Emergency Service Logistics:

Network Design and Dynamic Dispatching (‘DYNAMERGE’)

by Rob van der Mei (CWI and Vrije Universiteit)

Overview:
1. Background of the project
2. Goals of the project
3. First results: firetruck relocations during major incidents

Partners:
From **Reactive to Proactive Planning** of Ambulance Services (‘REPRO’)

**Facts:**
- 1 million calls per year, out of which 700,000 A1-calls
- 35,000 times do not meet the 15-minute target (93%)

**Challenges:**
1. How to forecast incident patterns?
2. **Optimal locations** of base stations?
3. How many ambulances at each base location?
4. How to keep good **coverage in real-time**?
Fire Department Amsterdam

Complication: Time and location of fires and other emergencies is uncertain

Important decisions:
• optimal location of fire stations?
• how many fire trucks to station?
• which fire trucks to dispatch

This problem is very similar to that of ambulance planning
Philips Healthcare

Maintenance of spare parts:
• where to locate spare parts storage?
• how many parts to store?
• how to dispatch spare parts?
• proactive relocations?

Again, this problem is very similar to that of fire trucks and ambulances
Emergency Service Logistics

Generic problem:
The problem of storing resources and dispatching them under time constraints and with a spatial component arises in many places.
Current situation

- separate models for spare parts and emergency services
- little overlap in methodology
- no awareness between respective communities

Our goal

- general framework for emergency service logistics
- apply models and methods from different applications
- collaboration between communities
Project Overview

Planning at three levels:
1. operational: dispatching, proactive relocations
2. tactical: resource storage decisions / staffing
3. strategic: determining location of resource storage
Operational planning: dispatching of ‘resources’

- **static**: fixed dispatching rule
- **dynamic**: take into account ‘network states’
- **pro-active**: preventively move resources between storage
- **time-dependent**: anticipate demand and lead-time fluctuations
**Tactical Planning**

*Tactical planning:* development of resource *storage* decisions

- **state of the art:** greedy algorithms for storage decisions under *static* dispatching rules and *stationary* demand.

- **challenge:** *integration* of operational and tactical decision layer. Incorporate *dynamic* dispatching rules and demand *fluctuations* on the storage decision.
Strategic planning: development of resource location models

- **state of the art**: mathematical programming formulations and solution algorithms based on the performance analysis of locations in isolation and stationary demand
- **challenge**: incorporate demand fluctuations and location interdependence
Implementation and pilot studies:

- year 4: implement methods developed during project
- one PDEng student each at Philips Healthcare Service Parts Supply Chain and Amsterdam/Amstelland Fire Brigade
- use data supplied by Philips and Fire Brigade
- test efficiency of models and methods
Philips
Service Parts Supply Chain

Henry van der Schoot
Philips
December 4th, 2017
Service Parts Supply Chain

Single service parts provider within Philips Healthcare that owns the end to end supply chain for all service parts of Philips medical equipment

**Service**
- ~1 million customer sales orders per year

*Our business governs a transactional value of*
- ~2 billion euros annually

**Our services span across over**
- 100 countries across the world

**Among the**
- top 20% of service providers across high tech industry

**Own the complete parts flow and supply chain performance from supplier’s factories to the markets**

**Global span of control with operations in**
- eight international sites

**Range of parts include normal to special parts that are**
- heavy, oversized or hazardous
Our interest explained

- Year on year business improvement need
  - Improve customer experience
  - Reduce global inventory level
  - Reduce operation costs

- Approach: funnel management

- Short term; brainstorm, analytics, problem solving

- Long term; research to enable the next breakthrough, find the “not so obvious”
Fire truck relocation during major incidents

D. Usanov\textsuperscript{1}  G.A.G. Legemaate\textsuperscript{2}  P.M. van de Ven\textsuperscript{1}  R.D. van der Mei\textsuperscript{1}

\textsuperscript{1}Centrum Wiskunde & Informatica  \textsuperscript{2}Brandweer Amsterdam-Amstelland
2663 demand locations
19 fire stations
22 fire trucks
21 incidents per day
avg duration – 1 hour
Maximum Coverage Relocation Problem (MCRP)

**Gain in coverage**

\[
W \left( \sum_{i \in S} \sum_{j \in E} x_{ij} (d_j - d_i) + \sum_{i \in M} \sum_{j \in E} x_{ij} d_j - \sum_{i \in M} z_i d_i \right) - (1 - W) \sum_{i \in N} \sum_{j \in E} x_{ij}
\]

**Number of relocations**

subject to

\[
\sum_{i \in N} a_{ik}^n \left( f_i + \sum_{j \in N} x_{ji} - \sum_{j \in N} x_{ij} \right) \geq 1 \quad \forall k \in K_n
\]

At least one of 3 closest FS should have a truck

Constraints to ensure feasibility
Simulation

Historical data -> rate per location, number of trucks, duration

Deterministic traveling times

Relocate when RN of size 3 gets empty

Relocation strategies

MCRP
Current Practice (CP)
No Relocations (NR)
Performance measures

Average response time ART

Fraction of late arrivals FLAR
## Aggregate performance

<table>
<thead>
<tr>
<th></th>
<th>MCRP</th>
<th>CP</th>
<th>NR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ART, sec</td>
<td>413</td>
<td>466</td>
<td>511</td>
</tr>
<tr>
<td>FLAR</td>
<td>32.2 %</td>
<td>45.3 %</td>
<td>56.1 %</td>
</tr>
</tbody>
</table>
Bigger incidents cause bigger troubles

Improvement in FLAR over NR

# of busy trucks
Risk Maps

NR

MCRP