Drone delivery service

Introduction

You are responsible for the drone delivery system in a city, and, given the occurrence of on-line order, you want to offer the best possible service to the customers deciding the drone fleet, the location of the dispatching hubs and the drone deployment policy.

The decisions that you have to make are:

- The drone fleet and the location of the dispatching hubs, i.e. the type and number of drones and from where the drones are dispatched.
- The deployment policy, i.e. the rules that you apply to deploy drone to the order location.

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 drone fleet, hub location and deployment policy.

During the "Optimization Project", the discrete event simulation is expanded, and the optimal solution in term of drone 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 order rate, drone 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. On-line order requiring a drone delivery happen with a rate a, in different locations within the city. Three different types of order can be done based on the weight of the item to deliver: light, medium and heavy.

As soon as an order is placed, a drone is deployed from a hub. Three different types of drones are present: basic, standard and complete. A basic drone can only deliver light items, and it costs 100,000 €. A standard drone can deliver both light and medium items, and it costs 150,000 €. A complete drone can deliver all item types, and it costs 300,000 €.

The delivery procedure is complicated (landing, removing the item, take-off), and the drone has a service time on site, defined by t. The drones always start and come back from the same hub after every delivery, independently of the item 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). Drones travel at 50 km/h, and the distance from the hub to the delivery location is the Euclidean distance.

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

There are two types of operating costs for the drones:

- Distance depended. 0.20 €/km for all drone types.

- Time depended. 100 €/hour for a basic drone, 120 €/hour for a standard drone, and 200 €/hour for a complete drone. The time depended operating cost is only charged when an drone is in service, i.e. not waiting at the hub.

We assume the following distribution for the variables:

- The on-line order occurrence rate *a* varies during the day. Three time periods are present:
  - Day (8:00-16:00) *a* is 150 orders per hour
  - Evening (16:00-24:00) *a* is 250 orders per hours
  - Night (24:00-8:00) *a* is 50 orders per hours
- Light items are ordered 50%, medium items 40% and heavy items 10%.
- The city is divided in two areas, city center and periphery. The city center has the shape of a square with the side of 3 km in length located in the center of the city. There is double probability that an order is located in the city center than in the periphery. The locations of the orders are uniformly distributed within the two different areas. The location is defined by the x-coordinate and y-coordinate, both in meters.
- The drone service time on site *t* is function of the item type to be deliver. The exact time varies due to weather condition, wind and customer familiarity with the system. The delivery procedure of light items requires 10 minutes plus an extra time uniformly distributed between 0 and 20 minutes. Medium items require 5 minutes plus a random extra time exponentially distributed with a mean of 5 minutes. Heavy items require 10 minutes plus a random extra time exponentially distributed with a mean of 10 minutes.

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 is an important factor for 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 drone deployment policy, i.e. the rules that you apply to deploy drones to orders. For example, you can consider difference queues for different types of drones, and to allocated orders to hubs based on the proximity.
- Evaluate the quality of the drone delivery service during 24 hours (from 8:00am) with two different configurations:
  - One hub open (hub number 1), and 30 basic drones, 50 standard drones and 15 complete drones
  - Three hubs open (hub number 1, 2 and 3), and 55 basic drones, 34 standard drones and 8 complete drones, all types equally distributed among the hubs.
  - (or other scenarios that show your simulation performance well)
- Make any necessary assumptions.

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Optimization

For the optimization project, you are requested to:

- Identify the decision variables of the problem.
- Define the objective function.
- Design an optimization algorithm and apply it to solve the problem. The value of the objective function is evaluated using simulation.
- Like in the simulation project, the objective function can reflect various policies of the decision maker: whether they want to optimize over the average, best, worst, or certain percentile of the objective function distribution. Decide what your position is and justify it, or present results for several alternatives.
- Use your creativity and design a new dispatching strategy that leads to better performance.

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