Karlsruhe Institute of Technology

Planning EMS patient transports

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EMS in Germany

Emergency Rescue

- Initial treatment for and transport of emergency patients
- Emergency doctors
- Time-critical transport of patients between hospitals

Patient Transport

- Transport of patients that need medical assistance
- Transport of non-emergency patients between hospitals
- Patients might be infectious

Planning patient transports - motivation

- Patient transport in Germany is in general a dial-a-ride problem
  - Patients with pickup and delivery
  - 20 – 80 % of transports are known in the morning (or in the evening the day before)
  - Currently, transports are usually not planned in advance

	2000	2010
% German population ≥ 65 years	16.44	20.63
# hospitals	2242	2064
# patient transports in Germany	3,935,884	5,317,425

Planning patient transports in practice

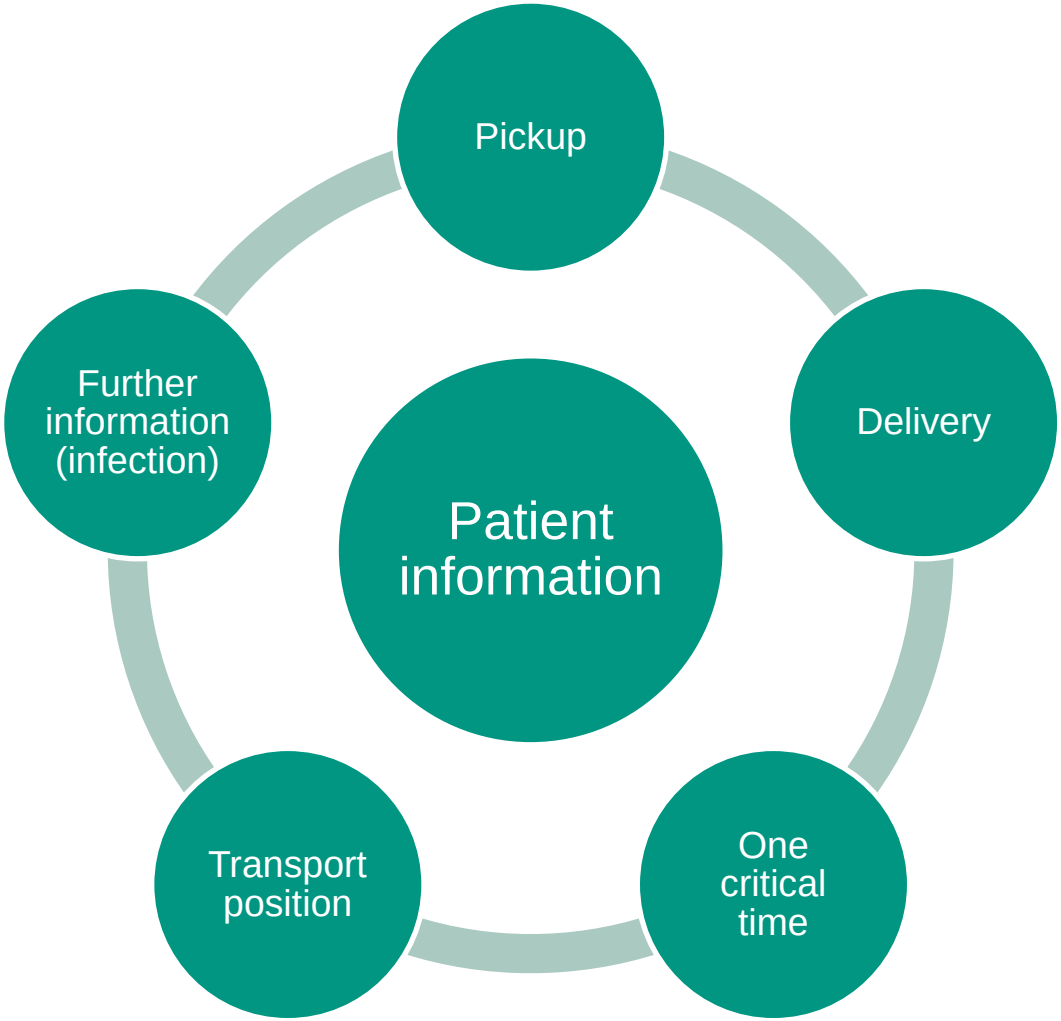
- Idea
  - Build a tool that helps the dispatcher to schedule the transportation tasks
    - Decision support tool
- Aim
  - Relief of the dispatchers
  - Identification of bottlenecks in time
  - Balanced utilization of the vehicles / balanced workload for the emergency medical assistants
- Difficulties
  - Including short-term requests might be tricky
  - Cooperation
    - Project proposal

Transportation tasks

Known transports	Short-term orders
Usually the larger part	Difficult to predict
e. g. Dialysis patients that are transported frequently	Sometimes need to be fulfilled immediately
Can be planned in advance	Rerouting in real-time needed

→ **The cancellation of tasks is also possible, of course**

Data requirements



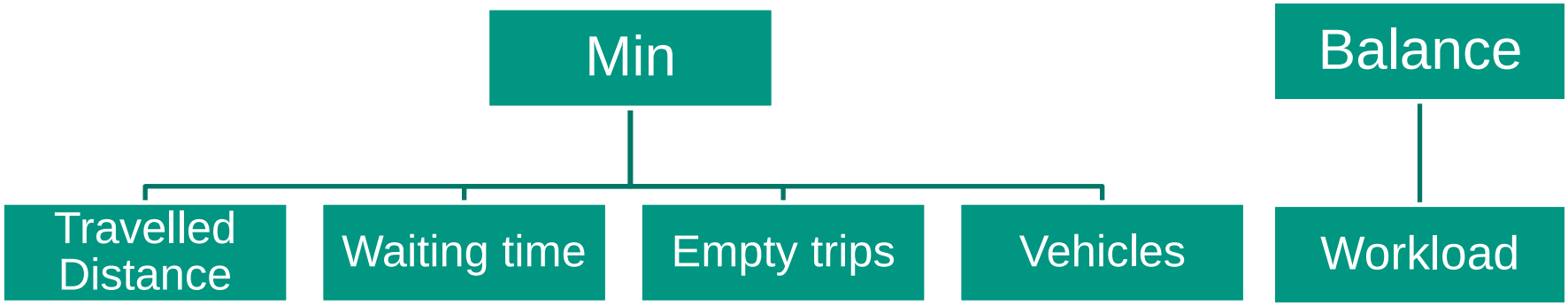
Available vehicles – three different problems

Two distinct sets of vehicles (RTWs and KTWs)	RTWs, KTWs and multifunctional vehicles	Only multifunctional vehicles
Easiest problem	Plan emergency rescue and patient transport separately	Most difficult problem
Emergency rescue and patient transport can be planned separately	Strategy for multifunctional vehicles unclear	Maybe just allocation with lower preference?

Focused on this for the beginning

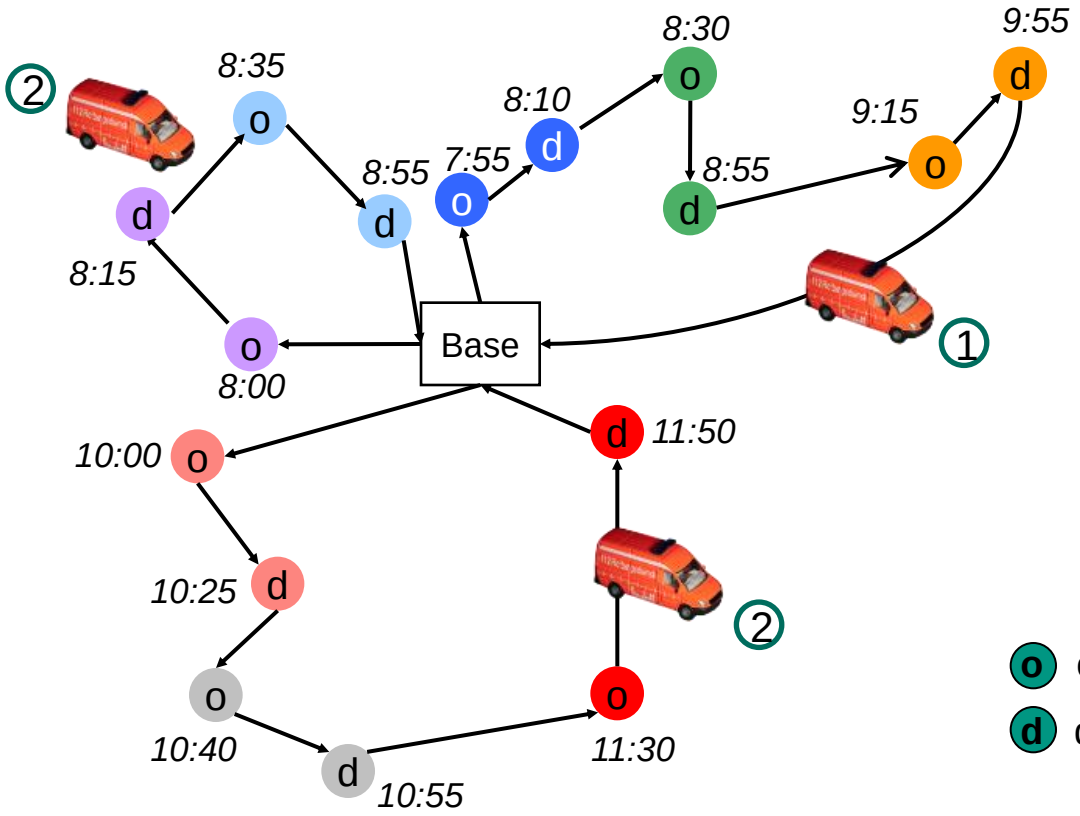
The more interesting problem

Objective functions



- Extend the lifespan of an ambulance
- No law
- Aim: 30 minutes max
- Contrary to costs
- Mainly for the case when planning for more than one region
- If not fixed
- Good for voluntary staff
- Max utilization
- Contrary to waiting time
- Between providers!
- Within an organization!?

Example



Decisions

- Clustering the tasks
- Allocation to vehicles
- Building the routes

o origin, e.g. home

d destination, e.g. hospital

Assumptions

- Fixed number of vehicles for given periods (working hours)
- 1 patient per vehicle
- 1 station (depot)
- Patient data incl. time window known
- Transports cannot be interrupted
- Vehicle goes back to station if there is “enough time” between tasks
- After transportation of an infectious patient, vehicle needs to be cleaned
- In case of a dynamic setting: not all tasks are known at the beginning, but at certain points in time / within fixed time intervals

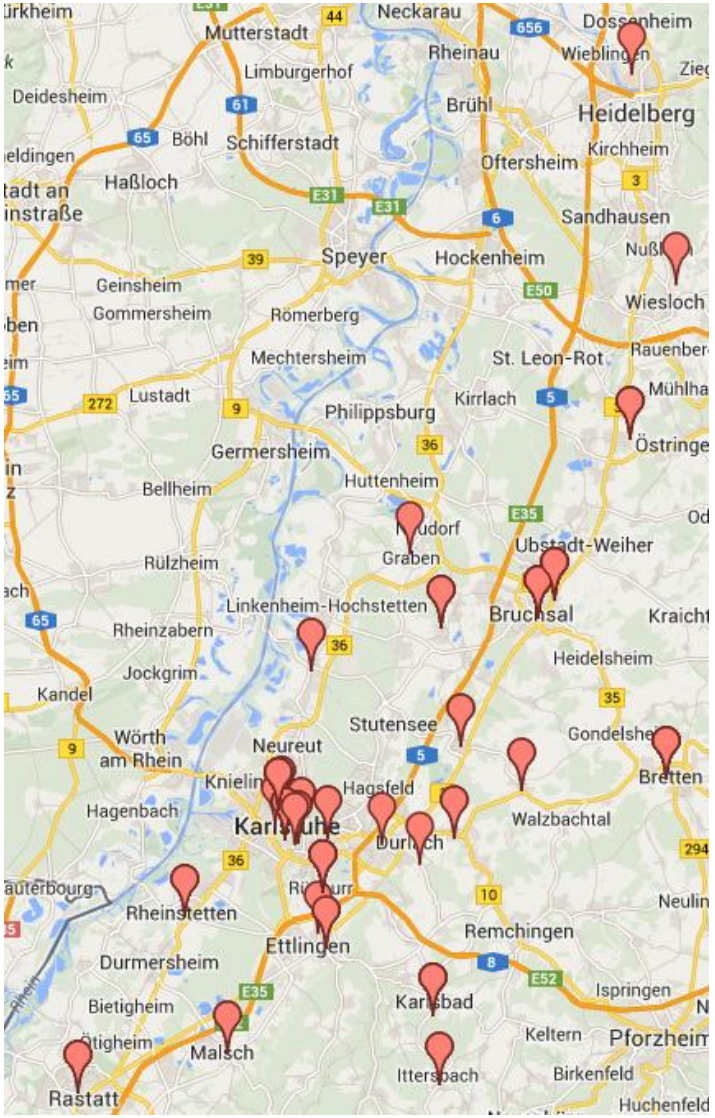
Models and methods

- Dial-a-ride formulation
  - Based on existing literature
    - Patient transports in hospitals and
    - EMS patient transports in Austria
  - Work-in-progress
    - Some specifics still need to be included
  - Objective function
    - Min empty travel time + waiting times for patients and staff

- Best insertion algorithm
  - Same objective function
    - Additionally balancing of tour length
  - Needed parameters for the objective function were determined automatically to improve the solutions
    - Worked well for all test instances

Test instances for Karlsruhe

- Random instances with the following input
  - 33 important points (e.g., hospitals) in the Karlsruhe region
  - Pick-up times between 6:30h and 20:00h
  - Probability distributions for pick-up locations and times as well as transports of infected patients based on information from practice
- Parameter
  - Max allowed deviation from time window
  - Handling time for pick-up and delivery depending on transport type
- Instances with 32, 52, 72 and 100 tasks



First results

- Solution times for the formulation
  - 32 tasks in 30 min
  - 52 tasks in 5h 20 min
  - 72 tasks in 7h 45 min
    - Max 100 tasks in an average German region; solve it optimally over night is possible
- Insertion heuristic
  - Including short-term demand was possible
  - Knowing “earlier” about same day demand in general helpful, but not significantly
  - Balancing tours enlarges the empty travel time only slightly

Open questions

- Other algorithms (evolutionary algorithms, merge-savings etc.) better?
- Build different mathematical models and compare their results
  - Is it beneficial to solve the problem optimally?
- Does it help to include stochasticity and for example include dummy tasks for the unknown transports?
- How to handle multifunctional vehicles?
  - Can we determine simple rules for the assignment of tasks?

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Thank you for your attention!

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