Departament d'Estadística i Investigació Operativa
UNIVERSITAT POLITÈCNICA DE CATALUNYA

inLab FIB talent & tech

Smart Mobility and New Mobility Concepts in Urban Context. On-going Projects and Achievements in the MPI Node

UNIVERSITAT POLITÈCNICA DE CATALUNYA
Departament EIO. InLAB. FIB
MPI (Modelització i Processament de la Informació. SGR)

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InLab FIB

InLab FIB es un laboratorio de innovación e investigación de la UPC especializado en aplicaciones y servicios basados en las tecnologías de la información.

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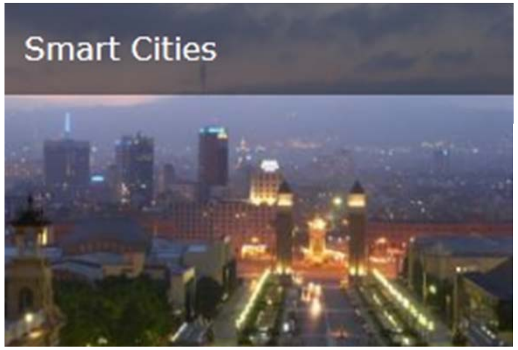

CONTENTS

Traffic State Estimation Using Cooperative Car Data. Probe Cars and Simulation Study

- Use of Probe Car data
- Methodology for Evaluation F. Magnitudes
- Simulation Results

Evaluation of a Multiple Passenger Dynamic Ride Sharing (MPDRS) by simulation

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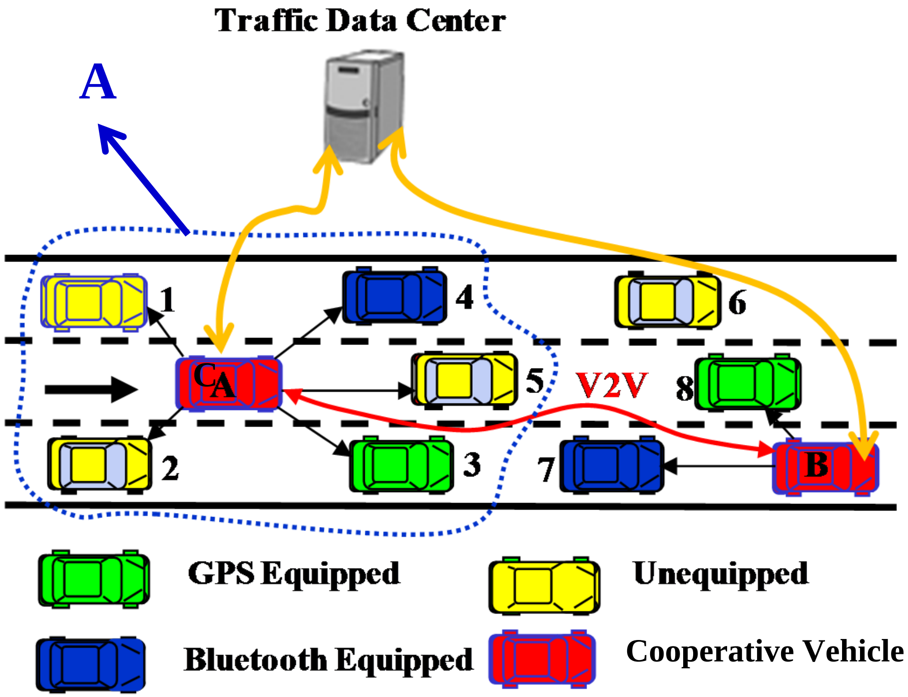
Connected Car project (Summary)

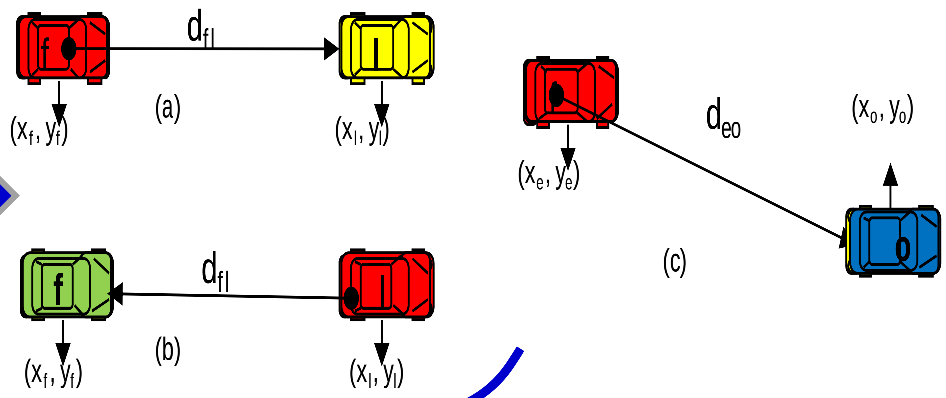
Explore the use of data provided by regular car sensors to estimate traffic state as the basis to develop a lane-level route guidance mobility service.

Realistic and large scale fleets of equipped cars → a simulation-based assessment study:

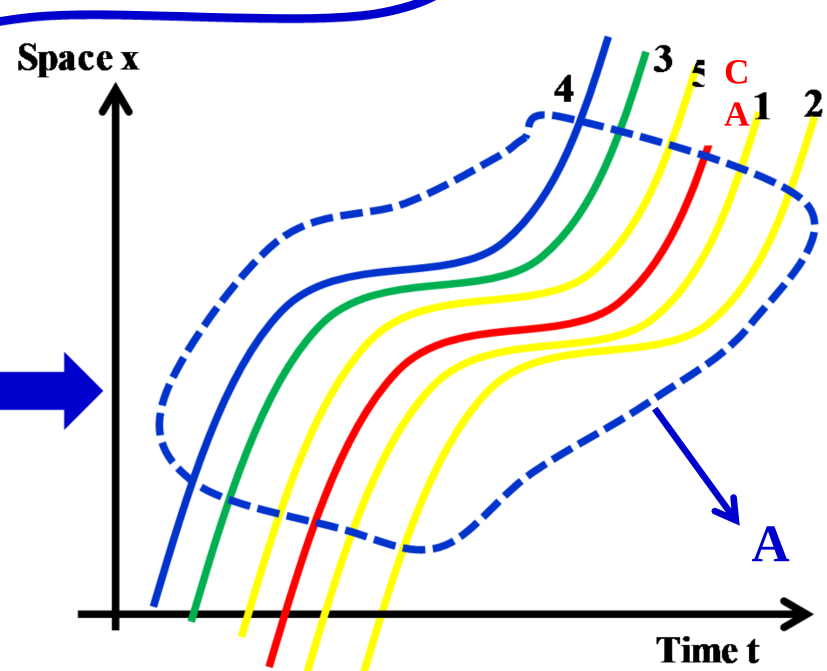
1. Undertaking a **field test data collection** in Barcelona: 3 cars x 5 day x 8 h/day, based on *adhoc* **experimental design.**
2. Developing and validating using field collected data, a C++ API **emulator of** data collection from equipped **car sensors**
3. Using **microscopic traffic simulation** to simulate traffic dynamics reproducing peak-period traffic conditions
4. Using L'Eixample in Barcelona as a **simulation test area**
5. Defining simulation scenarios according to **%equipped cars** and proposed **traffic variable estimates**.
6. Evaluating the defined scenarios in terms of ad-hoc KPIs
7. Implementing **lane-based guidance estrategies** to benefit customer vehicles from estimated traffic conditions

V2V TRACKED EQUIPPED VEHICLES "AWARE" OF SURROUNDING VEHICLES⇒ TRAJECTORY RECONSTRUCTION





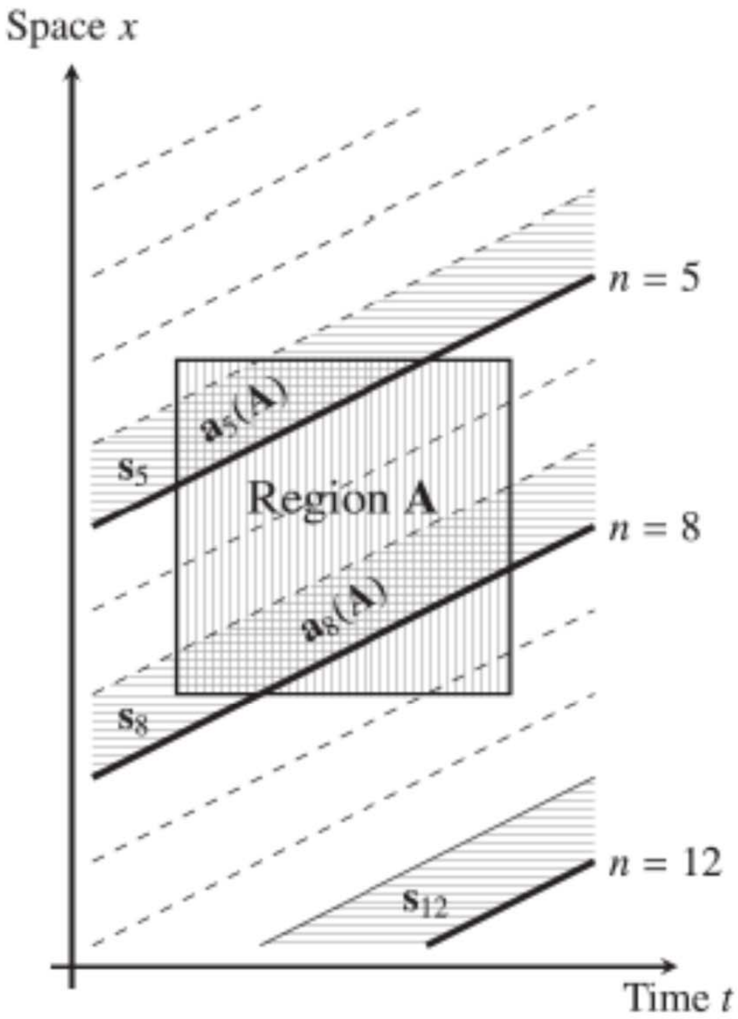
- The relative distance d_{eo} between the equipped and the observed car
- The relative speed v_{eo} between the equipped and the observed car
- The map-matched position (x_e, y_e) and speed v_e of the equipped car.



METHODOLOGY

- Extension of Leader Approach of: Seo, T., T. Kusakabe, and Y. Asakura. Estimation of flow and density using probe vehicles with spacing measurement equipment. *Transportation Research Part C: Emerging Technologies*, Vol. 53, 2015, pp. 134–150. To a Leader-Follower approach.
- Objectives:
  - Probe-vehicle based estimation method for volume-related variables
  - Validation of the method under actual traffic conditions
- The method does not rely on exogenous assumptions (e.g. fundamental diagram)
- One-way multi-lane corridor with merging/diverging sections
- Inputs for the method:
  - **Space headway** between the probe vehicle and its leader
  - **Space headway** between probe vehicle and its follower
  - **Position and speed** of the probe vehicle
  - **Relative speeds** for leader/follower vehicles
- Assumptions:
  - Error free measures
  - Random distribution for probe vehicles

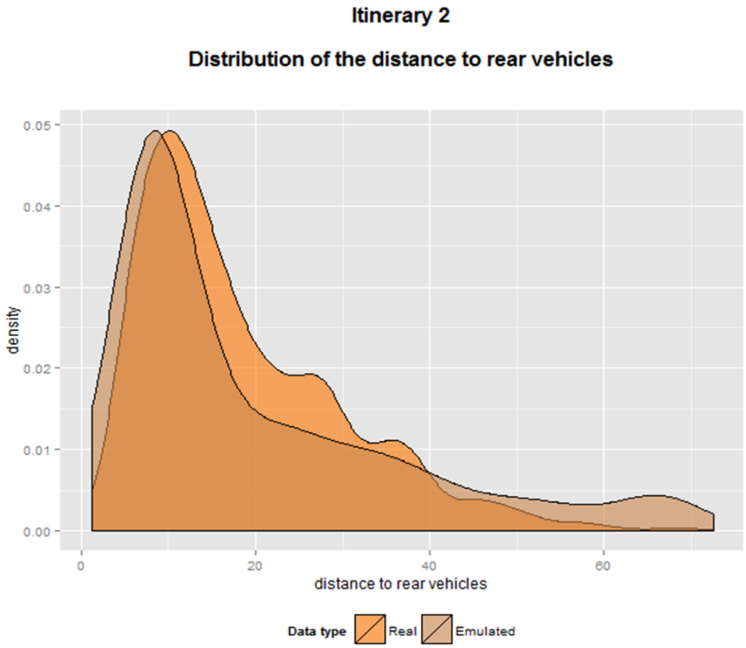
METHODOLOGY IMPLEMENTATION (I)

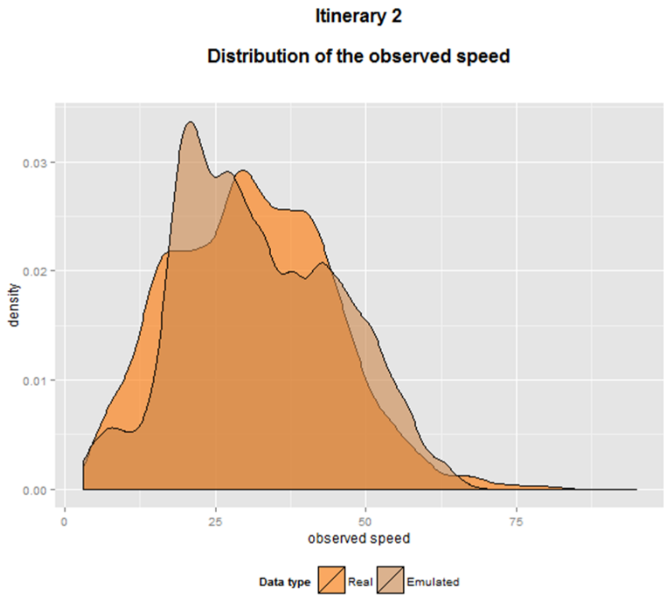


- ✓ Time-space discretization
- ✓ Eulerian rectangles
- ✓ Common discretization
- ✓ Example of a subregion A

ANALYSIS OF MEASURED DATA FROM PROBE CARS

1. Data was collected on three cooperative cars driving eight hours/day during 5 weekdays in November 2014
2. An exploratory analysis was performed to identify meaningful trends, covering the equipped as well as observed vehicles (position, heading, speed and acceleration).
3. Headways and number of observed vehicles per equipped vehicle were also considered.
4. Data were used to calibrate the simulation model and the cooperative data collection (by means of ad hoc APIs) in the simulation model

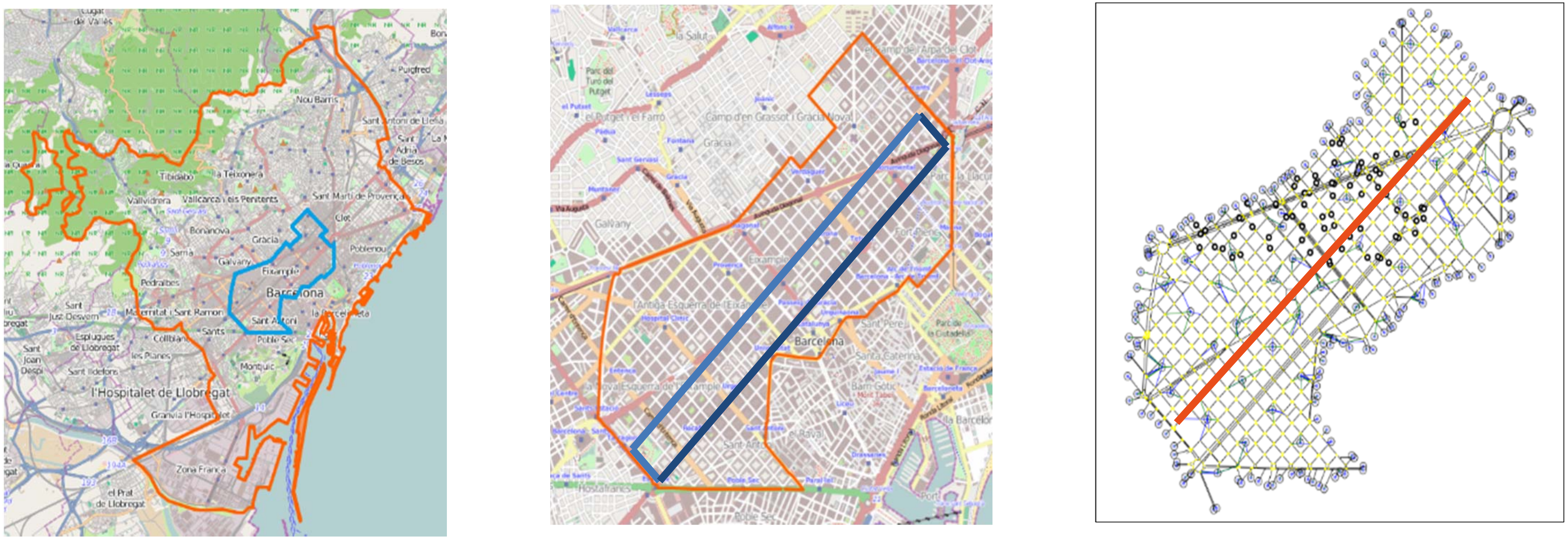




μ-SIMULATION EXPERIMENTS

- Simulation horizon 30 min.
- Design parameters
  - Penetration rate (%): 5,10
  - Time Window Length (s) : 91, 182, 364 (Time horizon discretizations)
- Amount of reading registers
  - Penetration rate of 5%: 209,969
  - Penetration rate of 10%: 431,480
- Time horizon discretized into time Windows
- Space discretized into Aimsun's sections
- For each time-space region:
  - Check if an estimation can be provided
  - If so, calculate and store the estimated fundamental variables

THE SITE



(a) (b) (c)

(a) Barcelona's CBD (7,46 Km^2, over 250,000 inhabitants)
(b) Physical data collection experiment (3 cooperative vehicles) Itinerary 2 (in blue) Aragó Corridor
(c) Aimsun microscopic traffic simulation model of Barcelona's CBD (2,111 sections, 1,227 nodes, 120/130 generation/attraction centroids, 877 non-zero OD pairs) in red Aragó Corridor in the model. Simulated horizon 30 minutes with a total of 20,700 vehicle trips.

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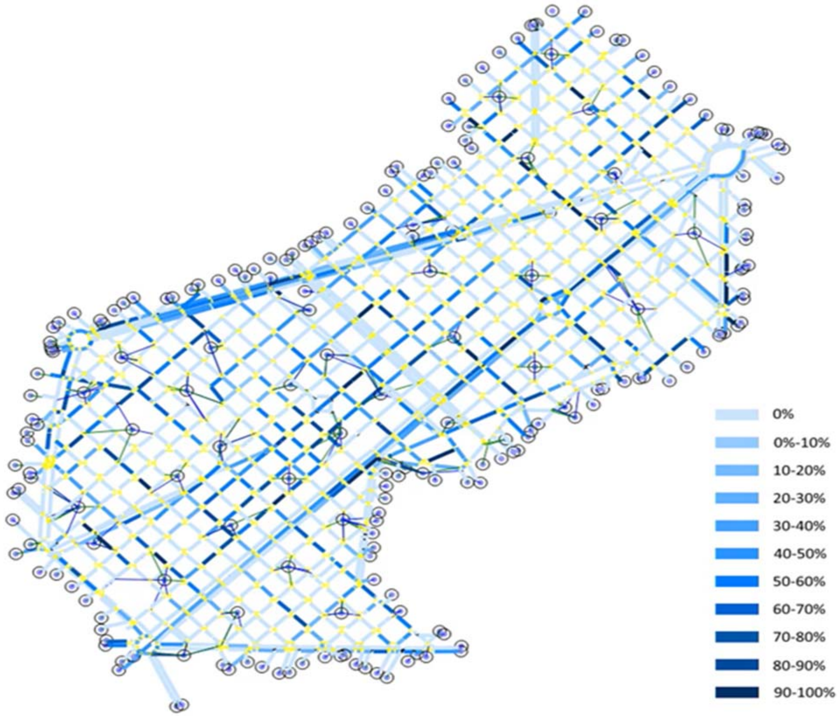
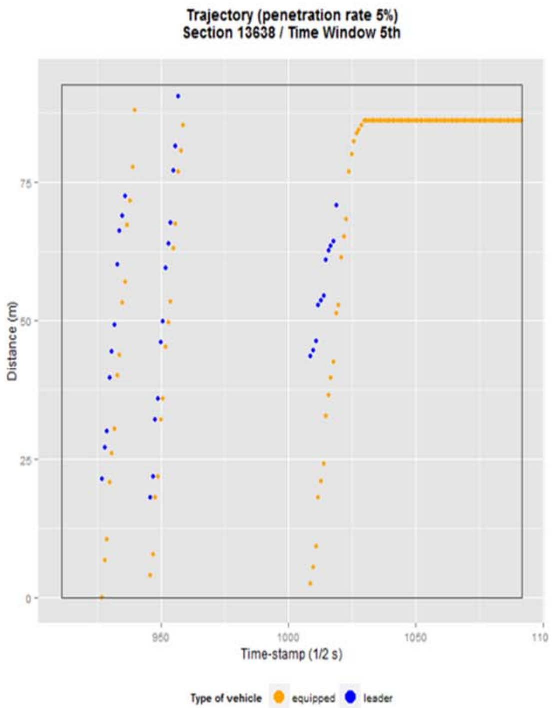
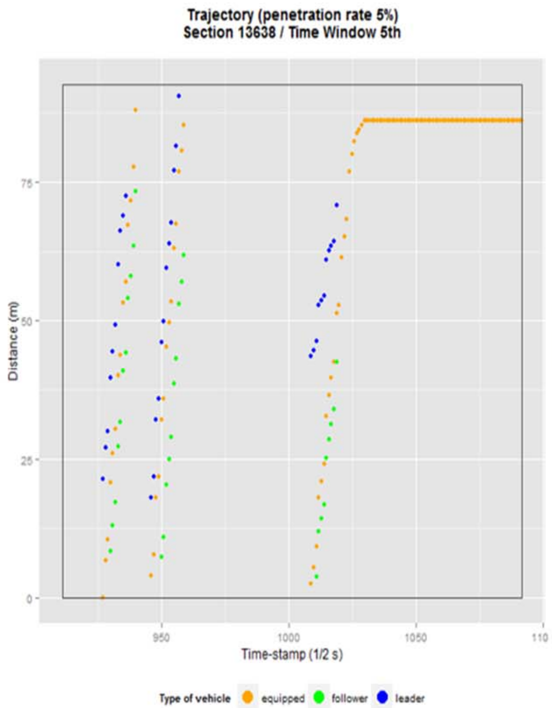
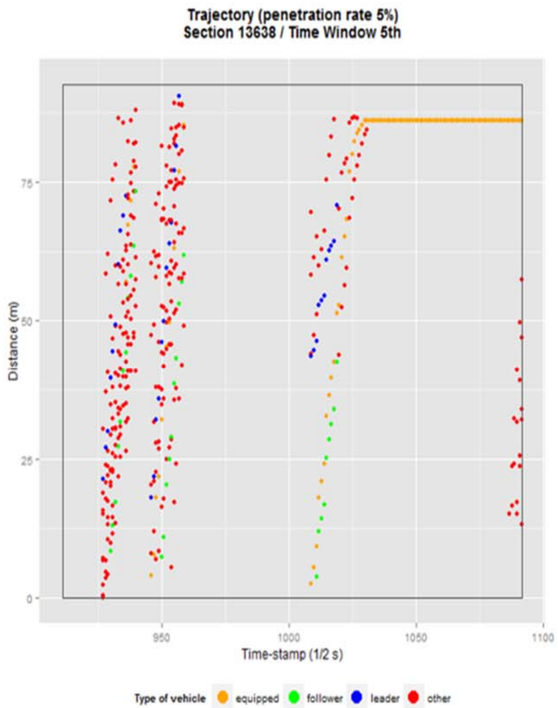
SIMULATION RESULTS

SIMULATED SCENARIO % OF VEHICLES MONITORED (5% PENETRATION) AND RECONSTRUCTED TRAJECTORIES









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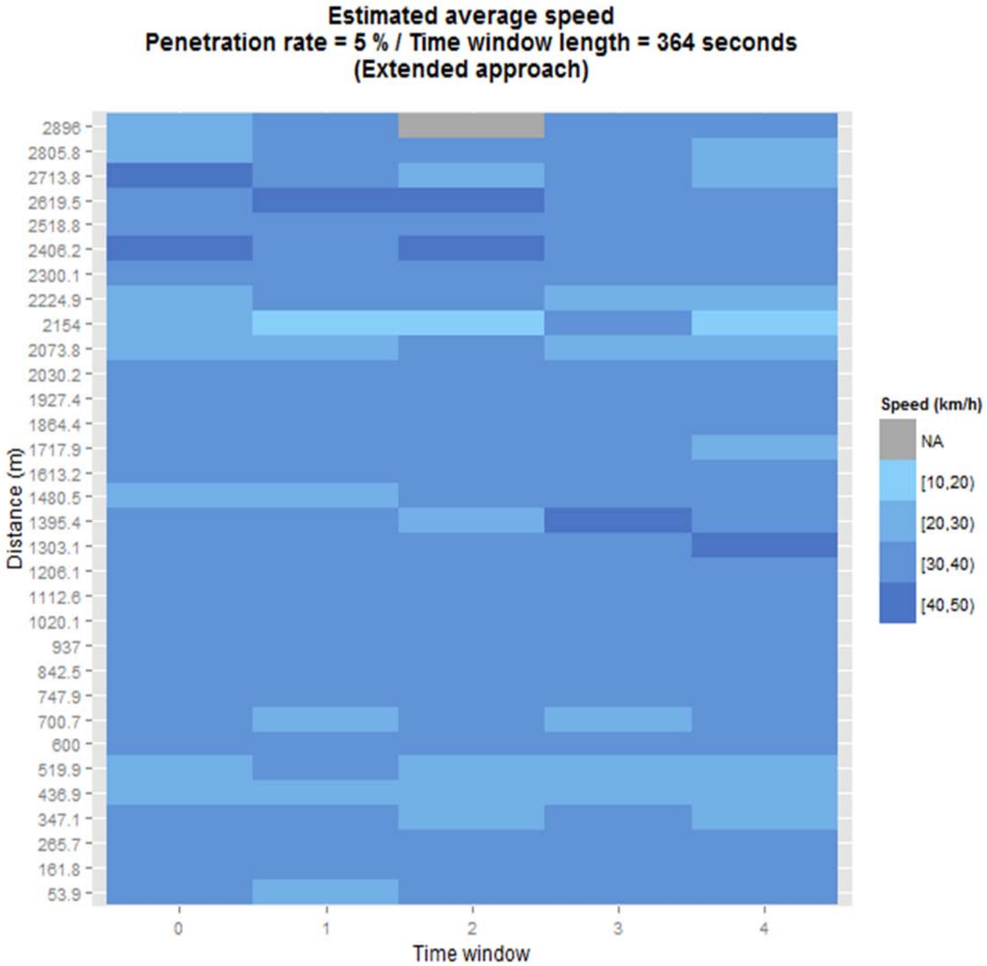
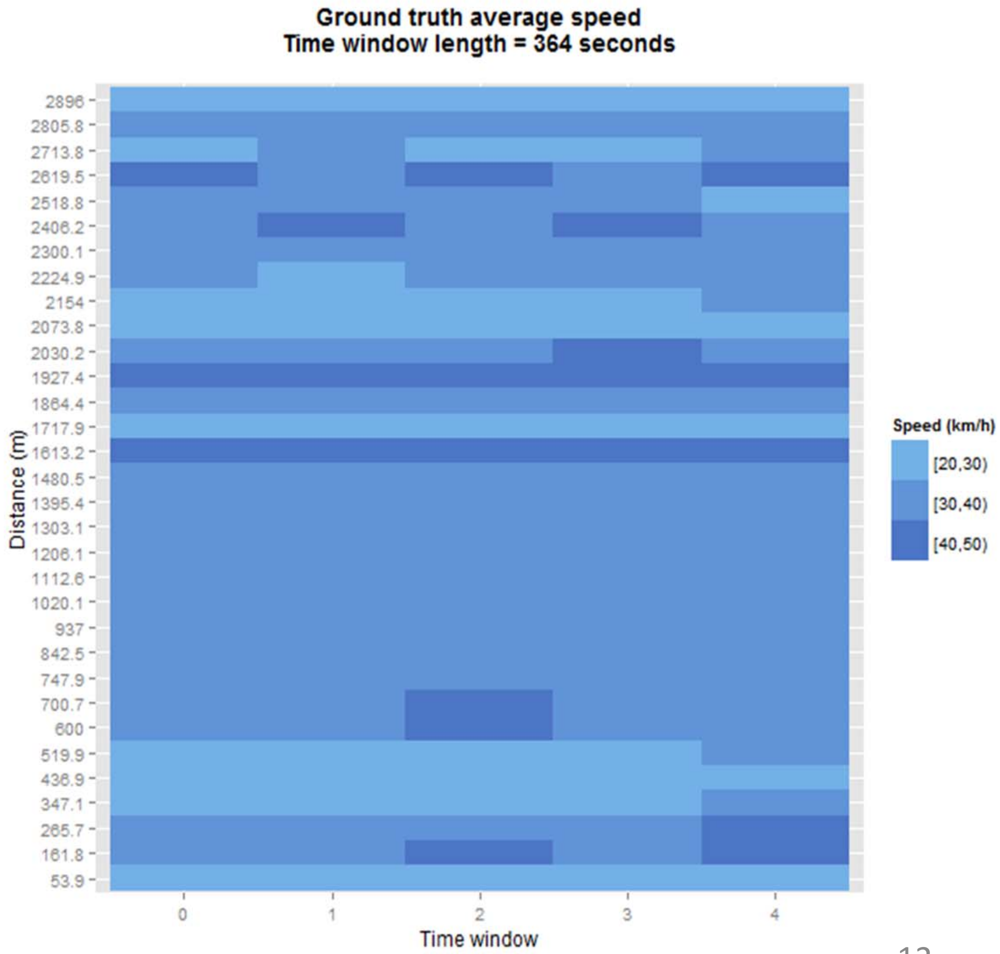
SPACE SPEED ESTIMATION IN THE SPACE-TIME DOMAIN: EXTENDED APPROACH





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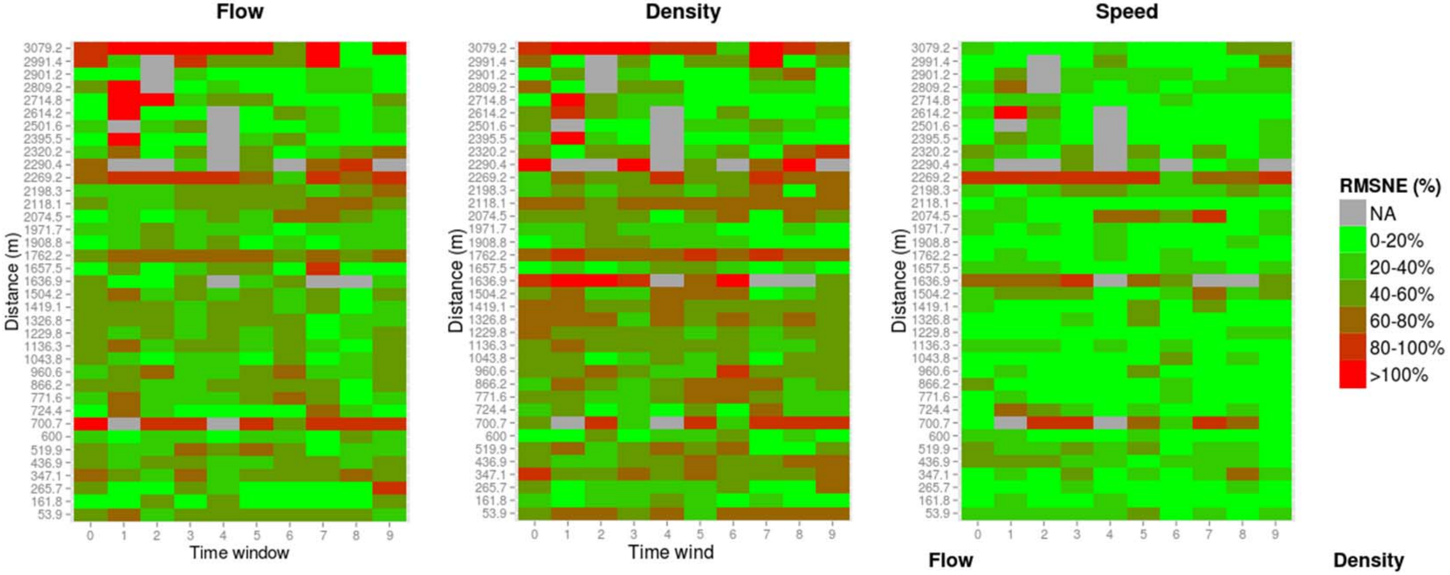
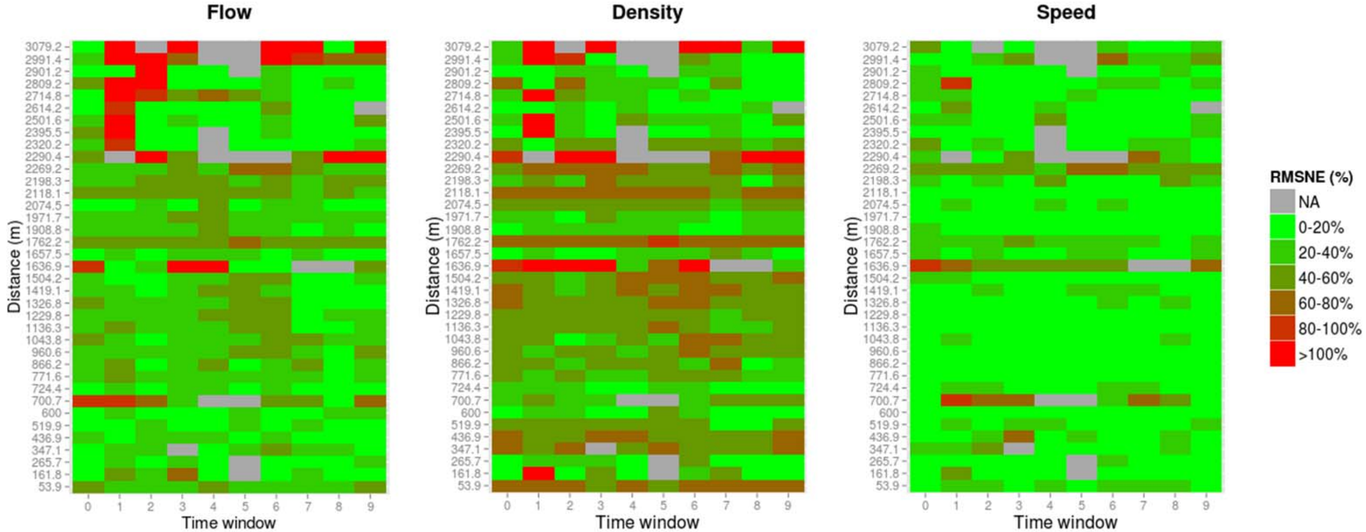
FUNDAMENTAL VARIABLES RMSNE ESTIMATION



SIMULATION RESULTS



RMSNE heatmap for the **Leader (Top)** and **Extended (Bottom)** approaches with a penetration rate of **10% -Leader** and **5% - Extended** and a time window length of 3'

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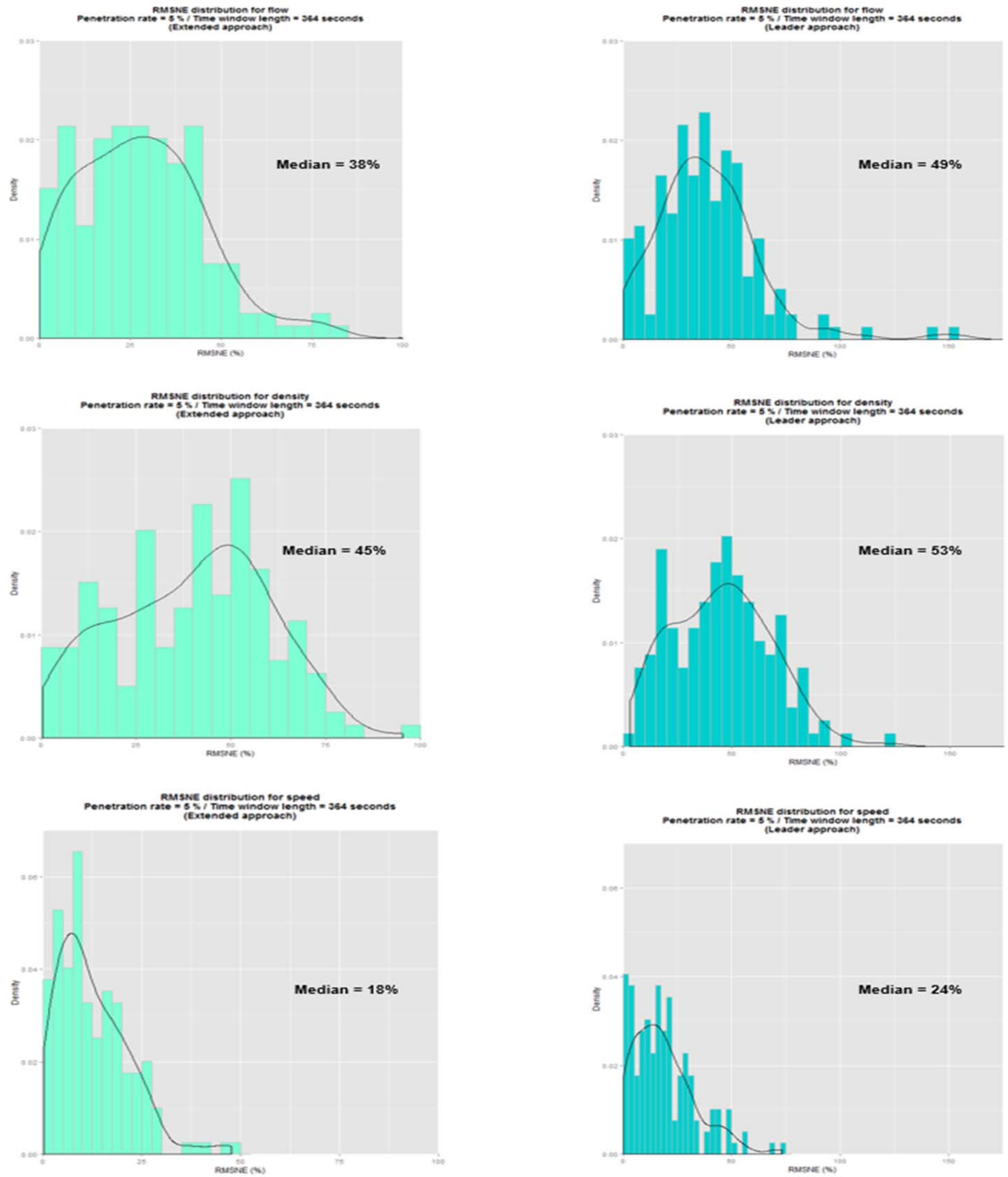
SIMULATION RESULTS

DISTRIBUTION OF THE RMSNE FOR FLOW, DENSITY AND SPEED ESTIMATES: EXTENDED (LEFT) VS LEADER (RIGHT) APPROACHES (5% PENETRATION RATE 6' TIME-WINDOW)



CONCLUSIONS AND FUTURE RESEARCH

- The simulation experiments have shown that probe car data open up a promising line of research for traffic state estimation.
- Probe car data can also be enhanced by data fusion techniques that combine traffic data from several sources.
- Market penetration in probe car technology is increasing, and this trend points positively to using probe car data to characterize the traffic state at a low cost for traffic authorities.
- Our results confirm the validity of the approaches in urban arterials, and they further provide guidelines for improving the involved technology for traffic state estimation and forecasting.
- Nevertheless, the length of the sections involved in the AIMSUN model seems to play an important role in the estimate errors, since they increase as space discretization decreases (shorter sections). A further study will be conducted.

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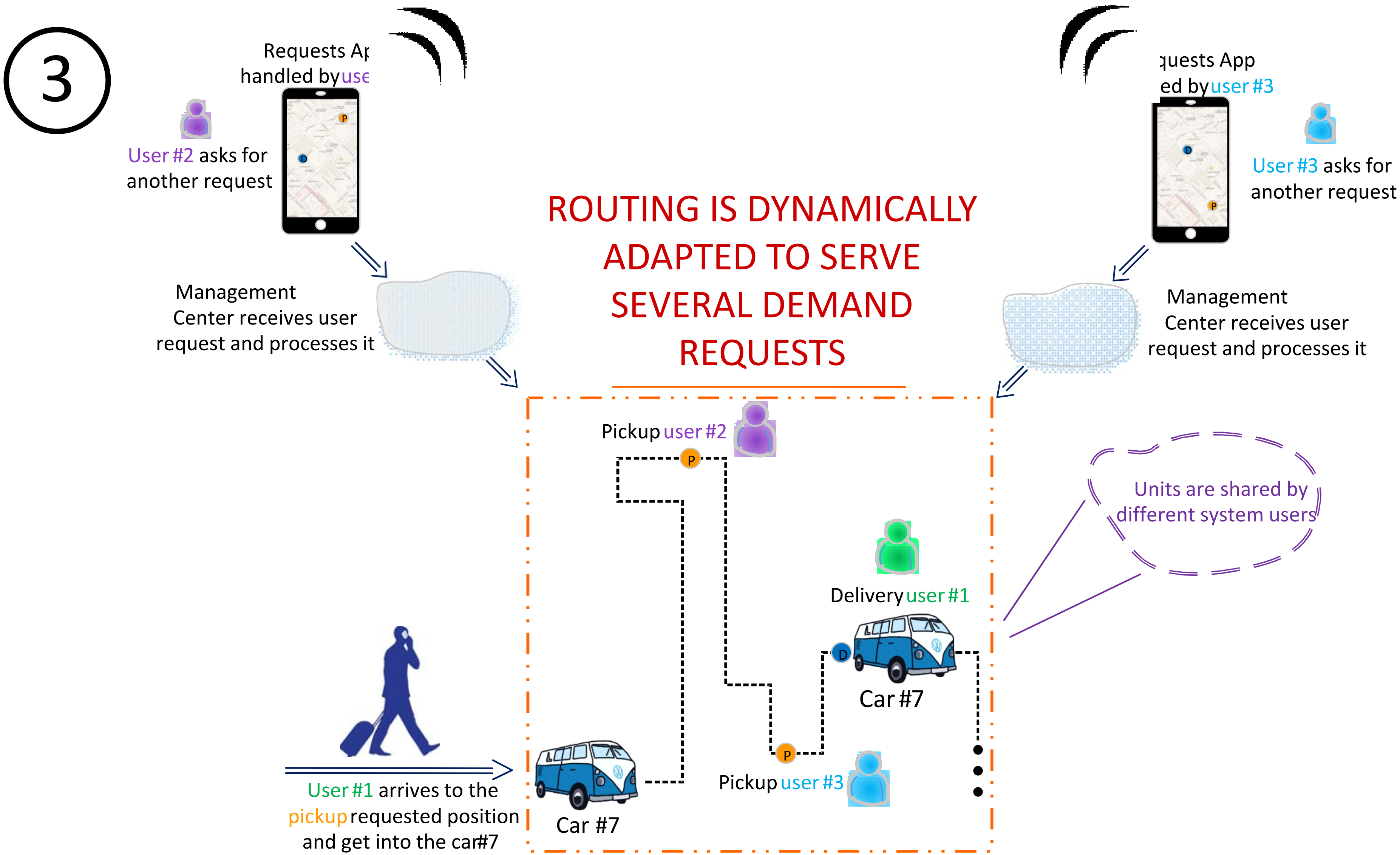
Multiple Passenger Dynamic Ride Sharing (MPDRS) Concept: Vehicle Routing Problem

The vehicles serving MPRS Concept follow individualized routes that are calculated depending on:

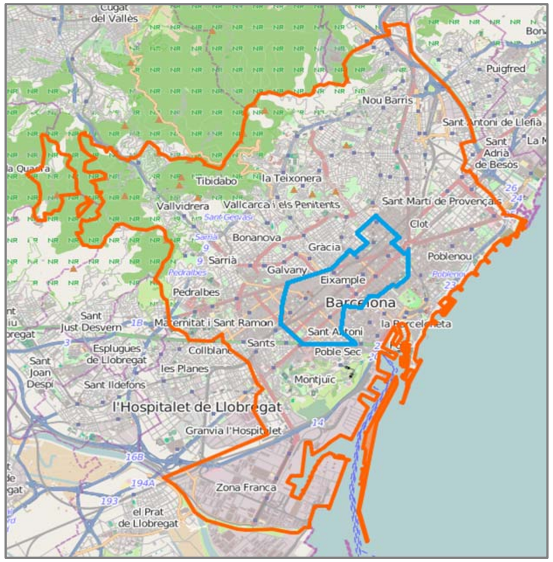
- the passenger's initial position (pickup)
- the passenger's final position (delivery)
- the passenger's requirements on terms of time windows: (time intervals in which the passenger must be picked up and delivered)
- the current traffic conditions

The calculated routes would also take advantage of the available traffic information provided by the ICT.

How does the system work?

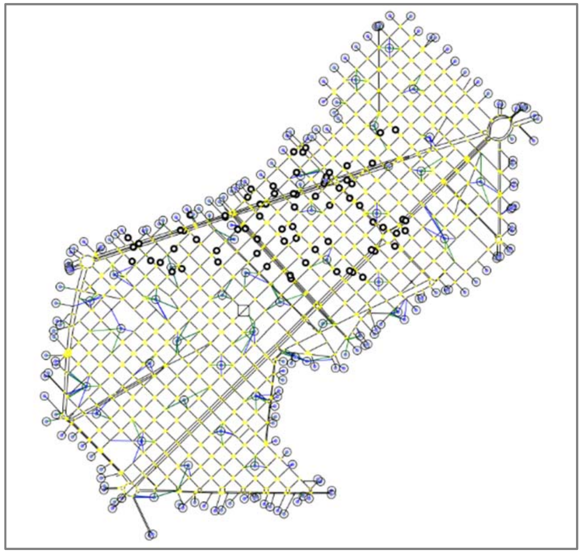


Test site: L'Eixample



L'Eixample in Barcelona

L'Eixample

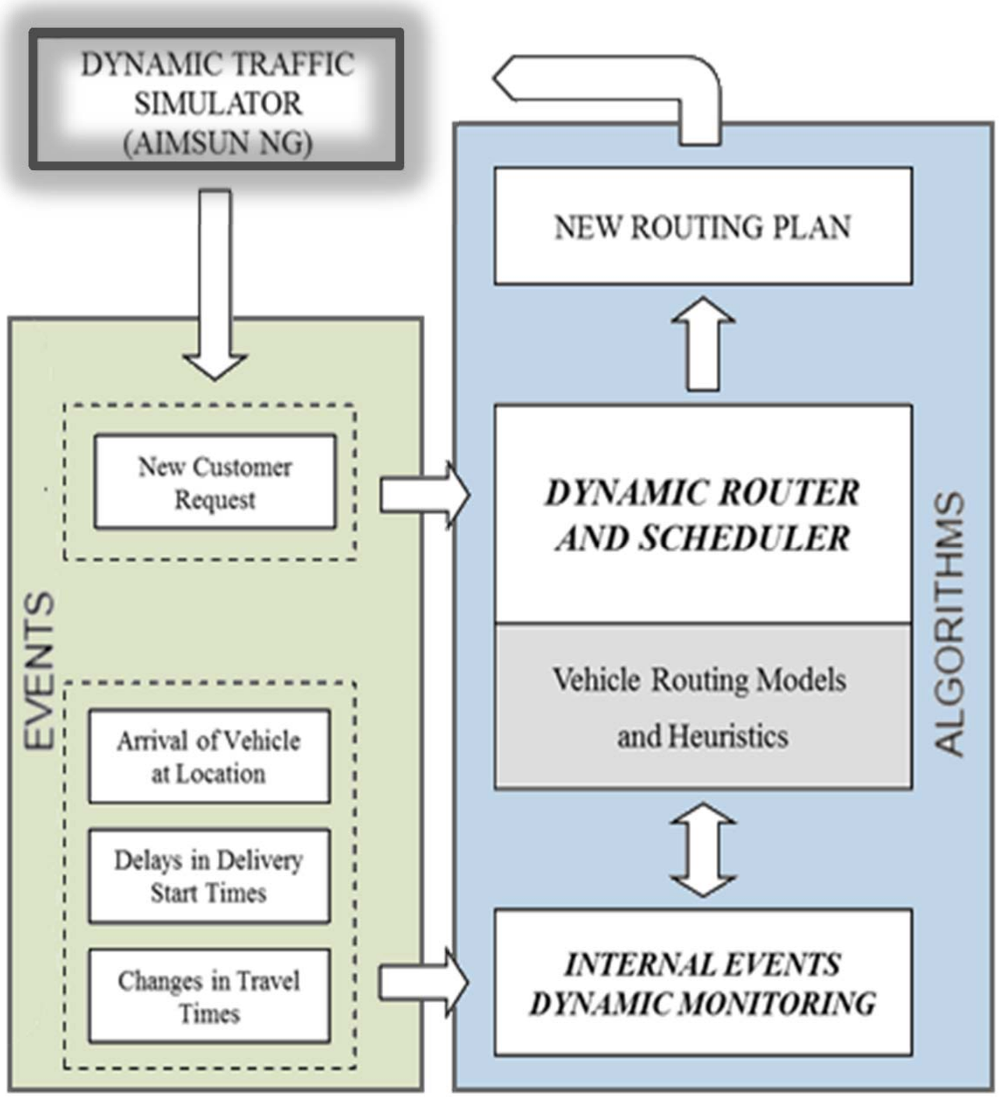


Aimsun's Eixample model

- **Total area**: 7.46 km^2
- **Population:**
  - Total: 262,485 hab.
  - 16% of the total city population
- **Density:** 35,185.46 hab/km2

- **Links: 1,720**
- **Nodes: 528**
- **Turns: ~ 3,000**
- **Centroids: 207**

Framework based on traffic simulation



The dynamic traffic simulator is used as a tool that:

- Models the road network.
- Generates databases of time-dependent link travel times.
- Randomly generates events.
- Moves vehicles along the road network, keeping track of their positions and state at every time step of the simulation.
- Guides vehicles through the network using the corresponding paths.
- Provides to the Dynamic Router and Scheduler the input data required by the algorithms.

Microscopic simulator:

Experimental Design: Key factors

A set of experiments based on different **key factors**:

- Scenario: rush-hour
- MPDRS Demand: Number of requests in percentage with respect to the total private demand of this scenario (33108 trips).
- Fleet Dimension: The number of vehicles in the fleet.
- Time Window Duration: The width of the time interval in which the demand requests must be served (pickup and delivery time windows).
- Degree of Dynamism: The % with respect to the total MPRS demand that is not known before the start of the journey.

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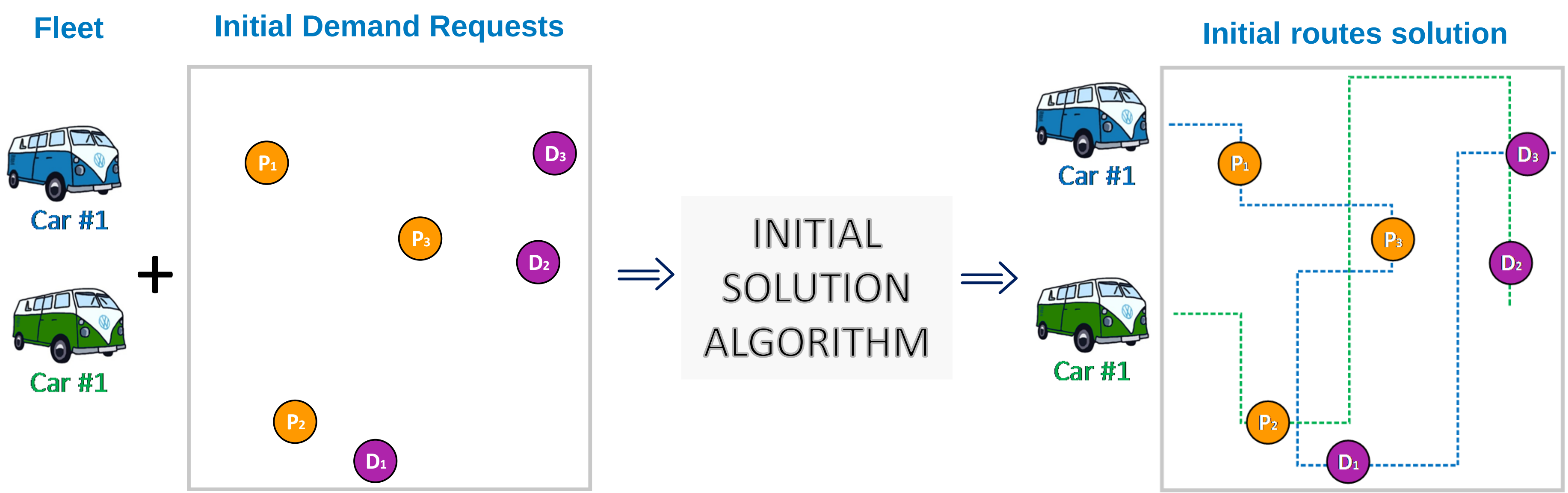
MPDRS vehicle routing algorithm

1. Initial Solution using time-dependent routing algorithms

- Demand pre-assignment
- Construction of initial routes (using time-dependent information)
- Post-optimization procedures



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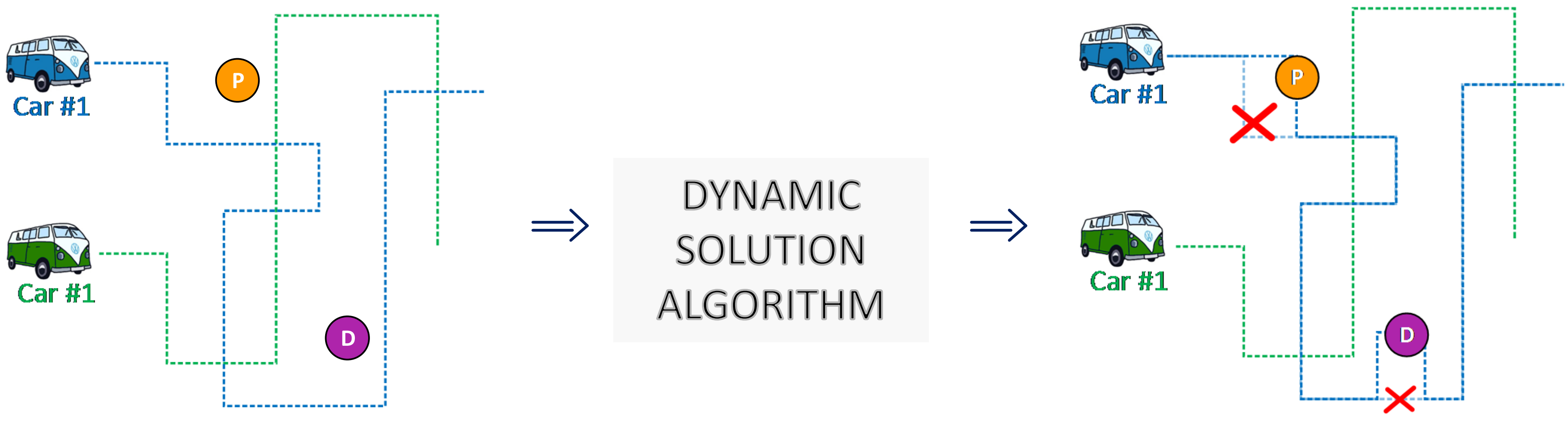
MPDRS vehicle routing algorithm

2. Dynamic Routing Algorithm

When a new demand request arrives to the system, the algorithm checks the current state of the vehicles and the traffic network state, selecting the candidate routes for the least cost feasible insertion. If no feasible insertion is possible, the demand request will be rejected. Otherwise, routes will be adapted to serve the new demand.

Current State of the Routes



New demand request arrives with Pickup (P) and Delivery (D) positions

Percentage of rejected demand requests (varying fleet size and % of MPDRS demand)

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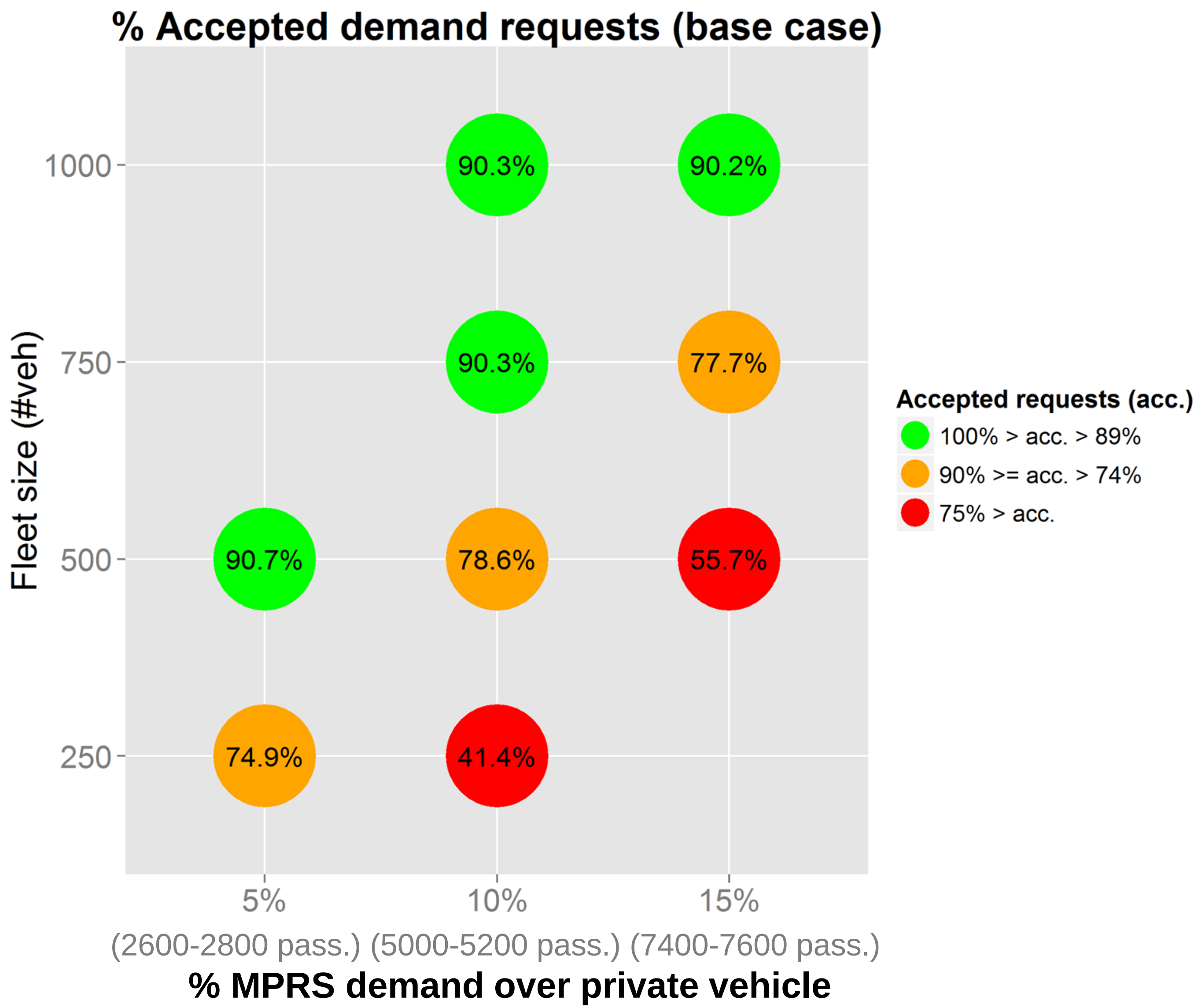
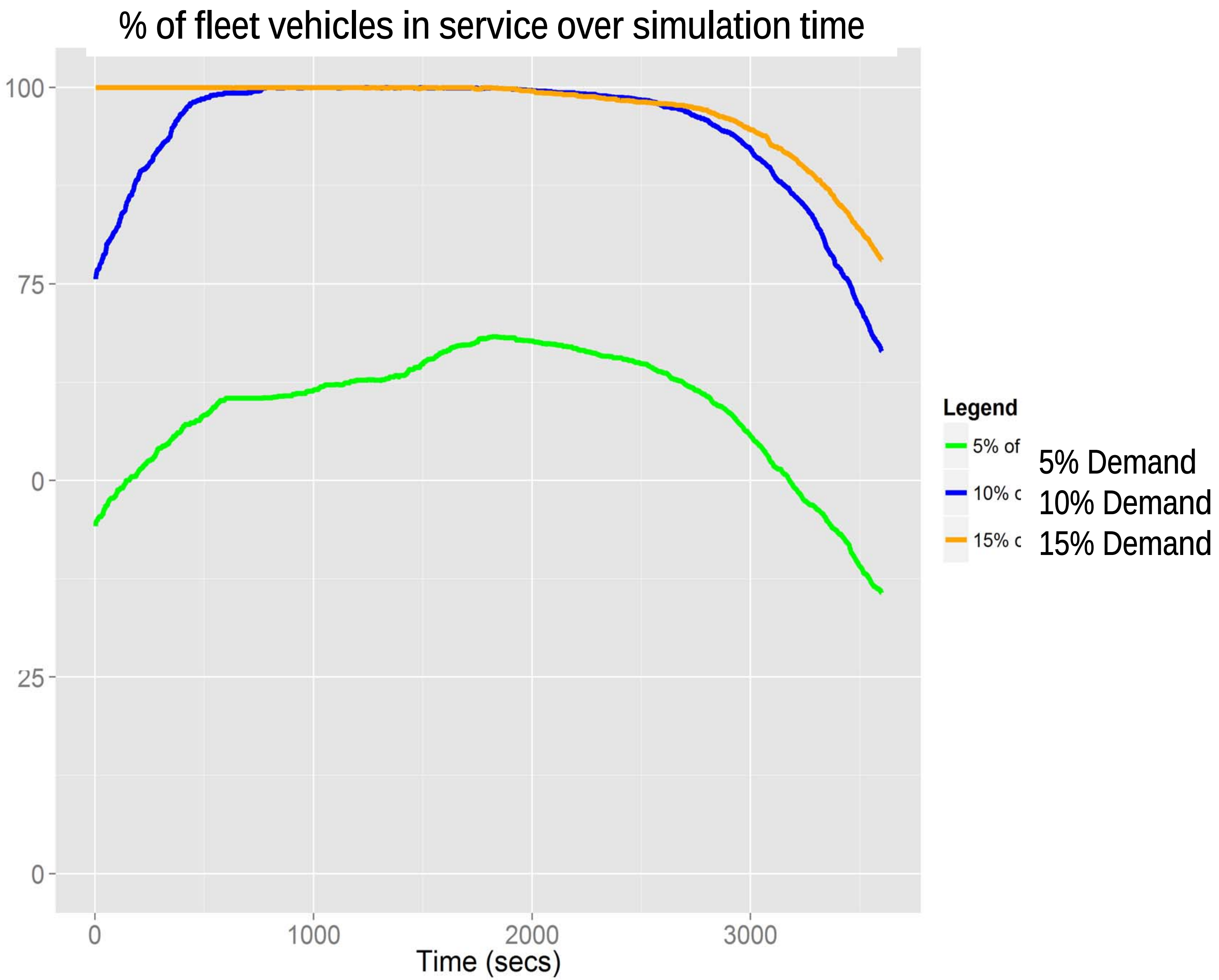
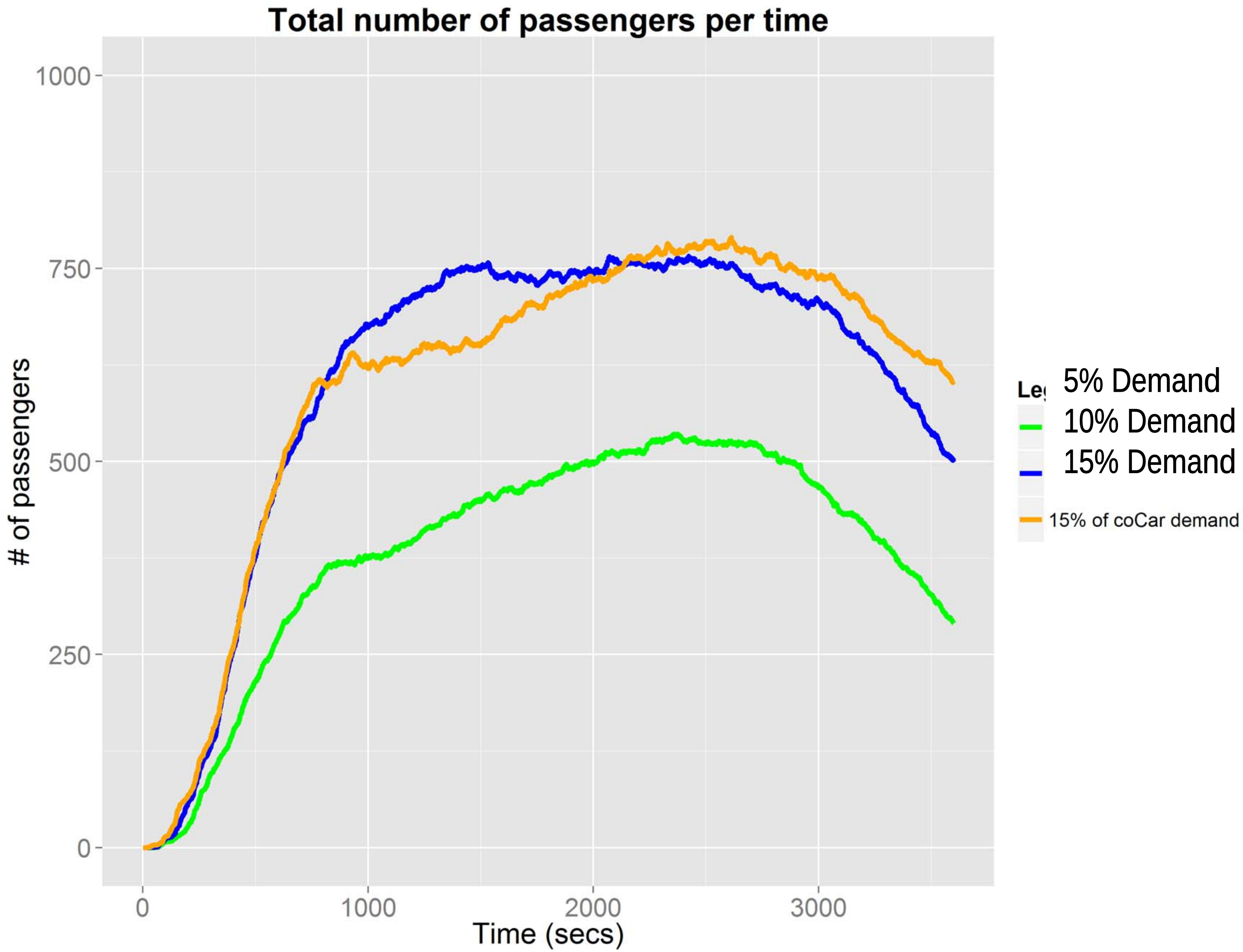


Percentage of units with respect to the total fleet size that are in-service at each instant of simulation time



The number of passengers that are travelling in the MPDRS System at each instant of simulation time



Conclusions

- The waiting time spent by the MPRS users has emerged as a critical factor: when this time is short, then the MPRS system seems better than regular public transport.

Possible Next steps

- Modification of the existing routing algorithm in terms of adding new customer or system requirements.
  - The new requirements can be included extending the already developed routing algorithm by adding new constraints or changing the optimization objective function.

- Study of particular commuting scenarios where a most simplified routing algorithm could be developed based on the MPDRS Concept.


THANKS FOR YOUR ATTENTION