

In the past, drones were used mainly in military domain for surveillance purposes. With the technological developments in recent years, drones become easy to use and economically accessible. Thus, drones have started to gain more attention in different areas ranging from photography to keeping an eye on wildlife, from humanitarian aid distribution to cargo delivery. At the beginning, the main purpose of using drones was monitoring areas, whereas especially in the last years due to the advantages that drones offer, they started to be frequently used in the last-mile delivery in logistics operations. The advantages of deploying drones in distribution logistics are to be able to fly over congested roads without any delay, to deliver parcels in shorter times with less energy consumption and lower courier cost, and to reach to the areas which are not easily accessible with traditional land vehicles. However, besides these advantages, drones have some physical characteristics restricting them to be used on the delivery networks alone such as payload volume, limited battery life and flight range. Thus, to benefit from the advantages of drones, they can be integrated into delivery networks in a way that they work with the current vehicles.

Since drones can move without being affected by the traffic jam and they do not need to follow the highways, they can reach their targets faster than the traditional vehicles. Besides, drones can carry parcels at a lower costs compared to the traditional vehicles as they use variety of batteries as energy sources and consume less energy per kilometer. Therefore, drones are both energy and cost efficient. Also drones enable to reach the areas having challenging geographical conditions, inadequate infrastructure or lower level of security. However, along with these superiorities, drones have some physical features that limit them to be solely used in distribution network.

Even though the carrying capacity, battery life, flight duration and flight range of the drones that are aimed to be used in the delivery networks are enhanced with the recent technological developments, these limiting factors do not allow to deploy drones alone in a delivery network that requires visiting several points and carry parcels to those points. For instance, when a drone is flying to its target, it can only carry one package at a time and up to a certain weight. If the parcel required to be delivered to a point exceeds the carrying capacity of the drone or there are several points required to be visited consecutively, since drone cannot carry heavy and multiple packages, in this case it is not possible to use drone alone in the network. In these kind of cases, using drones in coordination with traditional delivery vehicles minimize the effects of the restrictive features of drones and allows to benefit from the advantages that drones offer.

There are several ways to integrate drones into traditional delivery networks. One of the simplest one is to place the drones to the depot and allow them to serve the customers within their flight range. While the drones are serving relatively closer customers back and forth, the truck leaving the depot visits its own stops one by one and turns back to depot afterwards.

In this project, assume that there is only one drone at the depot and you have one truck available. There is a set of customers that you need to visit either by the drone or by the truck, and you want to **minimize the time at which both vehicles complete their visits and return to the depot**. Keep in mind that the drone can only serve the customers within its flight range. Also, assume that the drone needs to spend some time at the depot after each delivery for battery swap and loading a new parcel.

**Parameters provided:**

- Distances between all customers by main roads
- Flight distances between the depot and customers
- Average speeds of the drone and the truck
- Flight range of the drone (the maximum distance that the drone can serve)
- Time spent by the drone at the depot after each delivery

You need to model this problem and solve with given set of parameters. For the parameter values, see the excel sheet "DroneProjectData". Notice that the average speeds of the drone and the truck is fixed, and you need to solve your model with 4 sets of parameters for different flight ranges and time spent at depot.

**About Grading:**

- Report Format: 20%
  - A brief summary
  - Overall explanation and language
  - Clarity
- Quality of workmanship: 40%
  - Stating the assumptions if any
  - Explanation of methodology and technique
- Quality of the solution: 40%
  - Correctness
  - Comments on the solutions (comparison of the results)