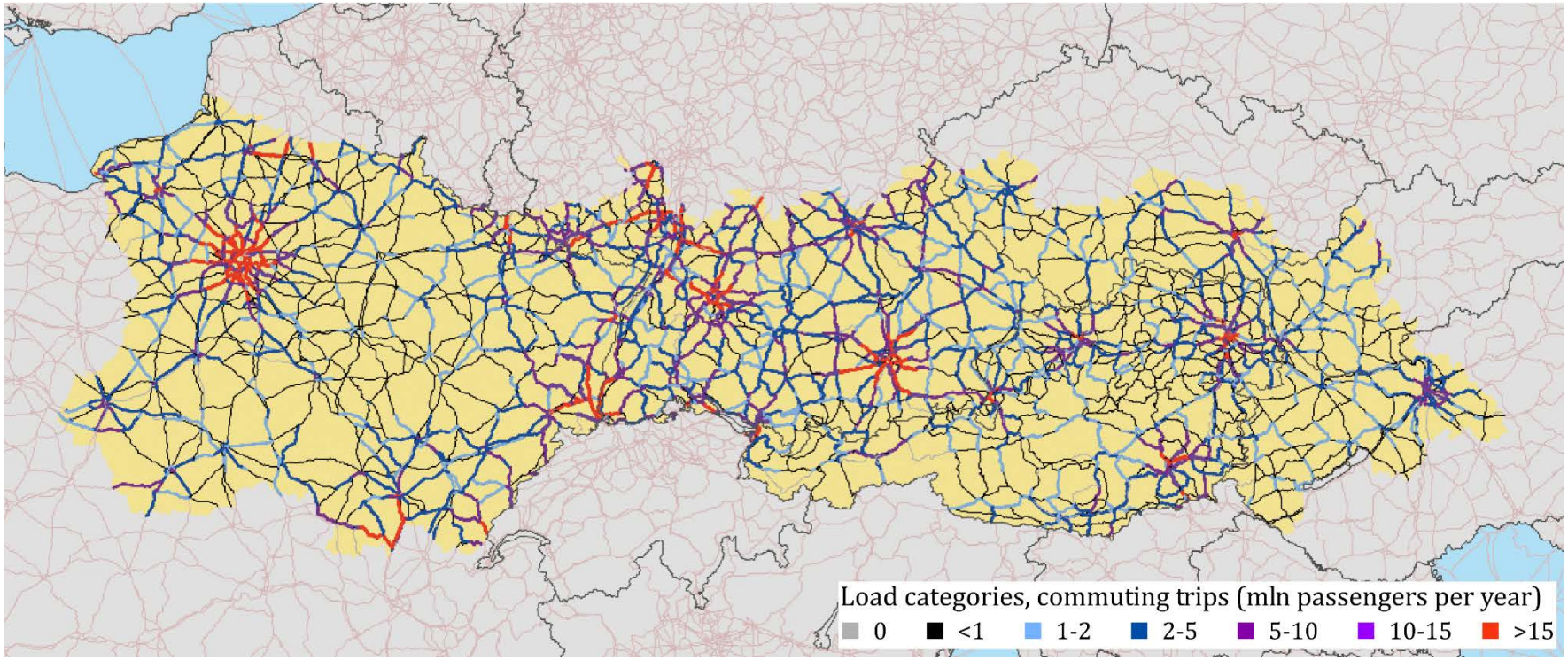
Network assignment produced for the NUTS-3 scenario is not optimal.

- Several gaps in the assignment results.



LAU-2 scenario provides an excellent basis for transport policy assessment.

- Traffic load patterns look realistic.
- Traffic loads are computed for (almost) all links.



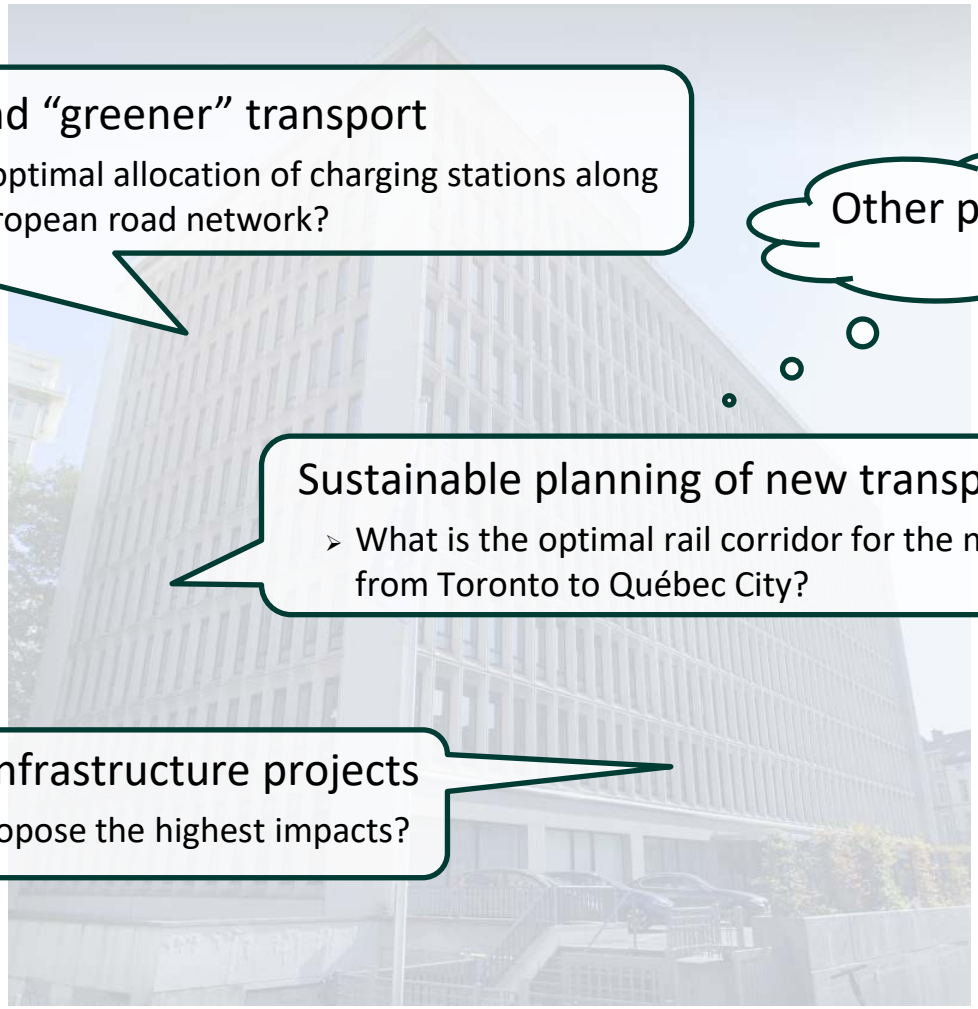
Main conclusions

- Prototype was implemented and tested successfully.
  - No runtime problems: 33,000 travel zones in two minutes.
- Quality of the results produced depends on the size of the travel zones.
  - The LAU-2-based HIPAT model provides excellent results.
  - Significant improvement between the NUTS-3 and the LAU-2 level.
  - Reminder: Current European transport models are bound to the NUTS-3 level.
- Future step(s): Application of HIPAT model for 150,000 travel zones.
  - One consistent transport model at LAU-2 level for the whole of Europe.
  - Impact assessment for long-distance and regional trips.

Agenda

- Introduction
- Foundation of data and methodology
- Avoiding runtime problems
- Case study and HIPAT prototype model
- Outline of policy scenarios

HIPAT model provides a good basis for policy assessment of infrastructure-related scenarios.



E-mobility and “greener” transport

- What is the optimal allocation of charging stations along the trans-European road network?

Other policy questions?

Sustainable planning of new transport corridors

- What is the optimal rail corridor for the new intercity line from Toronto to Québec City?

Prioritisation of infrastructure projects

- Which projects propose the highest impacts?

References

- Ihrig, J. (2018). *Spatial disaggregation in transport modelling : modelling Europe with more than 100,000 travel zones.* Karlsruhe Institute of Technology (KIT). Ph.D. thesis.
- Szimba et al. (2016). *Final Report, HIGH-TOOL Deliverable D10.5*. Project co-funded by the European Commission under the 7th Framework Programme (Grant Agreement no. 321624).
- Newton et al. (2013). *Final Report, ETISplus Deliverable D8*. Project co-funded by the European Commission under the 7th Framework Programme (Grant Agreement no. 233596).
- European Commission (2008). *Nomenclature of Territorial Units for Statistics (NUTS) 2006 – Statistical Units.* Eurostat (ESTAT), GISCO. Data set.

Jan.Ihrig@deutschebahn.com

Patrick.Jochem@dlr.de

Thank you very much for your attention!

Backup.

Calibration of the model is almost identical for the three scenarios.

- Method: Adjusting the deterrence function in gravity trip distribution model
  - Average trip length: 19.6 km

- Almost identical deterrence functions were used for all scenarios.