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Multi-agentbaserad simulering och utvärdering av stationärt snabbladdningsbehov för en helelektrisk tung lastbilsflotta

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Hur påverkar snabbladdningsstationers täthet elektrifiering av tunga lastbilar i Sverige?

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Agenda

- Who am I?
- Model development
  - Background
  - MATSim
  - Methodology
  - Example results
- Case study: Distance intervals
  - Background
  - Description
  - Results
  - Conclusions
- Future work

Who am I?

Mattias Ingelström

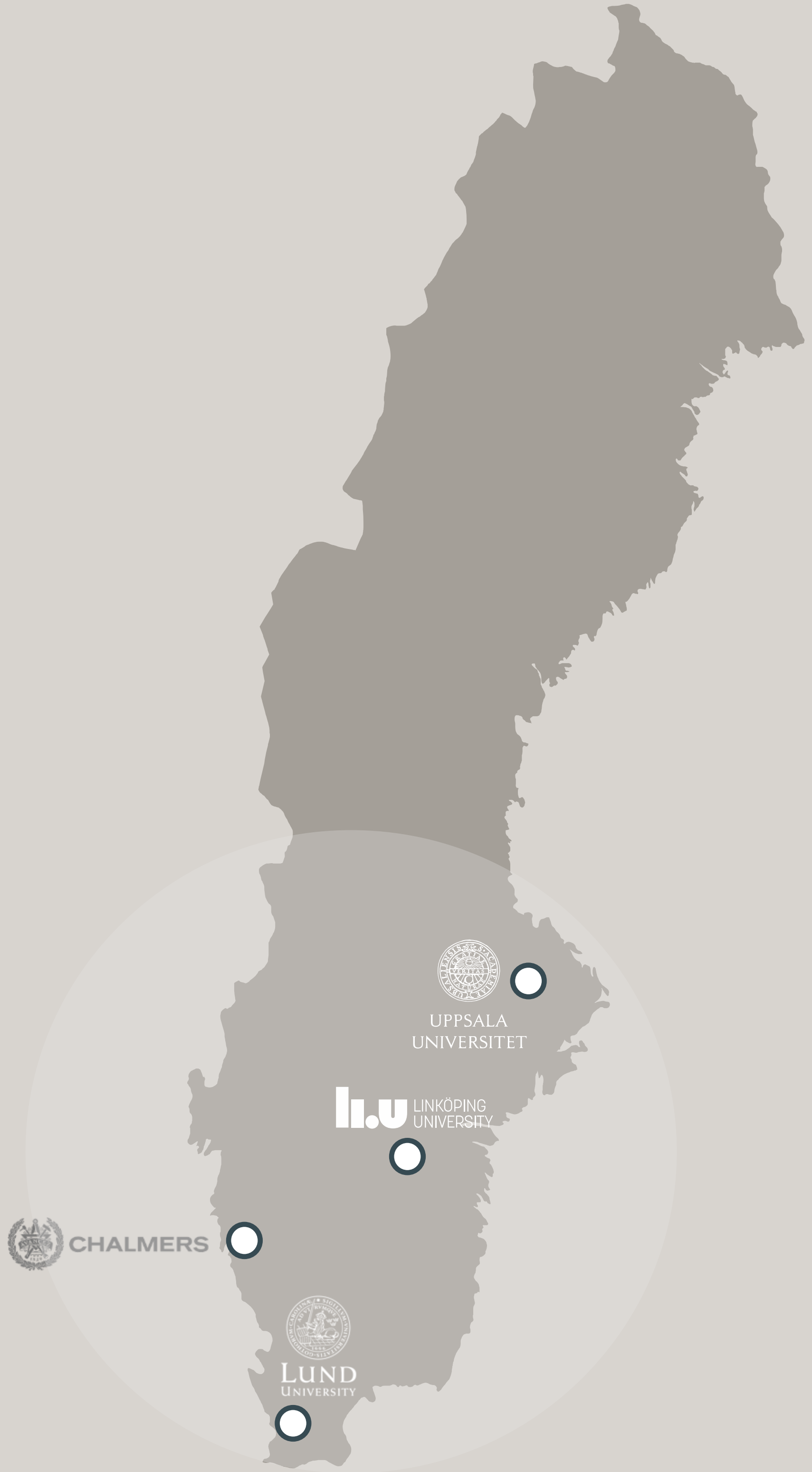
Doctoral student at Industrial Electrical Engineering and Automation (IEA), LTH, Lund University
email: mattias.ingelstrom@iea.lth.se

Supervisors: Prof. Mats Alaküla, Fran Marquez
Started April 2022

Previous experience

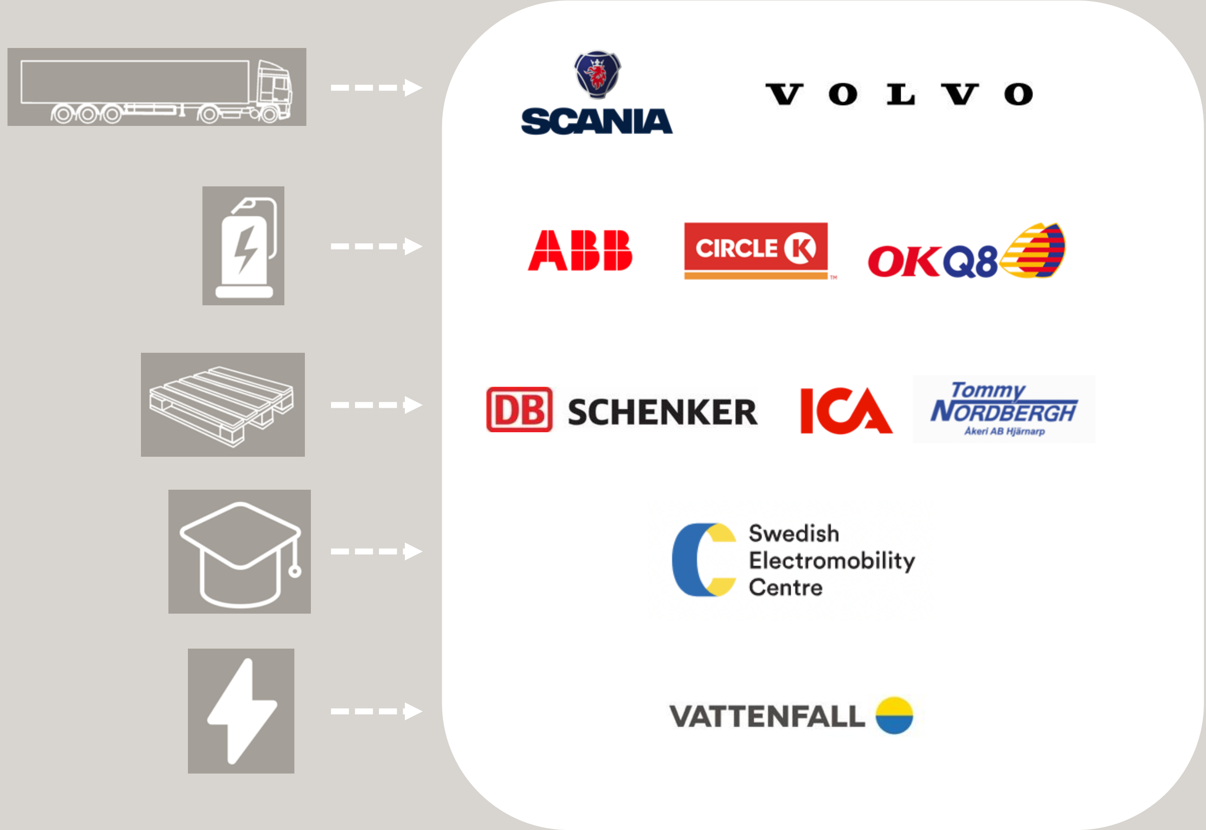
- M.Sc.Eng in Mechanical Engineering at LTH, Lund University, 2014-2019
  - Master thesis connected to optimisation of power plants at Siemens Turbomachinery (now Siemens Energy)
- Scania Engineering Program Autumn 2019 – Summer 2020
- Development/simulation engineer at Scania 2020-2022
  - Pre-development alternative fuel solutions

Background



E-Charge

System demonstration of electrified long-haul transport



FFI Fordonsstrategisk Forskning och Innovation | Energimyndigheten | TRAFIKVERKET | VINNOVA Sweden's Innovation Agency

Background

Research questions

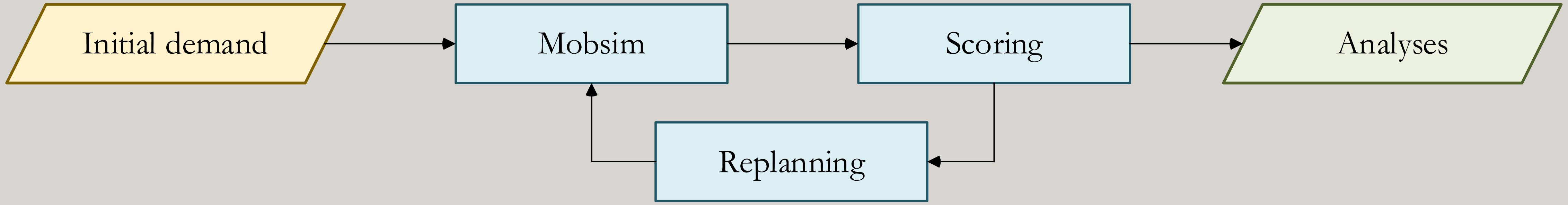
- **What infrastructural decisions are required to facilitate a full-electric long-haulage truck fleet?**

  Primary
  - Where to place charging stations?
  - What installed capacity is required at each charging station?

  Secondary (examples)
  - Is it possible to maintain today's logistic flows?
  - How will power grid be affected?
  - How will policies affect?
  - What will happen a snowy day in northern Sweden?
  - How will battery aging affect?
  - …

MATSim
Multi-Agent Transport Simulation

- Microscopic simulation
- Extendable (e.g., EVs)
- Co-evolutionary – egoistic "agents" competing with others
- Mainly developed at TU Berlin



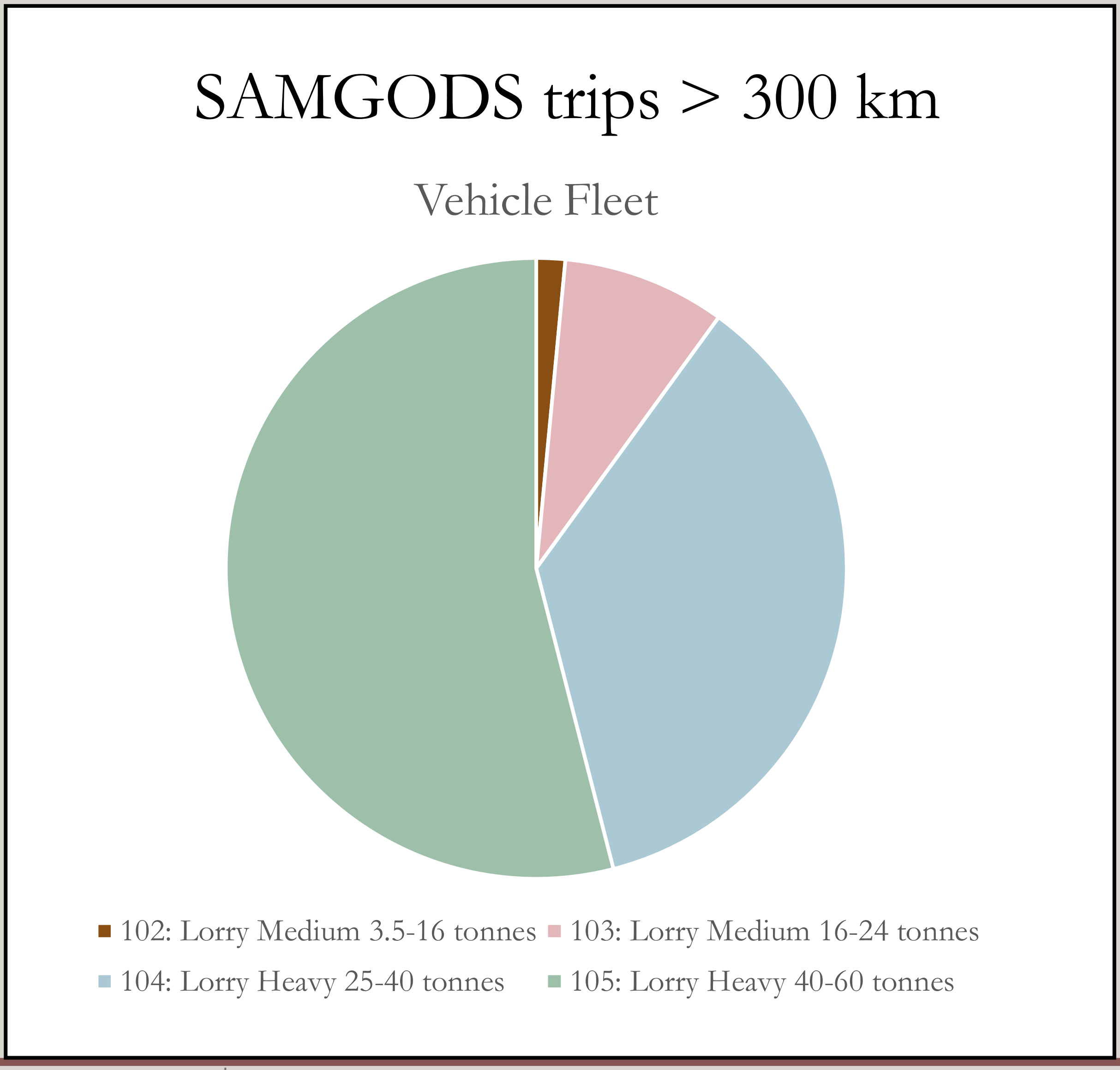
Project github.com/matsim-org

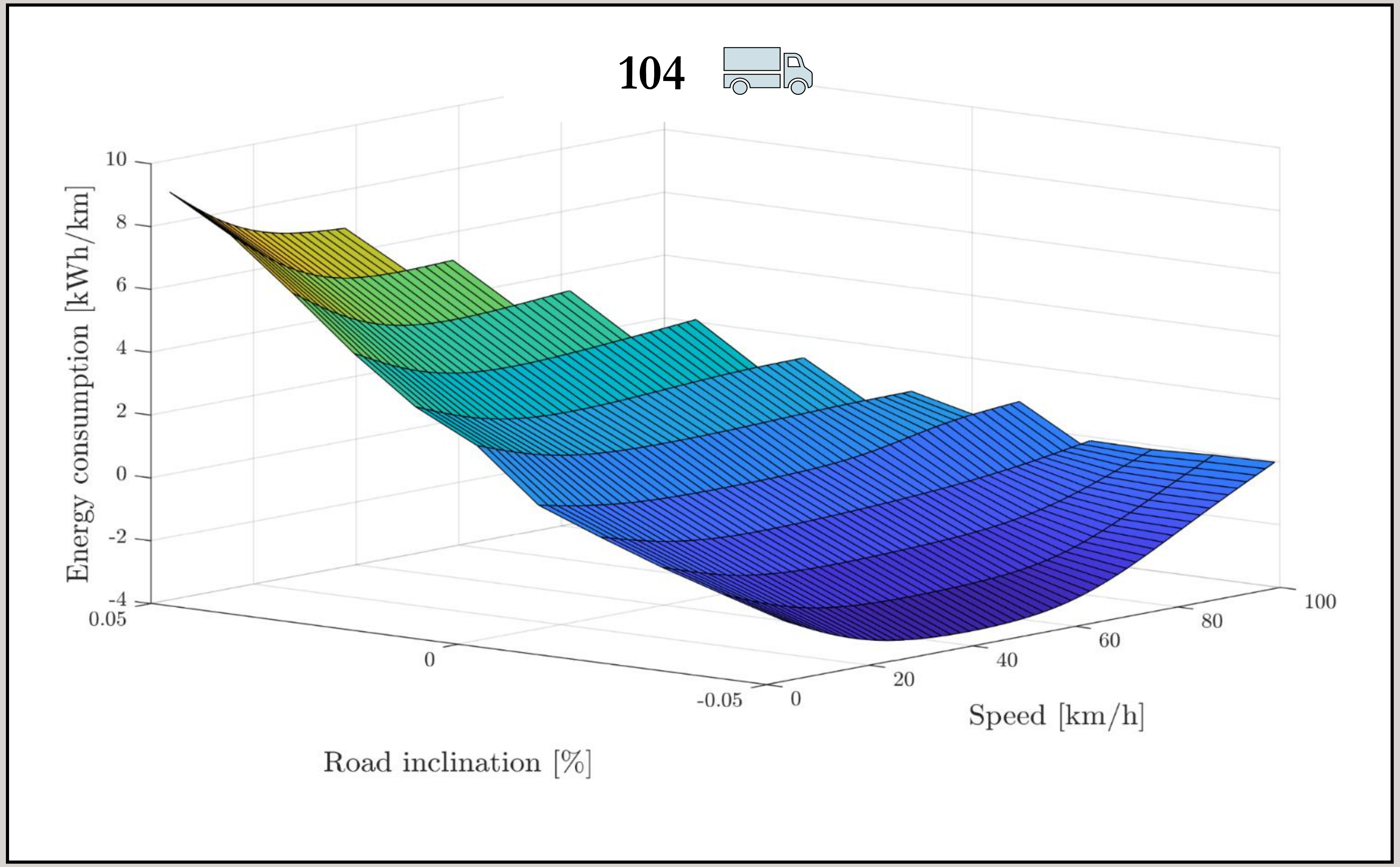
Info matsim.org

Public tutorial https://isis.tu-berlin.de/course/view.php?id=31123

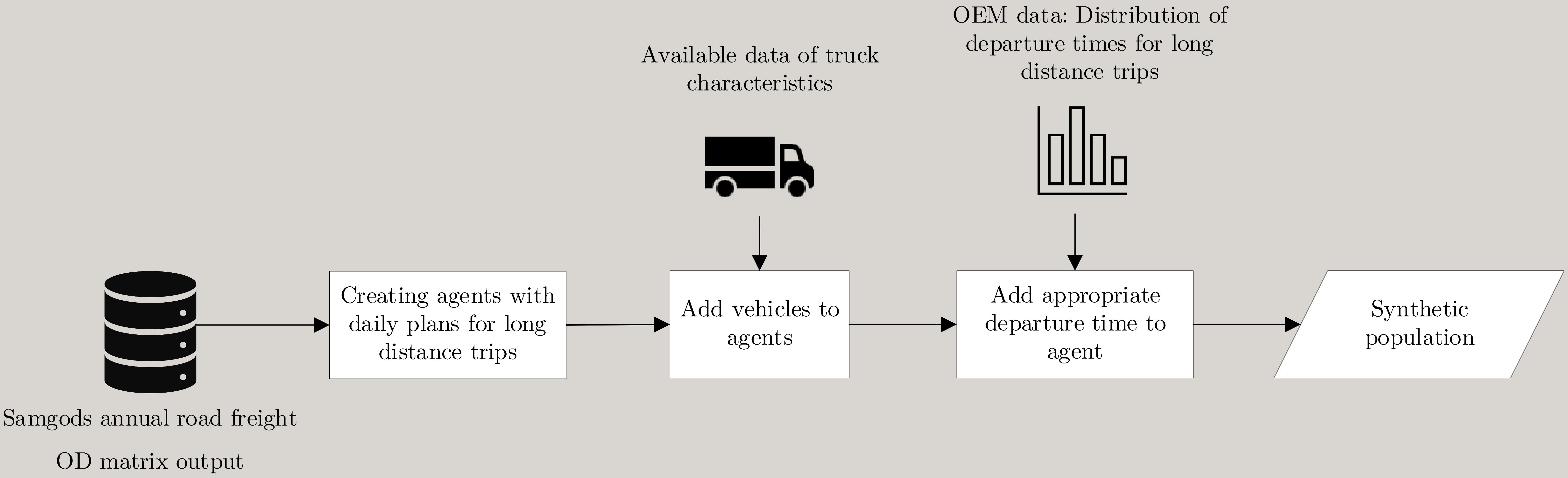
Methodology - Inputs

Truck weight class	Battery capacity [kWh]
102	180
103	300
104	400
105	500



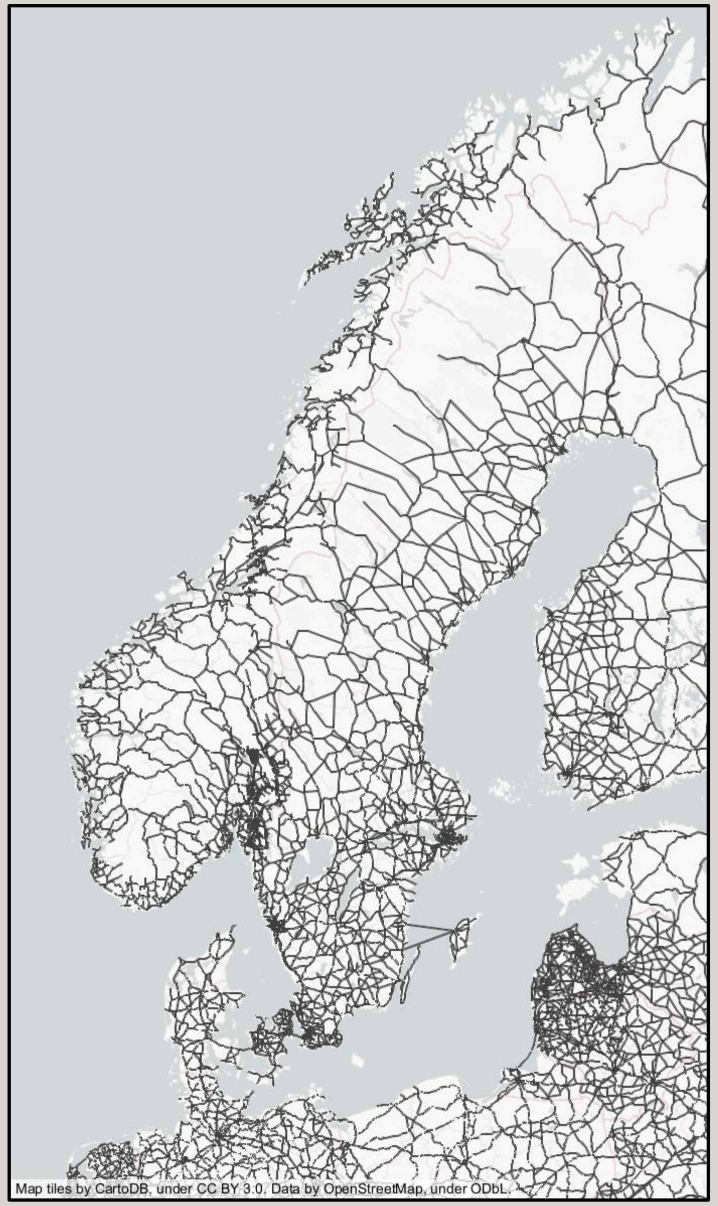


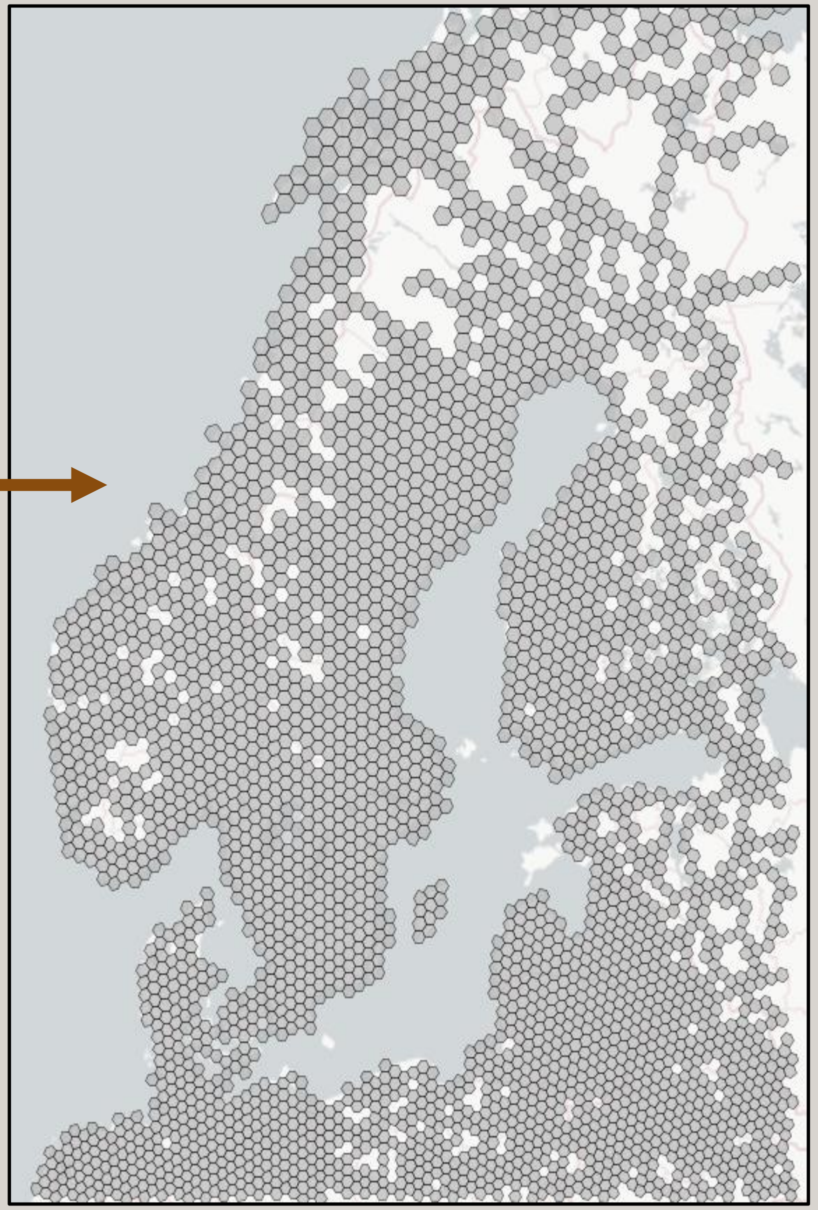
Methodology - Inputs

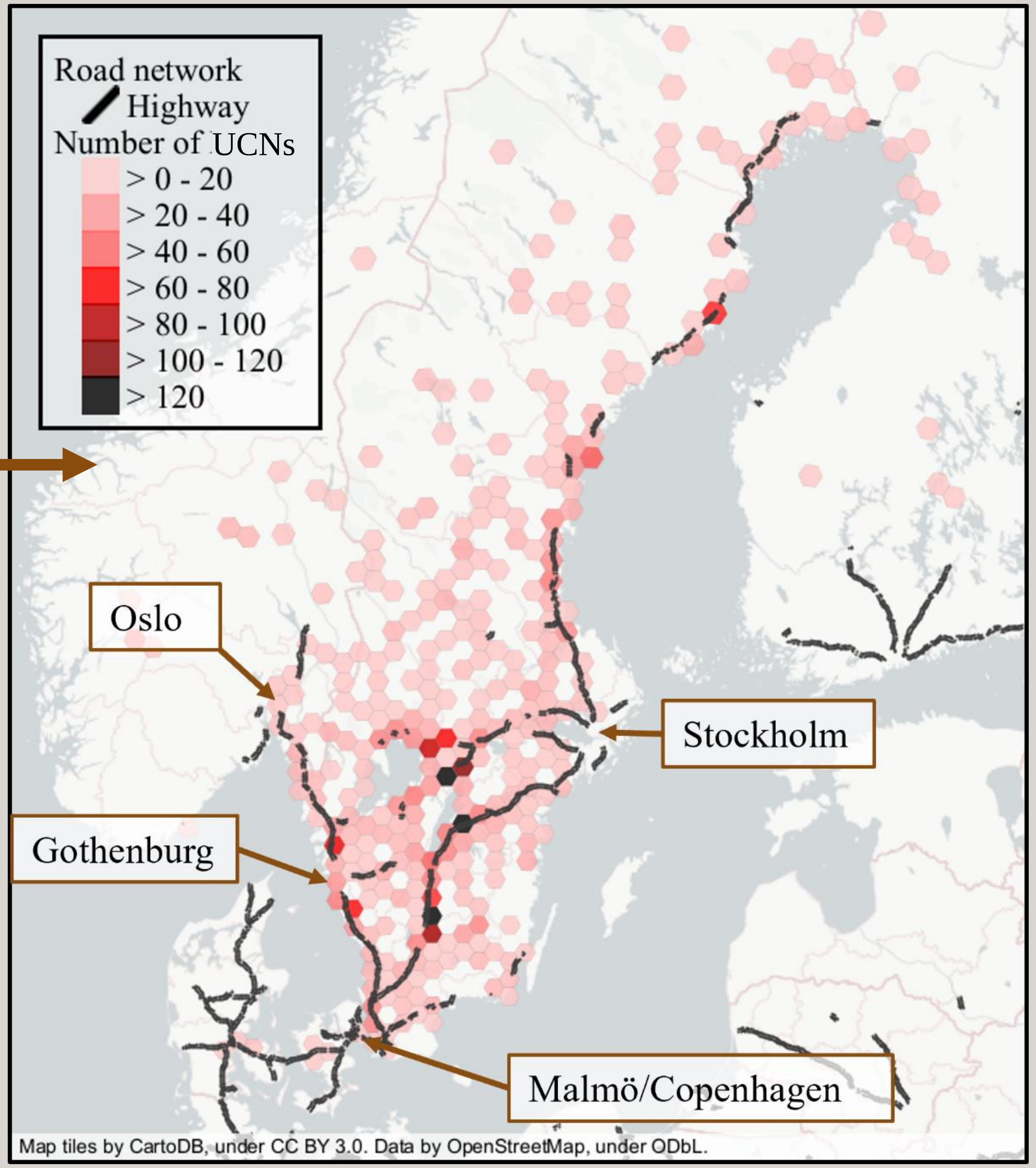


Methodology - Workflow

UCN = Unmet Charging Need
= Location of agent with a failed trip when it reached 20% State of Charge





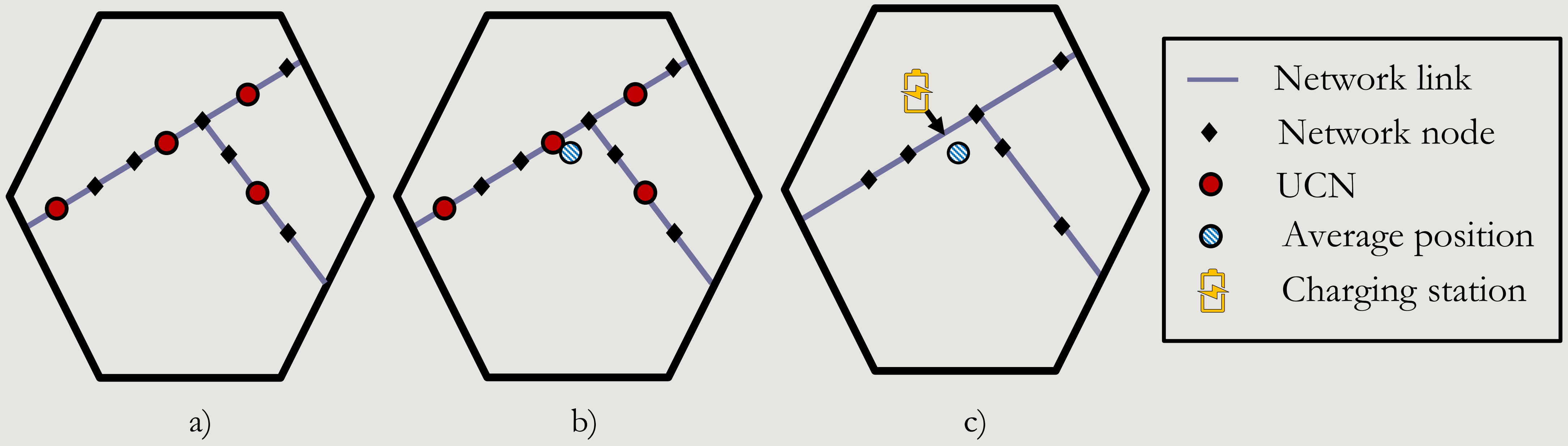


Figures made using tool Via from Simunto

Methodology - Workflow

Charging station placement

a) Count UCNs, rank zones and choose those with highest UCN intensity
b) Find average position of UCN
c) From the average position a charging station is placed at the closest link



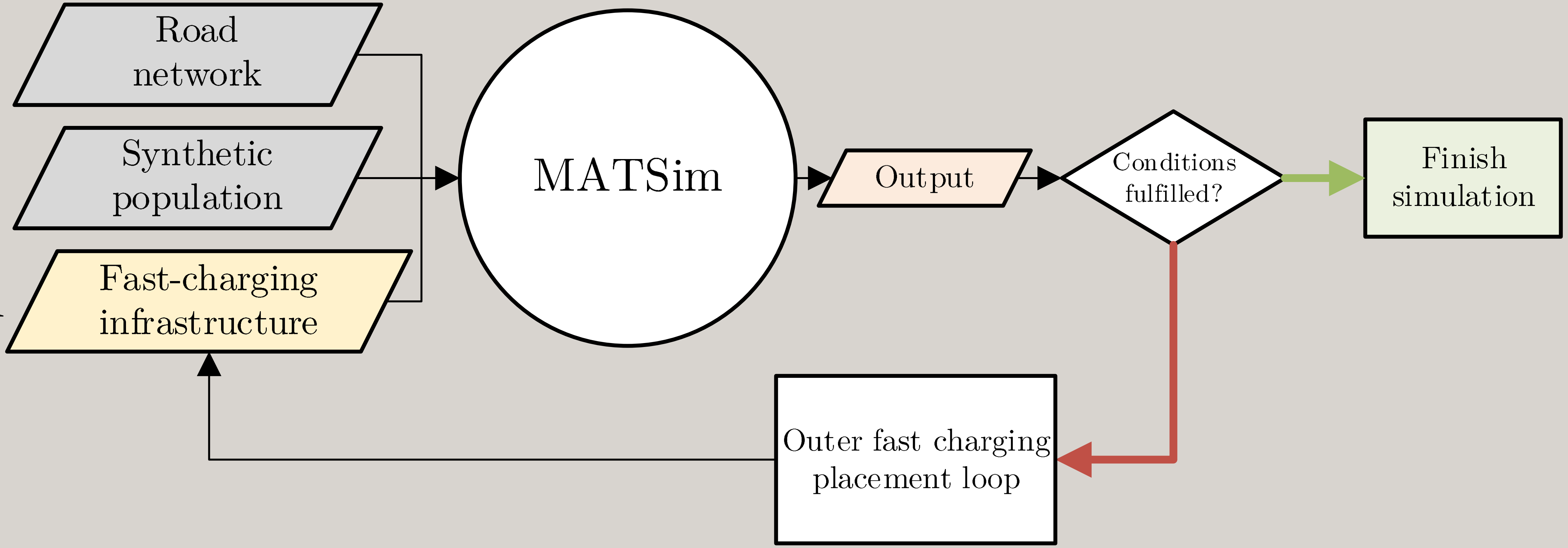
Methodology - Workflow

Charging station assignment

- Done first iteration and then 20% of agents each iteration
- Agents' vehicles' start with pre-defined initial SoC
- Agents start to look for the nearest chargers at **15-40% SoC** or **4.5hr driving** and chooses the nearest station
- Maximum charging time 45 minutes and rated charging power is 1 MW

Methodology - Workflow

- Charging demand based on OD and detailed energy consumption maps
- Start without any charging infrastructure and add charging stations until desirable electrification coverage has been met
- **Method suitable for primary research questions**



Example results

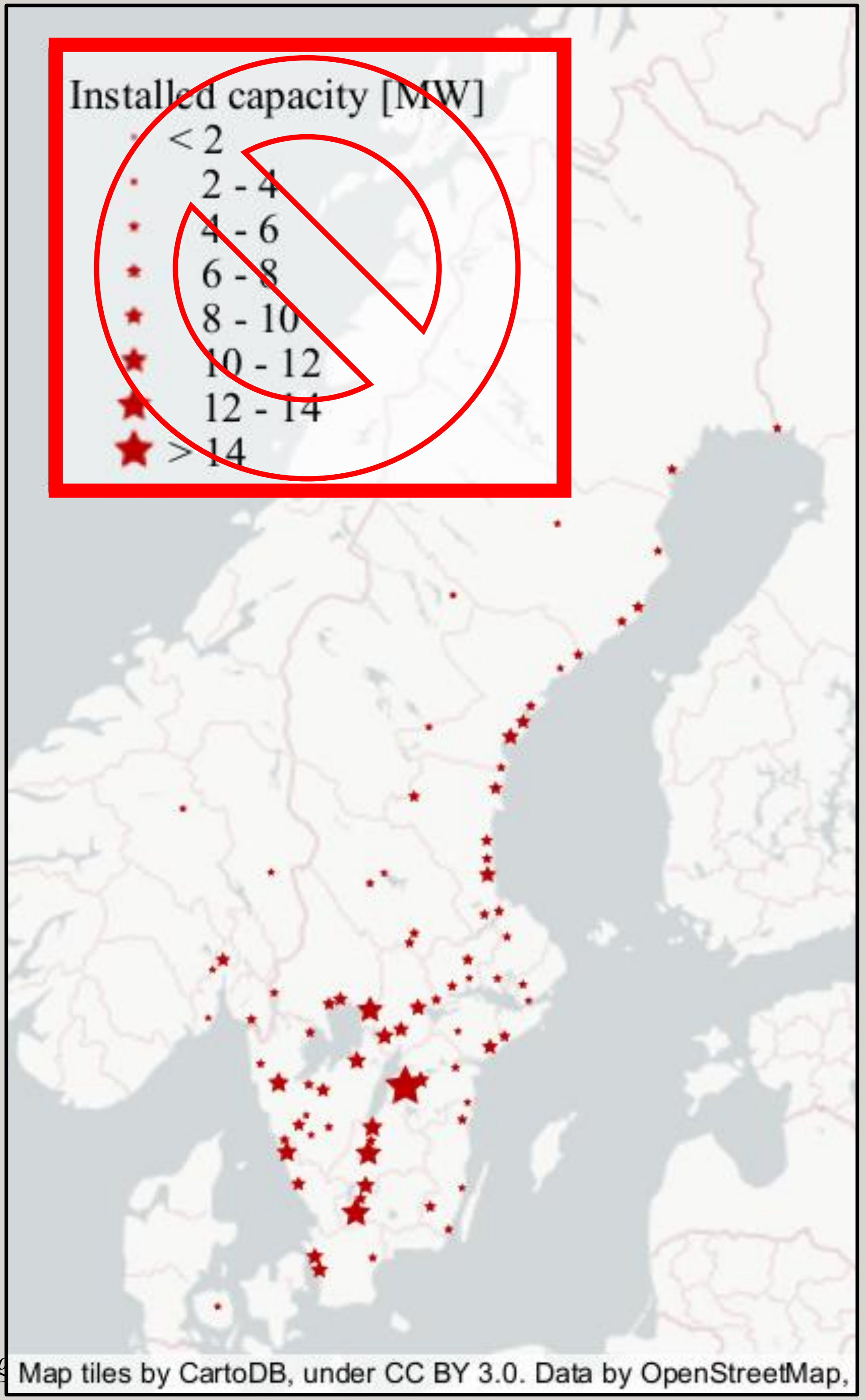
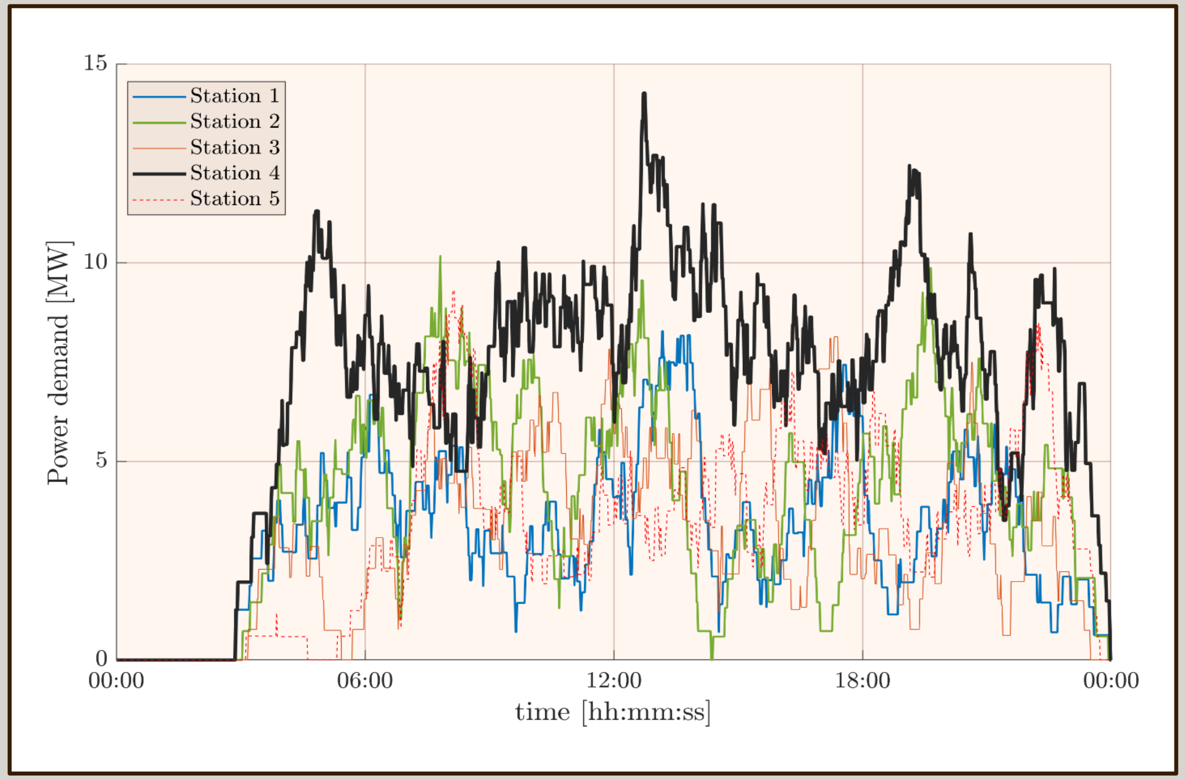
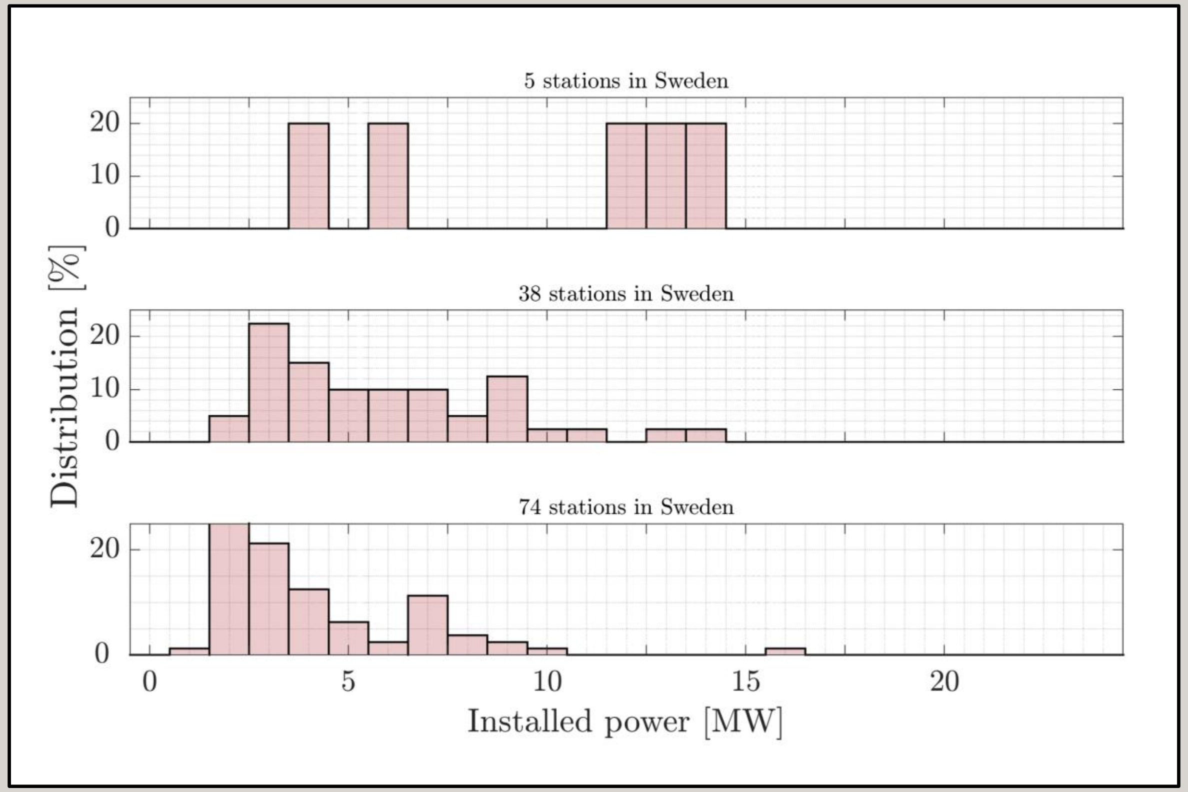


Figure made using





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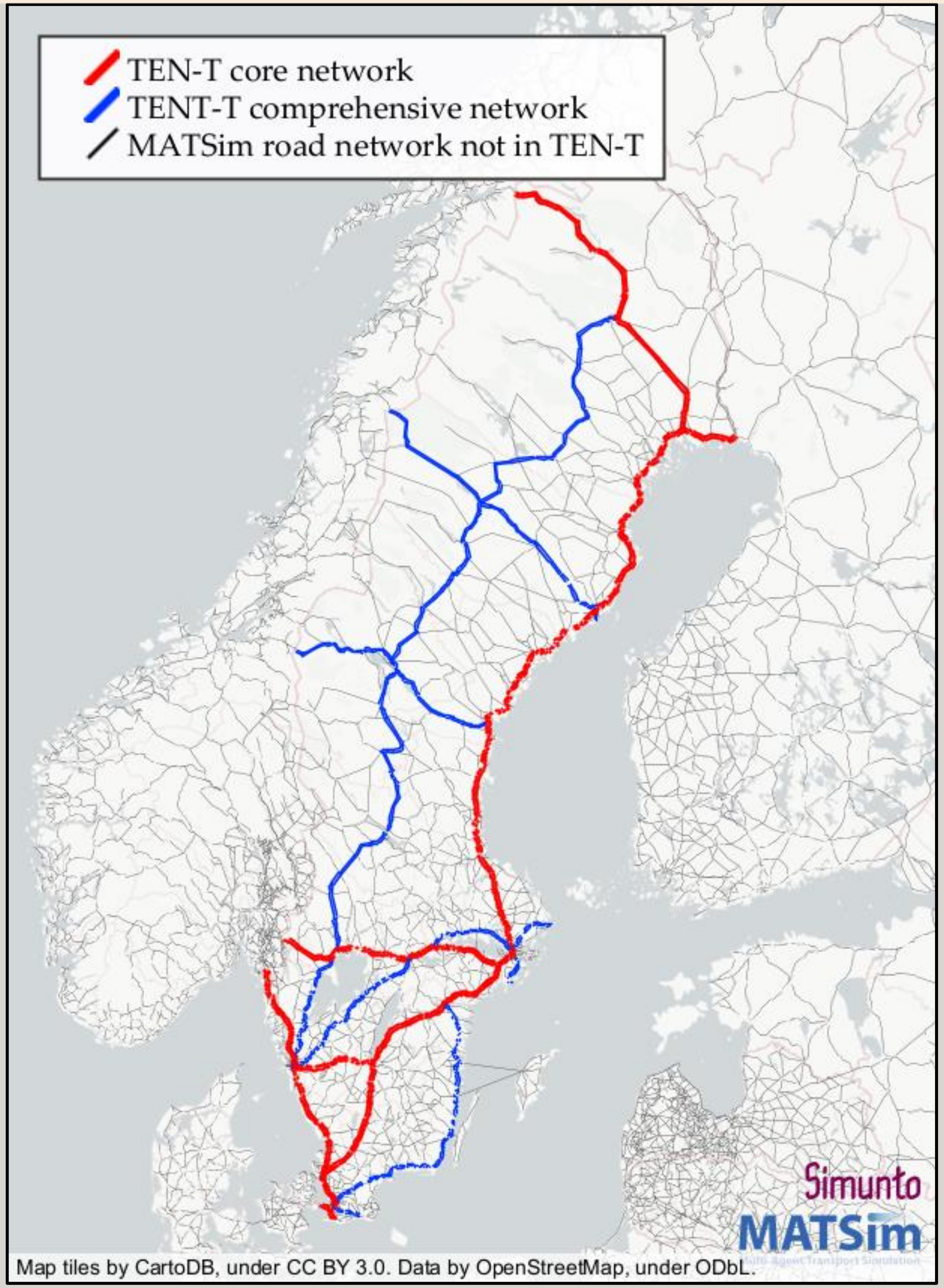
Background

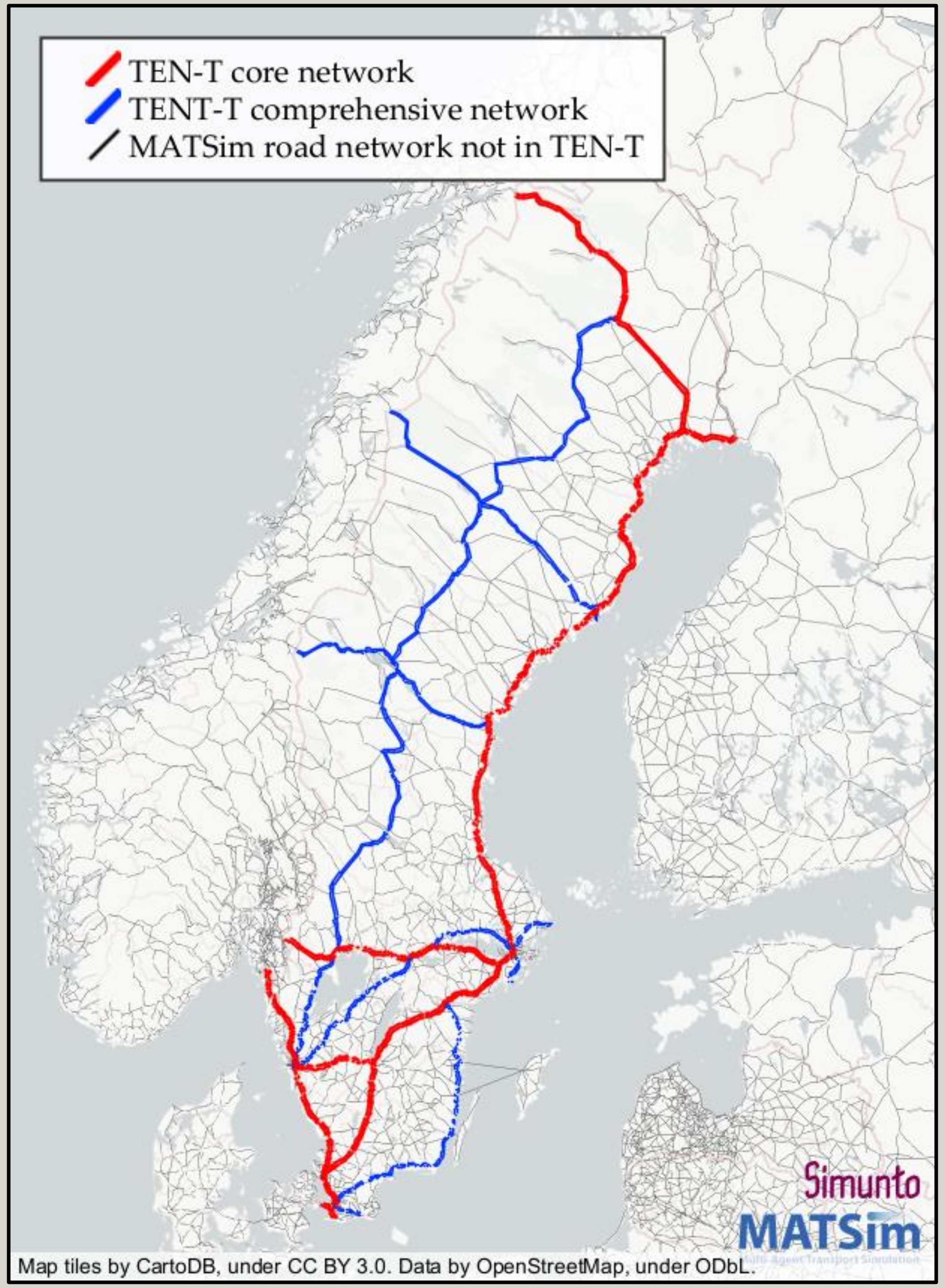
EU Regulation for alternative fuel infrastructure **(AFIR)** demands introduction of fast charging infrastructure along the TEN-T road network

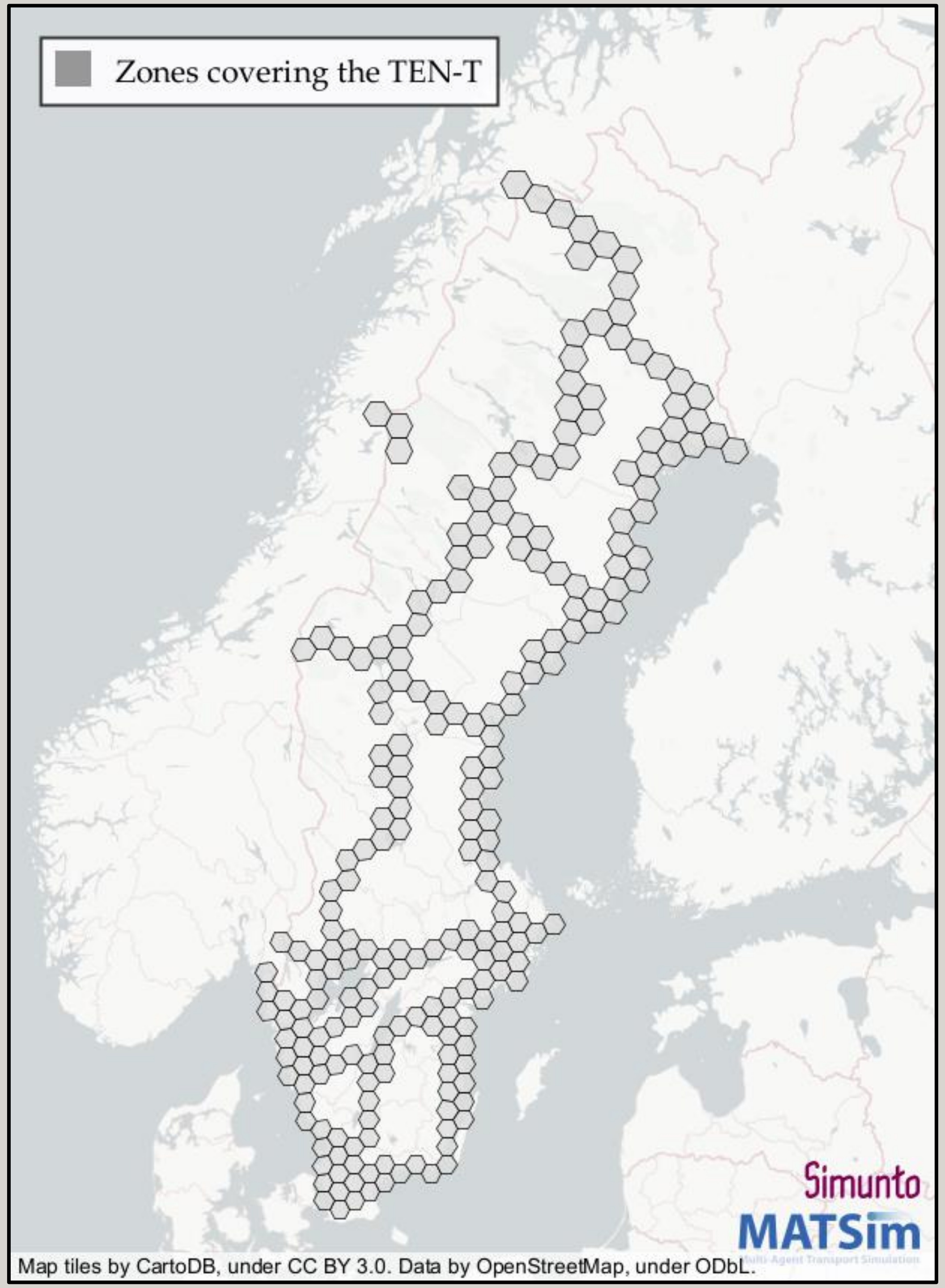
- Every **60 km** along **core network**
- Every **100 km** along **comprehensive network**

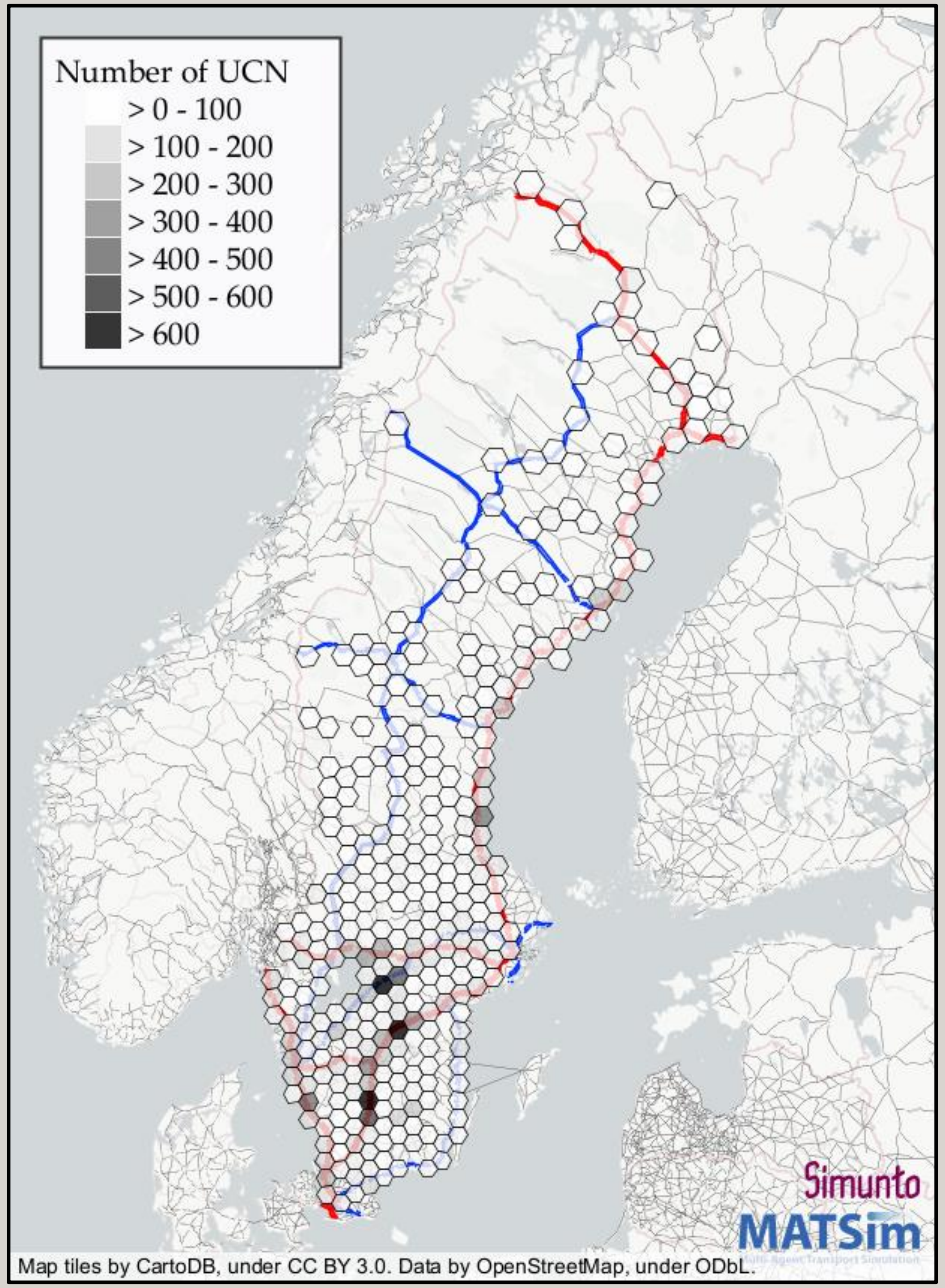
How will set intervals between stations affect road freight electrification possibilities?



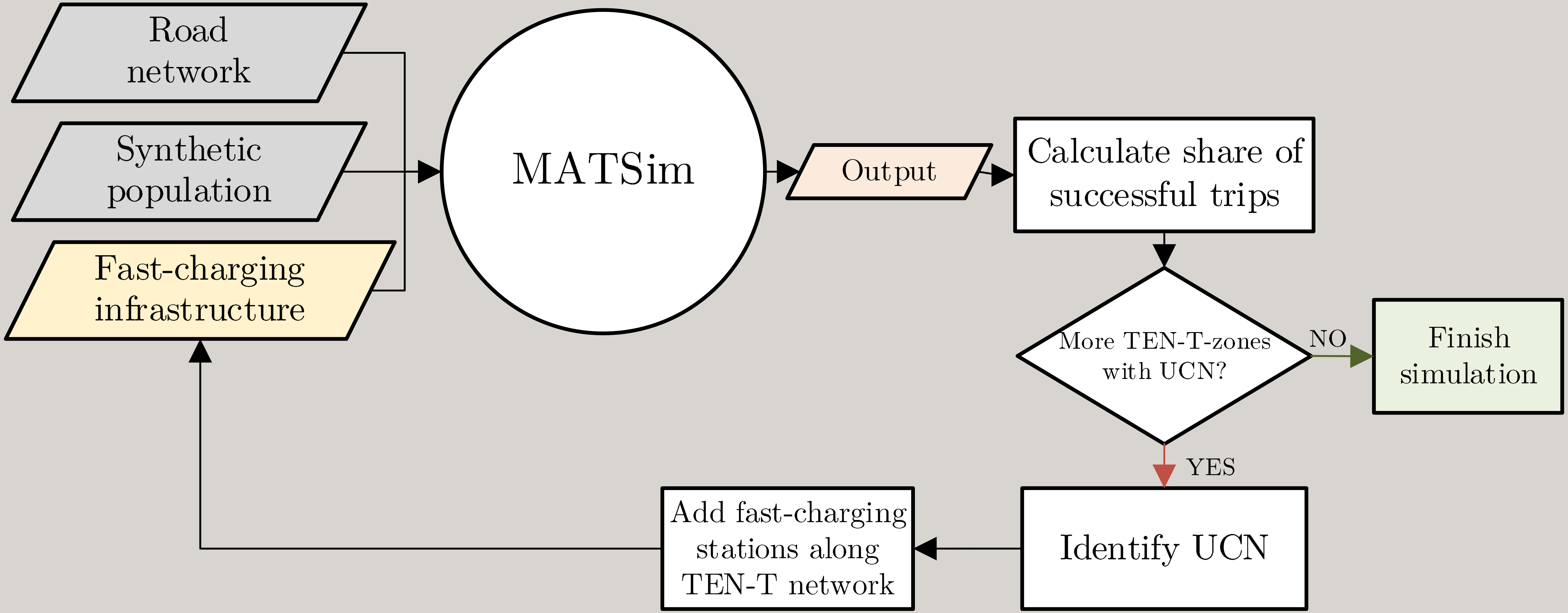
Case setup


TEN-T core network
TENT-T comprehensive network
MATSim road network not in TEN-T
Simunto
MATSim
Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

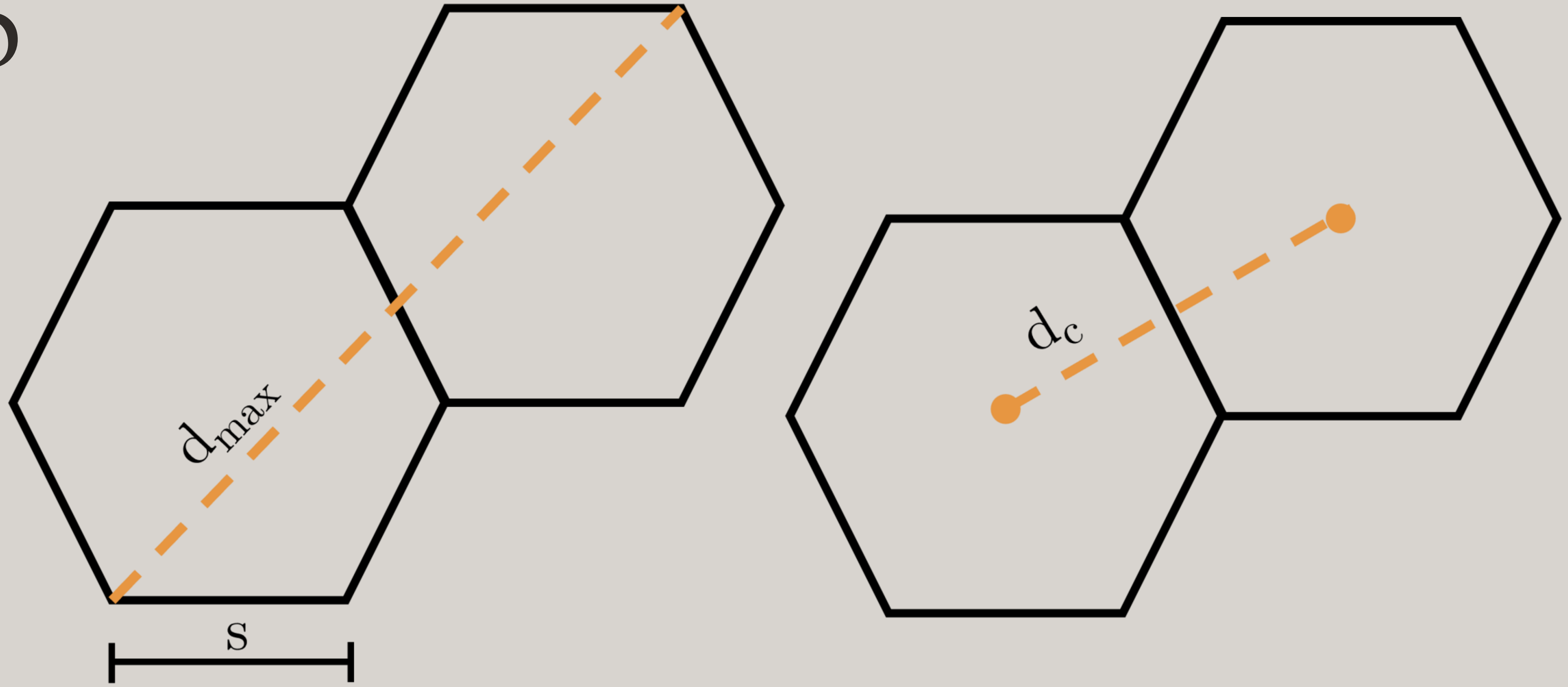

Zones covering the TEN-T
Simunto
MATSim
Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.


Number of UCN
> 0 - 100
> 100 - 200
> 200 - 300
> 300 - 400
> 400 - 500
> 500 - 600
> 600
Simunto
MATSim
Map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

Case setup


Road network
Synthetic population
Fast-charging infrastructure
MATSim
Output
Calculate share of successful trips
More TEN-T-zones with UCN?
NO
Finish simulation
YES
Identify UCN
Add fast-charging stations along TEN-T network

Case setup



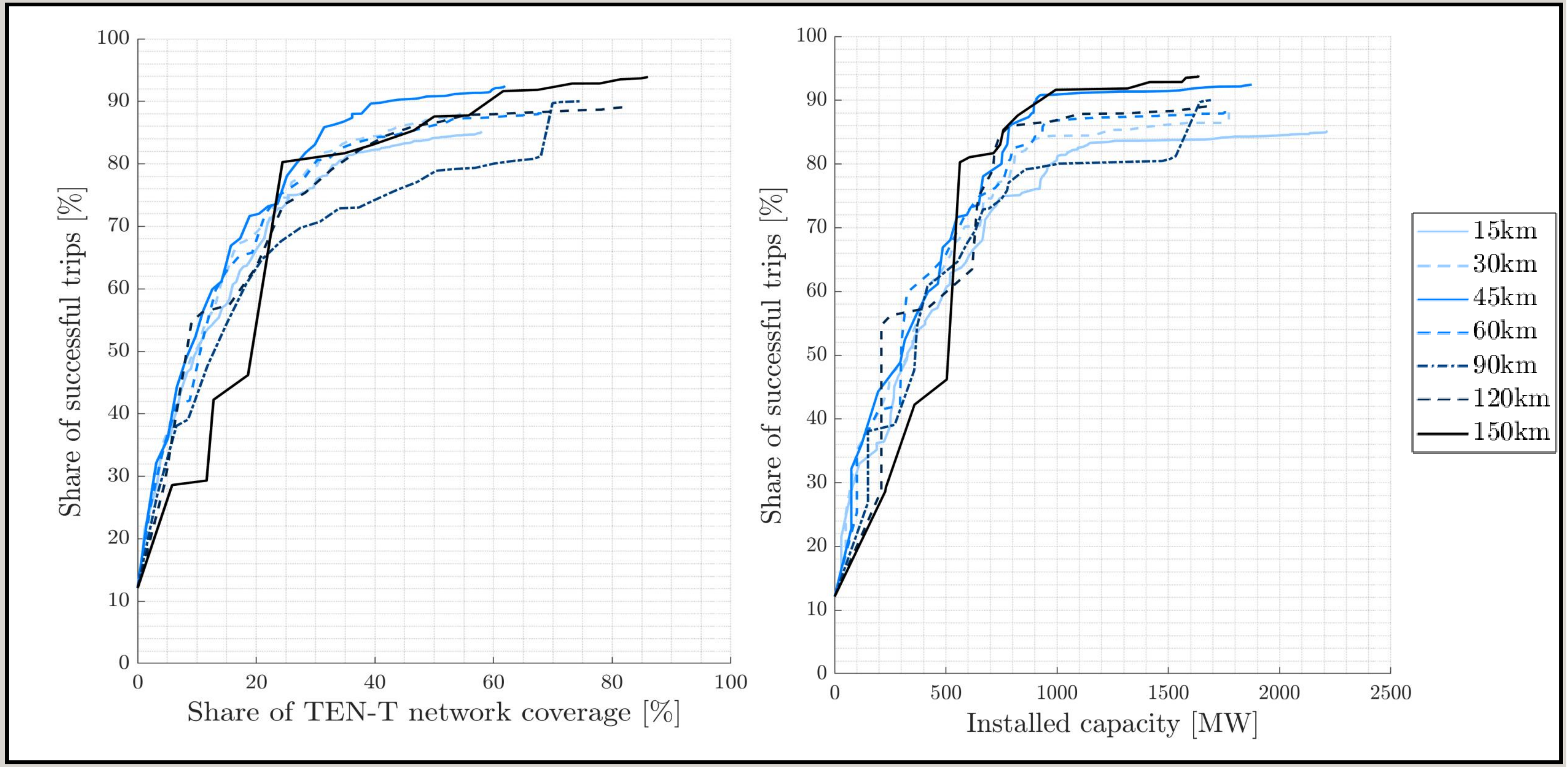
- Total possible installed charging power is same for each scenario
- For d_{max} = 60 km 20 MW per zone/station is set
- Rest of the scenarios are scaled based on the number of zones along the TEN-T

d_{max}	Number of zones along TEN-T	Maximum installed charging power per zone [MW]
15	848	6
30	470	10
45	318	15
60	**228**	**20**
90	153	30
120	110	42
150	86	54

Results

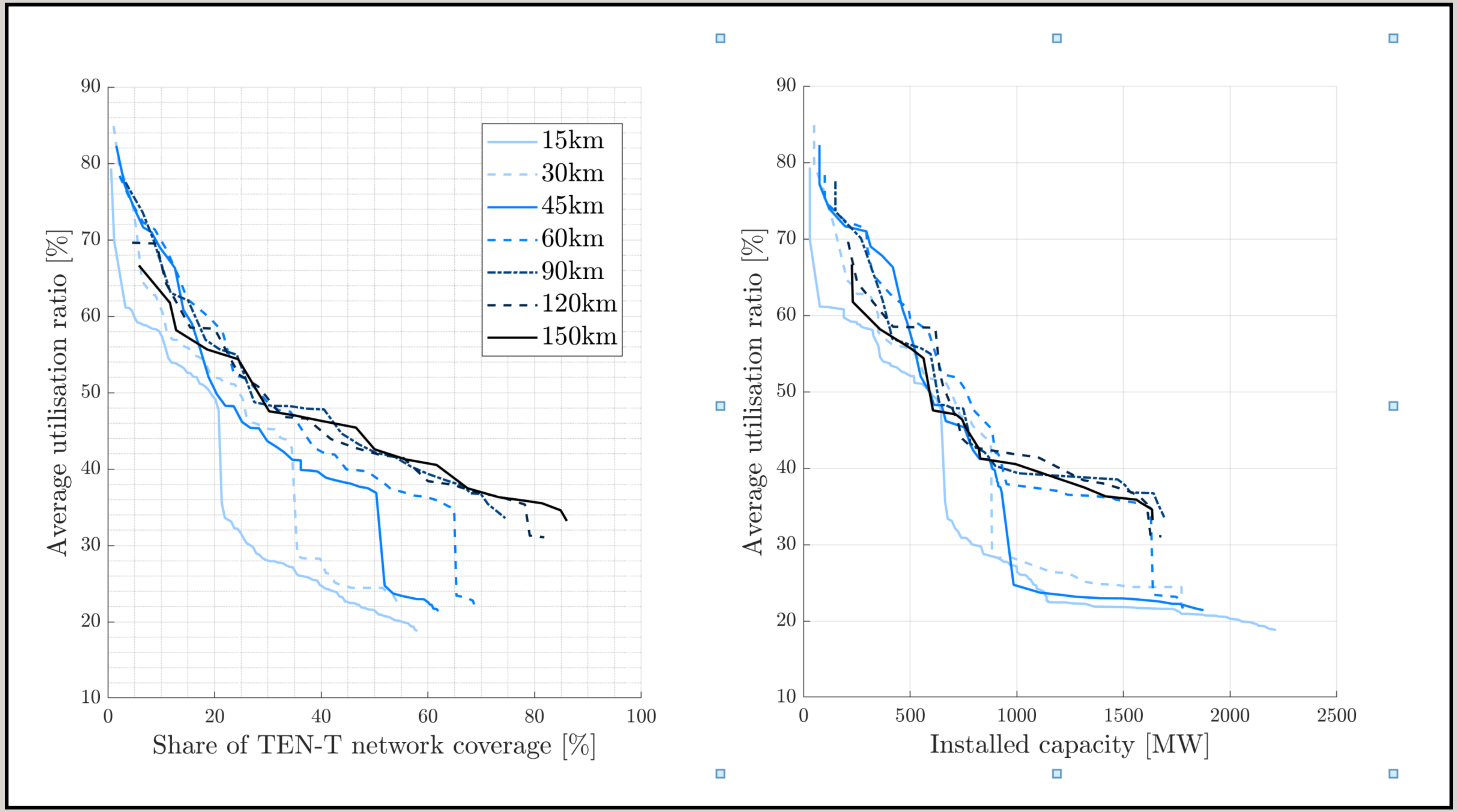
$$P_{\text{installed}} = \sum_{i=1}^{N_{\text{stations}}} N_{\text{dispensers,i}} \cdot P_{\text{rated,dispenser,i}}$$

- Tighter spacing favoured
- Places stations closer to the actual demand
- $d_{max} = 45$ km best scenario
  - Scenarios with shorter spacing lower maximum installed capacities increases risk of queues
  - Should be solved with higher number of iterations
- **ALL** scenarios stagnate
  - Demand *could* be outside of TEN-T



Results

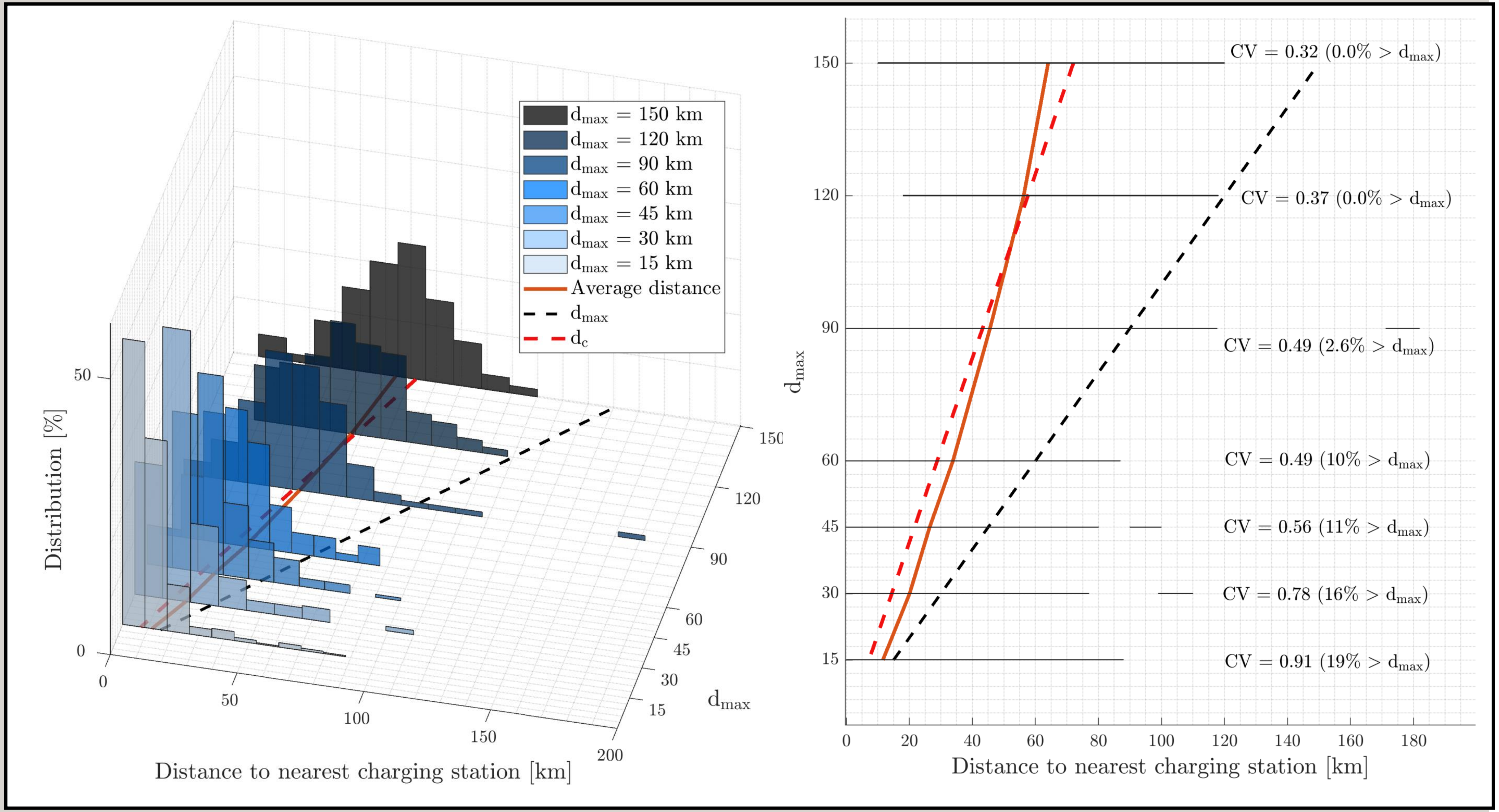
- Tighter spacing leads to faster drop in utilisation
- From Johannes Karlsson and Anders Grauers*, 30% is reasonable for a future full-electric scenario and stations would be profitable
- All scenarios show indication of distinct drop



* Karlsson, J., & Grauers, A. (2023). Agent-based investigation of charger queues and utilization of public chargers for electric long-haul trucks. Energies, 16 (12). Retrieved from https://www.mdpi.com/1996-1073/16/12/4704 doi: 10.3390/en16124704

Results

- CV = Coefficient of Variation (σ/μ)
- Average value close to d_c = demand uniform
- Shorter spacing leads to larger variation
  - stations placed closer to demand



Conclusion

- Detailed study of how distances (along TEN-T) between stations impact electrification rate and utilisation ratio
  - Evident that study requires further analysis
- All scenarios point to not all of TEN-T having to be covered
  - 60km along TEN-T might result in unprofitable stations
- Placing stations closer to demand will help maintain a high utilisation ratio
- Grid capacity data would greatly improve assumptions regarding maximum installed charging power per zone/station
  - Model is ready to incorporate grid capacity maps

Future studies & challenges

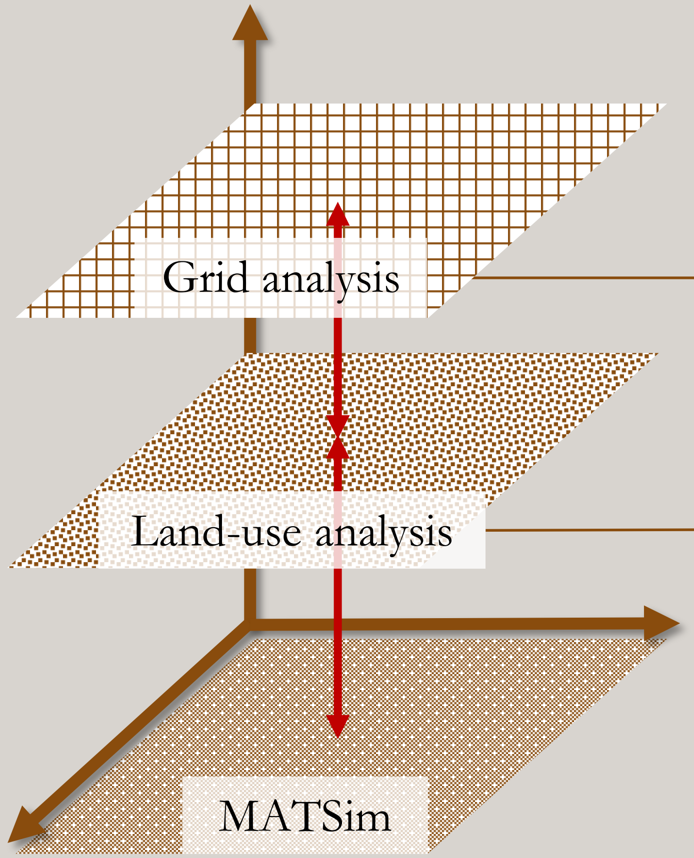
Specific to this study

1. Compare study to an AFIR scenario
2. Extend analysis: locations of need for stations outside of TEN-T
3. Run sensitivity analyses

In general

1. Study impact of departure times on power grid using OEM data
2. Land-use considerations and relate scenarios to cost models
3. Study resilience in the system

Future work & challenges



Validity - through neighbouring project

Attractiveness of candidate locations

Thank you for listening!
Questions?

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