# Creating emergency services shift plan

## Background

Our company develops systems for both dispatching emergency ambulances as well as planning and optimizing planned transfers. We are using multiple algorithms from operations research to allow customers to improve service quality and reduce costs.

Creating an optimal shift plan for emergency ambulances is an additional problem we want to help our customers with.

## Problem description

We deal with the following entities:

* Depot is where ambulances can be stationed. A depot has a geographical coordinate and maximum capacity for ambulances.
* Hospital is where injured patients can be transported. A hospital has geographical coordinate.
* Incident is defined by geographical coordinate, time of occurrence, expected on scene duration (treating and loading patient), delivery duration at Hospital and Incident type.
* Incident type is an element of an arbitrary defined set representing general severity and in turn demands on the servicing ambulance (e.g. oxygen or defibrillator required onboard). Incident type defines Maximum response time it can take an ambulance to arrive.
* Ambulance type defines which Incident types can be served. Ambulance type has a cost – more equipped ambulances with more skilled crew cost more to run.
* Shift is defined by starting and ending time, Ambulance type and the Depot the ambulance starts and ends the shift.
* Handled incident is an event when a particular shift can serve a given incident. This means that there must be enough time within the Shift’s remaining time to:
  1. Drive to the Incident from current location within the Maximum response time
  2. Handle the Incident (expected on scene duration)
  3. Drive to the nearest Hospital
  4. Deliver the patient within that Hospital (delivery duration at Hospital)
* And the ambulance has to be of allowed type, defined by incident types.
* Shift plan is a list of Shifts
* Simulation is processing input Incidents and trying to turn them into Handled incidents given a Shift plan. When more Shifts can handle the incident, the following rules are used:
  1. Use free shifts (those not finishing handling an existing incident) first
  2. If more exist, use the one with the earliest arrival time to the Incident
  3. If more exist, use the one with the least active time (least time spent on handling previous incidents)
  4. Use the Shift with lowest costing Ambulance type

When a shift is done with handling an incident and no other incident is scheduled on it, it starts driving back to the home base. During this the shift counts as free and can be interrupted by a new incident midway. The interruption, however, induces a penalty – the amount of time it takes for the ambulance to change course towards a new destination.

All Shifts must end at their Depot before they end.

The scope of the simulation is one day. Shifts that span midnight (e.g. 7PM to 5AM Shift) count as one, but are created twice in the Shift plan (one starting before midnight and ending 5AM and one starting at 7PM ending 5AM the next day). This is to allow handling Incidents close to the end of the simulation period.

## Input parameters

A customer provides:

* A set of depots *D*
* A set of hospitals *H*
* A set of historical incident data sets *S1* .. *Sn* where *S* is a set of Incidents, typically historical or randomly generated ones within the intended scope.
* A set of ambulance types *A*
* A set of Incident types *T* and a mapping *M* of Ambulance types to Incident types
* Maximum total number of Shifts and maximum number of Shits of given Ambulance type
* Allowed starting times and shift durations (typically 8, 10, 12, 24 hours)
* Minimum percentage achieved Handled incidents achieved from incident data sets *S1* .. *Sn*
* Re-route penalty

## Expected output

The output should be one or more valid Shift plans optimizing the following:

* Minimizing then number Shifts and their total duration. This can be expressed as a total cost of all shifts, where the cost of one Shift is the cost of the Ambulance type multiplied by the Shift duration.

Provided that the percentage of Handled incidents from historical incident data sets *S1* .. *Sn* does not drop below a specified threshold.

## Required steps

* Processing input data and requirements
* Being able to generate valid Shift plans
* Being able to run a Simulation on the historical incident data sets *S1* .. *Sn* on a Shift plan
* Developing one or more heuristic methods that will steer the generation of Shift plans towards more optimal solution

## What will be provided

We will provide sample Input parameters and a distance calculation system that will

* Provide the duration *r* needed to travel between two coordinates *c1*, *c2* at a given time *t*:   
  *f(c1*, *c2*, *t*) -> *r*
* Provide the current coordinate *c’* the ambulance is located when travelling between two coordinates *c1*, *c2* after a given duration *r* has elapsed:   
  *f(c1*, *c2*, *r*) -> *c’*This is used when interrupting driving midway.