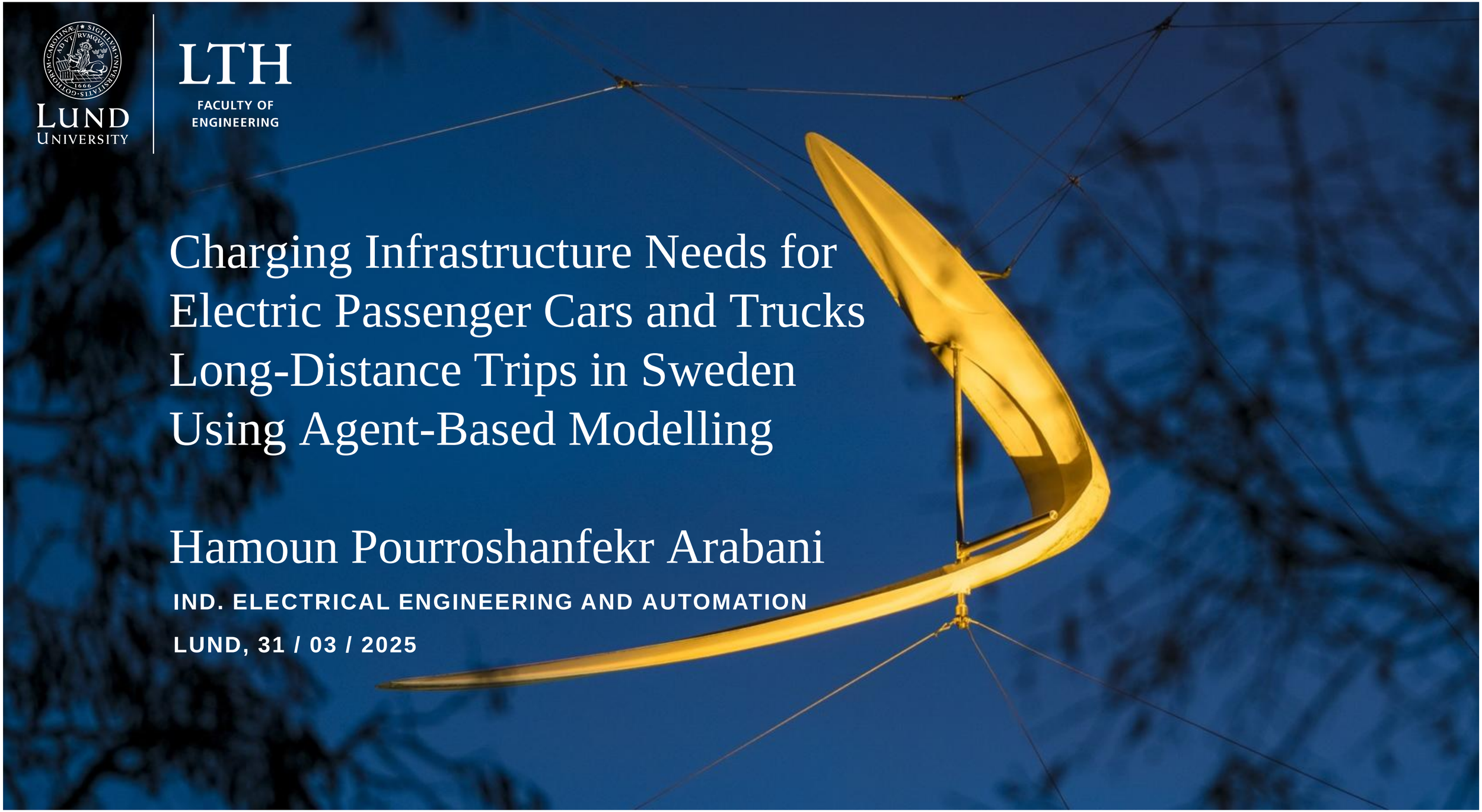

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Charging Infrastructure Needs for Electric Passenger Cars and Trucks Long-Distance Trips in Sweden Using Agent-Based Modelling

Hamoun Pourroshanfekr Arabani

IND. ELECTRICAL ENGINEERING AND AUTOMATION

LUND, 31 / 03 / 2025

Agenda

- Research Questions
- System Framework
- Methodology
- Result
- Discussion

Polestar EV / Arjan Kemeling/Wirestock Creators

https://www.dbschenker.com/global/insights/blog/the-scania-r-450e-e-truck-in-sweden-1776218

https://www.electrifyamerica.com/

Research question

Charging infrastructure needs for passenger cars and heavy vehicles long-distance trips in Sweden (“Ladda Sverige”)

How many ultra-fast charging stations (UFCSs) with which charging power are required at which location in the Swedish road network to satisfy the charging demand for EVs long-distance trips?

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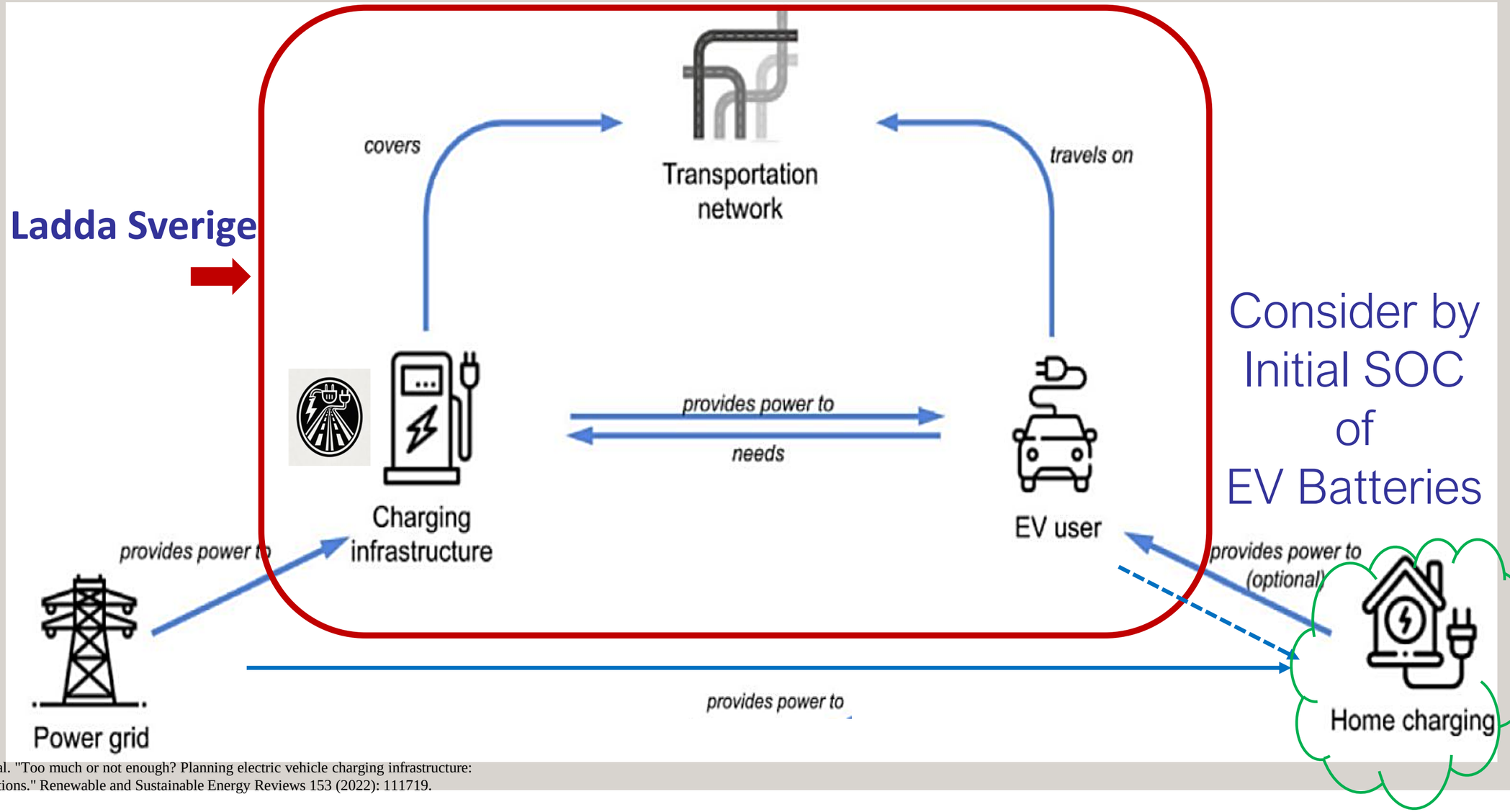
TRAFIKVERKET

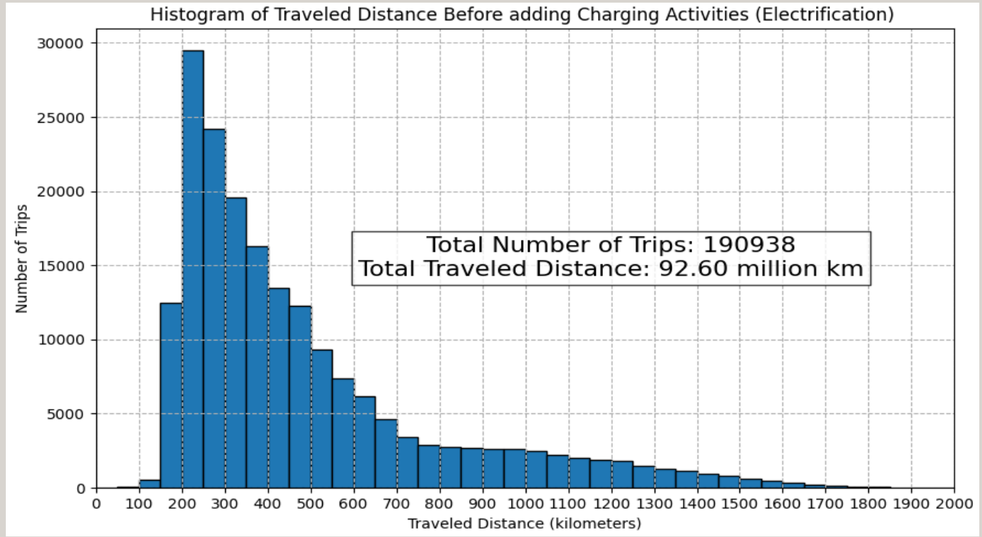
The electromobility system framework



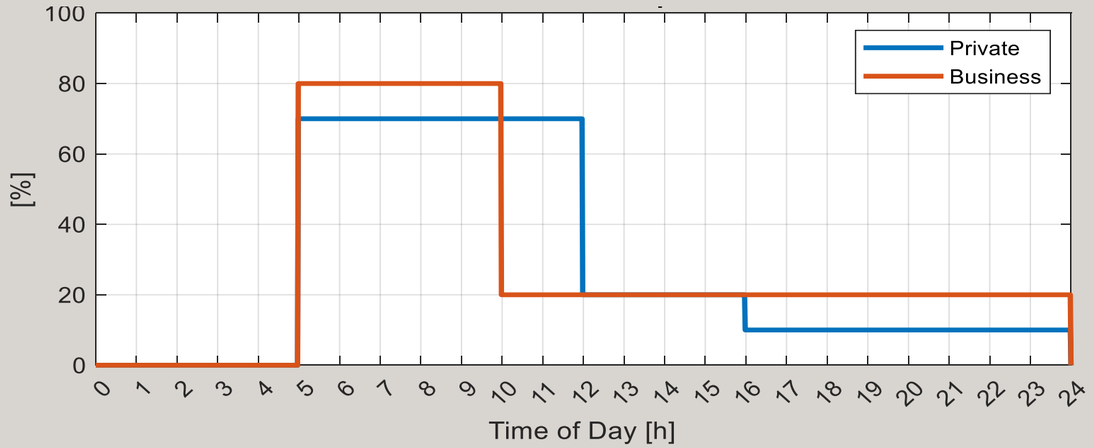
Metais, Marc-Olivier, et al. "Too much or not enough? Planning electric vehicle charging infrastructure: A review of modeling options." Renewable and Sustainable Energy Reviews 153 (2022): 111719.

Trips modelling

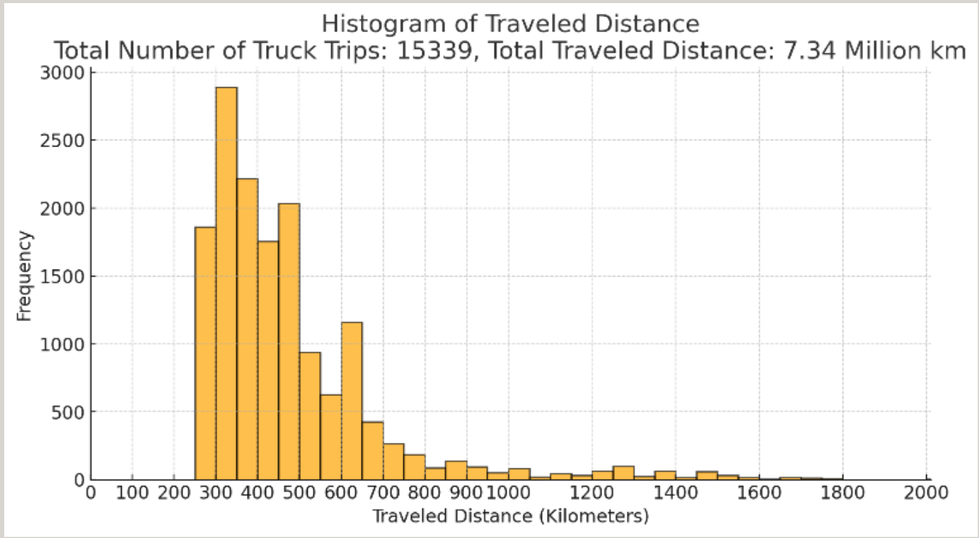
SAMPERS



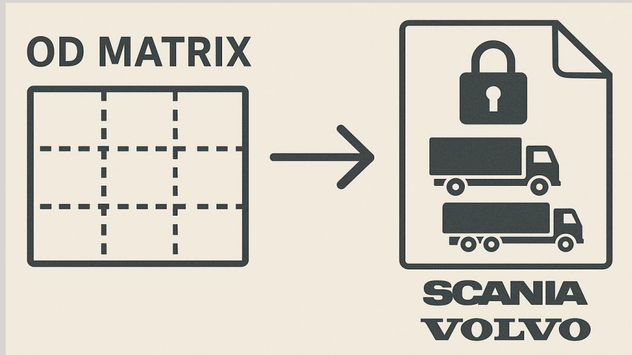
Assumptions on Departure Time Distribution



SAMGODS



Real-world departure time



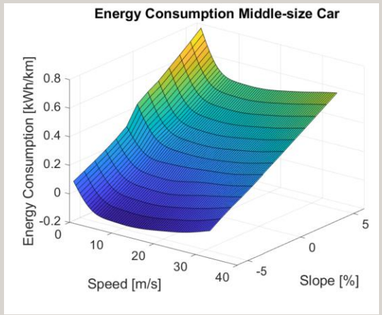
Vehicles modelling

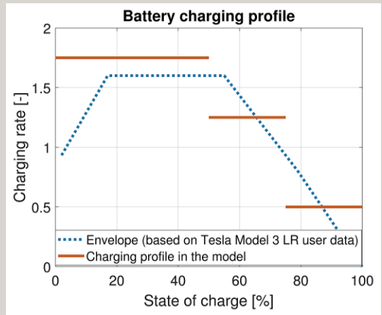
Vehicle Type	Battery Capacity kWh	Fleet Share %
Small	60	15
Medium	80	50
SUV	100	35

Initial EV Batteries SOC

SoC	Agents
50%-70%	20%
70%-90%	30%
90%-100%	50%

Vehicle class	Weight span [tonnes]	Battery capacity [kWh]	Share of the fleet [%]
Medium 103	16 – 24	300	6
Heavy 104	24 – 40	400	36
Heavy 105	40 – 60	500	58

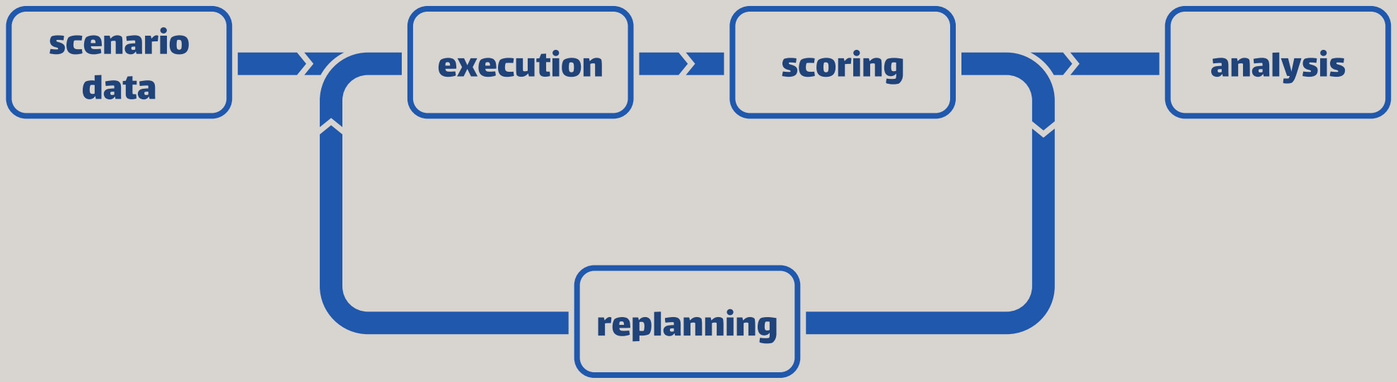




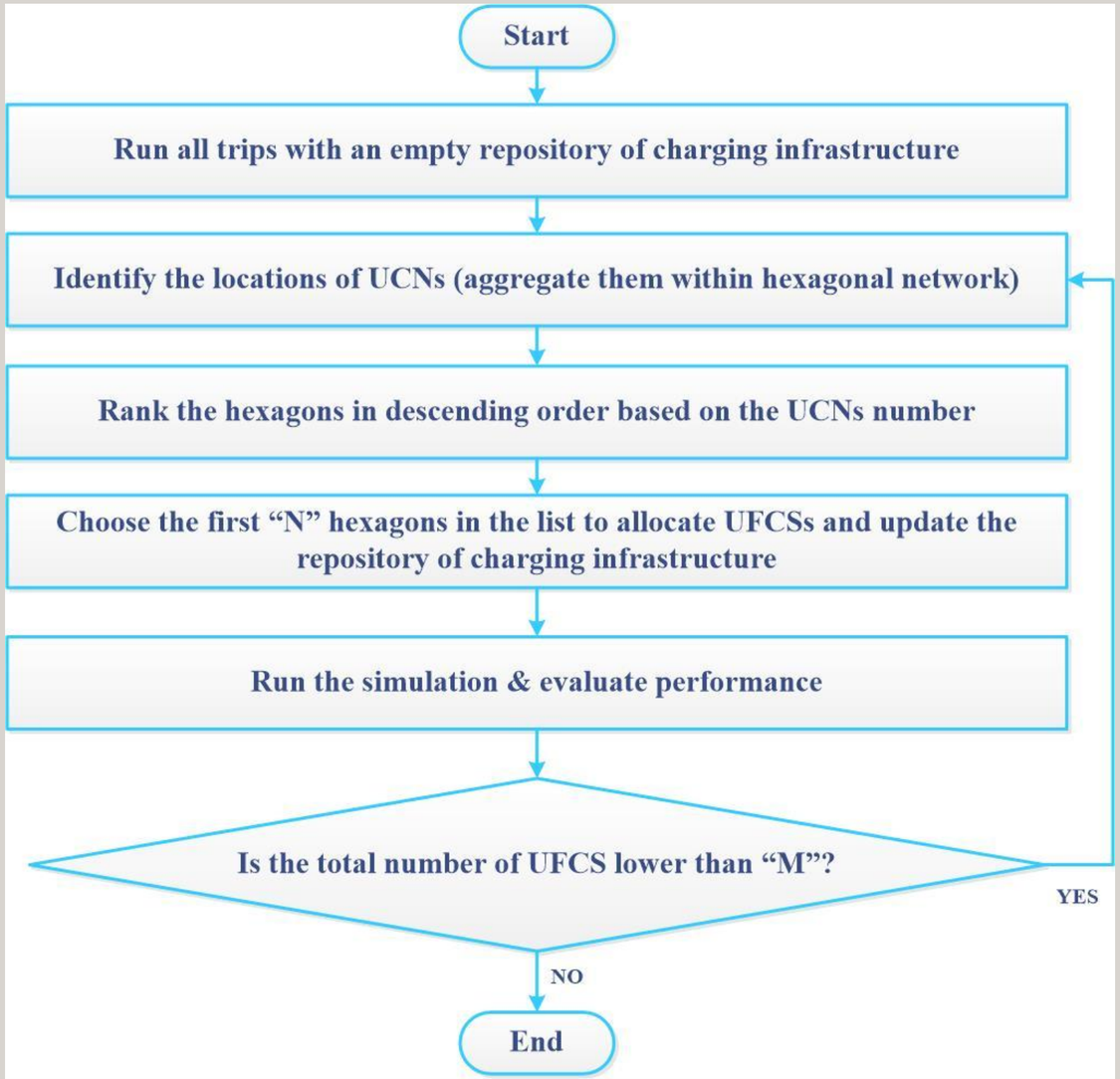
MATSim (Multi-Agent Transport Simulation)

How does MATSim work?

- MATSim simulates the movements of persons (“agents”) and vehicles on a given road transport network.
- Each agent tries to optimize its own day but is influenced by the activities and trips of other agents.
- With an iterative optimization process, MATSim is able to predict travel behavior in the real world.



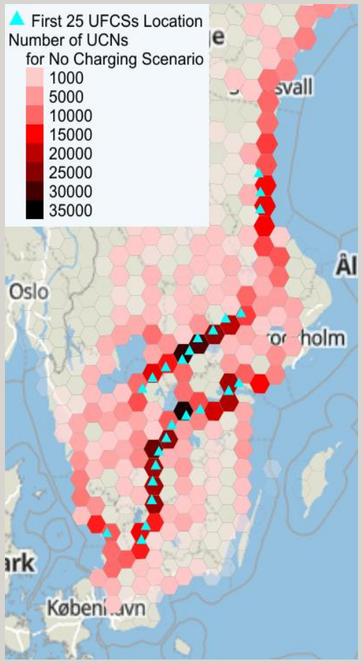
Flowchart for identifying UFCS candidate locations

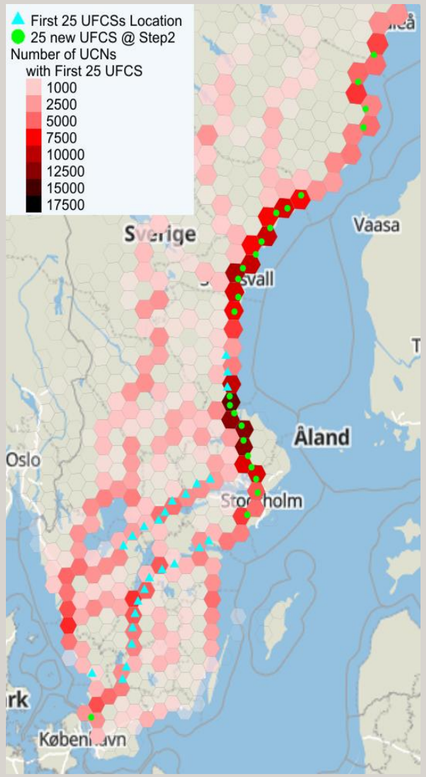


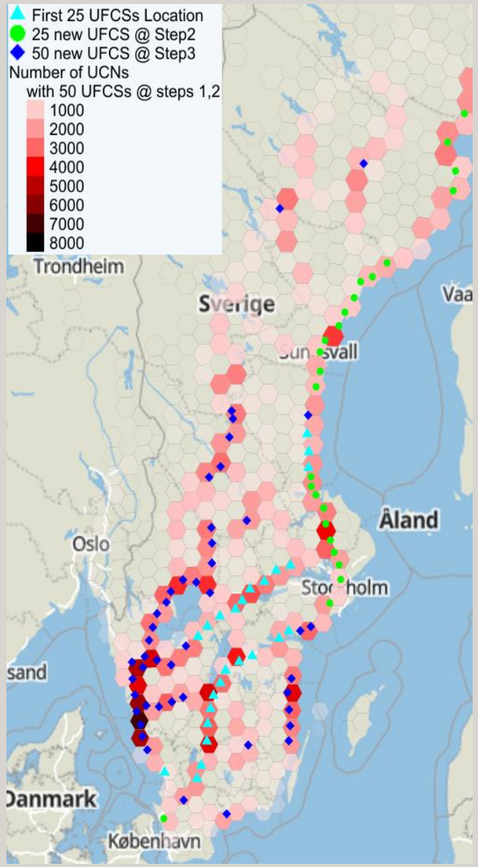
- The proposed algorithm is based on the low energy event (LEE) and missing energy event (MEE) concepts in MATSim.
- An EV will generate a LEE and/or MEE at the locations where its SOC reaches a predefined low value (typically 20%) and/or zero.
- Those LEEs that result in MEEs are called Unserved Charging Needs (UCNs)
- The algorithm utilizes the locations where UCNs occur to identify potential sites for ultra-fast charging stations (UFCSs).

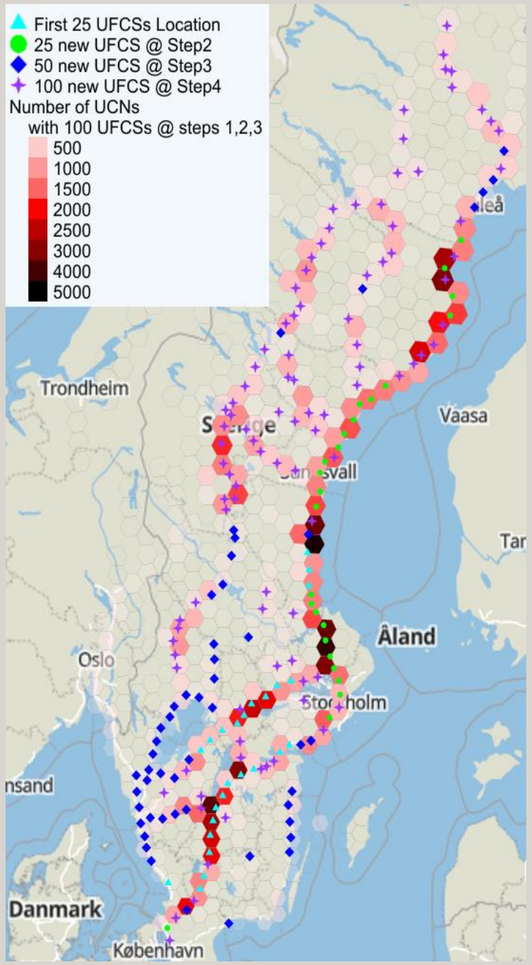
$$N=\{25,25,50,100,200\}\ ,\quad M=400$$

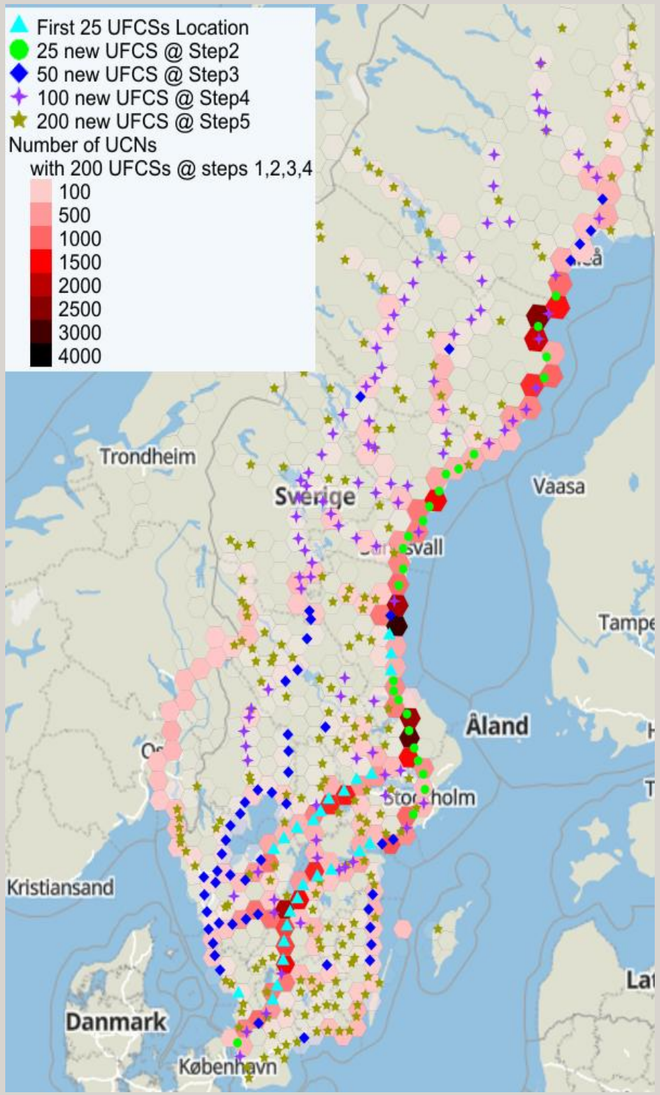
Step of UFCS candidate location Identification



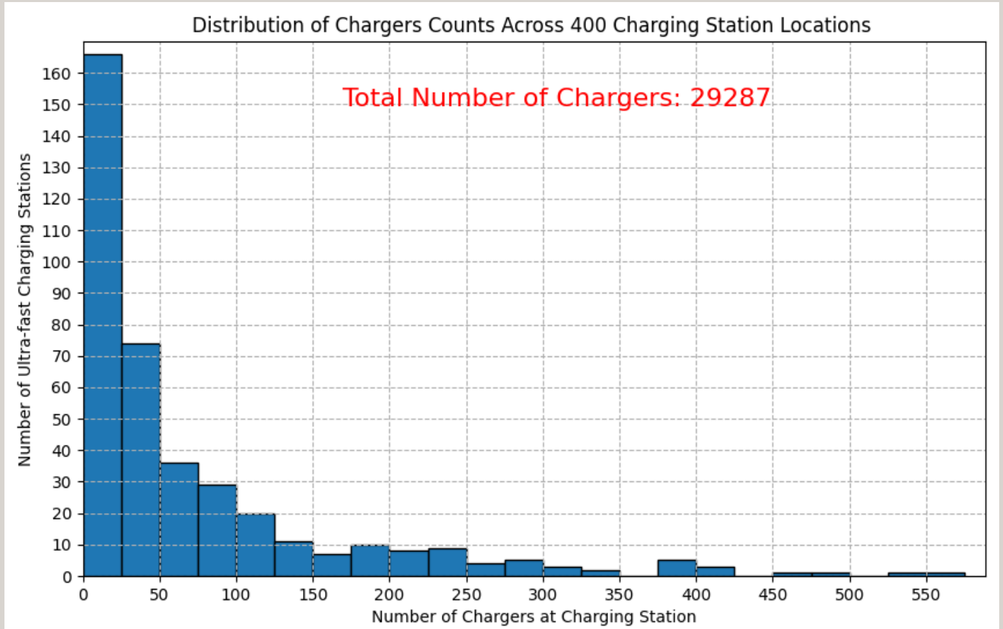


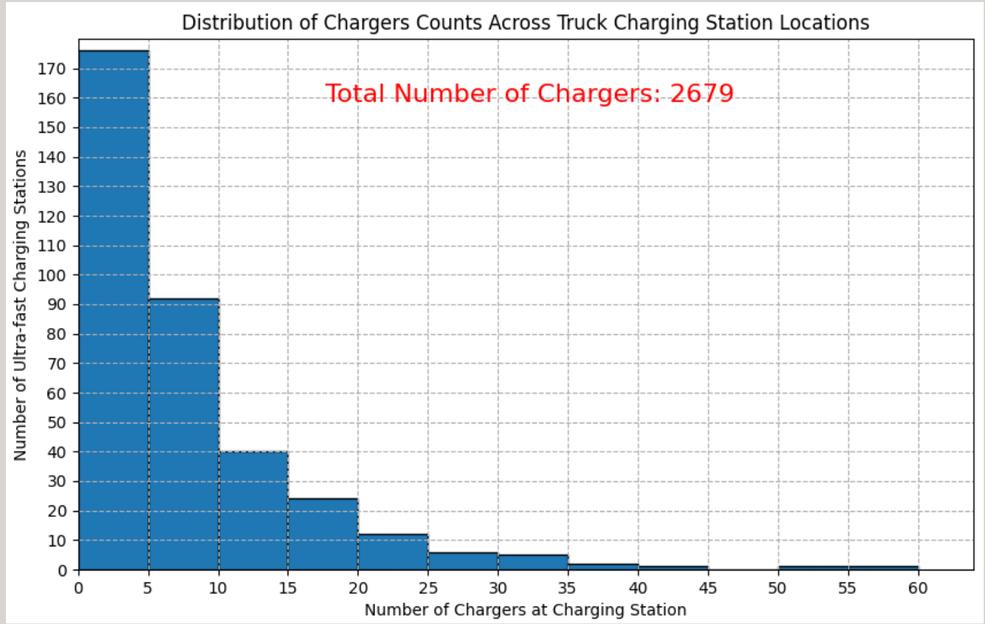






Distribution of UFCS Size





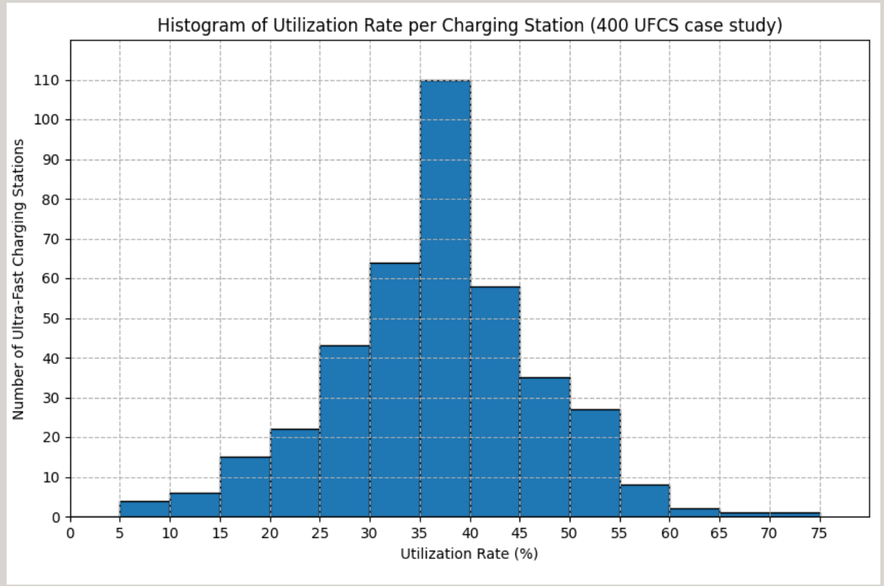
Assumptions:

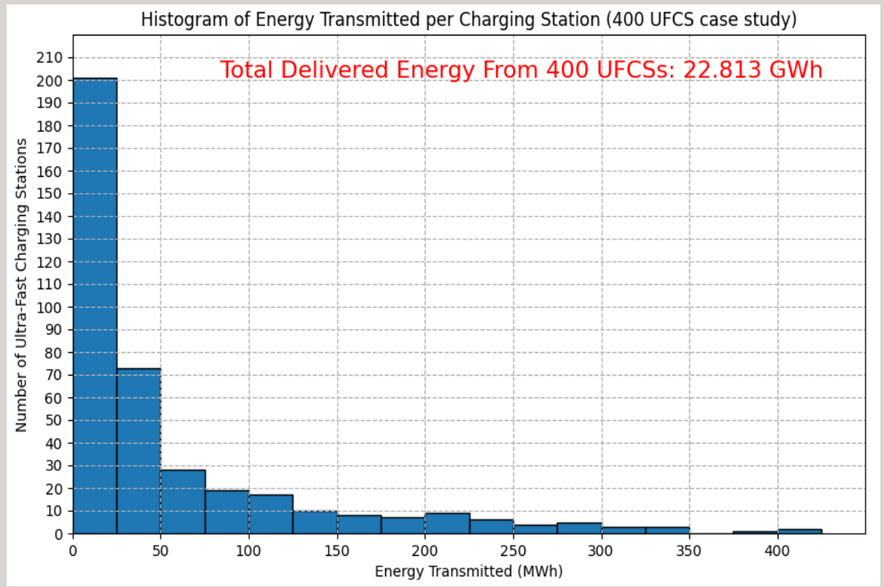
- There is no limit in the model for the UFCS size
- Real-world constraints, space, and power availability
- Charging starts at 20–30% SOC (80% cases) or 30–50% SOC (20% cases), randomly selected.
- Only 1 station per hexagon (30 km radius)
- The model assumes no queuing at the stations

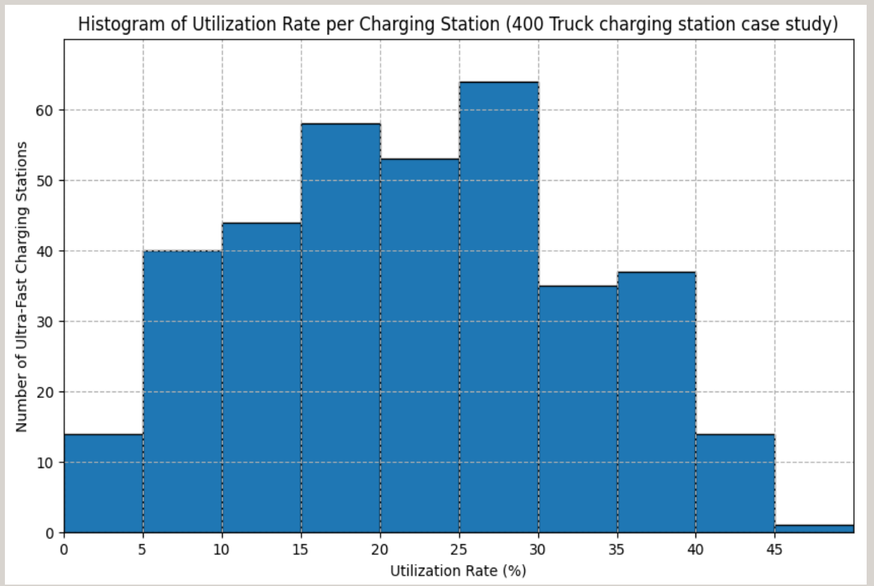
Result:

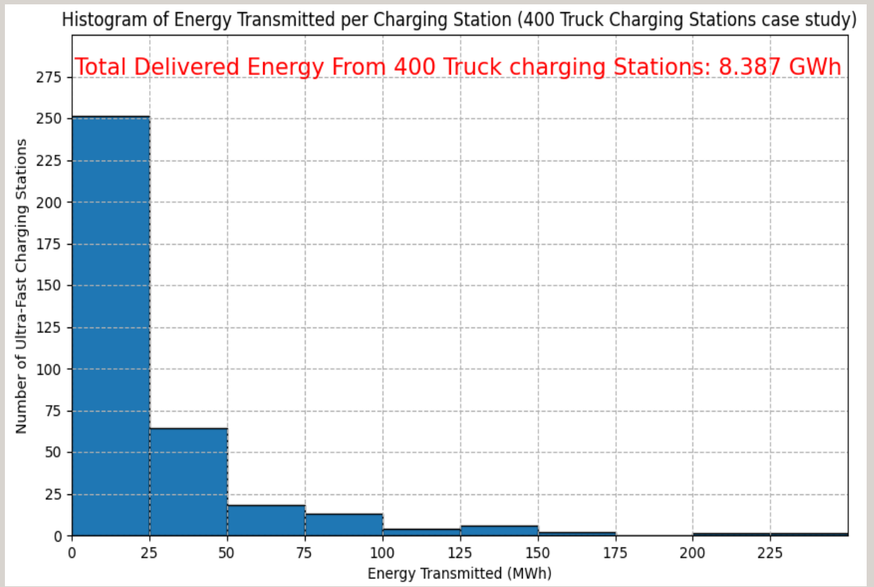
- Over 160 stations having fewer than 25 chargers (5 chargers)
- 75 % of the stations have less than 100 chargers (15 chargers)
- About 5 million cars -> 170 EVs per charger.
- In Norway 100 EVs / fast chargers,
  https://chargefinder.com/en/stats/country/norway

UFCSs' utilization rate and energy consumption distribution

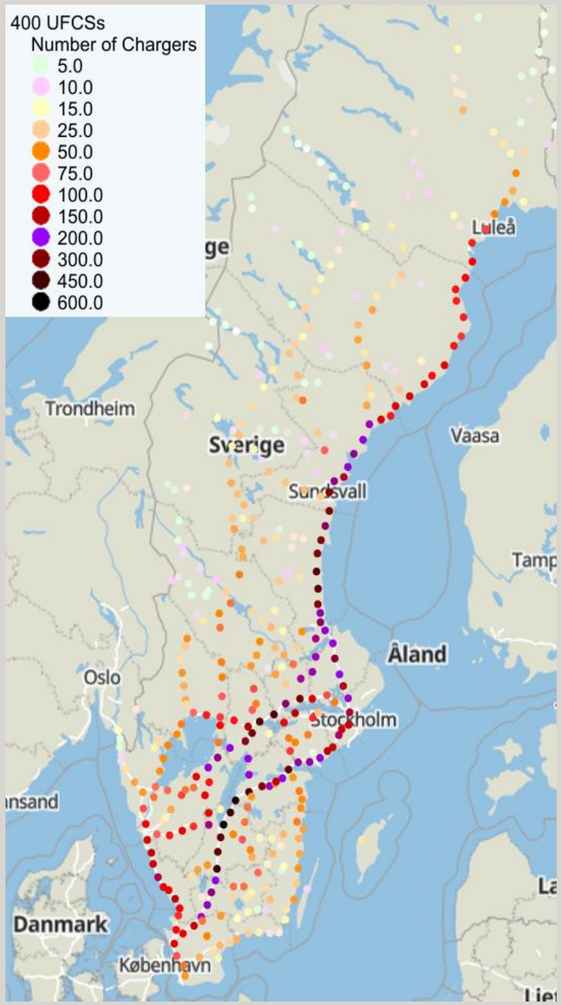


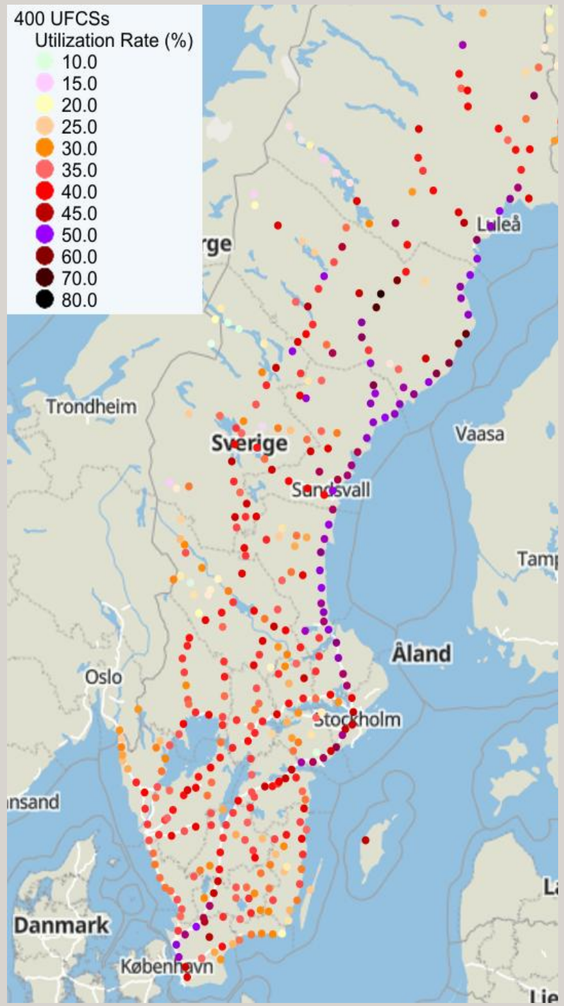




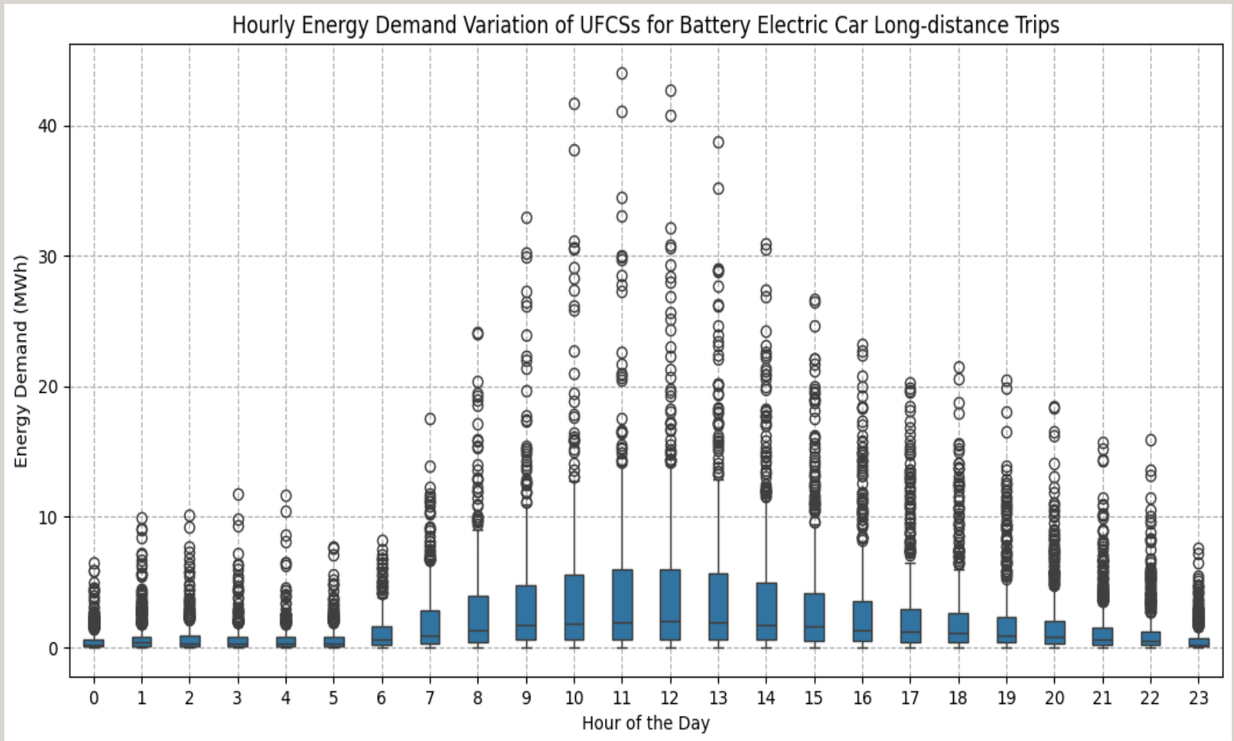


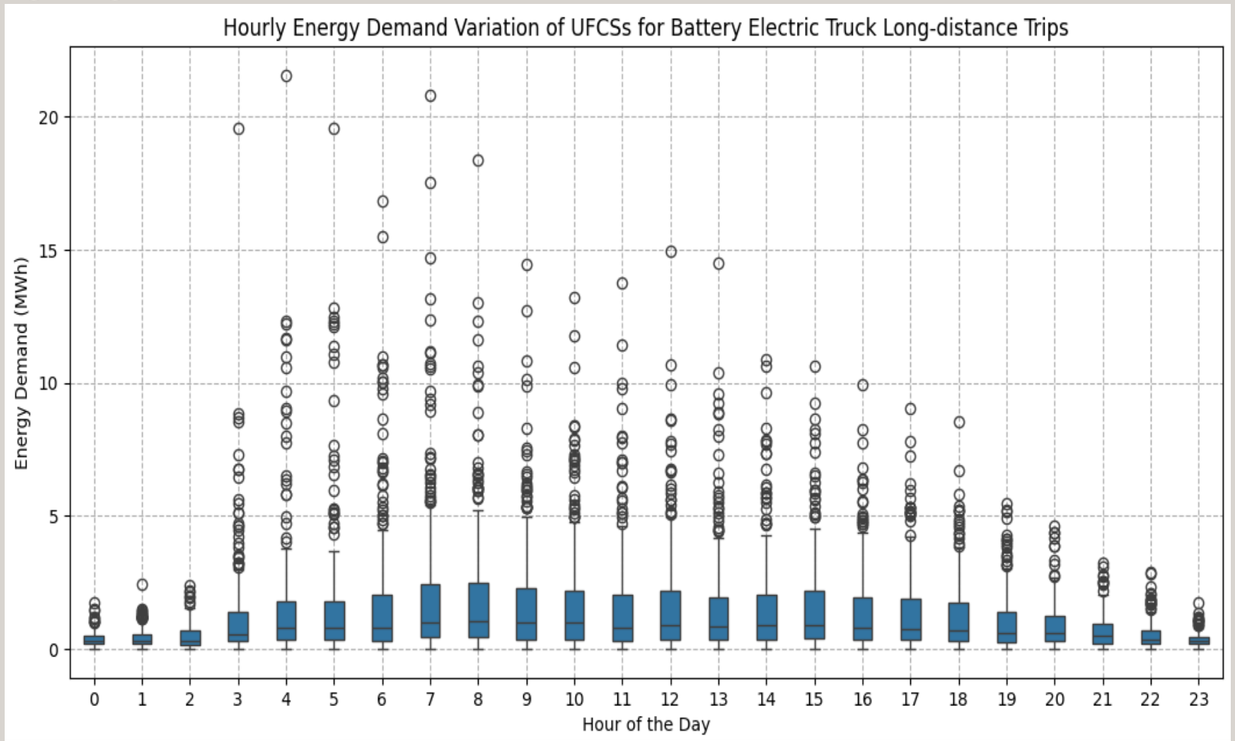
UFCSs chargers' number and utilization rate



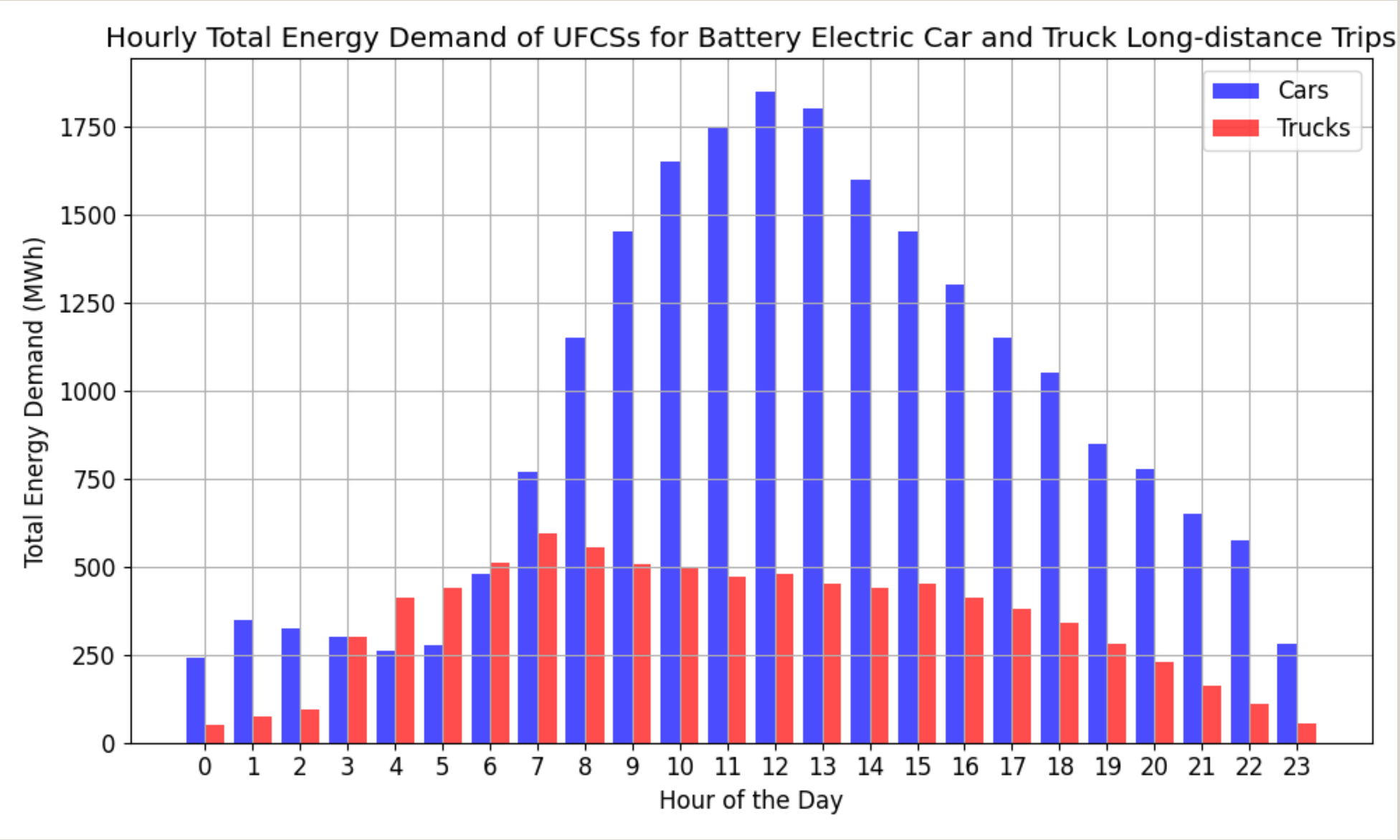


UFCSs hourly energy demand variation





Hourly total energy demand of UFCSs



Outcomes, conclusion and future work

- Utilized agent-based modeling to identify ultra-fast charging needs based on unserved charging events during EV long-distance trips.
- Results underscored the critical role of investing in fast-charging infrastructure for supporting a sustainable transportation system.
- Analysis of charging demand patterns revealed distinct peak periods, informing strategies for optimal station operation and grid management.
- The study provides a foundation for scalable infrastructure planning and offers insights that can guide policy formulation and strategic investments.
- Improve the accuracy and granularity of input data by refining synthetic population modeling in MATSim.
- Integrate additional spatial data on existing charging infrastructure for a more comprehensive assessment.

Thank you for listening

For questions or further discussion, feel free to contact me at:

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Questions

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