Algorithmic Planning, Simulation and Validation of Smart, Shared Parking Services using Last Mile Hardware

IAAS Research

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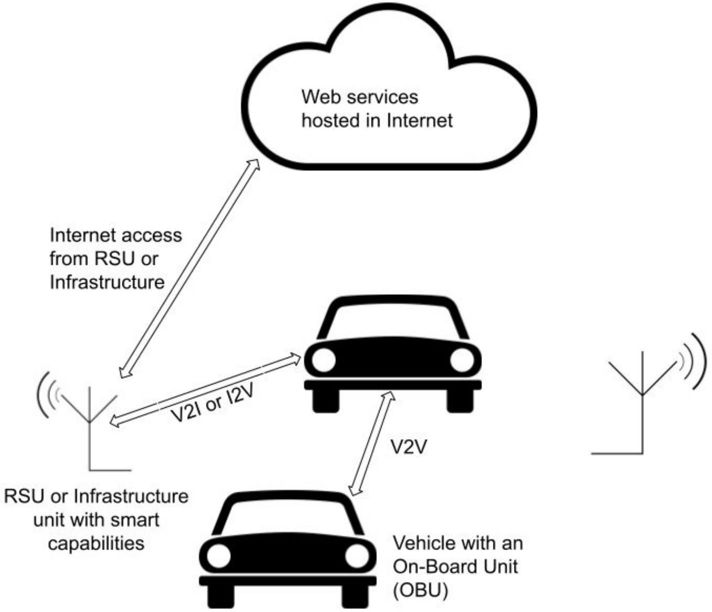
Institute of Architecture of Application Systems

Introduction

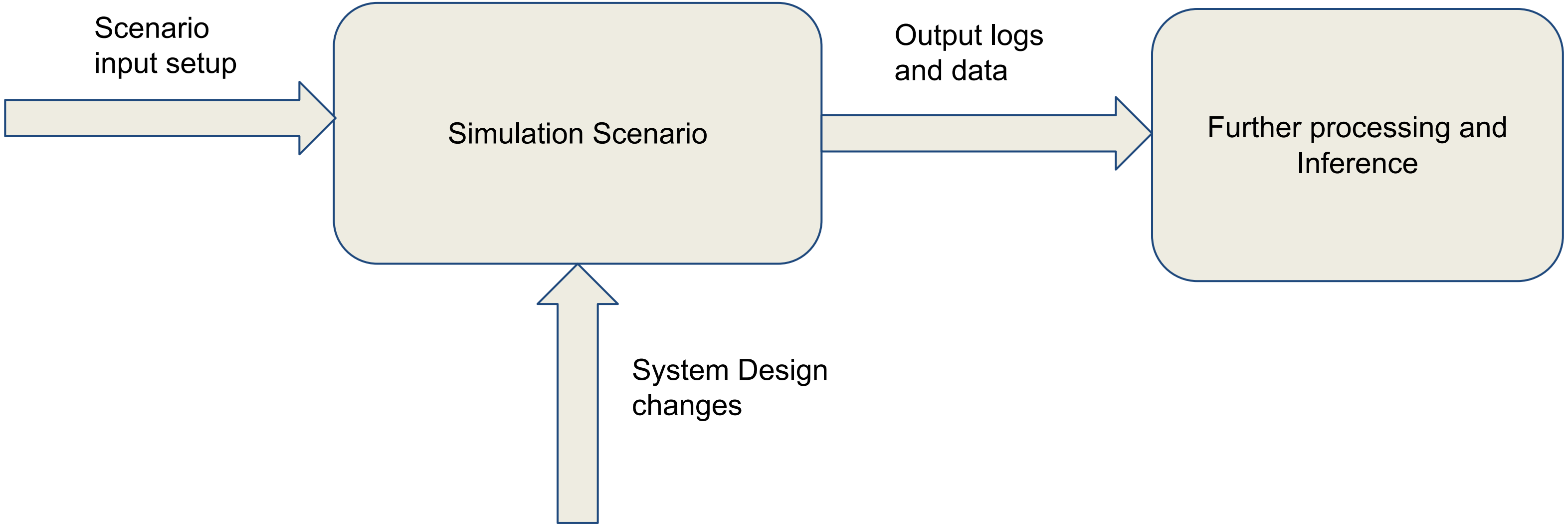
Important Background Terminologies

- Smart gate and Smart parking
- VANET



Contribution

- Setting up simulation-based testbed
- System design by extending existing mathematical models
- Analyse parameters related to various stakeholders



Limitations of previous work

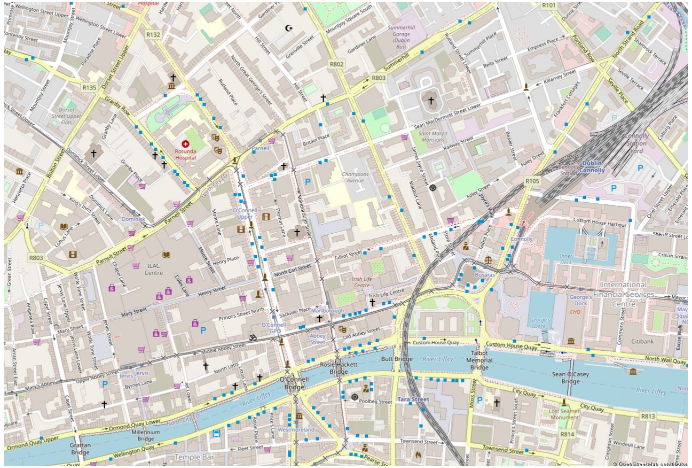
- Surveys to gather data
- Mathematical models - System design

System Design and Architecture

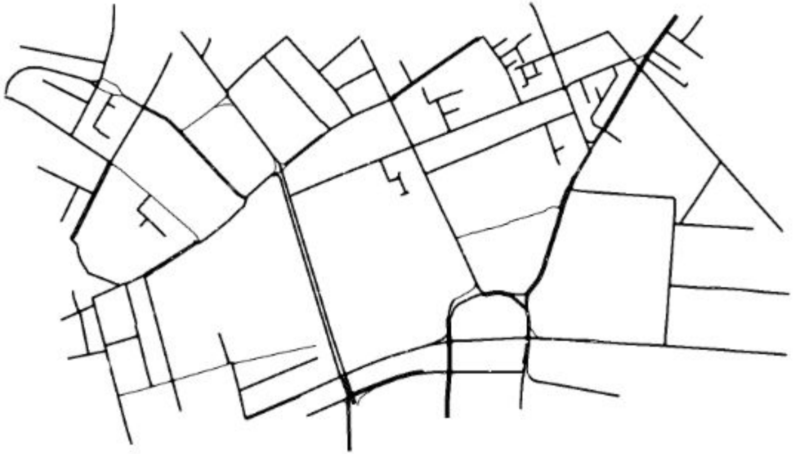
Research

Microscopic area or Simulation base map network

OSM



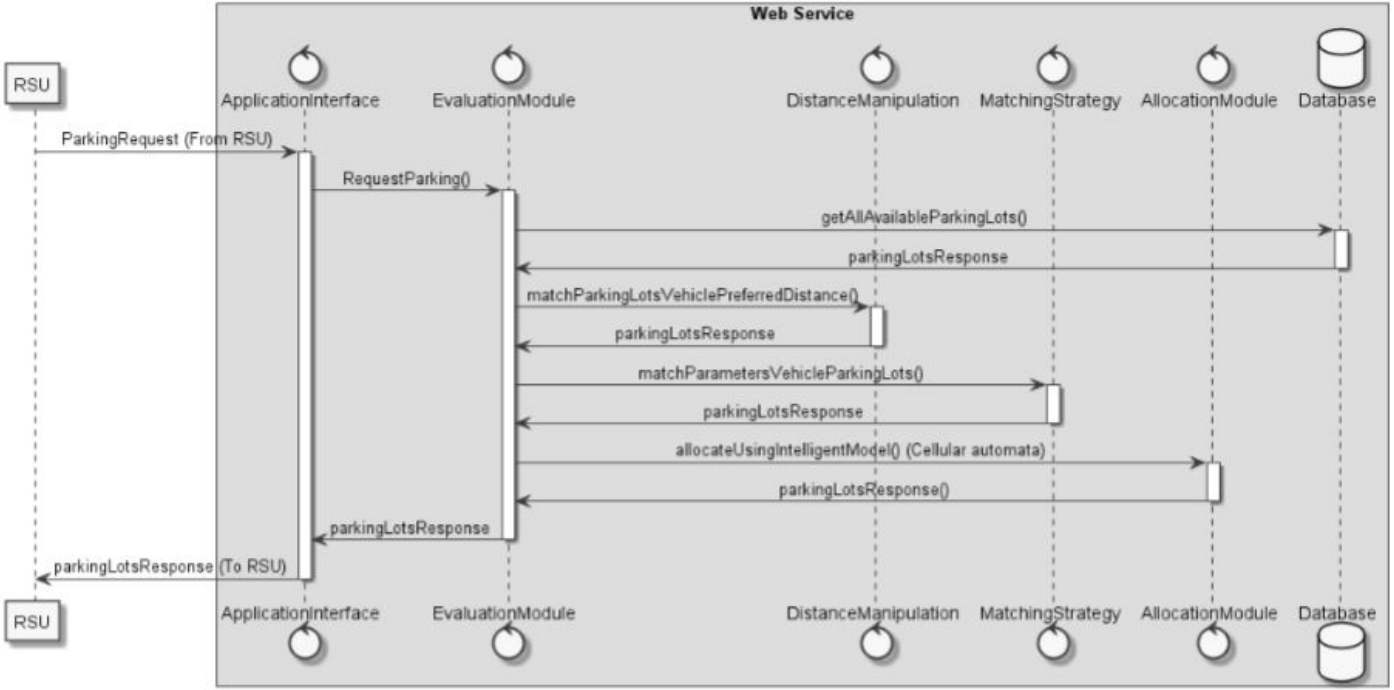
SUMO Network



ECLIPSE MOSAIC

SUMO

Approach - Shared Private Parking Model in Web Service



Researc
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Design of the system

- Mathematical model - I (Focus on preferred walking distance)

$$U_m = \frac{\sum_{n=1}^{N} t_{dur}^{n} \cdot x_{mn}}{T_m(H)}$$

$$x_{mn} = \begin{cases} 1 & if, (D_m \leq D_{max,n}) \;\&\; (P_m = P_n) \;\&\; (t_{start,m} < t + t_{dur}^{n} < t_{end,m}) \;\&\; (F_m > 0) \;\&\; (t - t_{lr,m} > t_{th}) \\ 0 & Otherwise \end{cases}$$

- Mathe

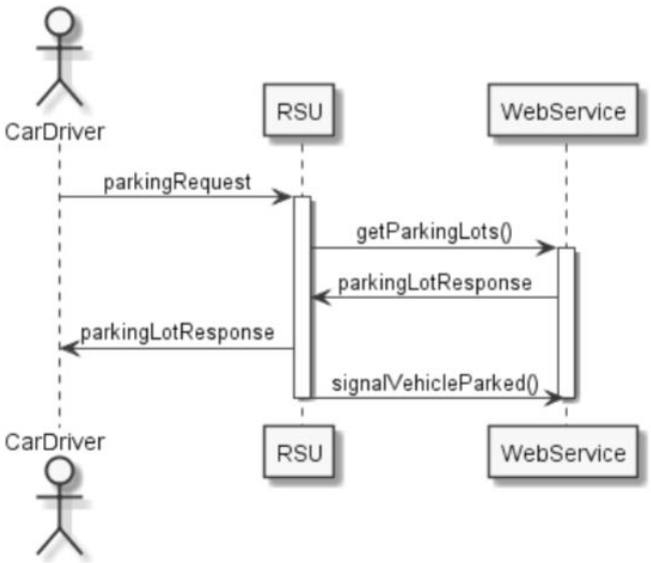
$$R_m = \sum_{n=1}^{N} [(t_{dur}^{n} \cdot x_{mn} \cdot c_m) + (t_{od}^{n} \cdot x_{od.mn} \cdot c_{od.m})]$$

$$x_{mn} = \begin{cases} 1 & if, (D_m \leq D_{max,n}) \;\&\; (P_m = P_n) \;\&\; (t_{start} < (t + t_{dur}^{n}) < t_{end}) \;\&\; (F_m > 0) \;\&\; (t - t_{lr,m} > t_{th}) \\ 0 & Otherwise \end{cases}$$

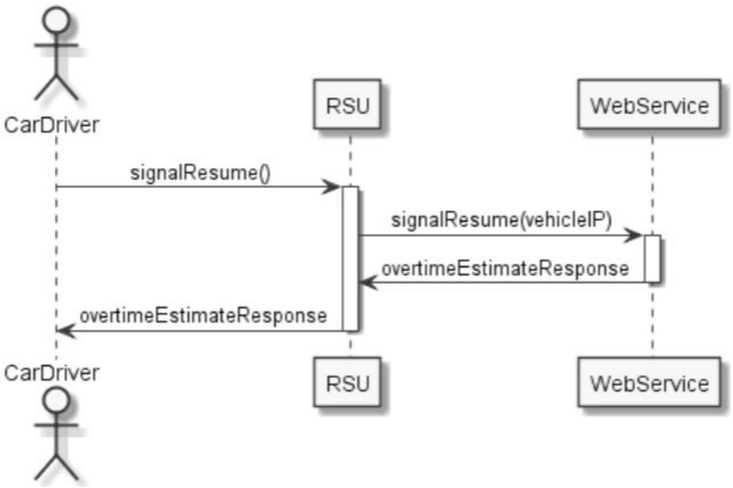
$$x_{od.mn} = \begin{cases} 1 & if, (t > t_{dur}^{n}) \;\&\; (x_{mn} = 1) \\ 0 & Otherwise \end{cases}$$

Data flow between components

Parking Request



Resume



Results

Metrics

- Vehicular Emission, Reroutes and Distance travelled
- Utilization rate of parking lots
- Revenue generated by parking lots
- Correlation heatmap

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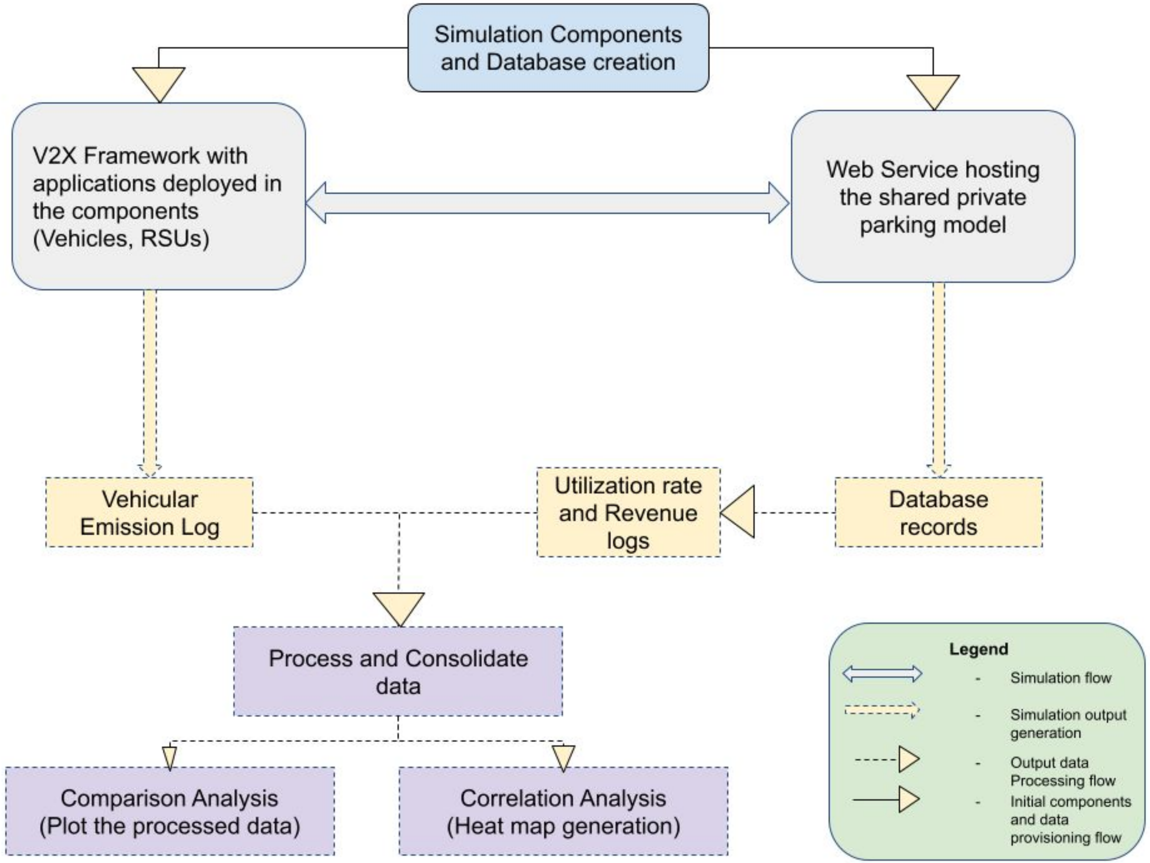
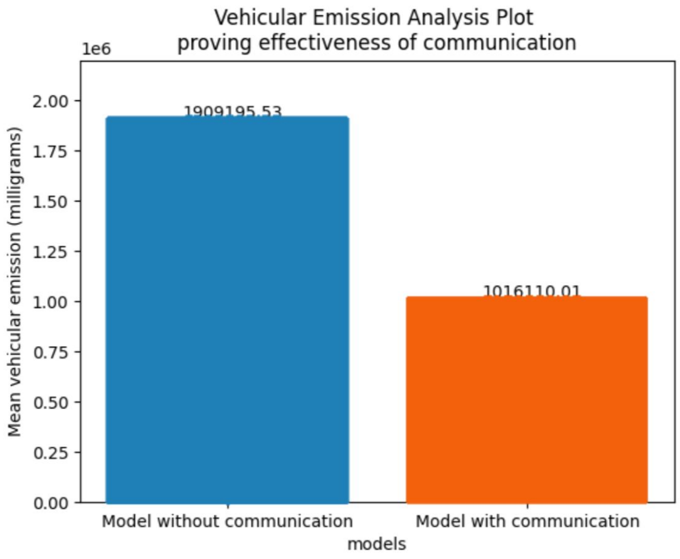
Simulation-based testbed setup



Employing a communication strategy to search for a parking spot



Metric	Unit	Base Scenario	Proposed model scenario
Mean Vehicular CO_2 Emission	milligrams (mg)	1.909×10^6	1.016×10^6
Reroutes	(No unit)	16	0

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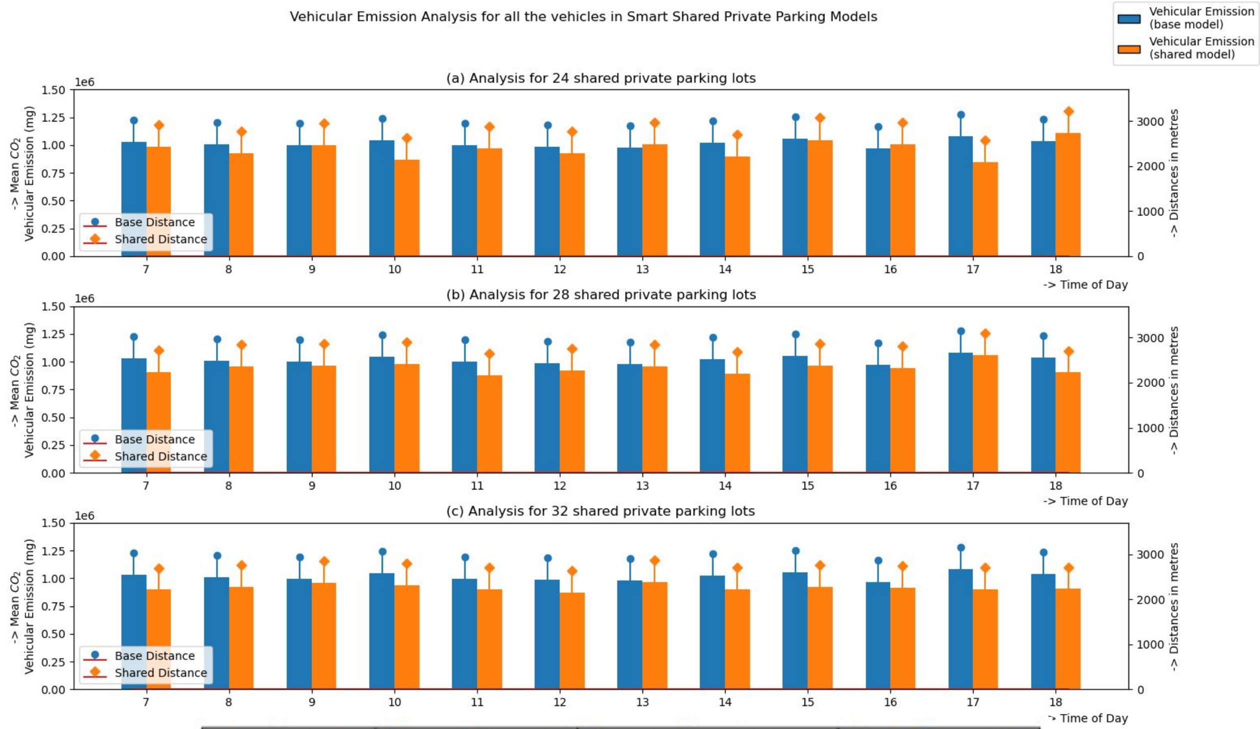
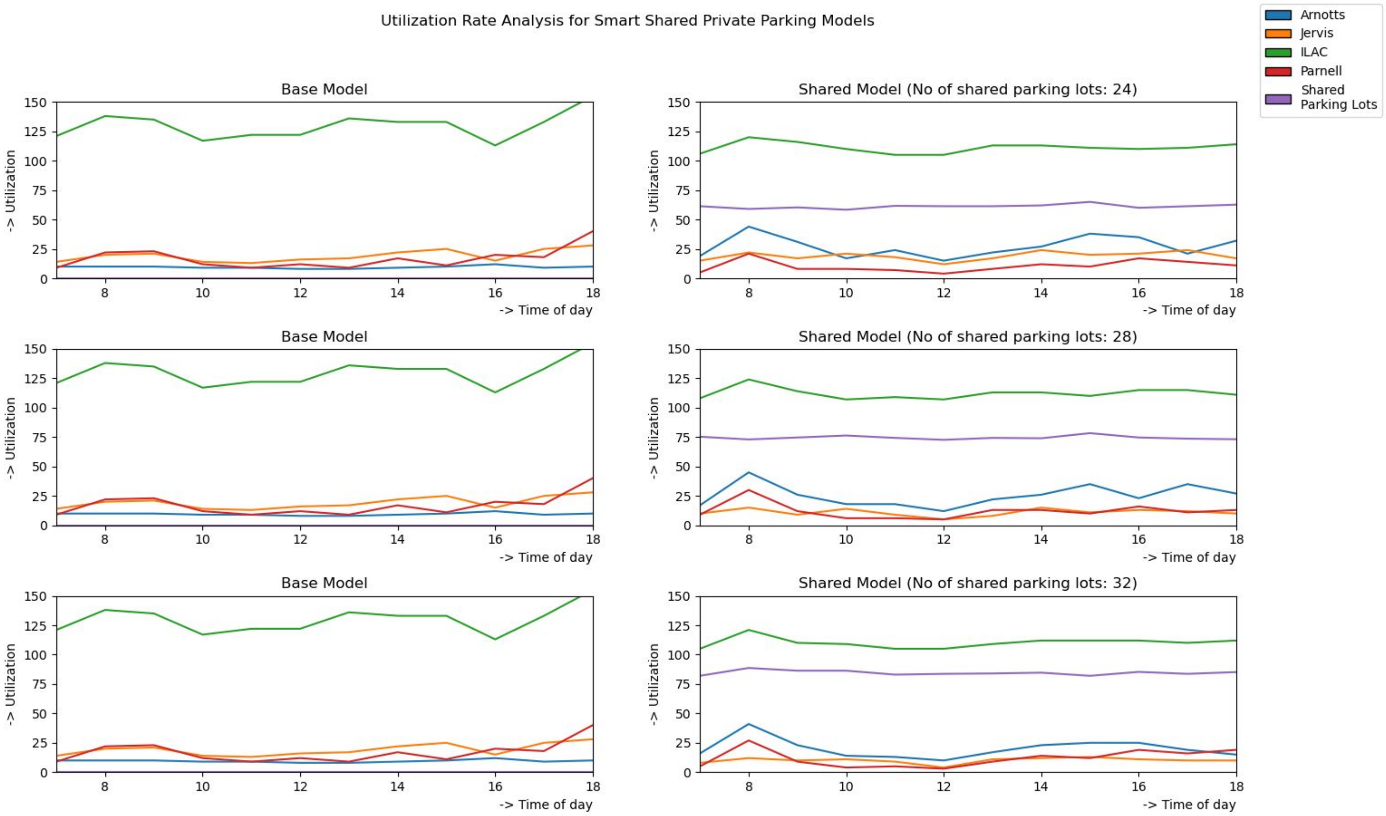
Benefits of shared private parking model to vehicle or drivers



Number of shared parking lots	Mean CO_2 emission in base parking model (mg)	Mean CO_2 emission in shared parking model (mg)	Rate of decrease in vehicular emission (%)
24	1.016×10^6	0.965×10^6	5.01
28	1.016×10^6	0.944×10^6	7.08
32	1.016×10^6	0.916×10^6	9.80

Benefits of shared private parking model to parking lot owners - Utilisation Rate



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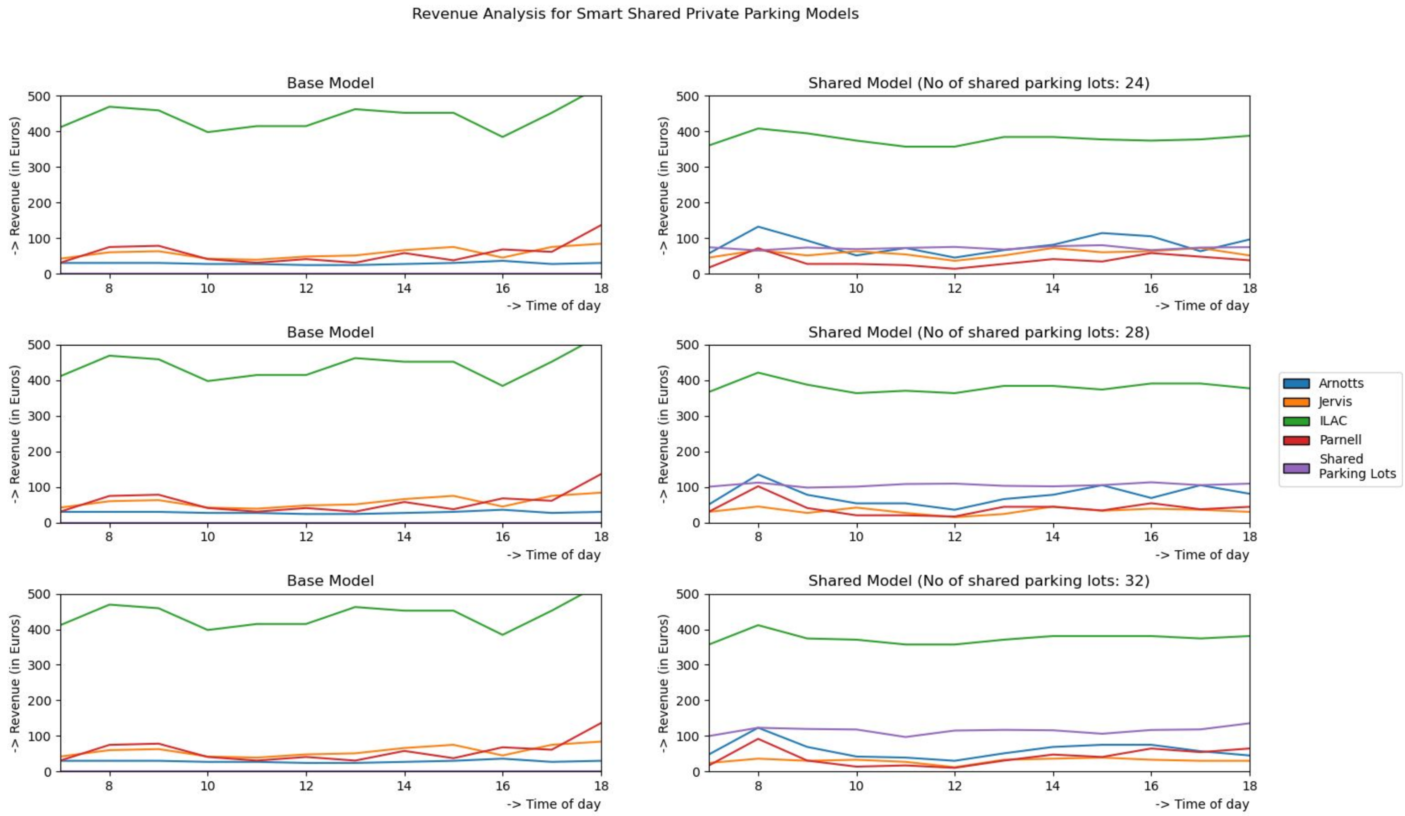
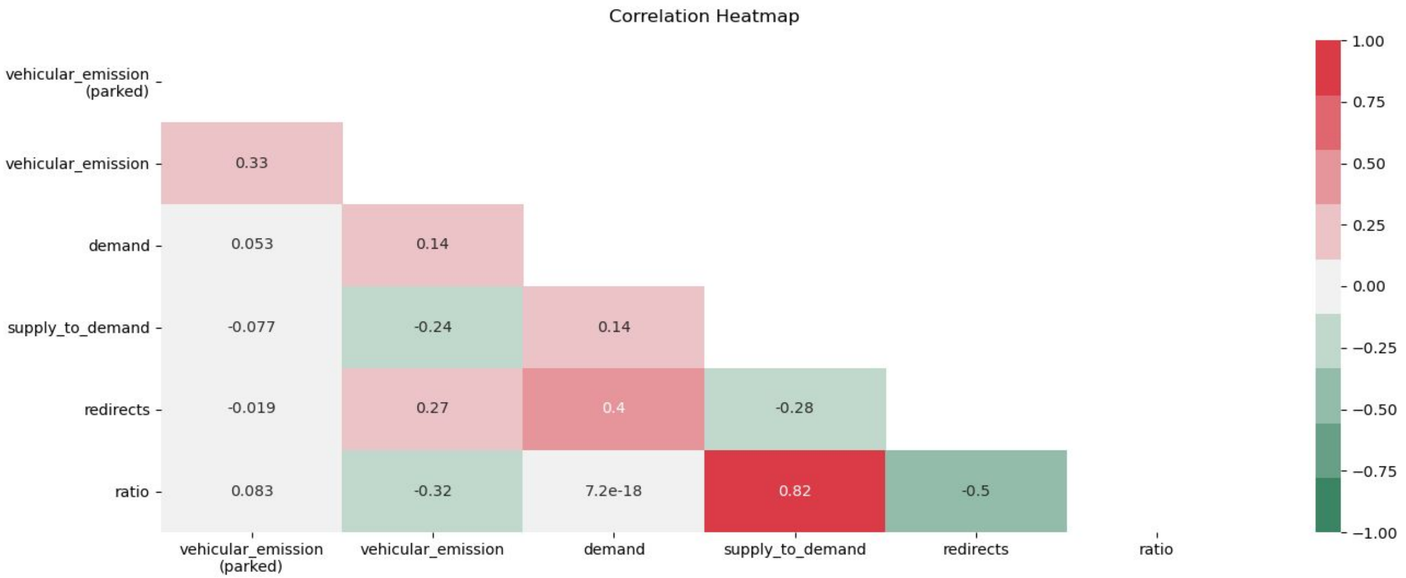
Benefits of shared private parking model to parking lot owners - Revenue



Effects of change in number of shared private parking lots



Conclusion

Conclusion

- Proving effectiveness of the shared private parking model
- Improvement to traditional model by lesser emissions
- Comparison analysis to prove effectiveness
- Correlation analysis to conclude reaction of vehicles and model.

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Out of scope

- Ensure better scalability
- Better route planning
- Needs parking and overtime parking behaviour model
- To improve standardisation of V2X messages

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Future Works

- Larger city-based scenario
- HIL Simulation or Digital testbed
- Bike travel as Intermodal travel option

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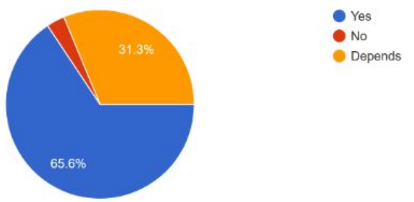
Questions?

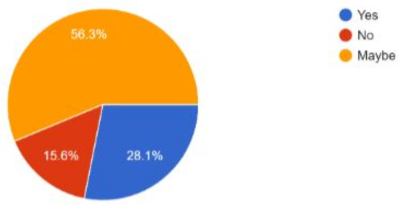
Appendix

Survey

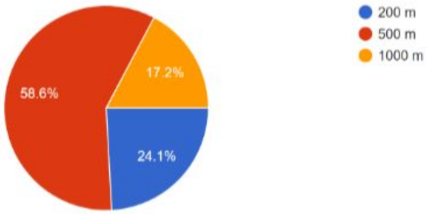
- Among 34 employees from itemis
- From different German locations
- To gather opinions on shared private parking model



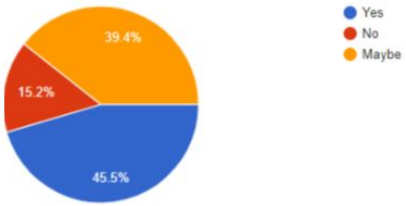
Result of Survey to know how many people are interested to reserve the parking in advance



Result of Survey to know how many people are interested to reserve with Inter-modal Travel option

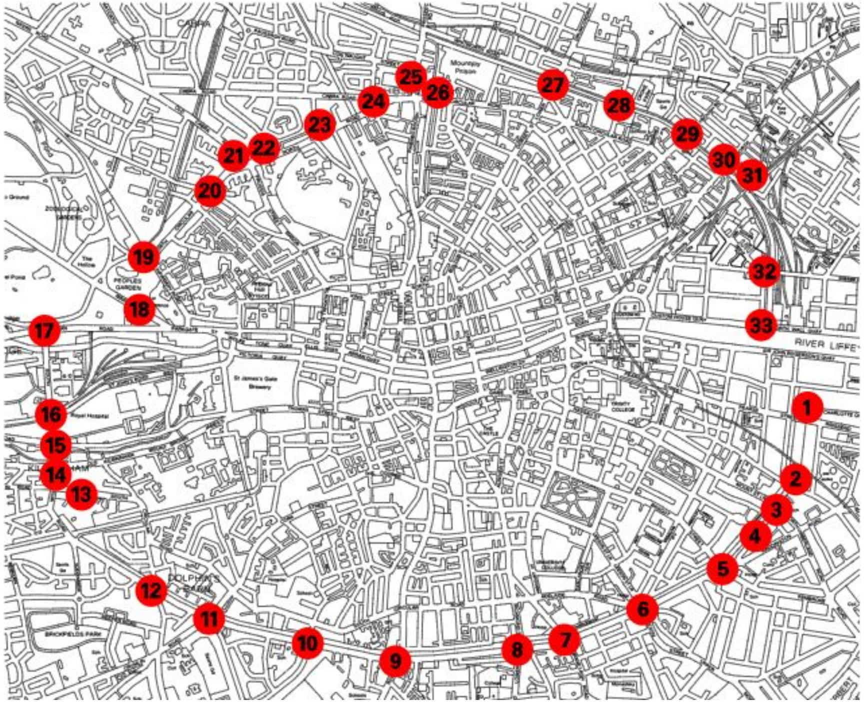


Result of Survey to know the preferred Inter-modal distance between the parking lot and the destination



Percentage of people interested to offer their parking

Demand data survey points



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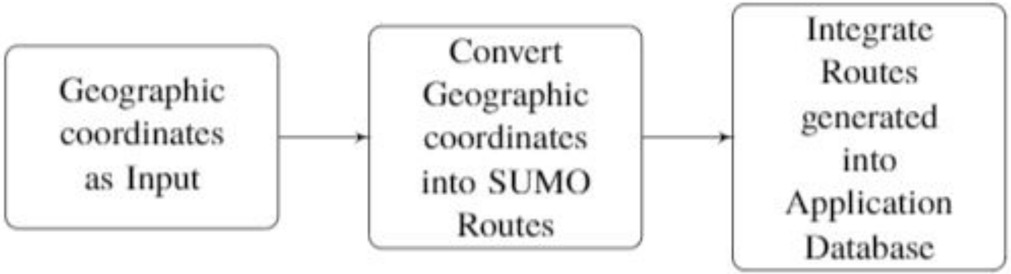
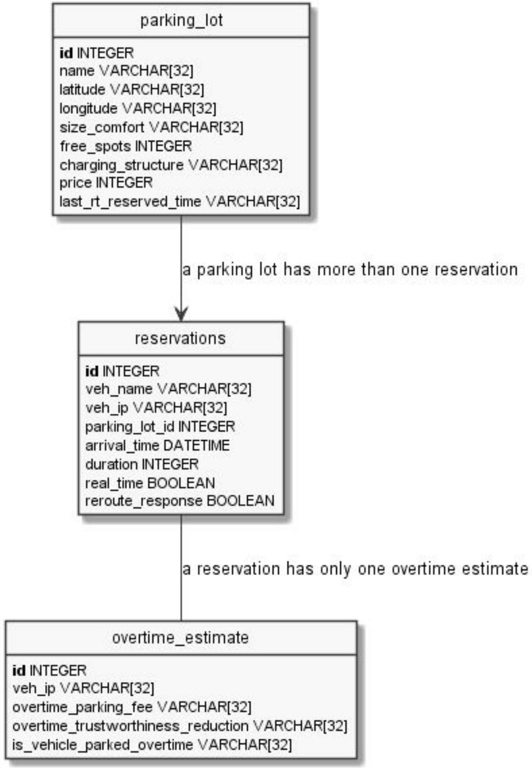
Route planning procedure

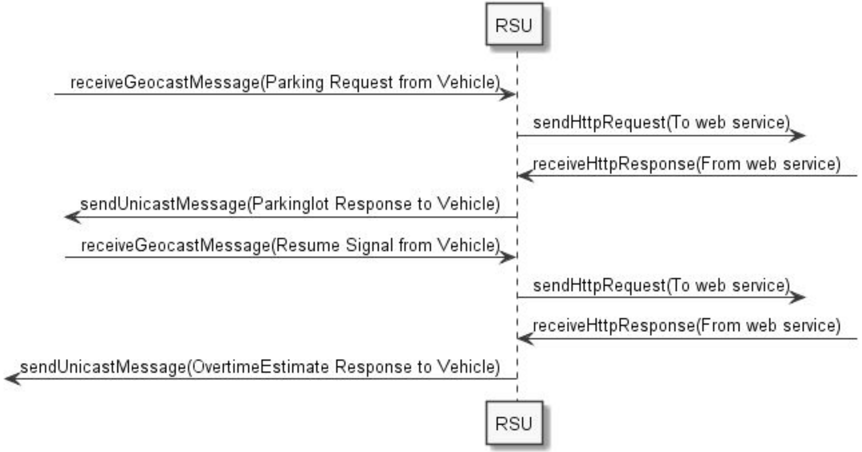
- Sources and destinations are chosen as geographic coordinates
- Fed to custom script
- Integrated database is used for navigation



Shared Private Parking Lots model database schema

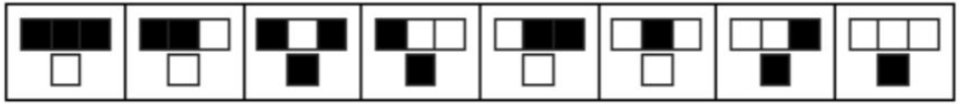


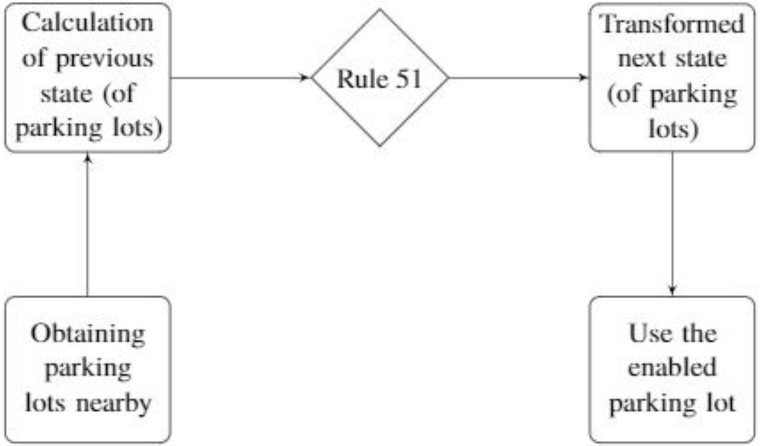
Applications deployed in vehicle and RSU



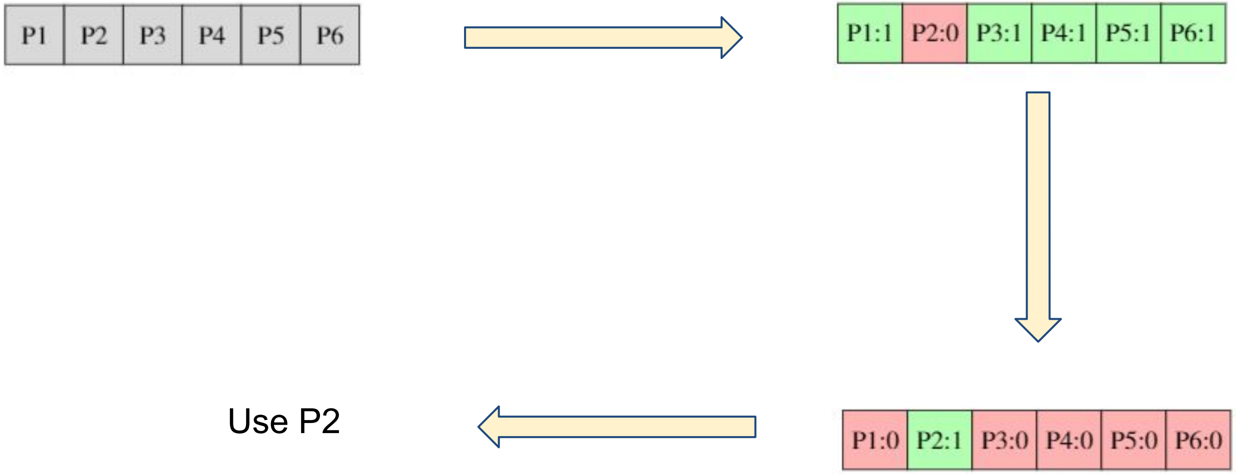
Design - Cellular Automata - Allocation module

- Cellular Automata used in allocation module
- Ensures even distribution
- Rule type - Rule 51
- Expression: $t - t_{lr,m} > t_{th}$

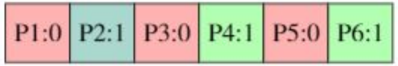




Allocation Module stages



Special Case



Approach - Technical stack

- Eclipse MOSAIC - V2X Framework with vehicles, RSUs
  - Eclipse SUMO - Simulates traffic
- Python based web service - Hosts the shared private parking model
- Python scripts for processing and analysis

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Simulation-based testbed setup

- Need for a setup
- Facilitates to extract logs
- Emission logs and Database records

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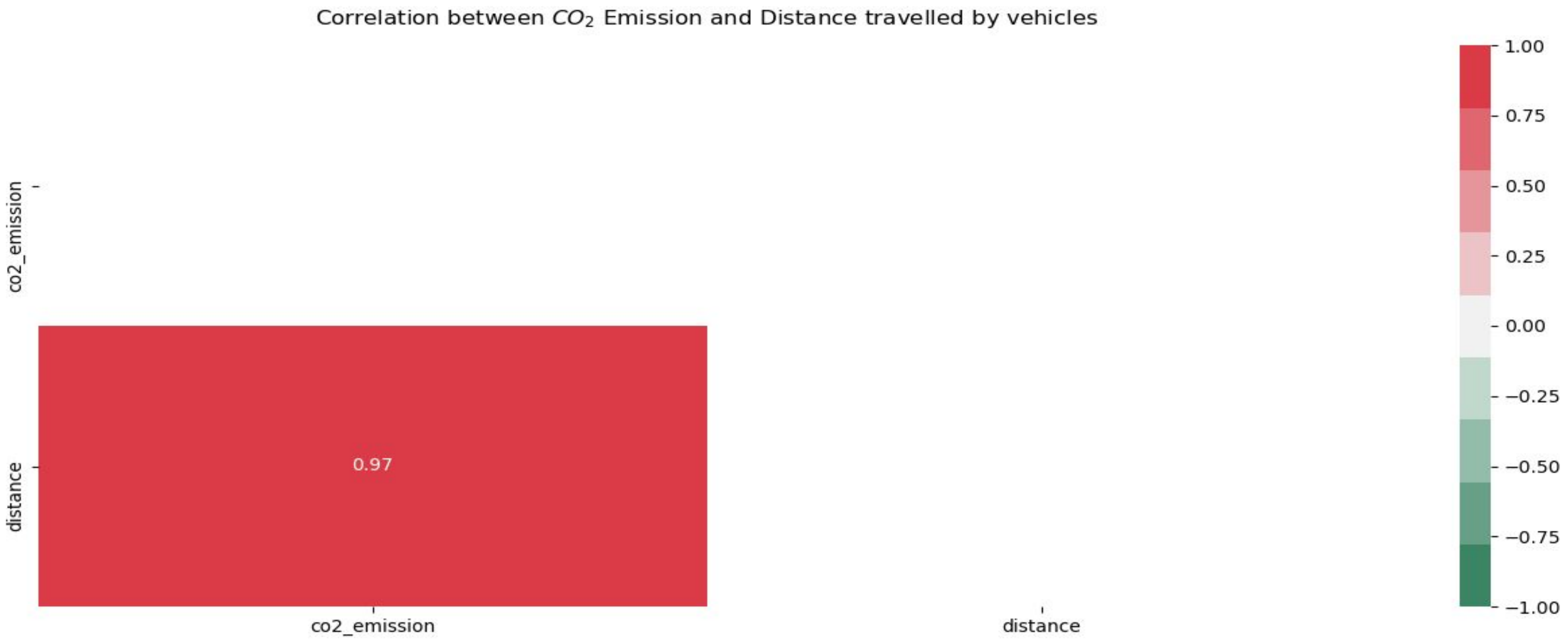
Correlation analysis between vehicular emissions and distance travelled



Utilisation of individual parking lots