

Improving Emergency Medical Dispatching with Emphasis on Mass-Casualty Incidents

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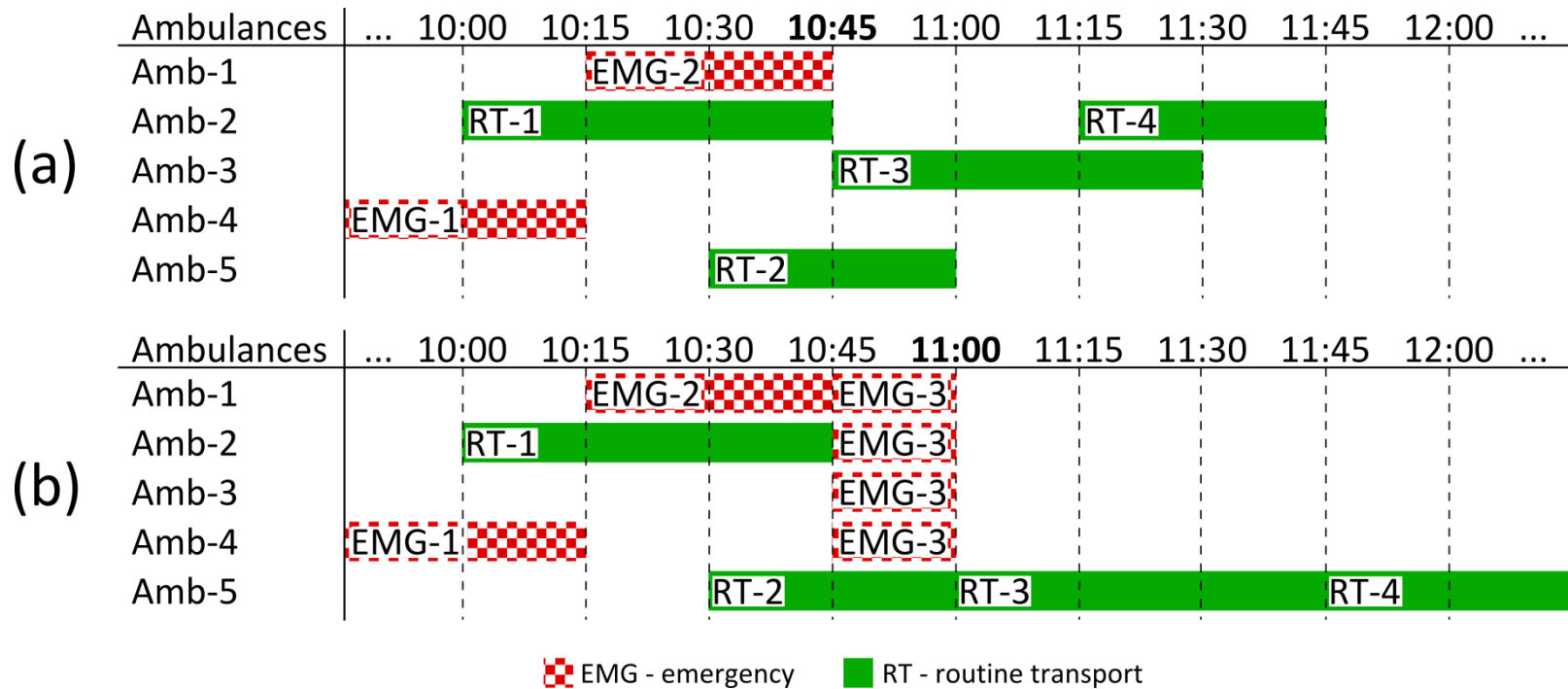
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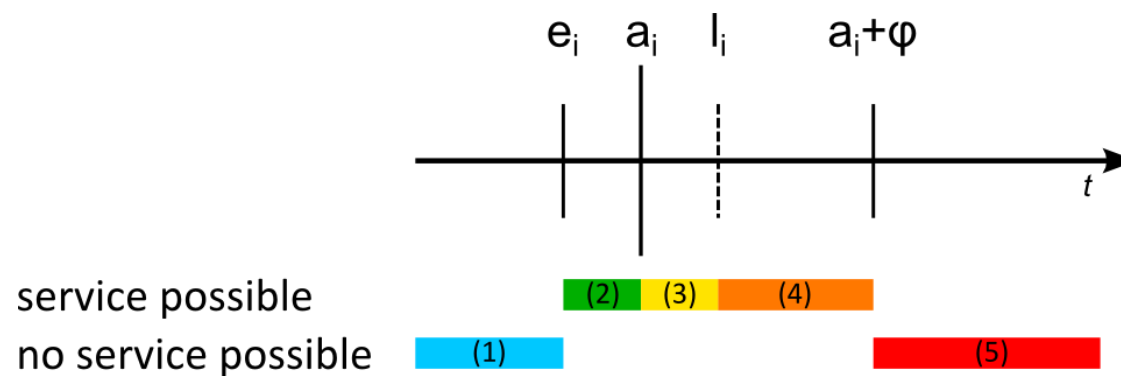
Dispatcher's Challenges

- Dispatching ambulances is demanding
- Planning about 30 to 90 minutes in advance



Constraints & Assumptions

- Pickup/delivery
- Separation of emergencies/routine transports
- 7 different ambulance types
- Application of time windows
- Multiple depots
- Combination of routine transports due to ambulance capacities
- 4 different transport types



Objective Function

$$\begin{aligned}
 w''_{i,k} &= \max(0, B_{i,k} - l_i) \\
 w'_{i,k} &= \max(0, B_{i,k} - a_i - w''_{i,k}) \\
 \min &\left(\sum_{k \in K} \left(\alpha \sum_{(i,j) \in A} d_{i,j} x_{i,j,k} + \beta \sum_{i \in N} (w'_{i,k} + \gamma * w''_{i,k}) \right) + \delta \sum_{h \in P^r} z_h^r \right)
 \end{aligned}$$

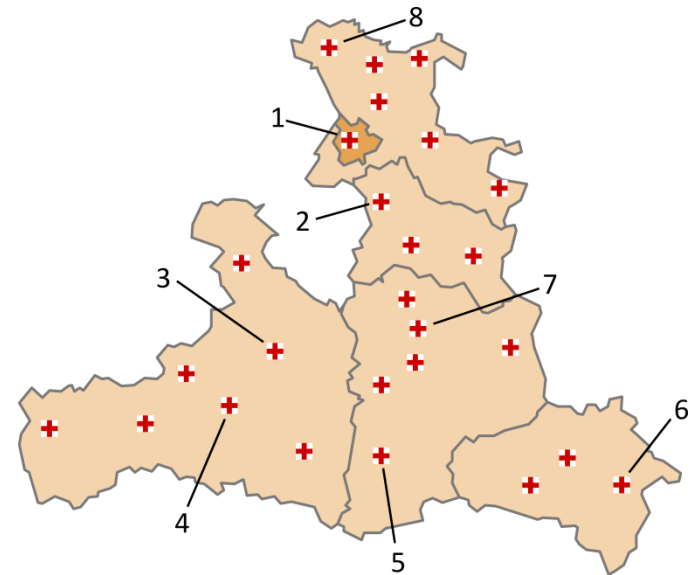
$k \in K$	Ambulance k out of the set of all ambulances	$(i, j) \in A$	Edge between the locations i and j
$i \in N$	Location i out of the set of all request locations	$h \in P^r$	Routine transport h out of the set of all routine transports
$w'_{i,k}$	Normal waiting time	$w''_{i,k}$	Excessive waiting time
$B_{i,k}$	Beginning of the service at location i by ambulance k	$d_{i,j}$	Distance between the locations i and j
a_i	Appointment at location i	$x_{i,j,k}$	1 if edge (i, j) is traversed by ambulance k
l_i	Point in time marking the boundary between <i>normal</i> and <i>excessive waiting time</i>	z_h^r	1 if routine transport h could not be included in the solution
α	Weight factor of the minimum distance objective	γ	Weight factor of the <i>excessive waiting time</i>
β	Weight factor of the minimum waiting time objective	δ	Weight factor of the number of unscheduled routine transports

Adaptive Large Neighborhood Search

- Searching different areas of the solution space
- Application of different destroy/repair heuristics
 - Random removal
 - Greedy insertion
 - Worst removal
 - Regret-2 heuristic
- Automatic weight adjustment due to solution quality
- Acceptance of worse solutions for diversification
 - Simulated annealing framework

Evaluation (I)

Instance	Depots	#Vehicles	#Requests
f_1_8_97	1	8	97
f_2_8_74	1, 4	8	74
f_2_8_89	1, 2	8	89
f_4_8_74	1, 4, 6, 7	8	74
f_8_8_81	all	8	81
f_8_27_272	all	27	272



- 1 – Salzburg Stadt
- 2 – Hallein
- 3 – Saalfelden
- 4 – Zell/See
- 5 – Gastein
- 6 – Tamsweg
- 7 – Bischofshofen
- 8 - Lamprechtshausen

Evaluation (II)

- Qualitative evaluation

Instance	Reference		Start solution		1 min		5 min		50,000 it.		t [h]
	Cost _b	Cost _n	Cost _b	Cost _n	Cost _b	Cost _n	Cost _b	Cost _n	Cost _b	Cost _n	
f_1_8_97	683	563	-24.3%	-8.1%	-28.4%	-13.1%	-31.5%	-16.9%	-36.8%	-23.3%	71
f_2_8_74	523	523	8.6%	8.6%	-9.0%	-9.0%	-11.0%	-11.0%	-13.9%	-13.9%	42
f_2_8_89	941	701	-24.4%	1.5%	-36.0%	-14.1%	-38.9%	-18.0%	-44.1%	-25.0%	58
f_4_8_74	1,202	902	28.2%	70.8%	8.7%	44.9%	0.0%	33.3%	-8.0%	-22.7%	20
f_8_8_81	970	910	2.2%	8.9%	-2.5%	3.9%	-4.9%	1.4%	-8.8%	-2.8%	27
f_8_27_272	3,171	2,511	-8.2%	15.9%	-12.3%	10.7%	-15.4%	6.8%	-26.6%	-7.3%	127

Evaluation (III)

- Performance evaluation

Data in [s]	#removed ambulances									Avg.
Instance	1	2	3	4	5	6	7	8	9	
f_1_8_97	3.70	11.98	17.85	32.56						16.52
f_2_8_74	1.63	3.76	9.98	10.02						6.35
f_2_8_89	3.26	9.47	13.57	20.05						11.59
f_4_8_74	1.06	1.90	3.23	3.75						2.48
f_8_8_81	1.63	3.29	3.99	4.15						3.27
f_8_27_272	6.64	7.90	16.71	28.62	31.14	43.02	49.99	58.08	67.53	34.40 (14.97*)
avg.	2.99	6.38	10.89	16.53	31.14	43.02	49.99	58.08	67.53	
* average value of the first 4 columns										

Conclusions

- More and different destroy/repair heuristics
- Include rostering of personnel, ambulance coverage, weather data, traffic status
- Connection of optimization system to the computer aided dispatch system

Thank you for your attention!

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