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15.093 Interim Report:

Non-Emergency Inter-Hospital Patient Transfers

The Boston metro area is widely regarded as being among the top places in the U.S. for access to quality healthcare. This is largely in part due to phenomenal specialists that are at the forefront of their respective fields. However, maximizing the impact of these exceptional providers is contingent on patients being located at hospitals that are most equipped to treat their particular condition. For this reason, inter-hospital patient transfers, most commonly arranged to access specialized care that is not available at their current hospital, are essential to positive patient outcomes. This project is taking the perspective of a fictitious third-party company that specializes in non-emergency inter-hospital patient transfers in the Boston metro area.

The goal of this project is to assign patient transfer routes to each ambulance within our fleet in order to satisfy all demand on a particular day while minimizing total distance traveled among all ambulances. In order to measure distances between each hospital, the coordinates of each hospital were obtained from Analyze Boston (https://data.boston.gov/) and a matrix of distances between these coordinates will be constructed using TravelTime API (essentially a free version of Google Maps API). To simulate demand, statistics from a real-life Canada-based company, called Hospital Transfer (https://sntransport.ca/), will be used to estimate the total demand per day. This will be done by first scaling the total daily demand of the Canadian company by the ratio of population densities. Then, the total daily demand will be synthetically broken down among each possible transfer (from hospital I to J) using the relative amount of beds for each Boston hospital. The number of ambulances in our fleet will also be based on the number of ambulances operated by the Canadian company.

To solve this problem, linear optimization will be conducted on a modified assignment network flow framework. Each patient (i) and each destination hospital (h(i)) will have a corresponding node, and there will be arcs connecting each patient to each destination hospital in the network. Each patient (i) will have a predetermined origin hospital that will not be represented as a node but rather will be represented by having zero distance from the patient node to that hospital node. There will be multiple bays from which the multiple ambulances can start at the beginning of the day and to which they must return at the end of the day, be it not the same bay as they started from.

The decision variable is, for each ambulance (k), whether it takes the route to transport patient i to destination hospital h(i). The objective is to minimize total distance traveled among all of the routes that all of the ambulances take. The constraints of this problem are that all patients must be transported to their destination hospital within that day. Because this problem is modeling non-emergency patient transfers, this model will use the assumption that patients simply need to arrive at their destination within that day. There will be a flow balance constraint ensuring that ambulances realistically travel from one patient node to a hospital node (or vice versa) through arcs and that they start and end at the bay. The arc from a hospital node to a patient represents picking up a new patient to begin another transport. If the new patient is at the same hospital as the previous patient's destination, the distance of this arc is zero. The sum of arcs (meaning number of ambulances) leaving the bay must be equal to that returning to the bay. Also, the sum of the arcs must be less than the capacity of the bay (meaning the number of ambulances in the fleet). This means that the bay starts and ends the day at full capacity, but not all ambulances are forced to leave the fleet. If time allows it, we will model having several different ambulance types (e.g. EV and combustion engine) with varying costs associated with their utilization. Lastly, there is a constraint ensuring that each patient is only transported to their destination hospital once, meaning by one ambulance.

Because each arc represents transporting a patient and picking up a new patient, the order that the patients were transported can be extracted from the output of the optimization. Our expected results are that the optimal solution is crafted in such a way that patients are transported to destination hospitals that have a patient waiting to be picked up. This is because there is zero distance traveled between dropping off a patient and picking up a new one. Further, we expect that ambulances organize their routes such that their trip from the bay and returning to the bay are of minimal distance. Lastly, we expect that ambulances will tend to complete consecutive trips to and from the same pair of hospitals. If this behavior is not observed, an additional constraint may need to be added because this would likely increase the satisfaction of ambulance drivers and would make the routes less chaotic.

Max	Both	Rachit
1. Build distance matrix (TravelTime API) 2. Visualize results	1. Formally write the problem as a LO formulation 2. Solve the problem using Gurobi	1. Build the demand matrix 2. Create visual representation of network 3. Develop project extensions