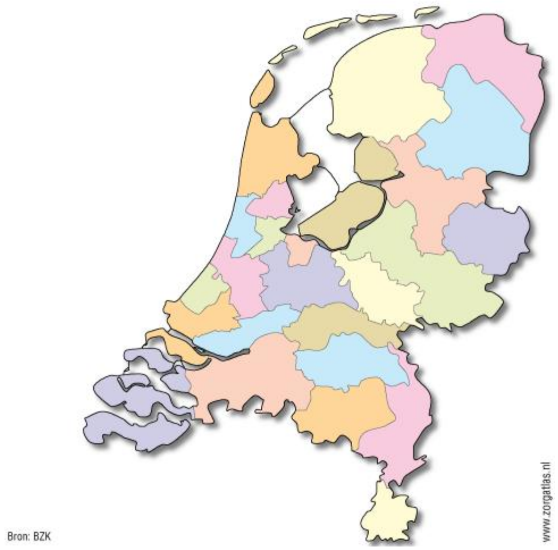
Ambulance planning with and without region borders

Theresia van Essen, Melanie Reuter
Johann Hurink, Stefan Nickel

Situation in the Netherlands



- 24 regions
- Low coverage at region borders
- Number of ambulances could be decreased

Model

- Extension of MEXCLP
  - Busy fraction for each demand location
  - Busy fraction is iteratively improved[1]
  - Binary search on number of ambulances

[1]*Optimal ambulance location with random delays and travel times*
A. Ingolfsson, S. Budge, E. Erkut in Health Care Management Science (2008)

MEXCLP

$$\max \sum_{i \in I} \sum_{k=1}^{p} d_i (1-q) q^{k-1} y_{ik}$$

Maximize coverage

$$\sum_{j \in W_i} x_j \geq \sum_{k=1}^{p} y_{ik} \text{ , } \forall i \in I$$

Determine coverage

$$\sum_{j \in J} x_j \leq p$$

Limit number of ambulances

$$x_j \in \mathbb{N}, \forall j \in J$$

$$y_{ik} \in \{0,1\}, \forall i \in I, k = 1, \ldots, p$$

MEXCLP-i

$$\max \sum_{i \in I} \sum_{k=1}^{p} d_i (1 - q_i) q_i^{k-1} y_{ik}$$

Maximize coverage

$$\sum_{j \in W_i} x_j \geq \sum_{k=1}^{p} y_{ik} \, , \forall i \in I$$

Determine coverage

$$\sum_{j \in J} x_j \leq p$$

Limit number of ambulances

$$x_j \in \mathbb{N}, \forall j \in J$$

$$y_{ik} \in \{0,1\}, \forall i \in I, k = 1, \ldots, p$$

Approach

- Start with initial busy fraction
- Repeat until local optimum is reached:
  - Solve MEXCLP-i
  - Determine new busy fraction

Determine new busy fraction

- Assign each demand location to one or more opened base locations, $z_{ij} \in [0,1]$
- Minimize the maximum busy fraction over all base locations, $\min \max_{j \in J} b_j$
- Busy fraction for each demand location is given by

$$q_i = \sum_{j \in J} z_{ij} b_j$$

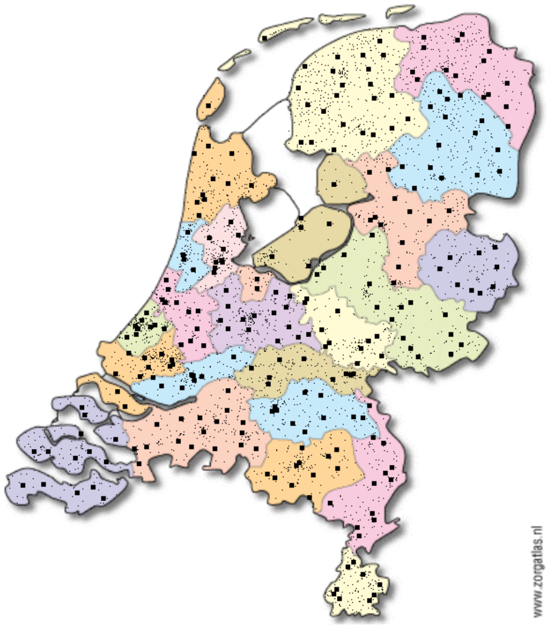
Binary search

- Minimize number of ambulances while guaranteeing a certain coverage
- Perform binary search on number of ambulances p

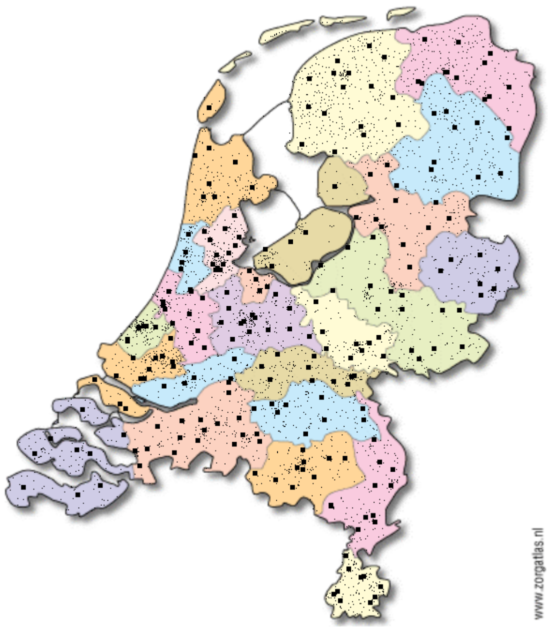
Case Study

- Data for the Netherlands
- 24 regions
- 4010 demand locations, 40 – 474 per region
- Response time ≤ 15 minutes

Results 0.97



With region borders



Without region borders

Results

	# Bases	# Ambulances
Regions (95%)	246	273
No regions (95%)	226	243
Regions (97%)	270	308
No regions (97%)	243	274
Regions (99%)	320	385
No regions (99%)	300	349

Results

	Min Coverage	Max Coverage
Regions (95%)	95.0%	97.1%
No regions (95%)	84.0%	99.2%
Regions (97%)	97.0%	99.0%
No regions (97%)	91.0%	99.4%
Regions (99%)	99.0%	99.5%
No regions (99%)	96.2%	99.8%

Results

	Comp. Time (s)	Avg. Gap
Regions (95%)	447	0%
No regions (95%)	4910	0.01%
Regions (97%)	449	0%
No regions (97%)	6999	0.02%
Regions (99%)	485	0%
No regions (99%)	7016	0.03%

Conclusions

- Number of ambulances can be reduced by ignoring region borders
- Coverage threshold not guaranteed for each region
  - → Further research

Questions?

essen@cwi.nl