Ambulance service

Introduction

You are responsible for the ambulance system in a city, and, given the occurrence of accidents, you want to offer the best possible service to the citizens deciding the ambulance fleet, the location of the medical hubs and the ambulance deployment policy.

The decisions that you have to make are:

- The ambulance fleet and the location of the medical hubs, i.e. the type and number of ambulances and from where the ambulances are dispatched.
- The deployment policy, i.e. the rules that you apply to deploy ambulances to accidents.

The aim of the "Simulation Project" is to develop a discrete event simulation that represents the system and to evaluate the performance of two solutions of ambulance fleet, hub location and deployment policy.

During the "Optimization Project", the discrete event simulation is expanded, and the optimal solution in term of ambulance fleet, hub location and deployment policy is identified by an optimization algorithm.

Develop the discrete event simulation with a modular structure. It should be possible to modify the various components, such as the accident occurrence rate, ambulance fleet and deployment policy, during the "Optimization Project".

Project description

The city boundary has the shape of a square with the side of 10 km in length. Accidents requiring an ambulance happen with a rate a, in different locations within the city. Three different types of accidents can occur based on the severity: mild, moderate and critical.

As soon as an accident occurs, an ambulance is deployed from a hub. Three different types of ambulances are present: basic, standard and complete. A basic ambulance can only serve mild accidents, and it costs 100,000 €. A standard ambulance can serve both mild and moderate accidents, and it costs 150,000 €. A complete ambulance can serve all accident types, and it costs 300,000 €.

To resolve the accident, the ambulance has a service time on site, defined by t. The ambulances always start and come back from the same hub after every service, independently of the accident type. The possible hub locations are reported in Table 1. We assume that the south-west corner of the city has the coordinate (0;0). Ambulances travel at 60 km/h, and the distance from the hub to the accident location is the Euclidean distance.

The total available budget to run the service is 16 million €. The budget is used to purchase ambulances or open hubs in the available locations. At least one hub should be open. The cost of a hub is 1 million €.

We assume the following distribution for the variables:

- The accident occurrence rate a is 150 accidents per hour.
- Mild accidents happen 50% of time, moderate accidents 40% and critical accidents 10%.

- The locations of the accidents are uniformly distributed within the city boundary. The location is defined by the x-coordinate and y-coordinate, both in meters.
- The ambulance service time on site *t* is function of the accident type. Mild accidents are resolved on site, and they require 10 minutes plus an extra time uniformly distributed between 0 and 20 minutes. Moderate accidents require 5 minutes to load the injured person plus a random extra time exponentially distributed with a mean of 5 minutes to stabilize the patient. Critical accidents require 10 minutes to load the injured person plus a random extra time exponentially distributed with a mean of 10 minutes to stabilize the patient.

Simulation

For the simulation project, you are requested to:

- Develop a discrete event simulation to represent the described project.
- Define the indexes used to quantify the quality of the service
    - Remember that extreme cases are important; evaluate other indexes in addition to the mean. Moreover, the waiting time for different accident types could have different impact on how your service is perceived.
    - Report the mean square error of your estimation using bootstrapping when necessary.
    - Use variance reduction techniques to reduce the computational time.
- Decide the ambulance deployment policy, i.e. the rules that you apply to deploy ambulances to accidents. For example, you can consider difference queues for different types of ambulances, and to allocated accident to hubs based on the proximity.
- Evaluate the quality of the ambulance service with two different configurations:
    - One hub open (hub number 1), and 30 basic ambulances, 50 standard ambulances and 15 complete ambulances
    - Three hubs open (hub number 1, 2 and 3), and 55 basic ambulances, 34 standard ambulances and 8 complete ambulances
- Make any necessary assumptions.

Table 1 Hub location coordinate in meter

Hub	X coordinate [meter]	Y coordinate [meter]
1	3658	5254
2	7635	5303
3	4484	938
4	4046	6963
5	6279	8611
6	7720	4849
7	9329	3935
8	9727	6714
9	1920	7413
10	1389	5201