A polynomial-time ambulance redeployment policy

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Overview

- EMS: Static vs Dynamic Solutions
- Performance Estimation
- Our proposed method
- A tractable case study
- A realistic case study

Emergency Medical Services

1. Accident occurs
2. Closest idle ambulance is sent
3. Ambulance arrives at accident scene
4. Patient may need transportation to hospital
5. Ambulance becomes available

How to position ambulances in order to minimize response times?

Problem formulation

Given:

- Locations of bases
- Number of available ambulances
- Expected demand at every location
- Driving times between locations

Optimize:

- Distribution of idle ambulances over the bases in order to minimize fraction arrivals later than a certain threshold time (patient friendly)
- We may relocate an ambulance <u>only</u> when it becomes idle (crew friendly)

Static vs dynamic solutions

- Static solution: each ambulance is sent back to its ‘home base’ whenever it becomes idle.
  - Note: the ambulance does not need to arrive there, it can be dispatched while on the road
  - A solution is a base for each ambulance
- Dynamic solution: make decisions based on current realizations (e.g., locations of accidents, which ambulances are idle, etc.)
  - A solution describes how to redistribute ambulances

Estimating performance

Simulation model:

- Specify locations (x,y,p)
- Calls arrive according to a Poisson distribution
- Closest idle ambulance is sent
- Patient needs hospital treatment w.p. 0.8
- When an ambulance becomes idle, make a decision (relocation)
- <u>Performance</u> (cost) is measured by the fraction of ambulances arriving later than a certain threshold

CWI

A Dutch region modeled

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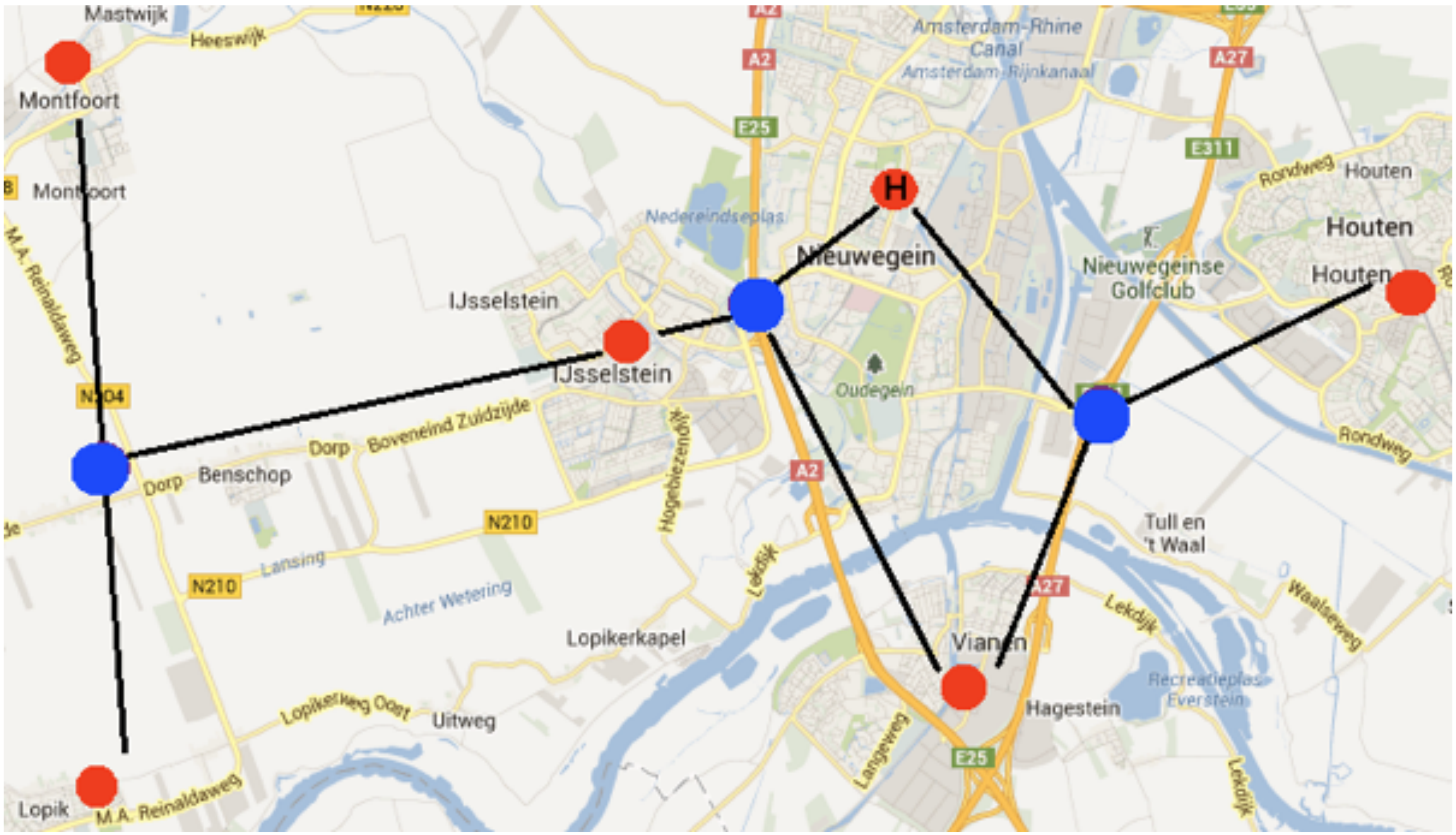
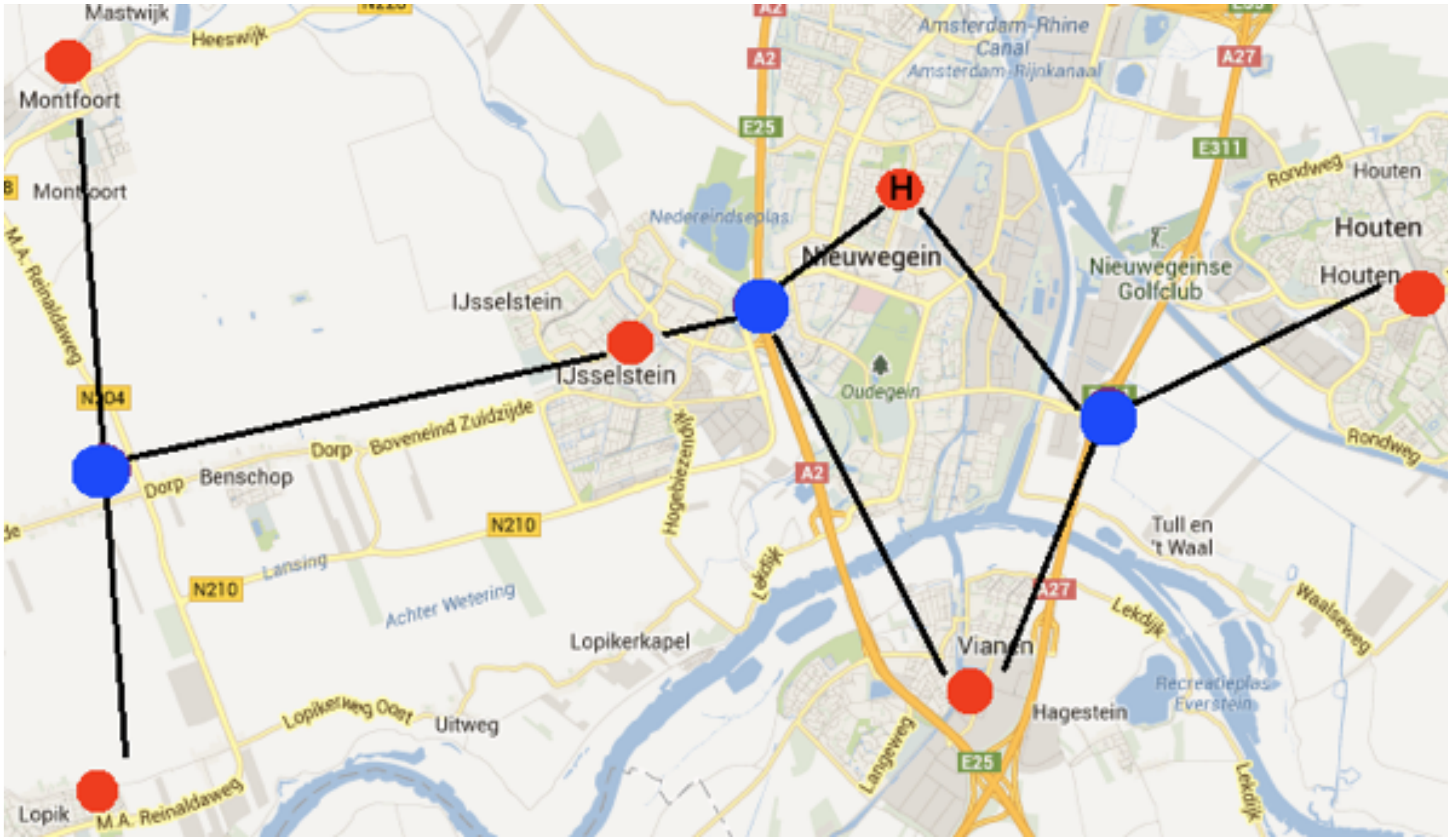
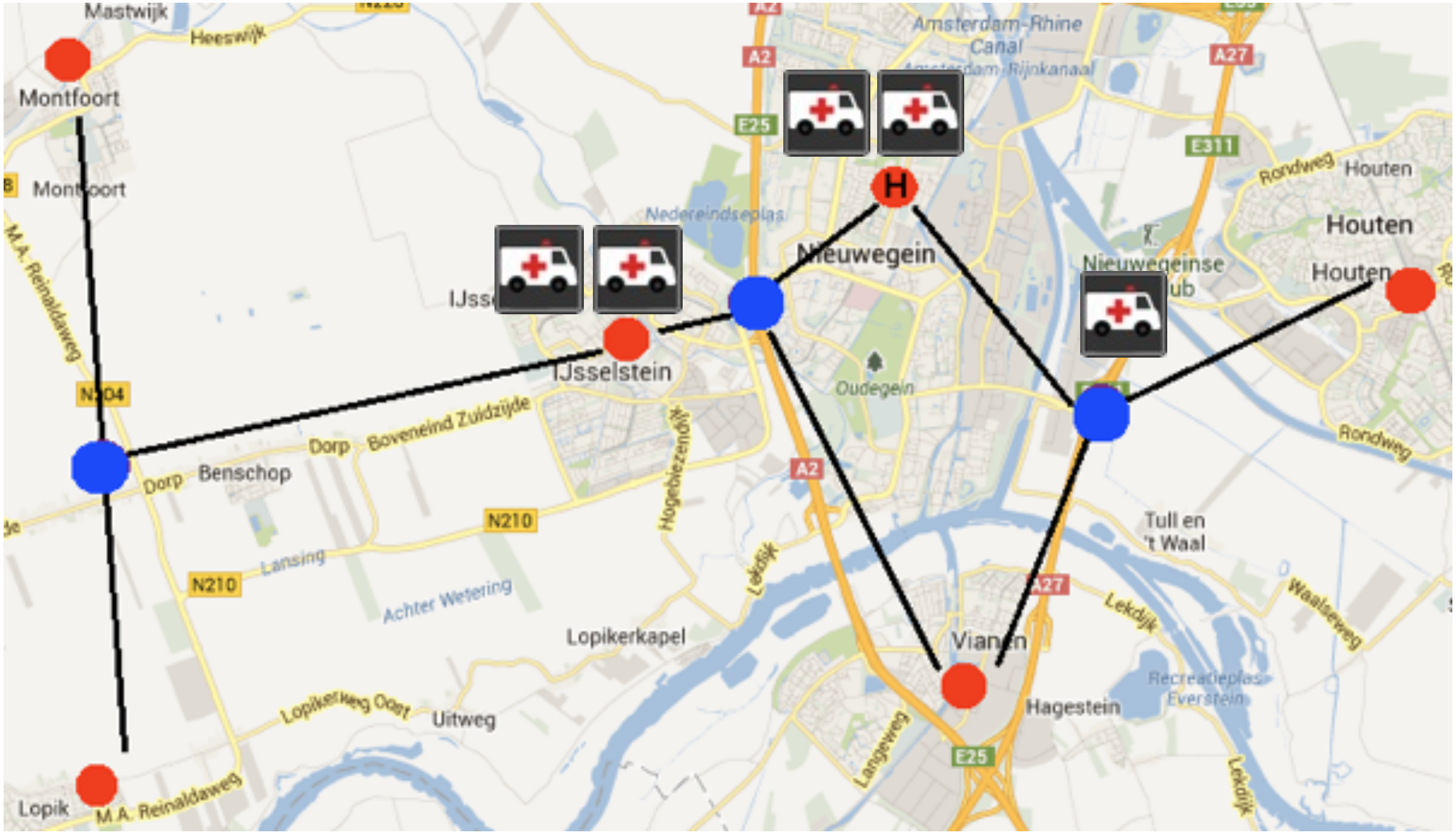


The best static solution?



The best static solution:



Dynamic solution: Ambulance redeployment policy

Previous work:

- R. Alanis, A. Ingolfsson, B. Kolfal (2013)

‘A Markov Chain Model for an EMS System with Repositioning’

- M. S. Maxwell, S. G. Henderson,

H. Topaloglu (2009)

‘Ambulance redeployment: An Approximate Dynamic Programming Approach’

A heuristic based on MEXCLP:

Maximum Expected Covering Location Problem (MEXCLP) Daskin, 1983

Uses a pre-determined 'busy fraction' *q*:
If a demand node has *k* ambulances nearby, the node is covered w.p. $1 - q^k$

Let d_i be the demand at location i.
Then the coverage of location i is given by:

$$E_k = d_i(1 - q^k)$$

Dynamic MEXCLP

- Only consider *currently idle* ambulances
- Pretend moving ambulances are already at their destination
- At a decision moment, calculate marginal contribution in coverage for each possible base:

$$E_k = d_i(1 - q^k) \quad \rightarrow \quad E_k - E_{k-1} = d_i(1 - q)q^{k-1}$$

- Choose the base that yields the largest marginal contribution (greedy)

Computation Time

- $O(|W| * |A| * |J|)$

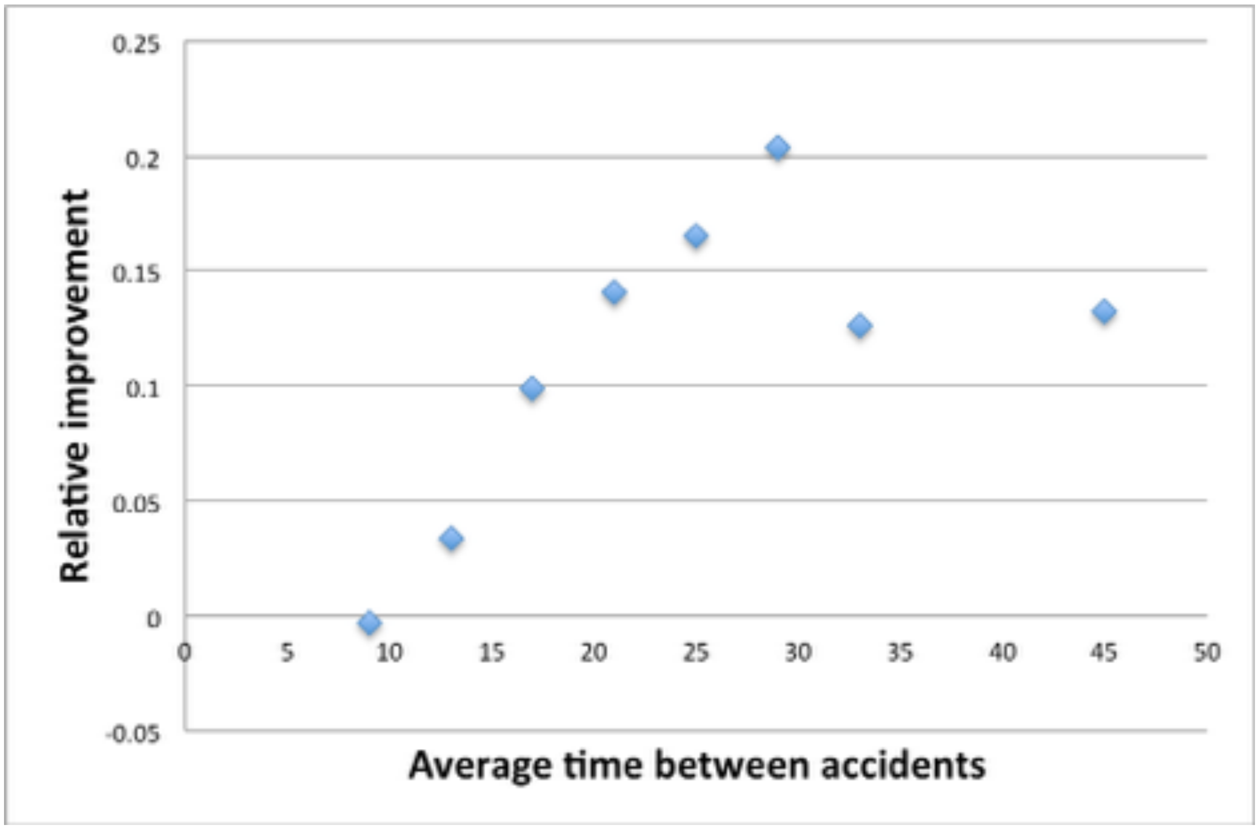
  Where:
  - W are the base stations
  - A are the ambulances
  - J are the demand nodes

Performance

- Benchmark: the best static policy has a performance of ~ 7.4%

- The Dynamic MEXCLP heuristic has a performance of ~ 6.2%

Performance



A larger, more realistic region

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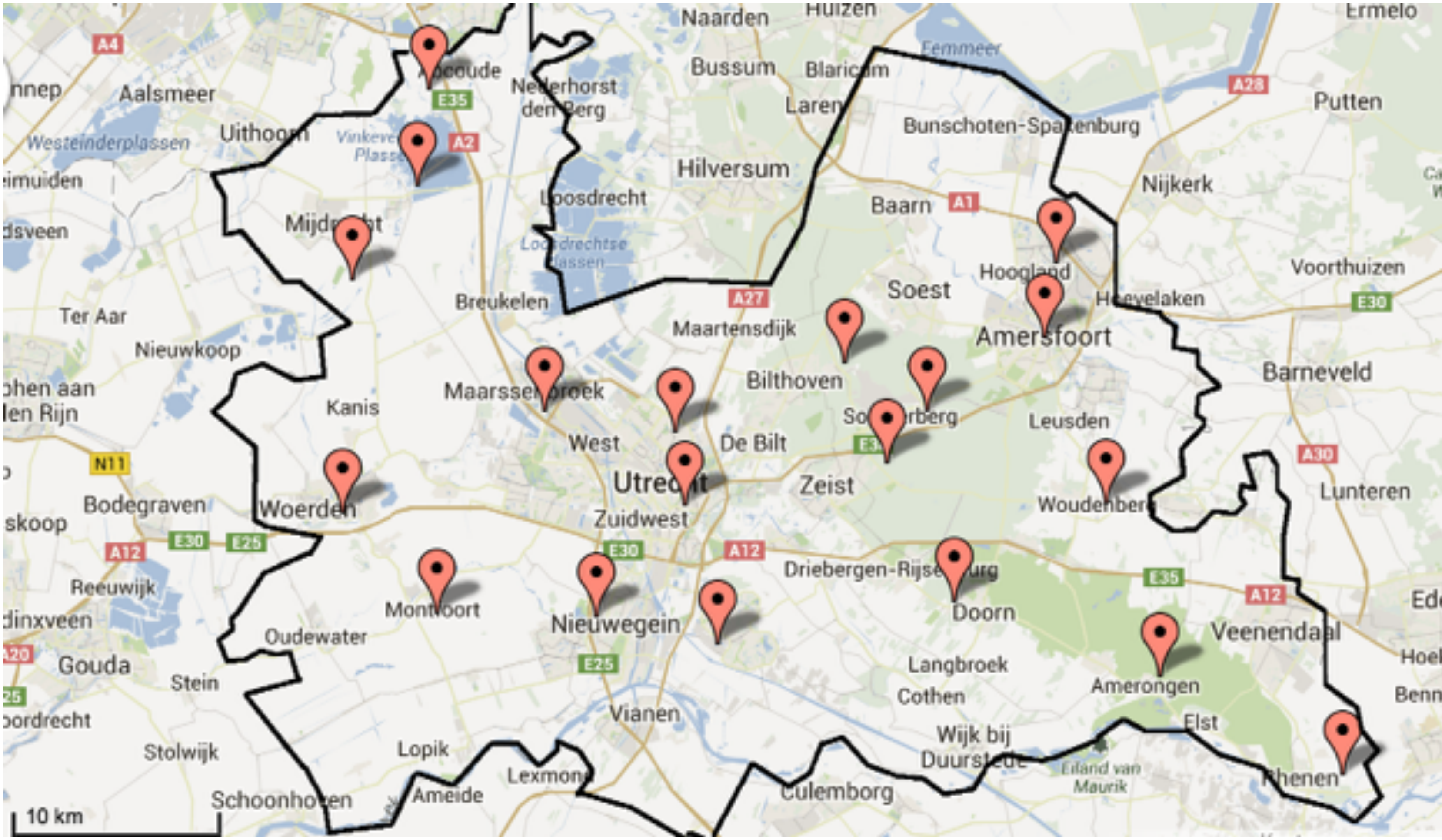
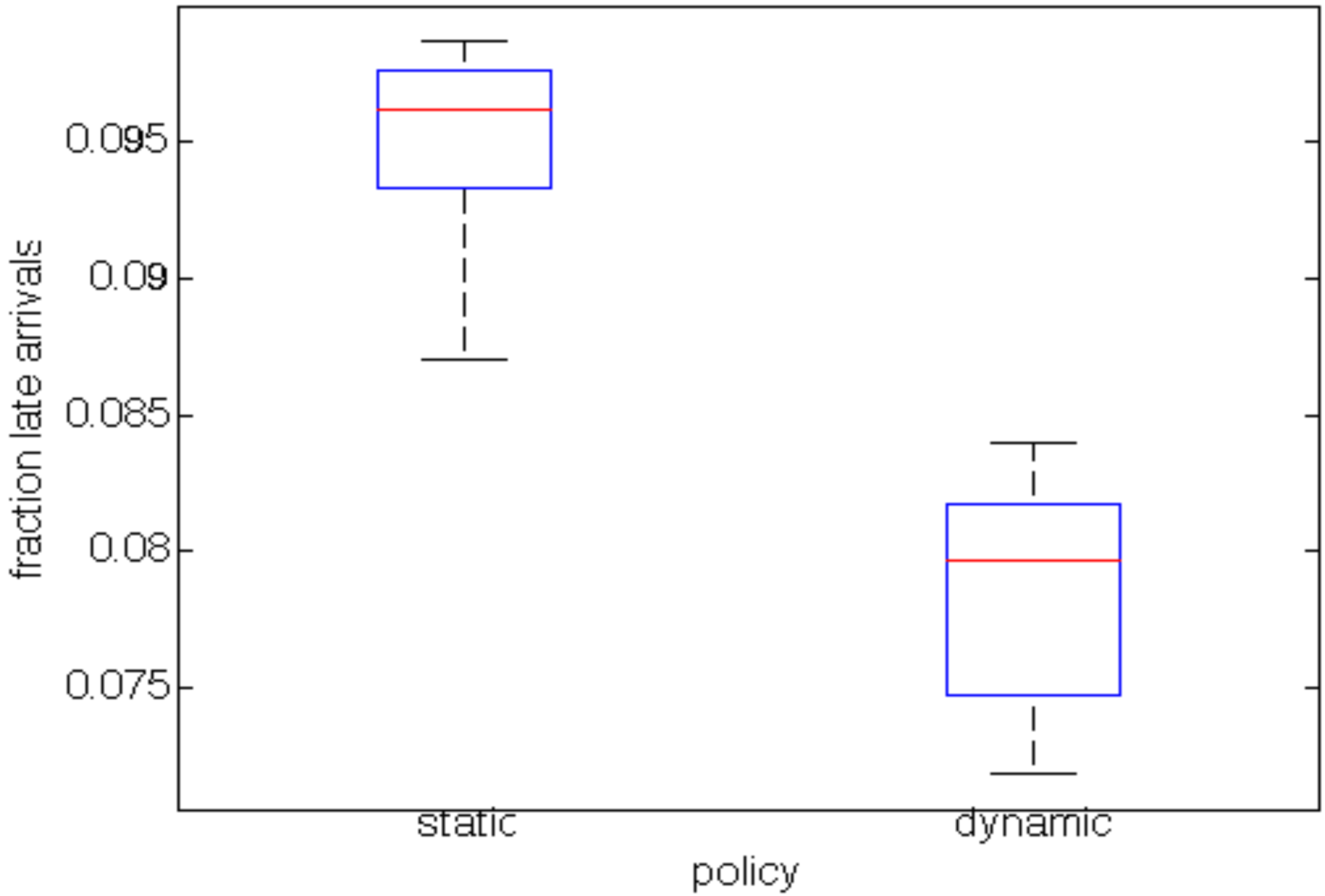
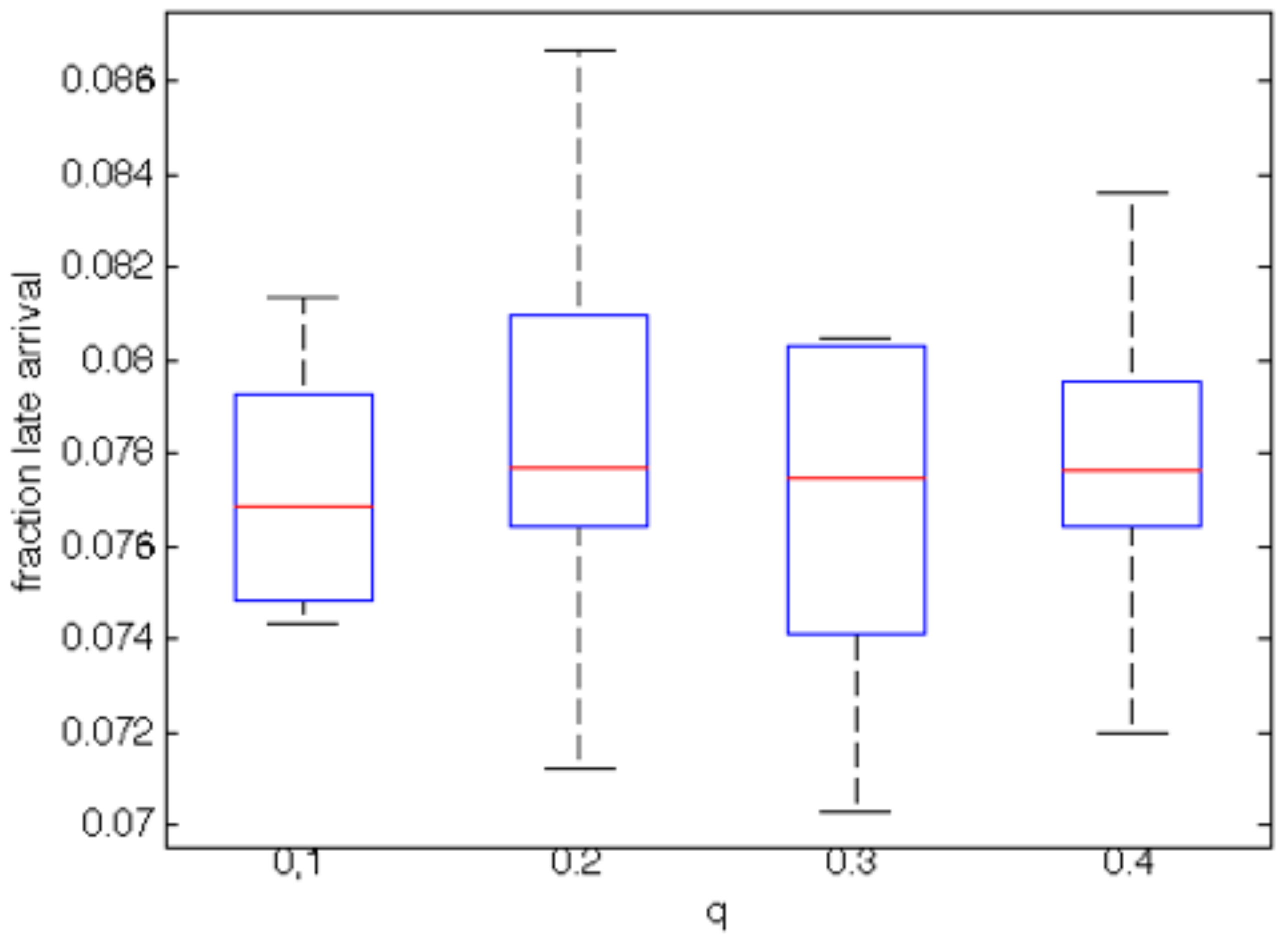


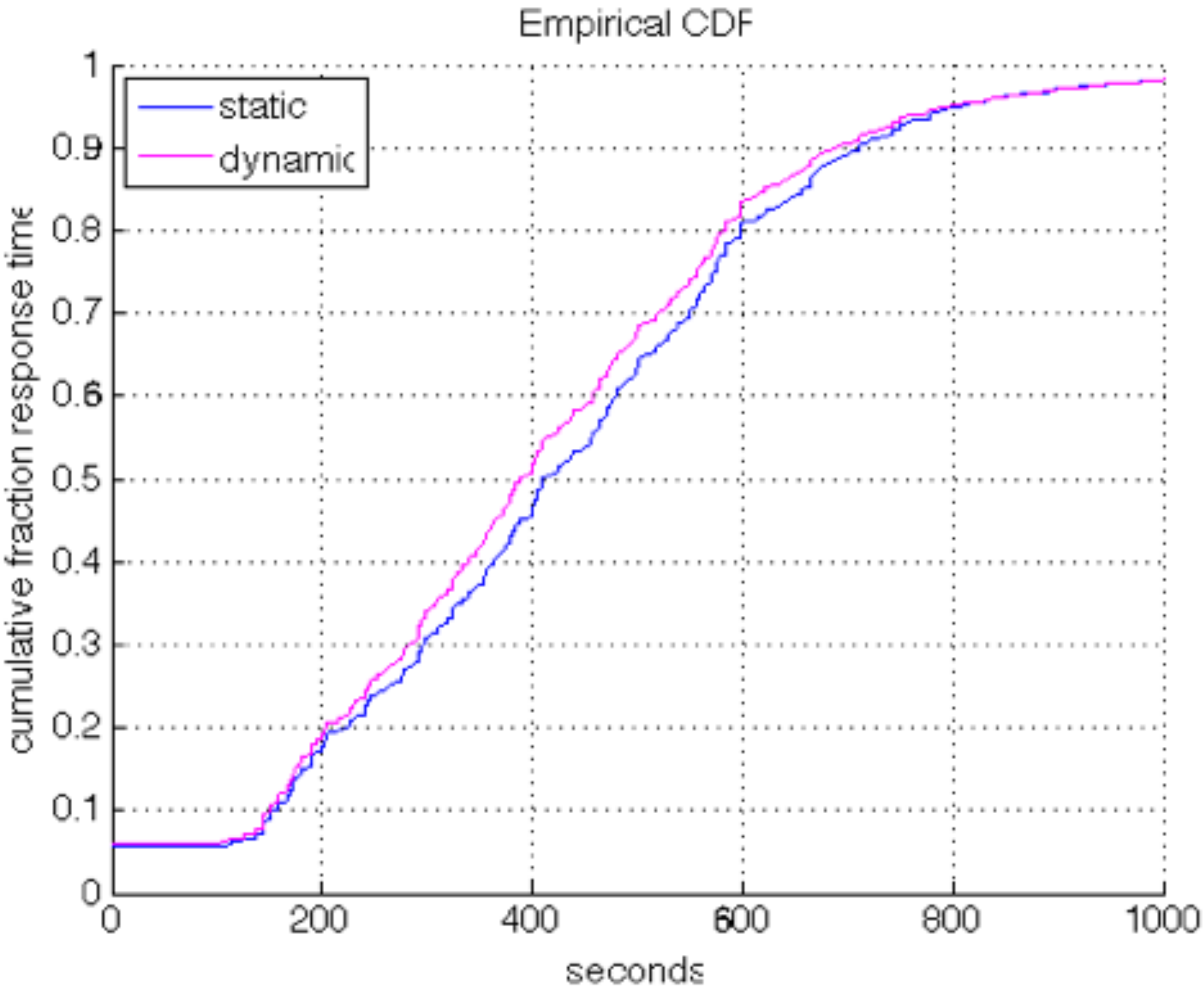
Static and dynamic MEXCLP policy



Sensitivity to the busy fraction



Response times



Possible improvements

- Also taking into account ambulances that will become available soon
- Calculate the trade-off between distance and coverage improvement

Thank you for your attention

Questions?