Incorporating coverage for emergency calls in scheduling patient transportations

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Outline

1. Introduction
2. Model description
3. Preliminary results
4. Conclusions

Ambulance care in the Netherlands

- 24 ambulance regions (RAVs)
- 1.100.419 calls in 2012
- Three urgency classes:
  - A1: Most Urgent, should be served in 15 min (45%)
  - A2: Less Urgent, should be served in 30 min (25%)
  - B: Non-urgent patient transportations (30%)

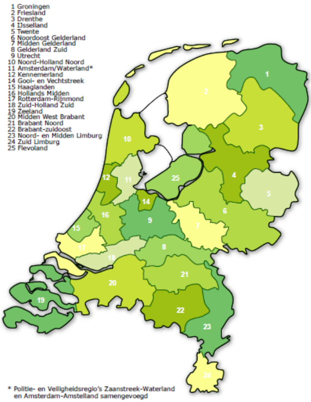

Figure: RAVs in the Netherlands

Patient transportation

- Transport of patient from and to hospital
- Non-urgent
- Special ambulance (BLS)
- ALS ambulance can also be used
- Known in advance?
- Two types:
  - B1: Must be executed by ALS ambulance
  - B2: Can be executed by either ALS or BLS

Some numbers

Data

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- Percentage B2: 43.7%
- Percentage known: 39.2%
  - 29.1% of B1
  - 47.4% of B2

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- Not within 60 minutes from requested time: 22.0%

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- Flexibility in execution time for B2
  - Different possible start times per call
- Maximize coverage that remains for emergency calls

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- Calls
- Flexibility in call execution
- BLS shifts
- Travel times

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  - Demand points
  - Base locations
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Preprocessing

- Create graph
  - Source and sink for each BLS shift
  - Node for every possible start moment of call
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  - Arcs between nodes that can follow eachother
- Occupation of ALS vehicle
  - Depends on assigned base
  - Travel time from and to base
  - Call duration

Offline formulation

Objective

Coverage by remaining ALS capacity

Constraints

All transportations scheduled

All tours are feasible

Objective function

$$\max \sum_{t \in T} \sum_{l \in L} d_{tl} \text{ coverage}(C_{tl})$$

C_{tl} number of ALS vehicles that can cover demand point $l \in L$ during time period $t \in T$ within the given time threshold.

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Coverage function

- Every static location model can be included
- We use MEXCLP
- Busy fractions vary within the region
- Time dependent

Every call executed

$$\sum_{n \in M_i} \left(\sum_{j \in J} X_{nj} + Z_n \right) = 1 \qquad \forall i \in I$$

X_{nj} binary variable which is one when appointment $n \in M$ is assigned to an ALS vehicle stationed at base $j \in J$, and zero otherwise.

Z_n binary variable which is one when call $n \in M$ is assigned to a BLS vehicle, and zero otherwise.

Tour feasibility

$$\sum_{k\in K}\sum_{h\in A_n} W_{nhk} = Z_n \qquad \forall n \in M$$

W_{nhk} binary variable which is one when BLS vehicle $k \in K$ executes node $n \in N$ directly before node $h \in N$, and zero otherwise.

Tour feasibility

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$$\sum_{n\in B_h} W_{nhk} - \sum_{n\in A_h} W_{hnk} = -1 \qquad \forall h \in O, k \in K;$$

$$\sum_{n\in B_h} W_{nhk} - \sum_{n\in A_h} W_{hnk} = 0 \qquad \forall h \in M, k \in K;$$

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Coverage constraints

$$Y_{jt} + \sum_{n \in M} b_{njt} X_{nj} = a_{jt} \qquad \forall j \in J, t \in T$$

$$\sum_{j \in J_l} Y_{jt} \geq C_{tl} \qquad \forall l \in L, t \in T$$

Y_{jt} the number of ALS vehicles at base $j \in J$ that remain available for emergency calls during time period $t \in T$.

Preliminary results

- Region of Utrecht
- March 2014
- 2511 patient transportations
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	# B2 calls	% by BLS	Busy fraction	Calls per shift	Comp. time
Weekday	44	95.4%	50.1%	4.2	100 sec
Saturday	17	91.9%	22.9%	2.3	4 sec
Sunday	16	93.7%	20.4%	3.0	3 sec

Preliminary results

Shift	Number of calls
23:00:00-08:00:00	2.2
07:30:00-14:30:00	4
08:00:00-16:00:00	4.5
08:00:00-18:00:00	6
09:00:00-18:00:00	5.4
09:00:00-18:00:00	5.3
09:00:00-19:00:00	5.3
15:00:00-22:00:00	3.1
15:00:00-23:00:00	3.0
16:00:00-23:00:00	2.9

Conclusions

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Future research

- Online version
- What is optimal number of BLS shifts?
- What is impact of earlier requests?
- What is impact of more flexibility?

Thank you!