Preparedness and Prediction in Emergency Care

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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
Trends in Ambulance Care

- Average increase **4.2% annually** over 2008-2013
- Growth mainly explained by **demographic developments**
- Internationally consistent growth (VS, UK, Canada, Australia, Switzerland)

Source: RIVM
Ambulance Care in NL

A1-calls: Urgent and life threatening < 15 min
• severe accidents

A2-calls: Urgent but not life-threatening < 30 min
• broken leg

B-calls: Ordered transport
• ‘taxi’ transport between health institutions and to/from home

Requirement: 95% within deadline
Ambulance Care in the Netherlands

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

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Ambulance Service Process

112!

New incident happens

call center

‘Closest’ available ambulance allocated

garage

Ambulance departs

hospital

To closest base location

Patient handed over

To closest hospital

Medical treatment on the spot

Rotterdam, May 25, 2016

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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)
• **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

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

Based on expert opinion
Unpreparedness Heuristic

**Basic idea:** minimize ‘unpreparedness’

- **System state:**
  for each ambu: (location/destination, phase)

- **Unpreparedness:**

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

- Driving time from destination of closest phase-0 ambu to node i
- Expected time till closest phase-4 ambu present at node i

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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)

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**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 simultaneous relocations

**Q**: Minimum relative gain in unpreparedness

\[
q := \frac{U(S^{\text{static}}) - U(S^{\text{opt}})}{U(S^{\text{static}})} \times 100\% \quad (0 \leq q \leq 1)
\]

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

Good news:
1. No need for many relocations (what drivers don’t like anyway…)
2. Allowing at least some proactive locations already boosts performance!
Observations

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