Preparedness and Prediction in Emergency Care


Wiskunde redt levens

Kansberekening en modellering moeten ambulanceplanning in Amsterdam verbeteren.

'Ambulance is eerder ter plekke'

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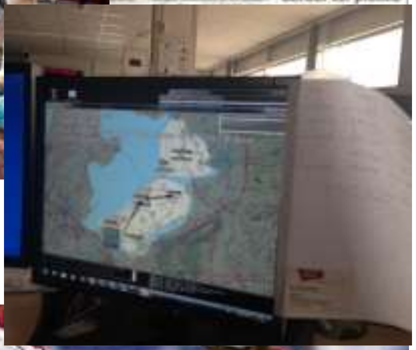
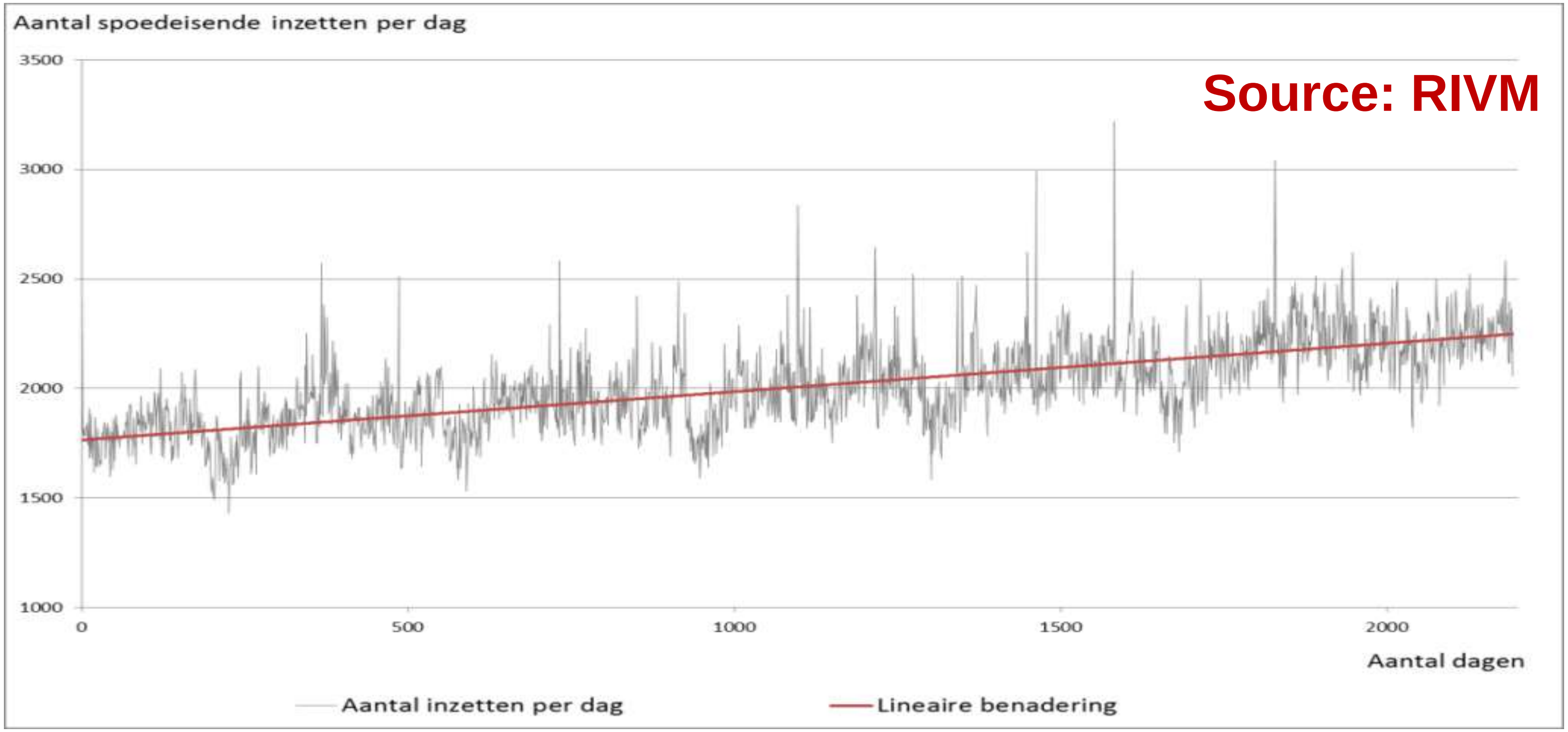


Agenda:

1. Emergency care in Netherlands
2. Dynamic Ambulance Management ("DAM")
3. Algorithms for pro-active relocations
4. Stokhos emergency software

Rotterdam, May 25, 2016

Trends in Ambulance Care



- **Average increase 4,2% annually over 2008-2013**
- **Growth mainly explained by demografic developments**
- **Internationally consistent growth (VS, UK, Canada, Australia, Switzerland)**

Ambulance Care in NL

A1-calls: Urgent and life threatening **< 15 min**

- severe accidents

A2-calls: Urgent but not life-threatining

- broken leg **< 30 min**

B-calls: Ordered transport

- 'taxi' transport between health institutions and to/from home

Requirement: 95% within deadline

Ambulance Care in the Netherlands


Wiskunde redt levens

Kansberekening en modellering moeten ambulanceplanning in Amsterdam verbeteren.

Facts:

- **1 million calls per year, out of which 500,000 A1-calls**
- **35,000 times do not meet the 15-minute target (93%)**

Challenges:

1. **Optimal locations of base stations?**
2. **How many ambulances needed per base location?**
3. **How to keep good coverage in real-time?**

REPRO : from Reactive to Proactive

Idea: Use **analytics and models** for prediction and mathematical optimization of ambulance, firefighter and police services

Ambulance Service Process

112!

New incident happens

call center

'Closest' available ambulance allocated

garage

Ambulance departs

Medical treatment on the spot

To closest hospital

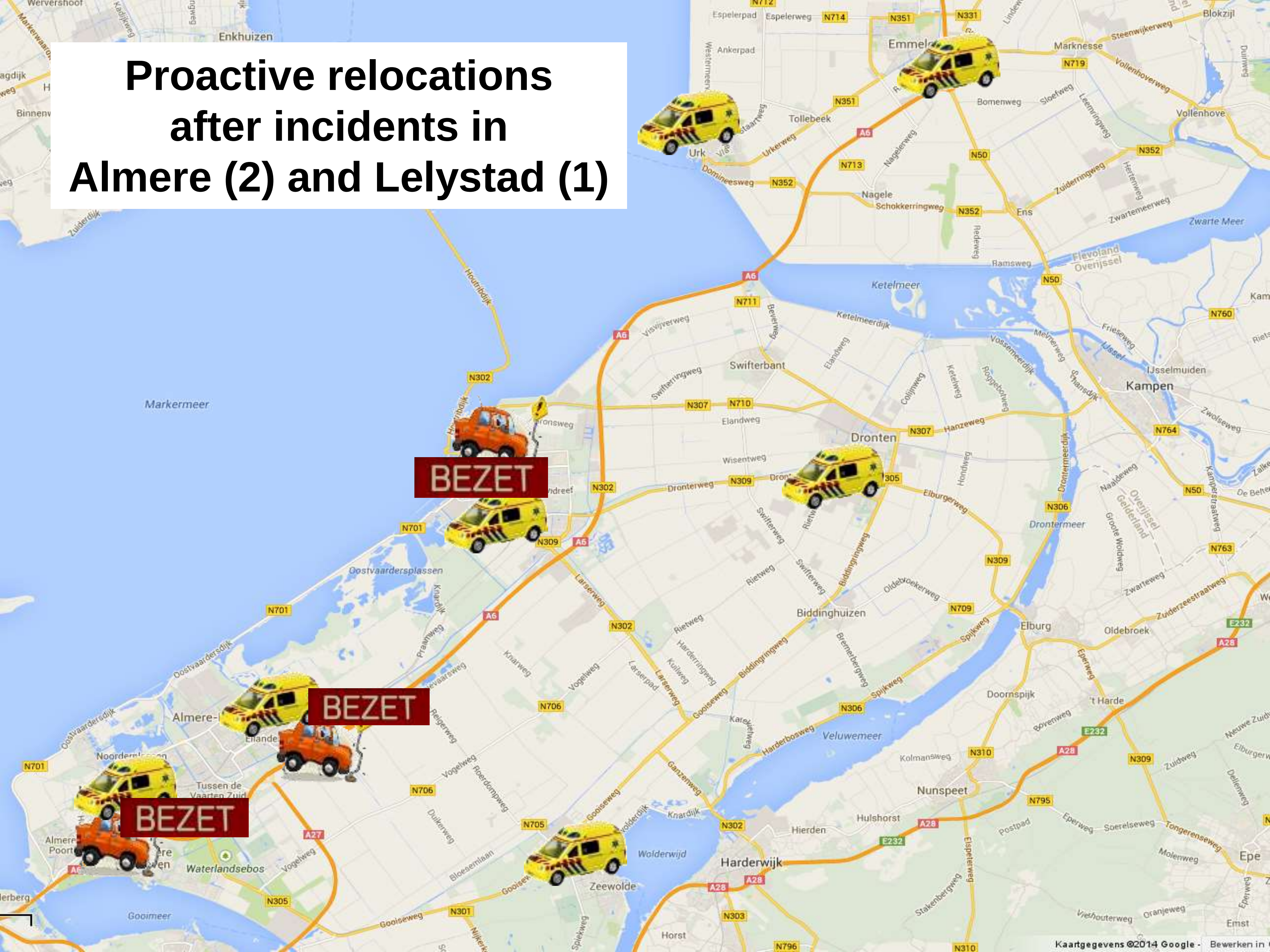
hospital

Patient handed over

To closest base location

Basic situation (no incidents)

Proactive relocations after incidents in Almere (2) and Lelystad (1)



Theory versus Practice

In theory, it is assumed that…

1. …the computed relocation action is always carried out. But it is always really necessary?

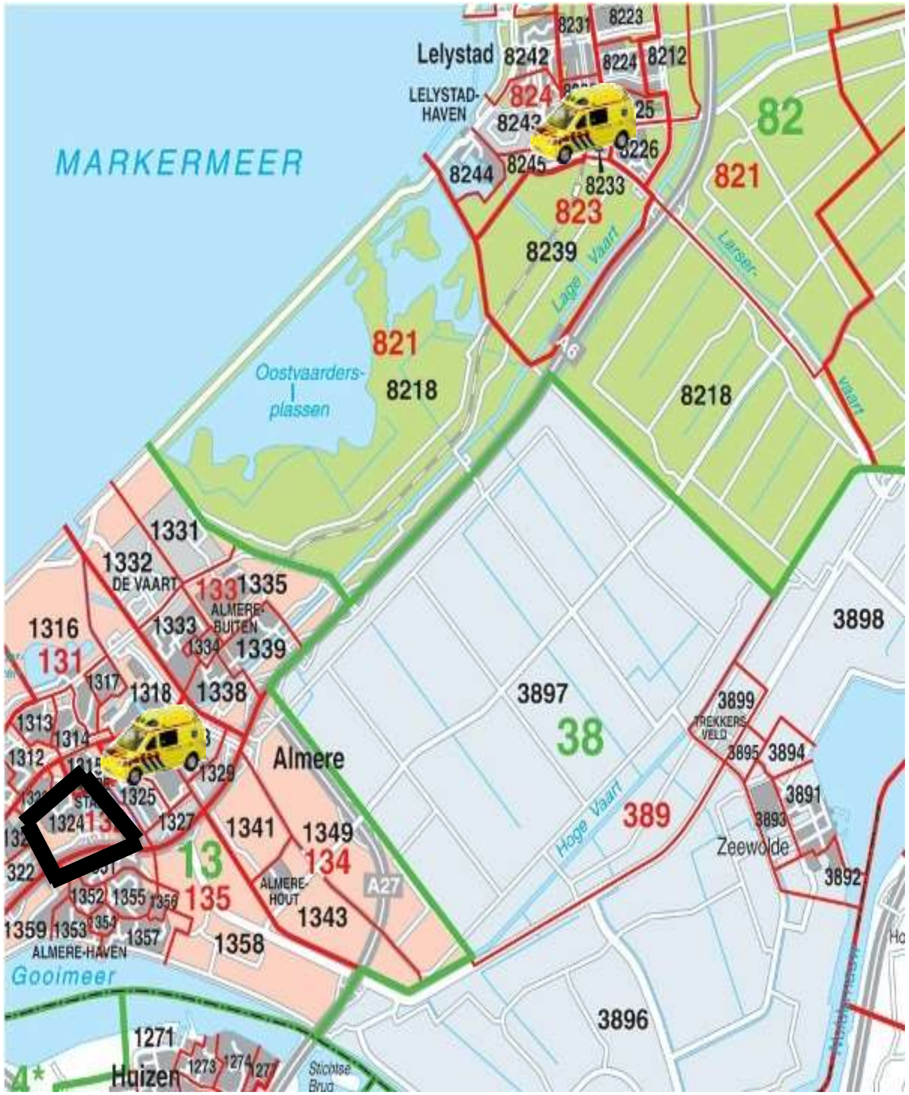
2. …it is clear how to 'move' from the current to a desired configuration. But how to do that? There are many ways to do that….

In practice, however…

- **Acceptance:**
    - not too many relocations
    - only at specific time epochs (e.g., departure from hospital)
- **Only acceptable if really better than 'static' solution**

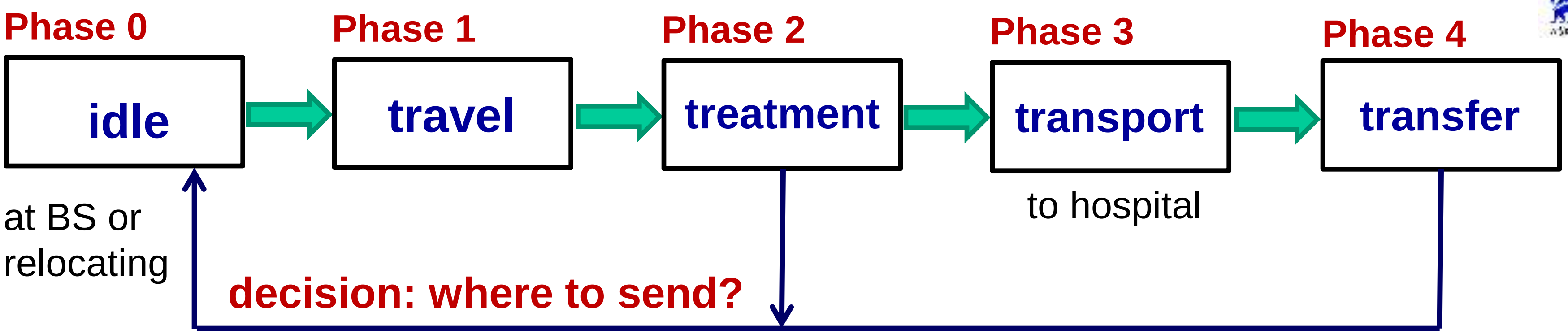
How to get to desired configuration?

Model



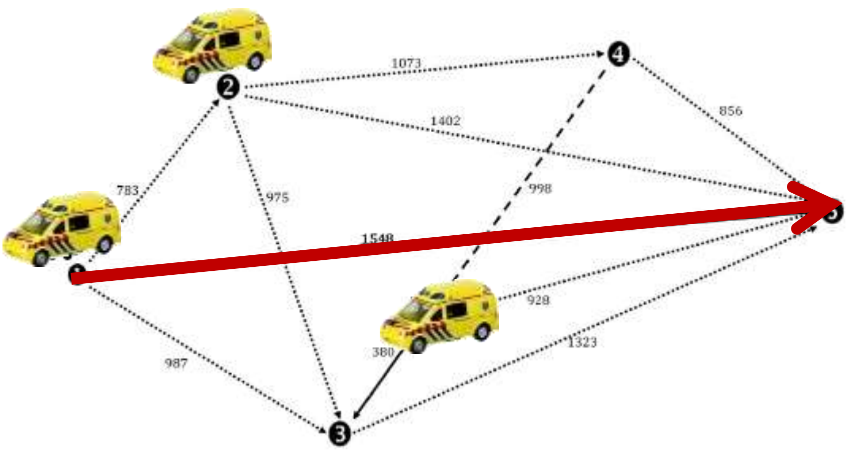
- Region subdivided in N nodes (postal areas)
- Base locations
- Locations of hospitals
- **Next incident:** at node i with probability p_i
- **Arrivals:** Poisson
- All incidents of highest urgency
- Travel distance matrix R (fixed)

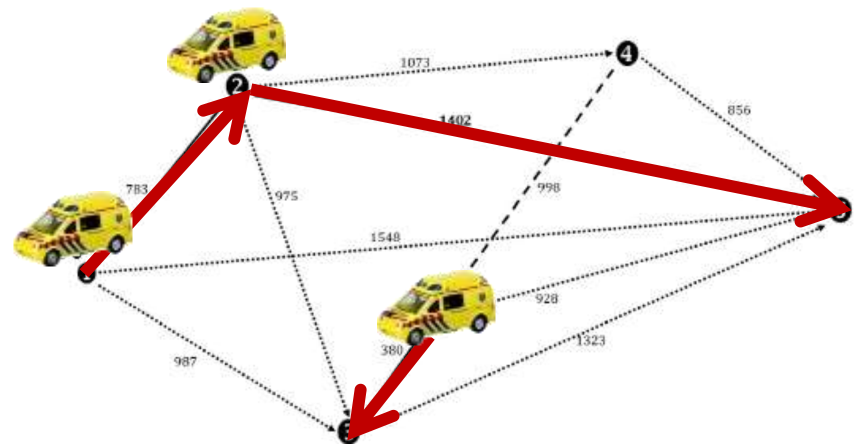
Model



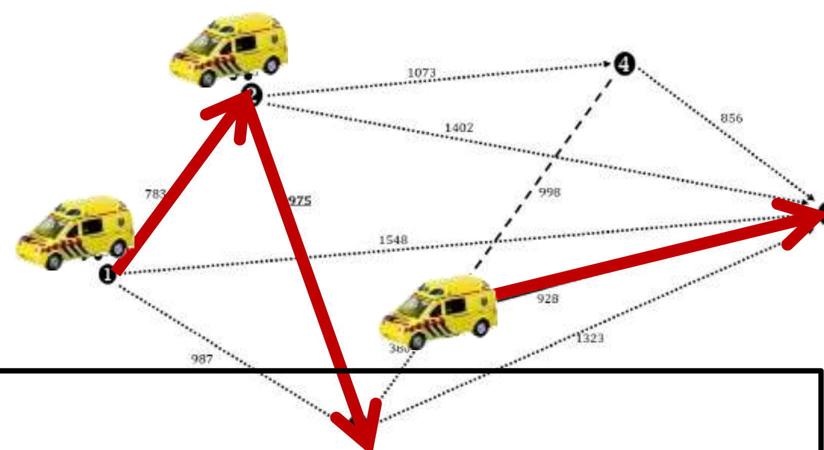
- **Transfer to hospital: preemption possible after time T**
  - Often transfer finished, but dispatcher not yet informed
  - Transfer does not necessarily have to be done by ambulance crew
- **Decision epochs:**
  - **Type 1:** ambulance dispatched to newly incoming incident (phase 0)
    - Select at most 1 pair of base locations to change configuration
  - **Type 2:** ambulance becomes idle (either from phase 2 or phase 4)
    - Origin is given: current location
- **Ambulance motion may consist of multiple relocations**

Simultaneous Relocations





Idea: Move to 'optimal' configuration as quickly as possible

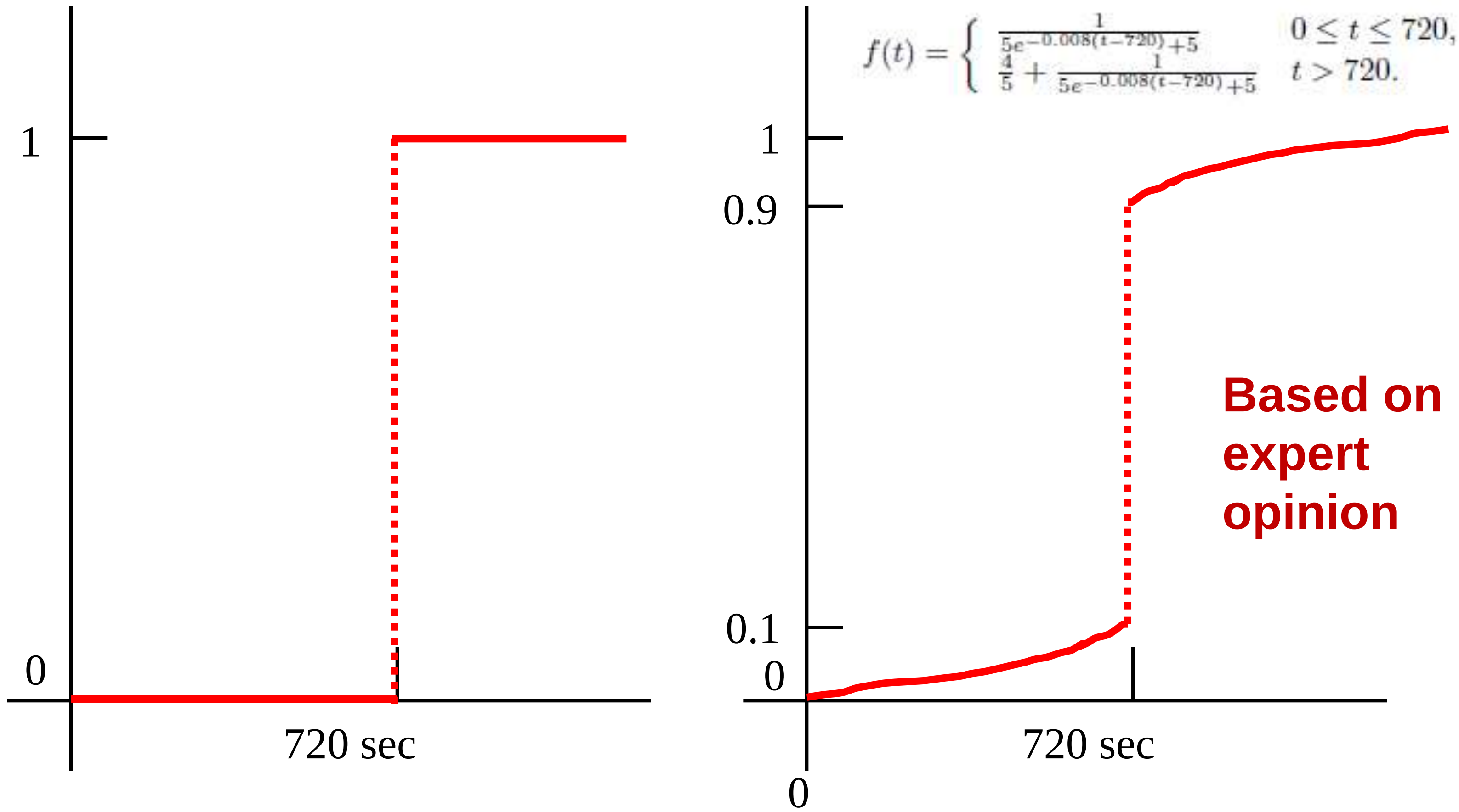


Tradeoff:

Short time to 'optimum' versus number of movements

Solution: Linear Bottleneck Assignment Problem (LBAP)

Penalty Function



$$f(t) = \begin{cases} \frac{1}{5e^{-0.008(t-720)}+5} & 0 \le t \le 720, \\ \frac{4}{5} + \frac{1}{5e^{-0.008(t-720)}+5} & t > 720. \end{cases}$$

Target: 12 minutes = 15 minus ‘time to finish coffee’

Unpreparedness Heuristic

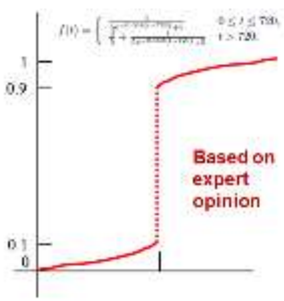
<u>Basic idea</u>: minimize 'unpreparedness'

- **System state:**

  for each ambu: (location/destination, phase)

- **Unpreparedess:**

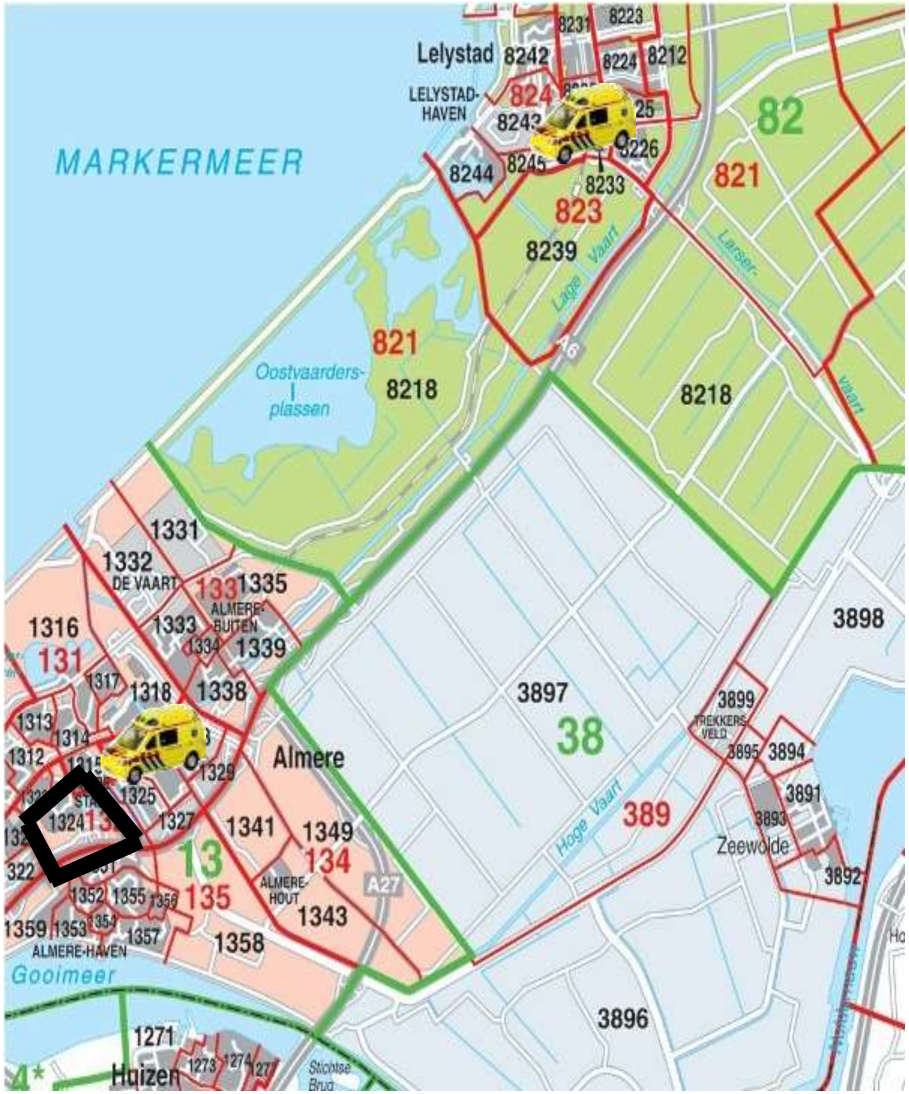
$$U(s) := \sum_{i=1}^{N} f(\min\{r_i^0(s), r_i^4(s)\} p_i$$



driving time from destination of closest phase-0 ambu to node i

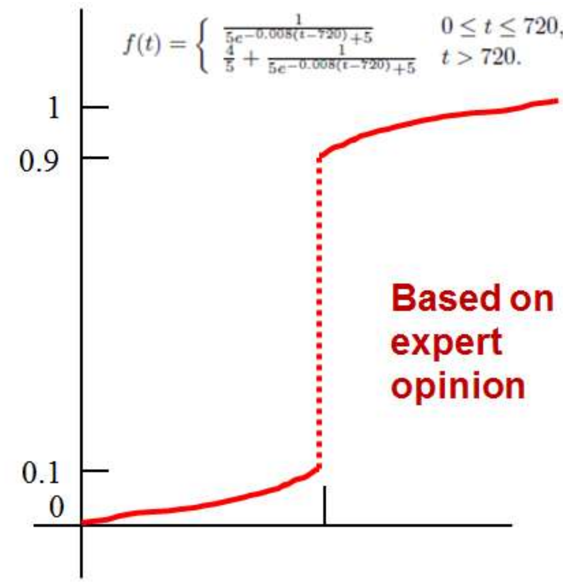
expected time till closest phase-4 ambu present at node i

Unpreparedness Heuristic



"Unpreparedness" of zipcode area:

- Time till closest ambulance present = 276 seconds
- Probability that next call is in that area = 0.033



Unpreparedness = 0.006 x 0.033 = 0.00018

Unpreparedness Heuristic

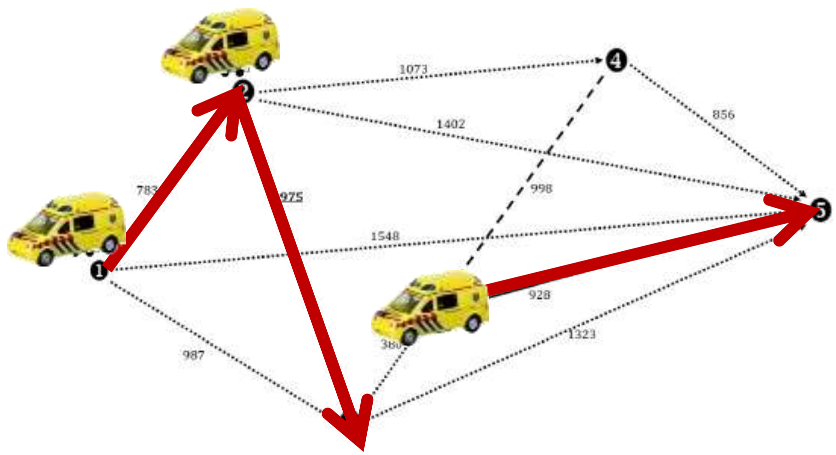
"Unpreparedness" of whole region
=
Total of unpreparedness per zipcode
≈
Probability that arbitrary call can NOT be reached within 720 seconds (for 0-1 function)

	A	L	Z	D	E	U
A	0.49201	0.71491	0.95077	0.8746	0.80672	0.82788
Z	0.52587	0.29001	0.49201	0.44969	0.38181	0.40297

Example: unpreparedness in given situation = 0.49201

Sending an ambulance from Zeewolde to Lelystad reduces unpreparedness by from 0.49 to 0.29

Two Threshold Parameters



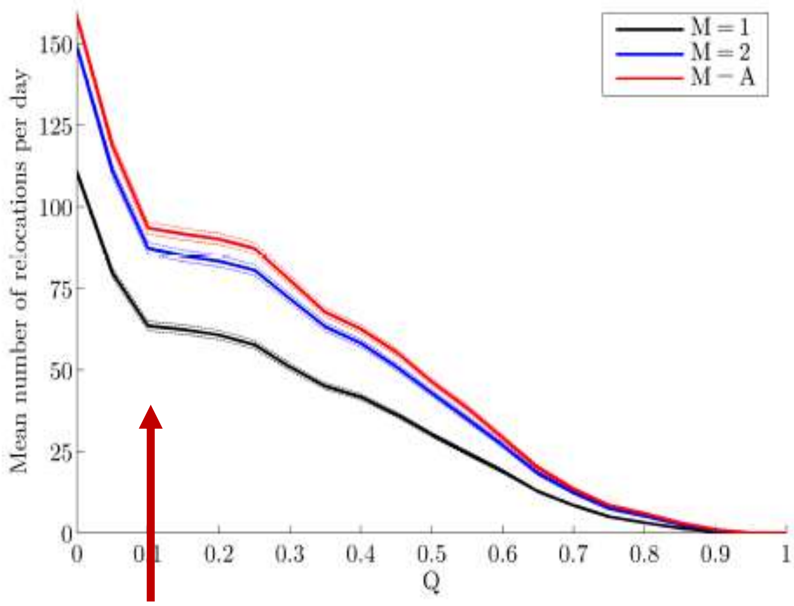
M: Maximum number of simutaneous relocations

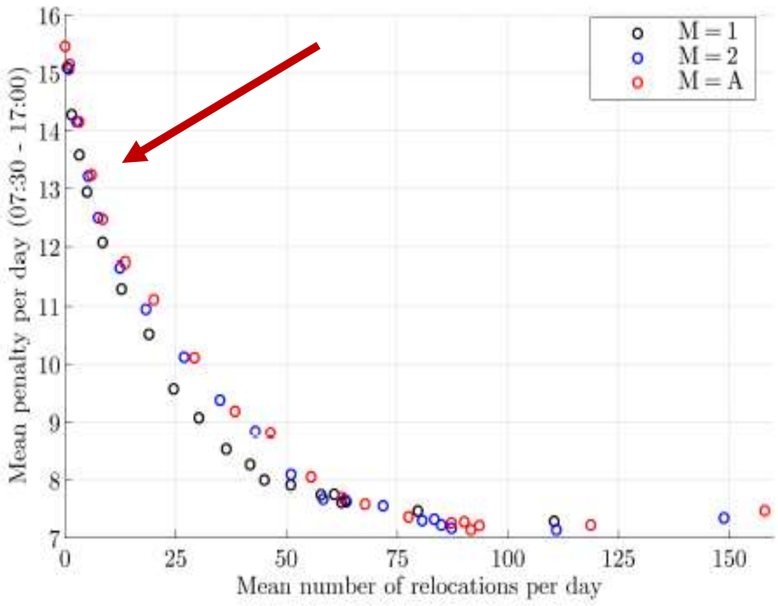
Q: Minimum relative gain in unpreparedness

$$q := \frac{U(s^{static}) - U(s^{opt})}{U(s^{static})} \times 100\% \quad (0 \leq q \leq 1)$$

Here, ‘static’ mean ‘no move’ (for phase 0), or ‘move to closest base location after incident’ (for phase 2 or 4)

Effectiveness Trade-offs

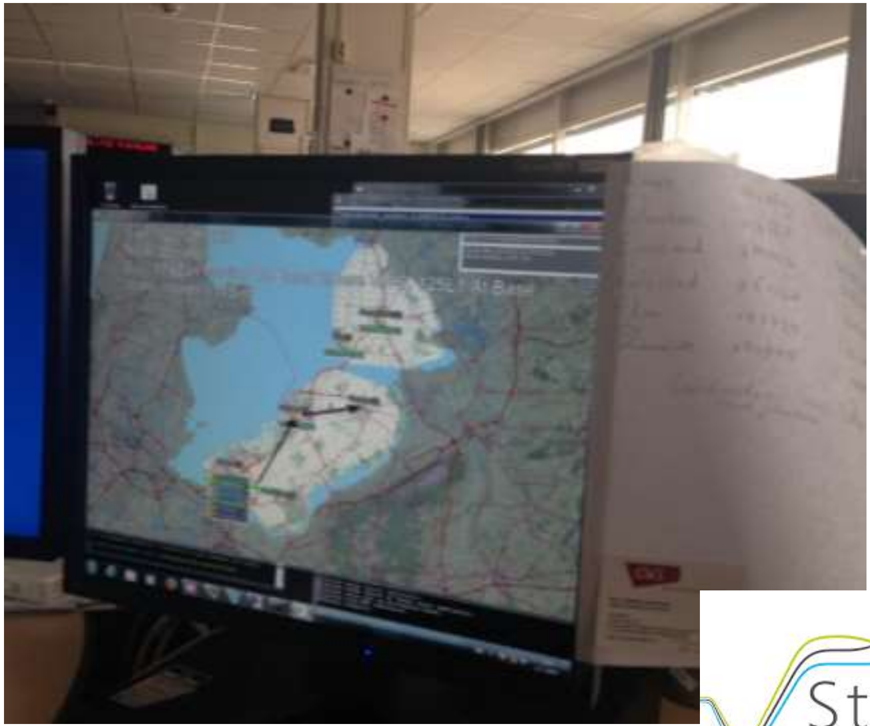




<u>**Good news**</u>**:**

1. **No need for many relocations (what drivers don't like anyway…)**
2. **Allowing at least some proactive locations already boosts performance!**

Stokhos Emergency Software



Stokhos
emergency mathemathics

Observations

- **Acceptance: important support for call center agents**
- **In practice: strong reduction response times and fraction late arrivals!**

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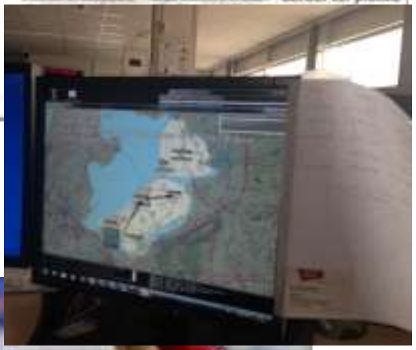

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