Game of Drones…in the City

Brent McCunney & Kristof Van Cauwenberghe
Advisor: Mohammad Moshref-Javadi

Content

Background Information

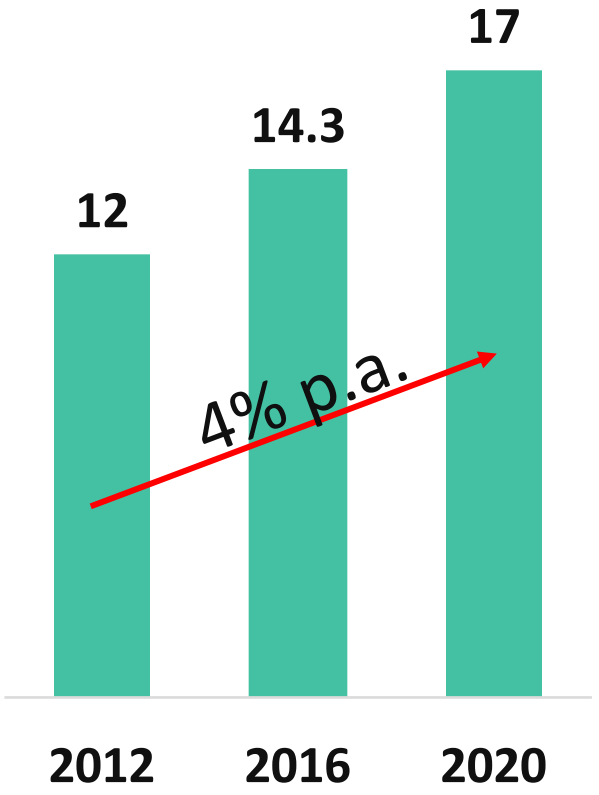
70 PERCENT OF GLOBAL POPULATION WILL LIVE IN CITIES BY 2050
United Nations

60 PERCENT OF GLOBAL GDP GROWTH UNTIL 2025 WILL COME FROM 600 LARGEST CITIES
McKinsey Global Institute

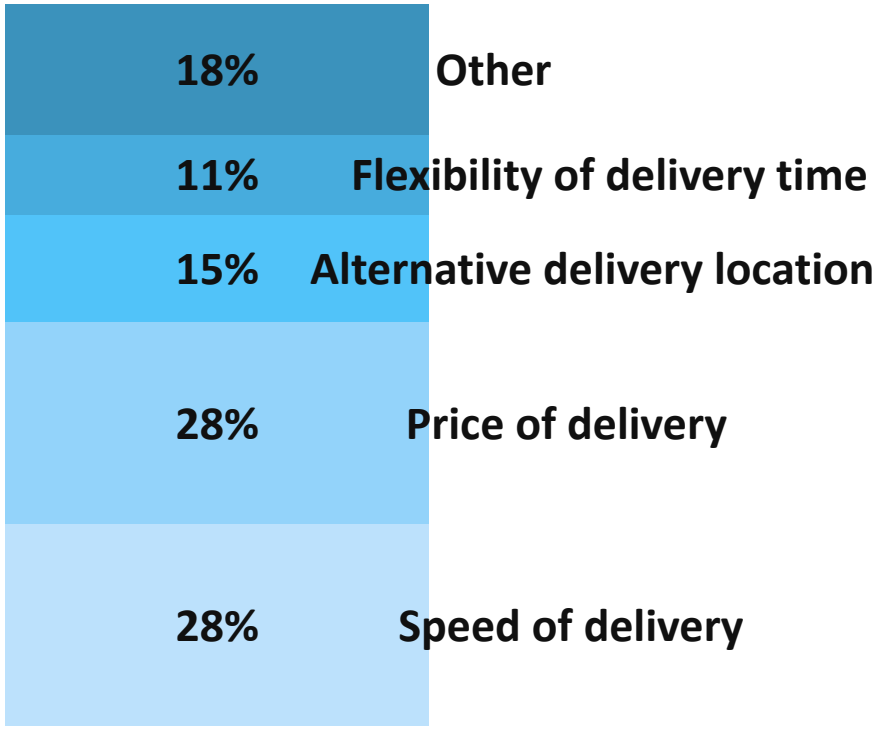
24 PERCENT ANNUAL GROWTH RATE OF GLOBAL E-COMMERCE VOLUME IN 2016
eMarketer

28 PERCENT OF TRANSPORTATION COST OCCUR IN THE LAST MILE
Council of Supply Chain Management Professionals

Domestic B2C shipments (shipments per adult)



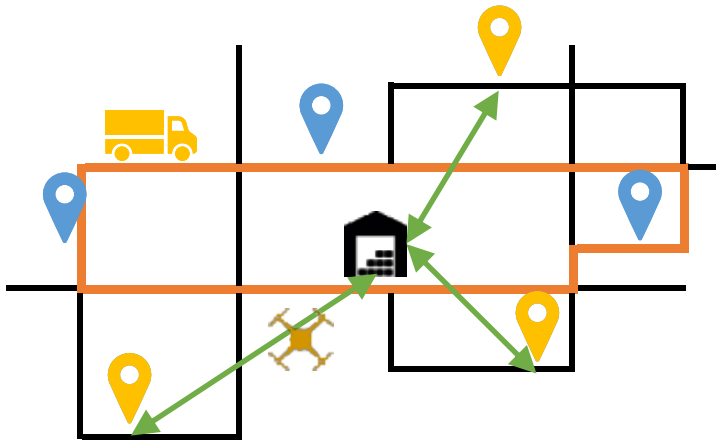
WHICH DELIVERY FEATURE MATTERS MOST?



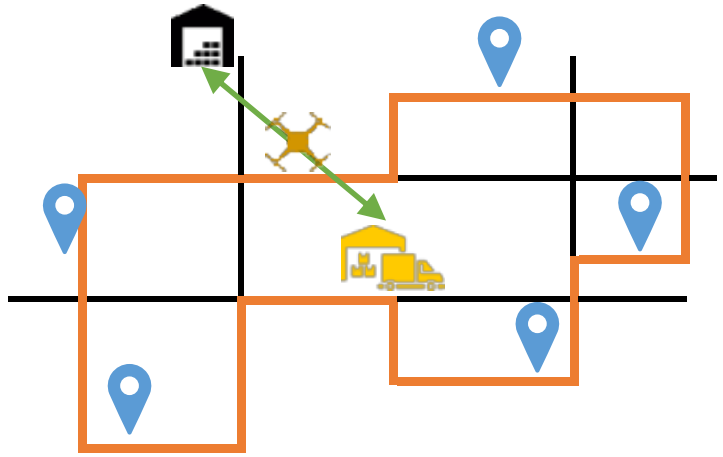
Source: Forrester; Datamonitor: Online survey conducted in June 2013, n=1016 (UK, France, Germany, and Sweden)

Drones as delivery solution

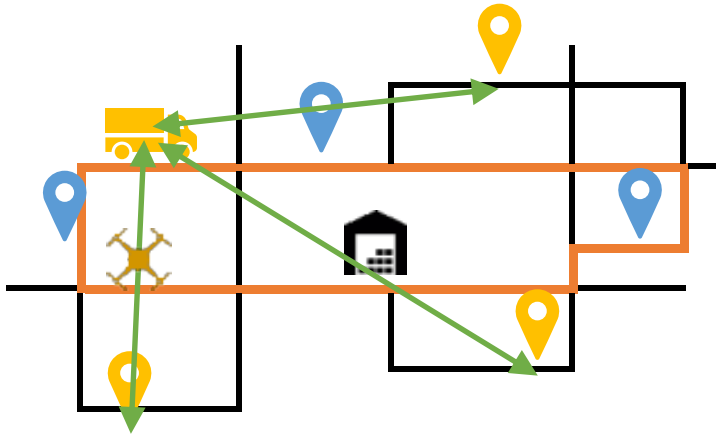
Direct to Customer



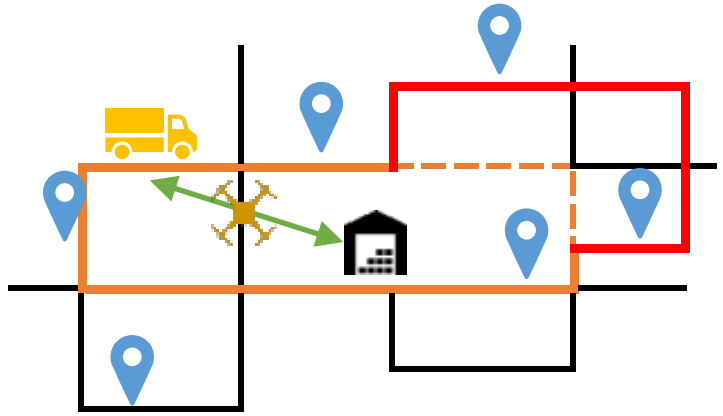
Drone Resupplied Transshipment Points

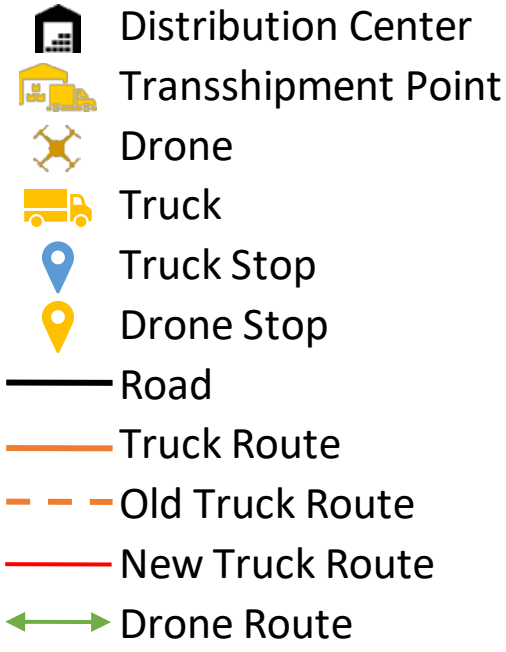


Flying Sidekick



Drone Resupplied Trucks





Stakeholders

Online Retailers

Courier companies

Consumers

Assumptions

- 1 distribution center per city
- 5020 deliveries per 8-hour day in Boston
- 260 deliveries per 8-hour day in Pittsfield
- 10% of all deliveries request same-day delivery & are drone size
- 30 minutes drone max flight time
- 20 seconds per package drone (un)load time
- 90 seconds plus 20 seconds per package truck unload time
- 20 seconds per package truck load time
- Truck routing is based on nearest neighbor
- No time is accounted for charging drones (battery swaps)

Data

- 176 Delivery locations in Boston
- 122 Delivery locations in Pittsfield
- Google Distance Matrix API

Transshipment Point Location Optimization

$$Minimize \sum_i \sum_j x_{ij} \times (t_{ij} + \alpha \times t'_j)$$

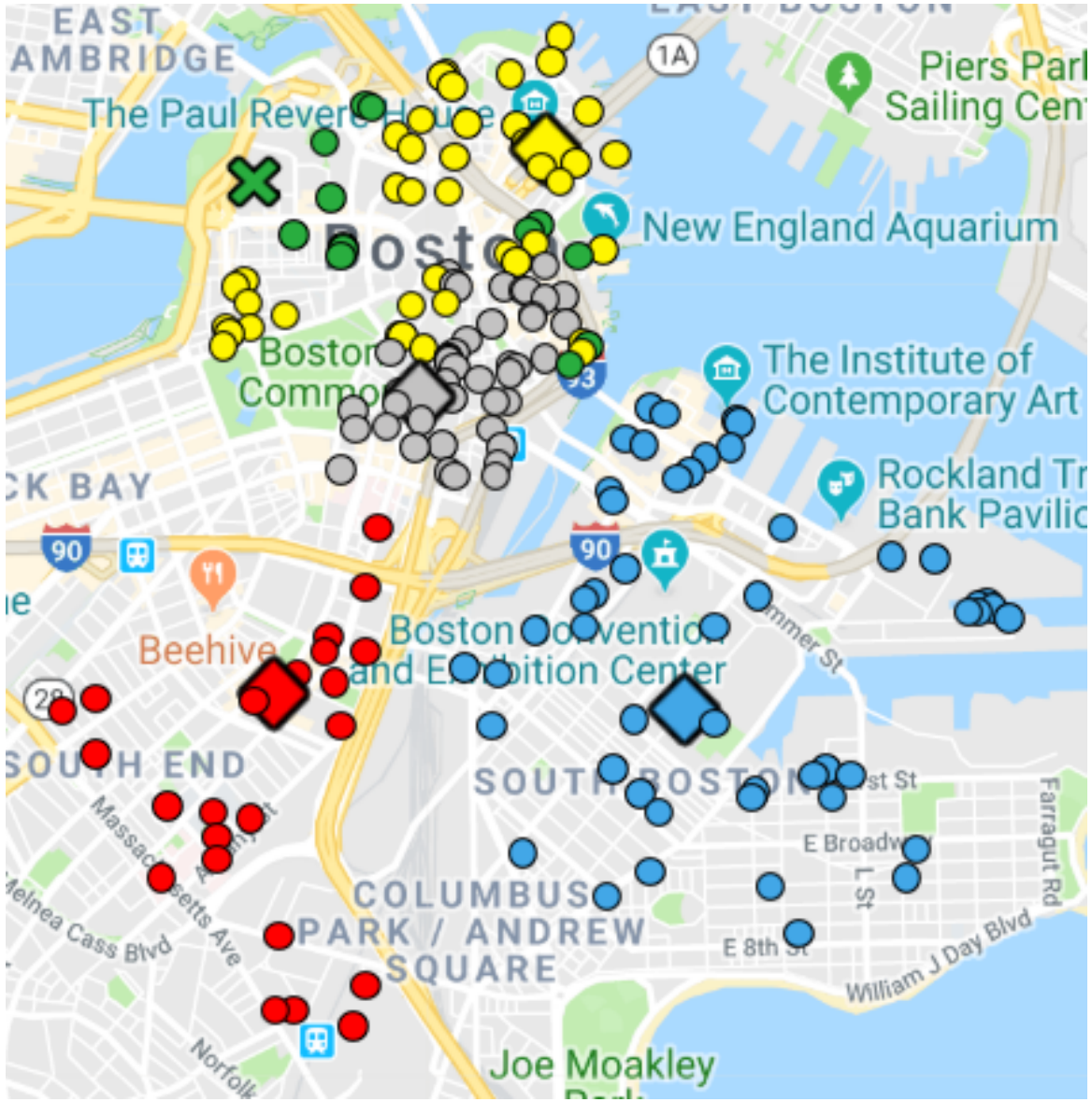
x_{ij} = *TP to Customer Decision Variable*

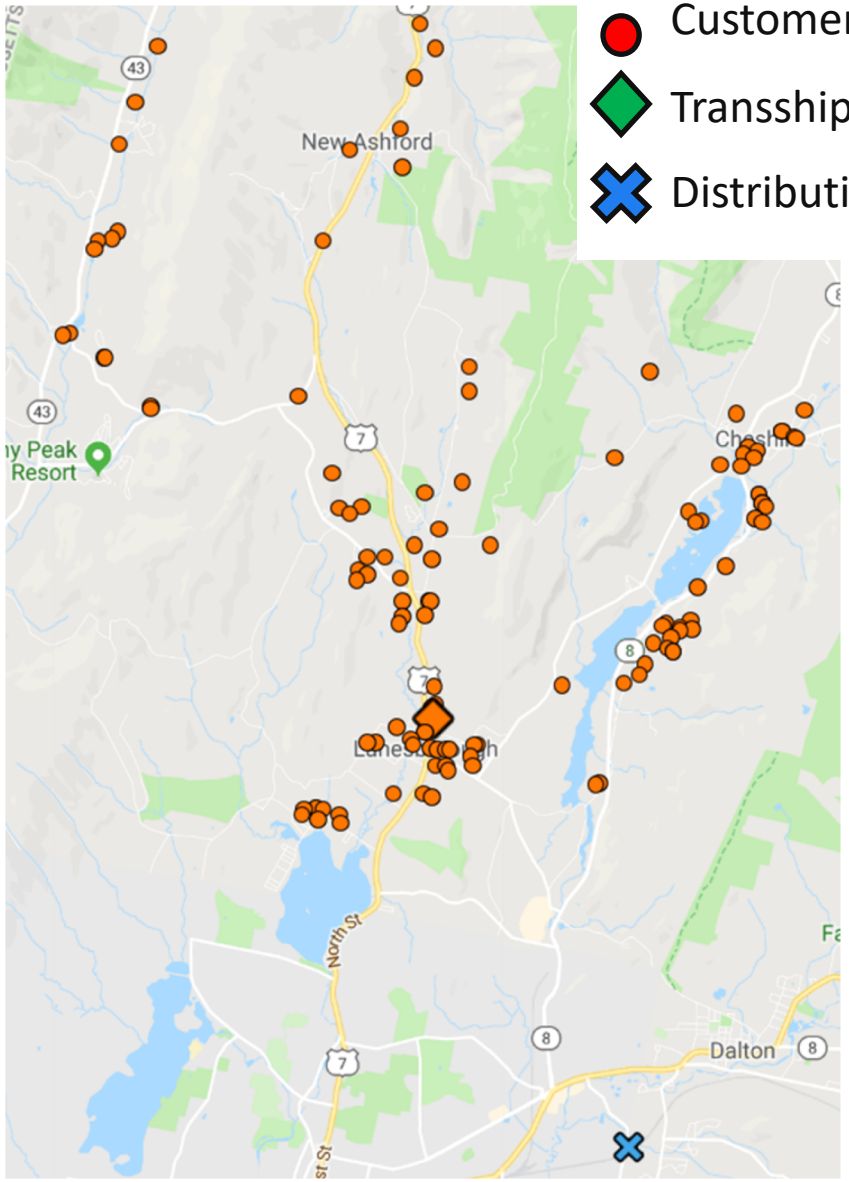
t_{ij} = *Time from TP to Customer*

t'_j = *Time from DC to TP*

α = *drone cost prioritization factor*

Transshipment Point Optimization Results





Customer

Transshipment Point

Distribution Center

Supply Chain MANAGEMENT

Scenario Parameter Ranges Tested

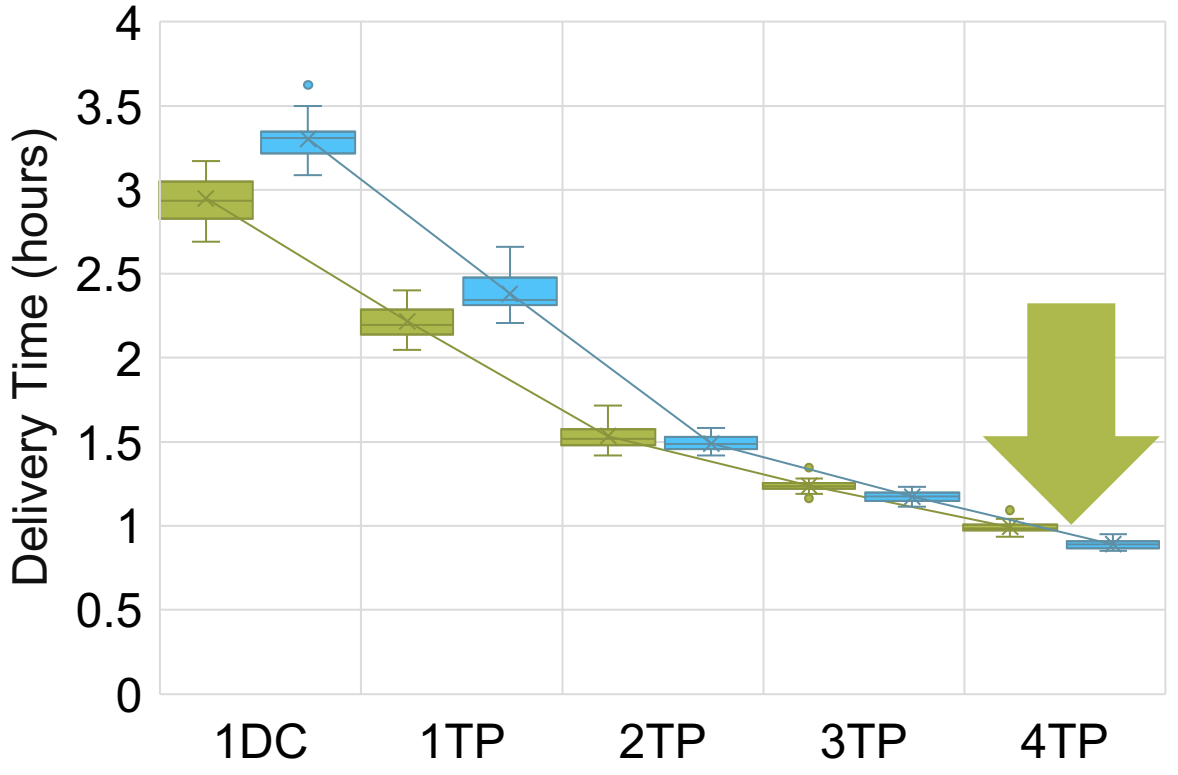


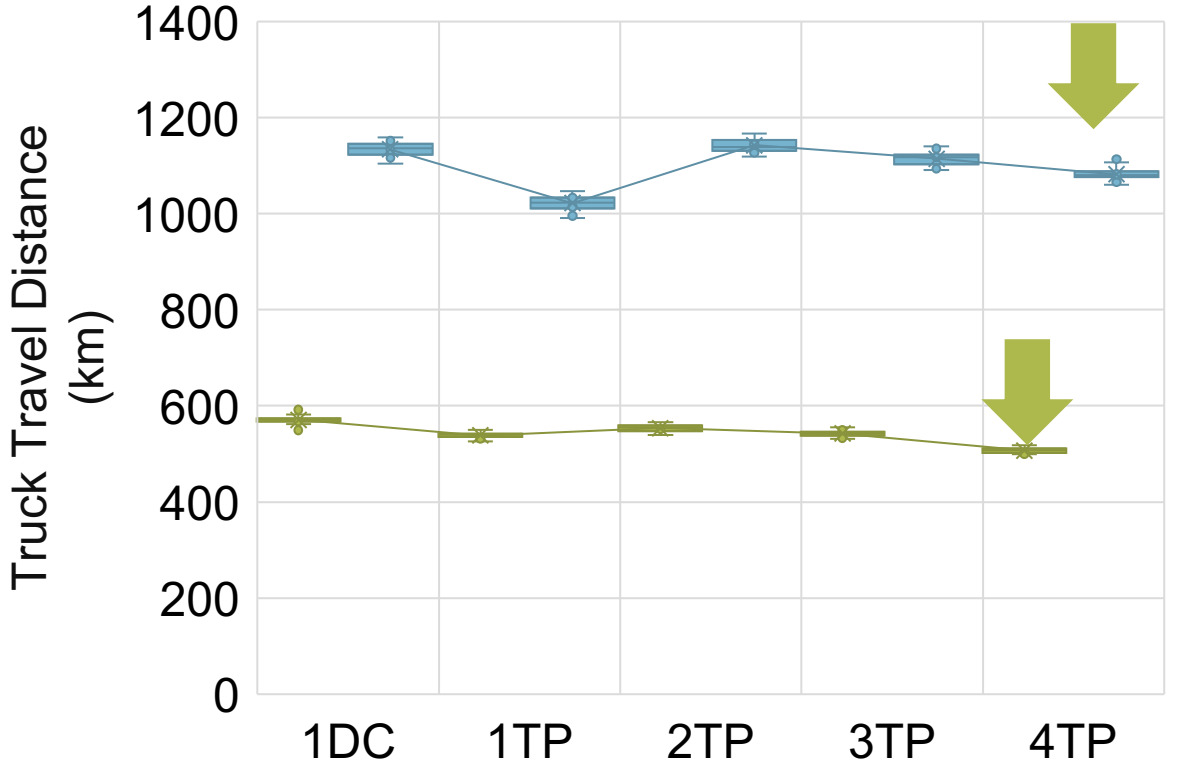


	Interarrival Time (minutes)	Number of Transshipment Points	Number of Trucks	Number of Drones	Drone Capacity (packages)	Drone Speed (km/hr)
Boston	1	0 to 4	5 to 9	3 to 7	4 to 8	40 to 60
	0.5	0 to 4	12 to 16	3 to 7	4 to 8	40 to 60
Pittsfield	18	0 to 5	1 to 5	1 to 5	5 to 9	40 to 60
	9	0 to 5	1 to 5	1 to 5	5 to 9	40 to 60

Simulation: Boston

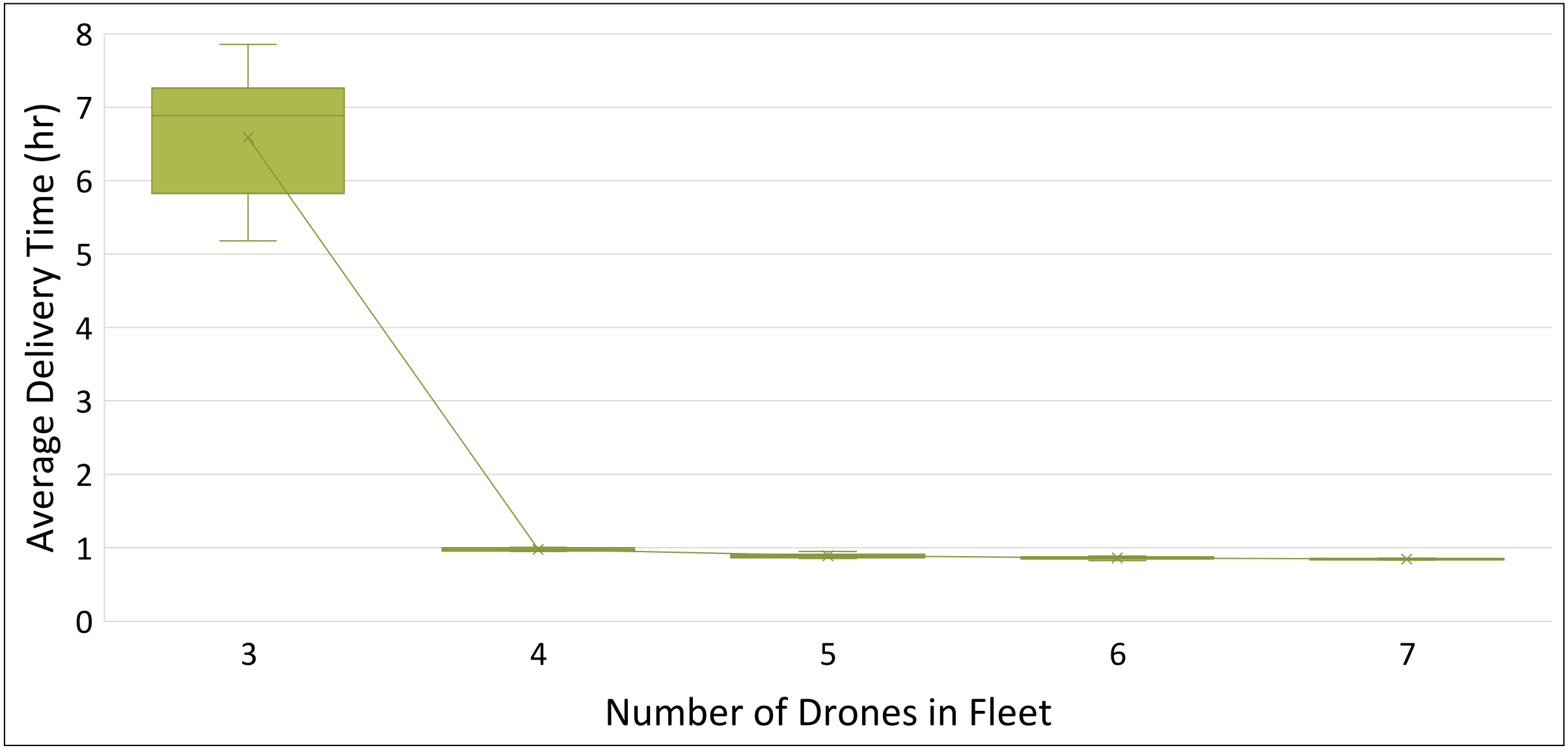
Delivery Time & Truck Distance for Varying Number of TPs



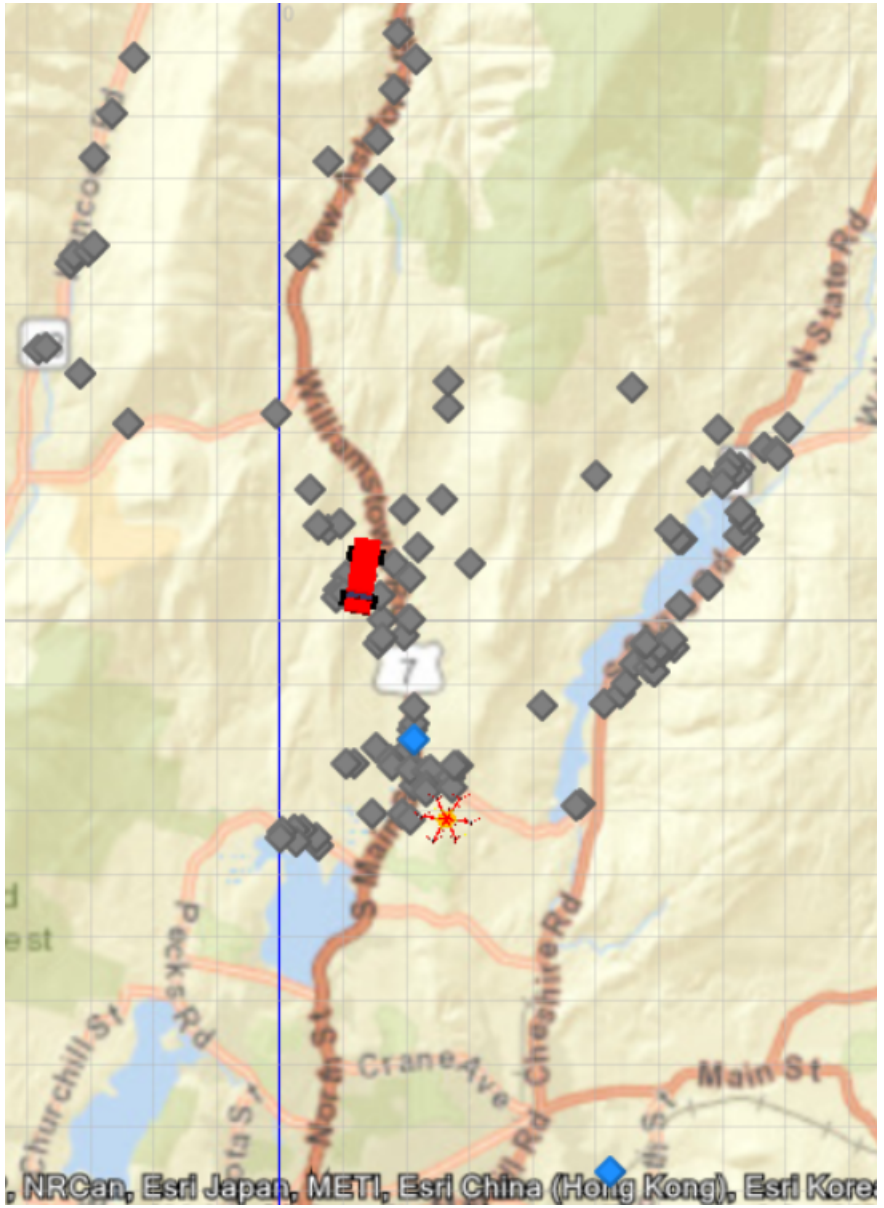


Interarrival Time (min.)	Transshipment Points	Number of Trucks	Number of Drones	Drone Cap. (packages)	Drone Speed (km/hr)
1	0 to 4	7	5	5	50
0.5	0 to 4	14	5	5	50

Delivery Time for Varying Number of Drones: IAT 0.5



Simulation: Pittsfield



Transshipment Point/DC

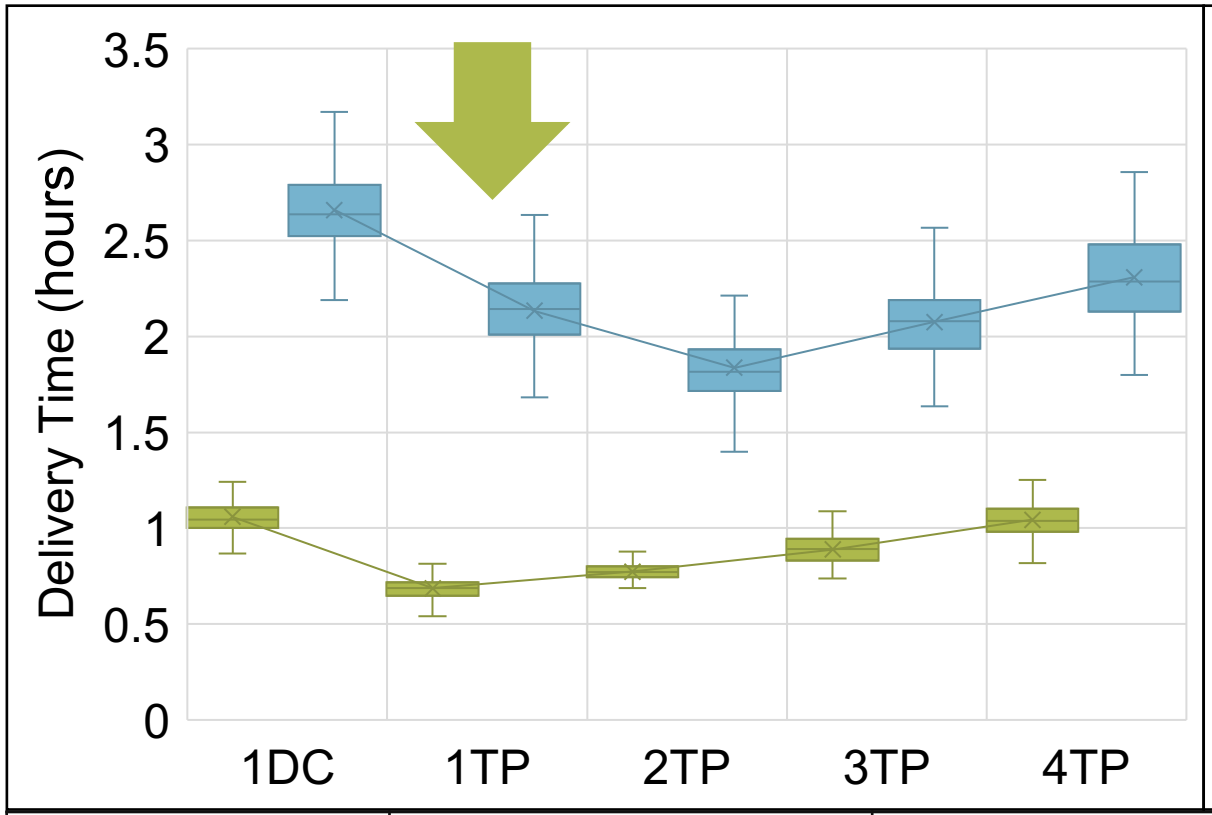
Delivery Point

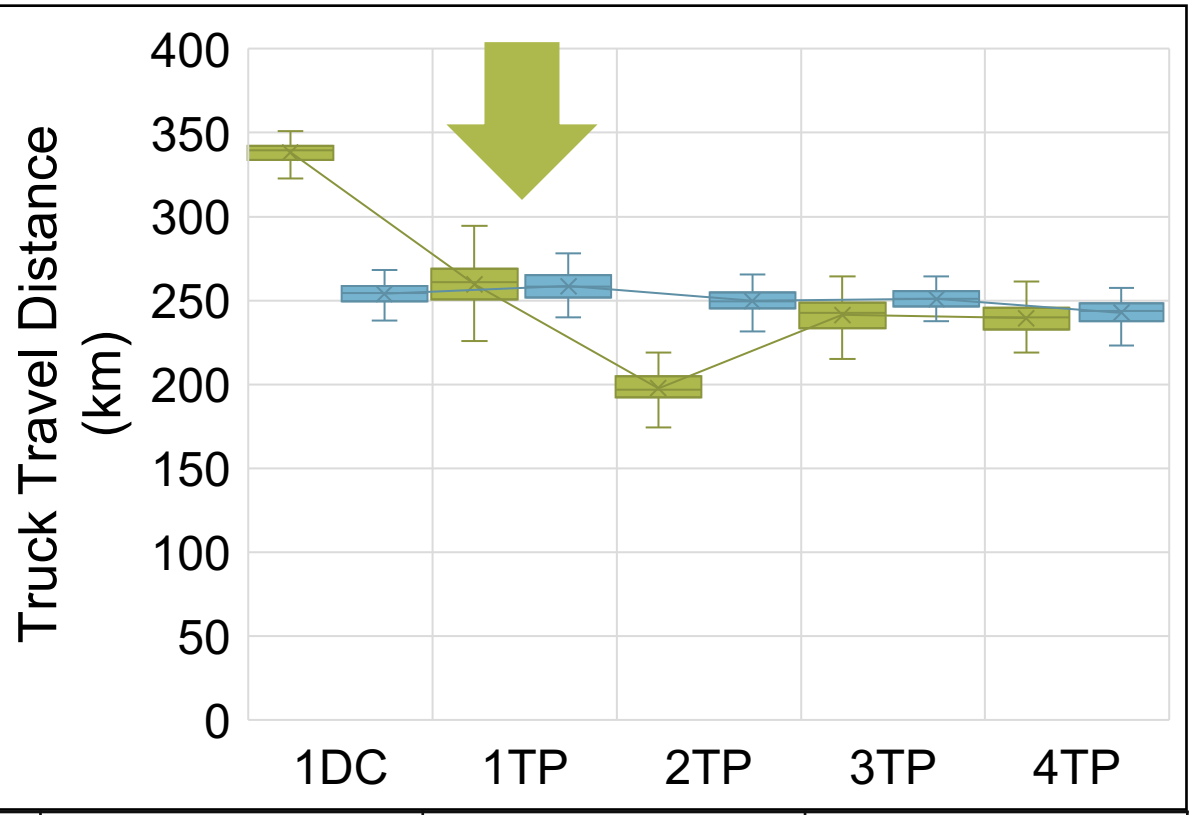
Truck

Drone

Supply Chain MANAGEMENT

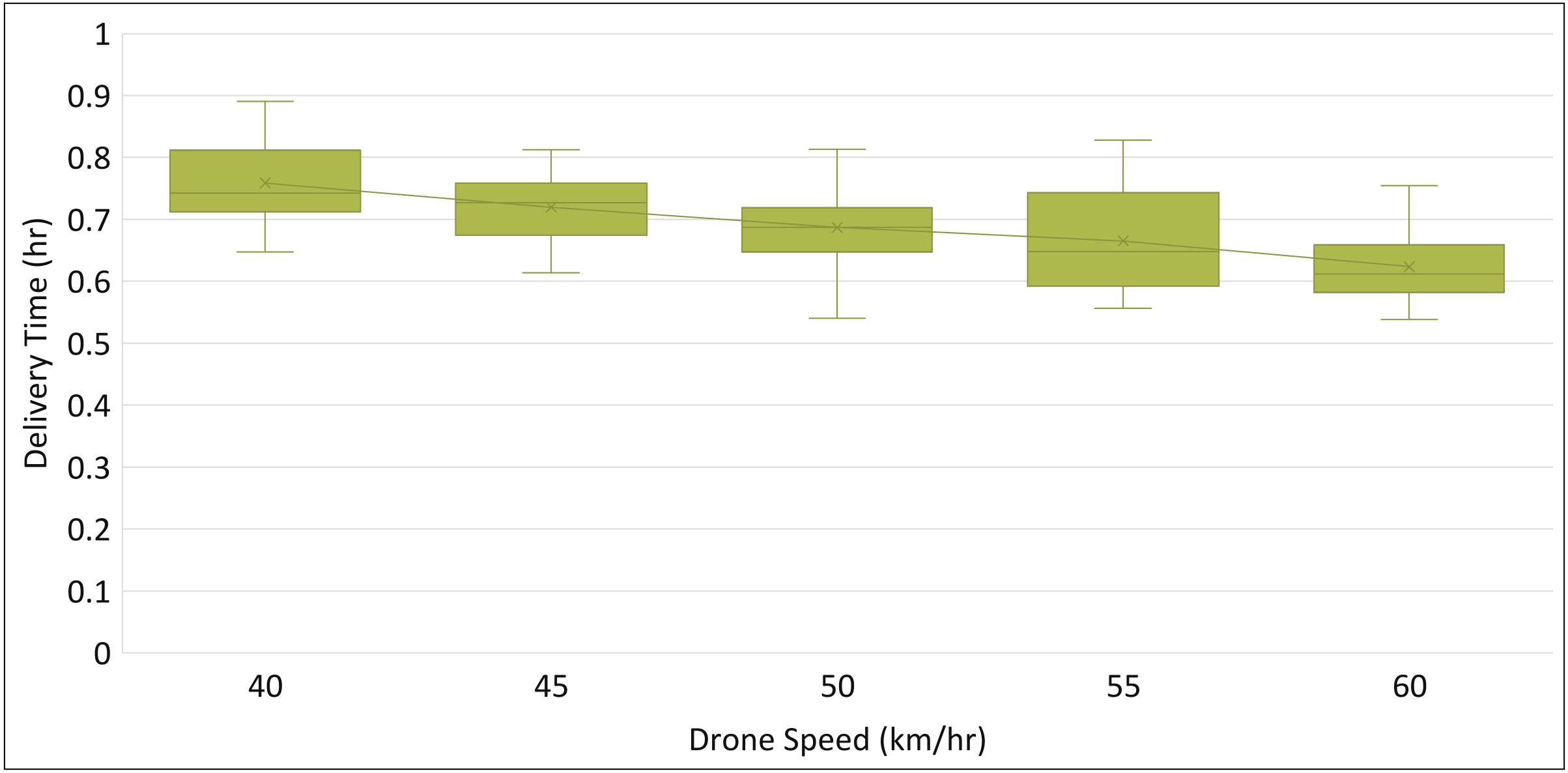
Delivery Time & Truck Distance for Varying Number of TPs





Interarrival Time (min.)	Transshipment Points	Number of Trucks	Number of Drones	Drone Cap. (packages)	Drone Speed (km/hr)
9	0 to 4	1	1	5	50
18	0 to 4	1	1	5	50

Delivery Times for Varying Drone Speeds: IAT 18



Conclusion

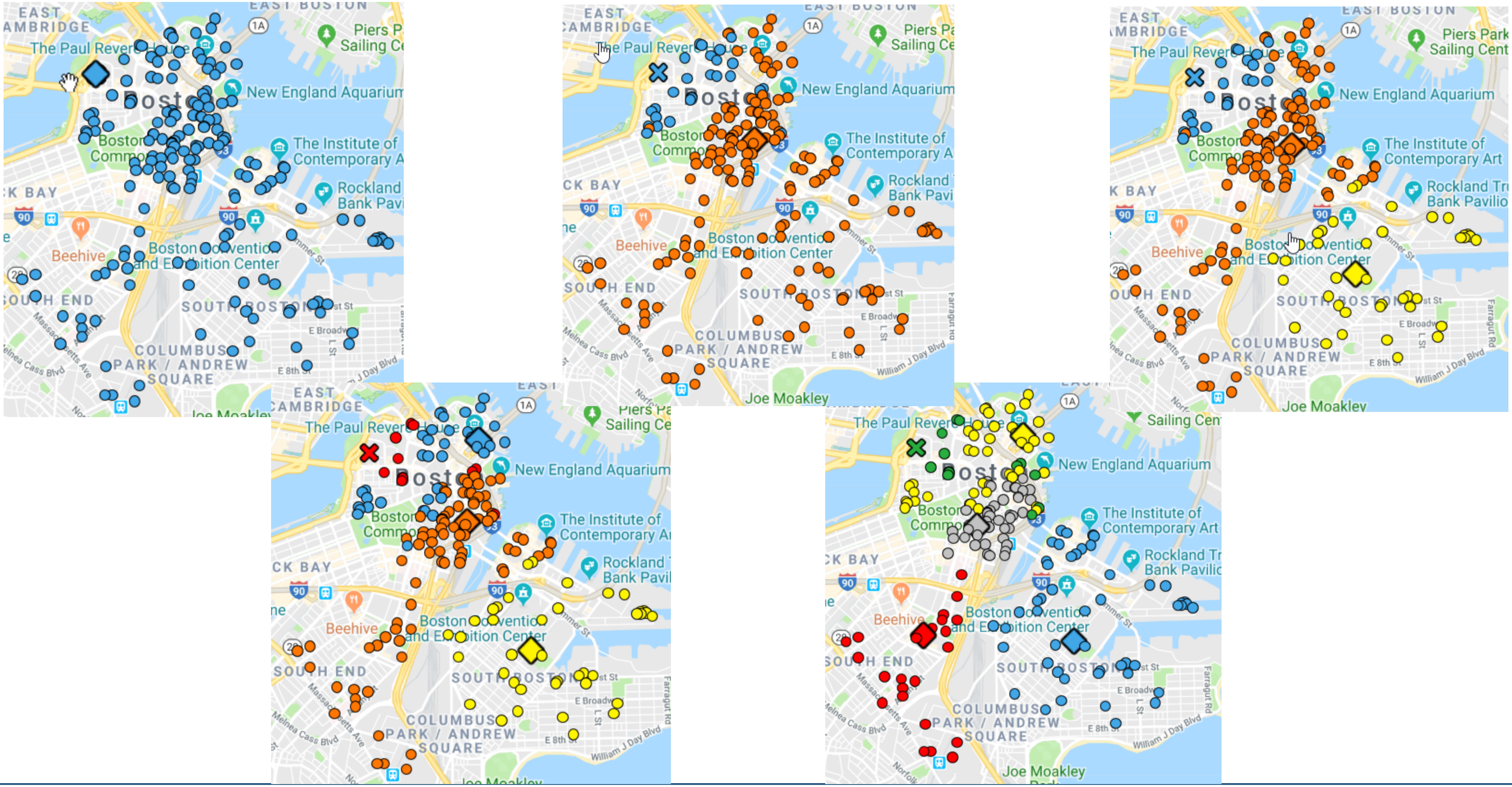
1. Using drones to resupply transshipment points will greatly reduce delivery times and distance traveled.
2. The number of drones is determined by the interarrival time of the orders, drone capacity, and speed.
3. When choosing the number of trucks, there is a tradeoff between delivery time and distance traveled.
4. More transshipment points and drones cannot always make the delivery times and distance traveled go down.

Future Research

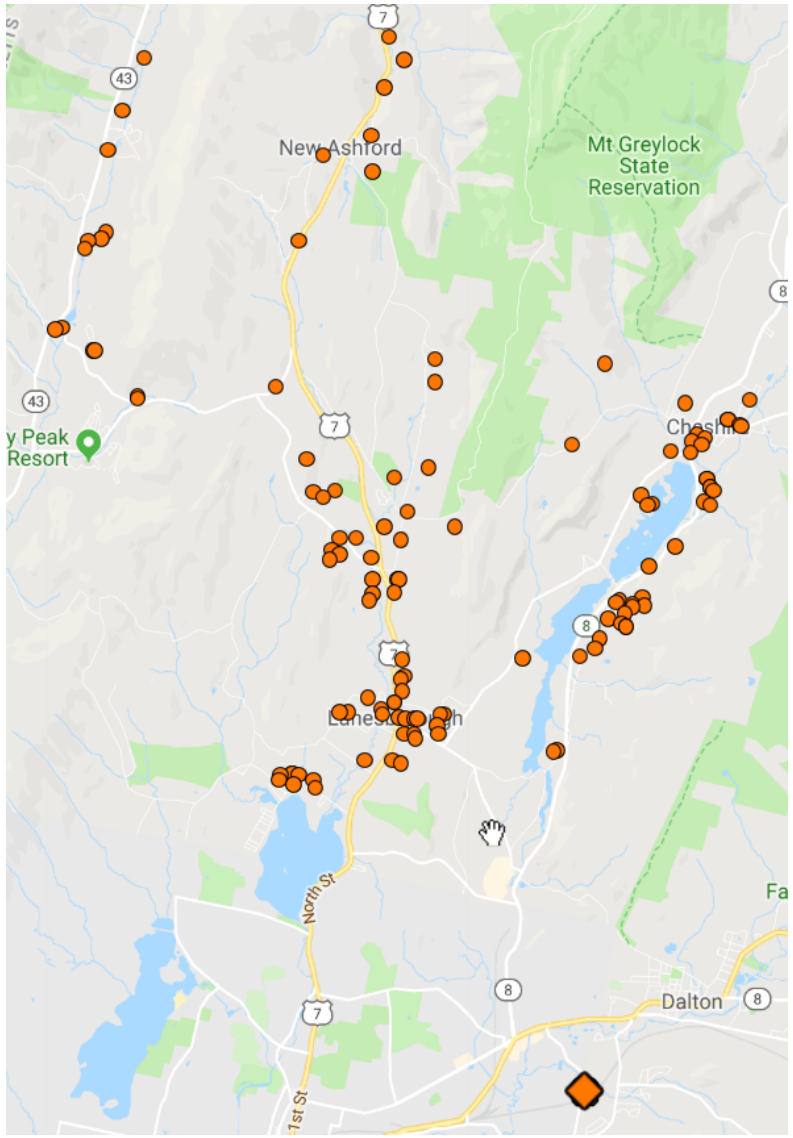
1. Use algorithm to better batch and select what packages to bring to the transshipment points.
2. Use more advanced Vehicle Routing algorithms to plan the truck routes.
3. Model Drones to Resupply Trucks
4. Add a deadline to package delivery times.

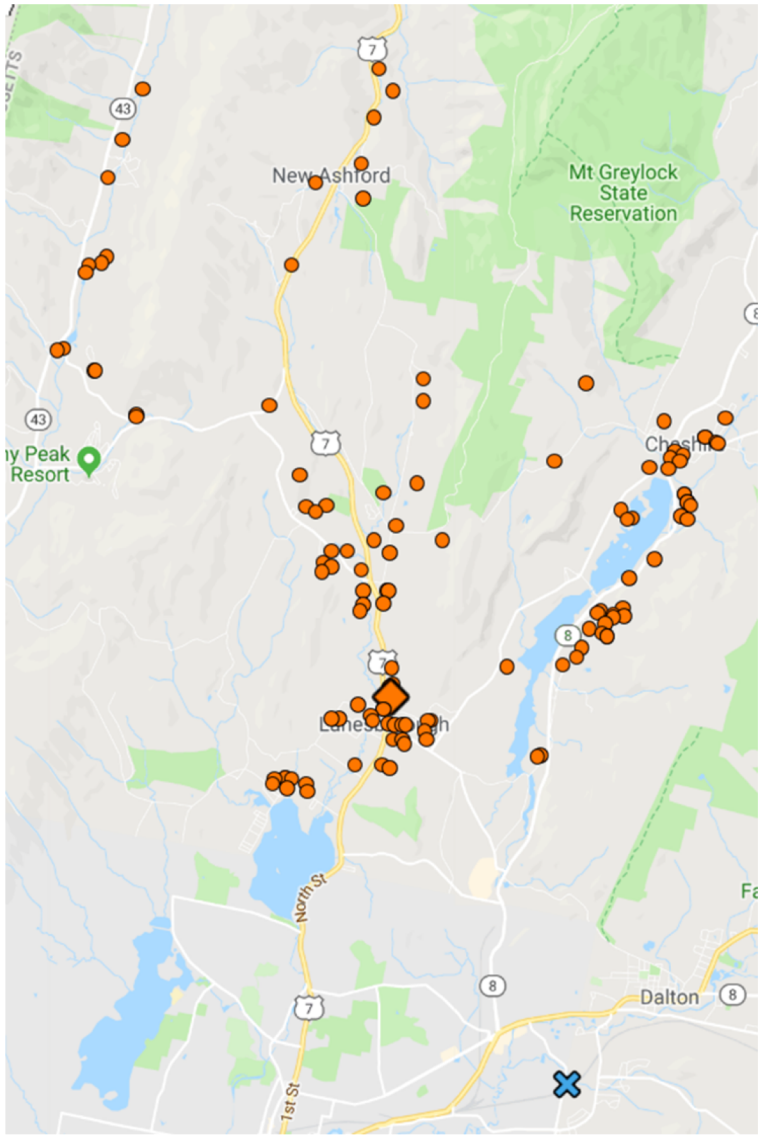
Questions?

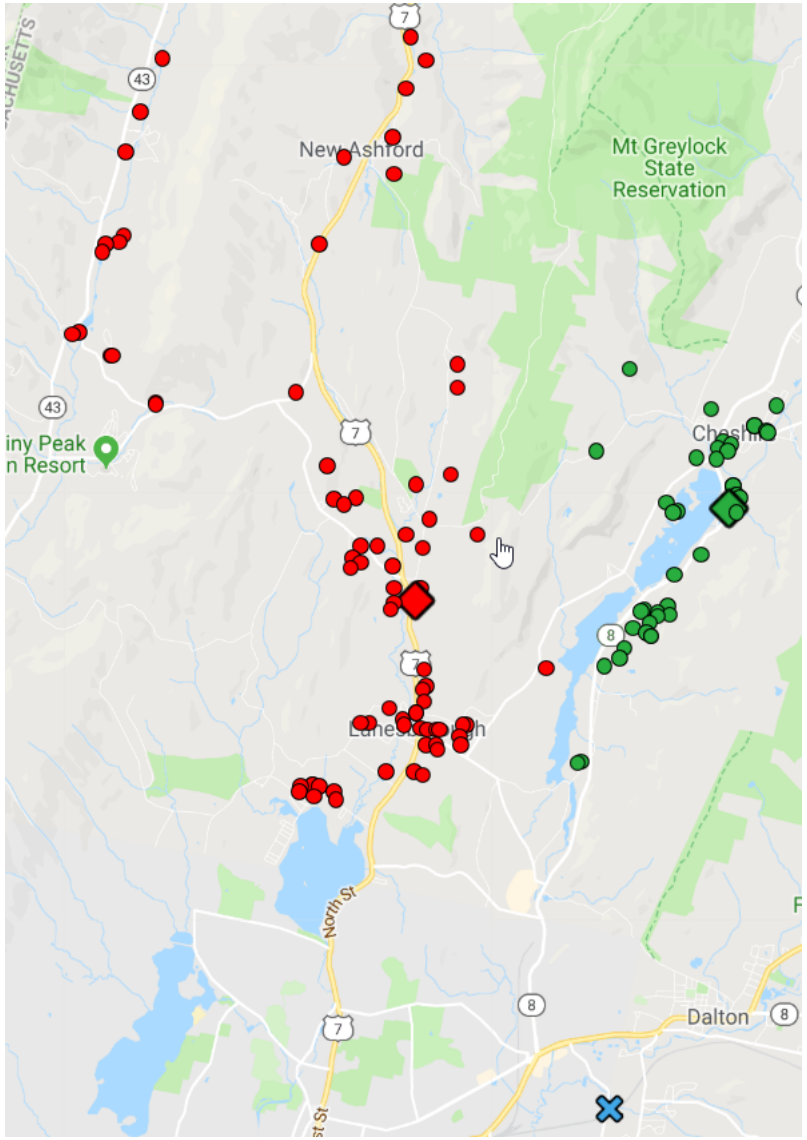
Boston: 0-4 Transshipment Points



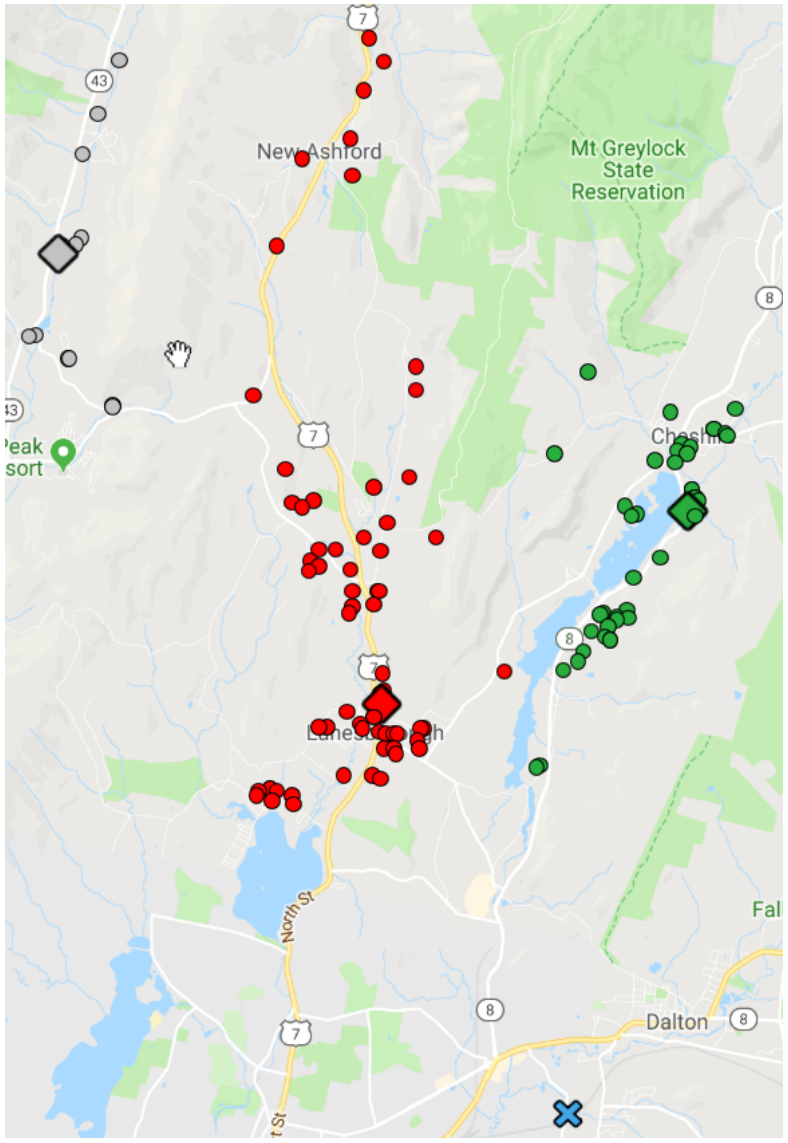
Pittsfield: 0, 1, and 2 Transshipment Points

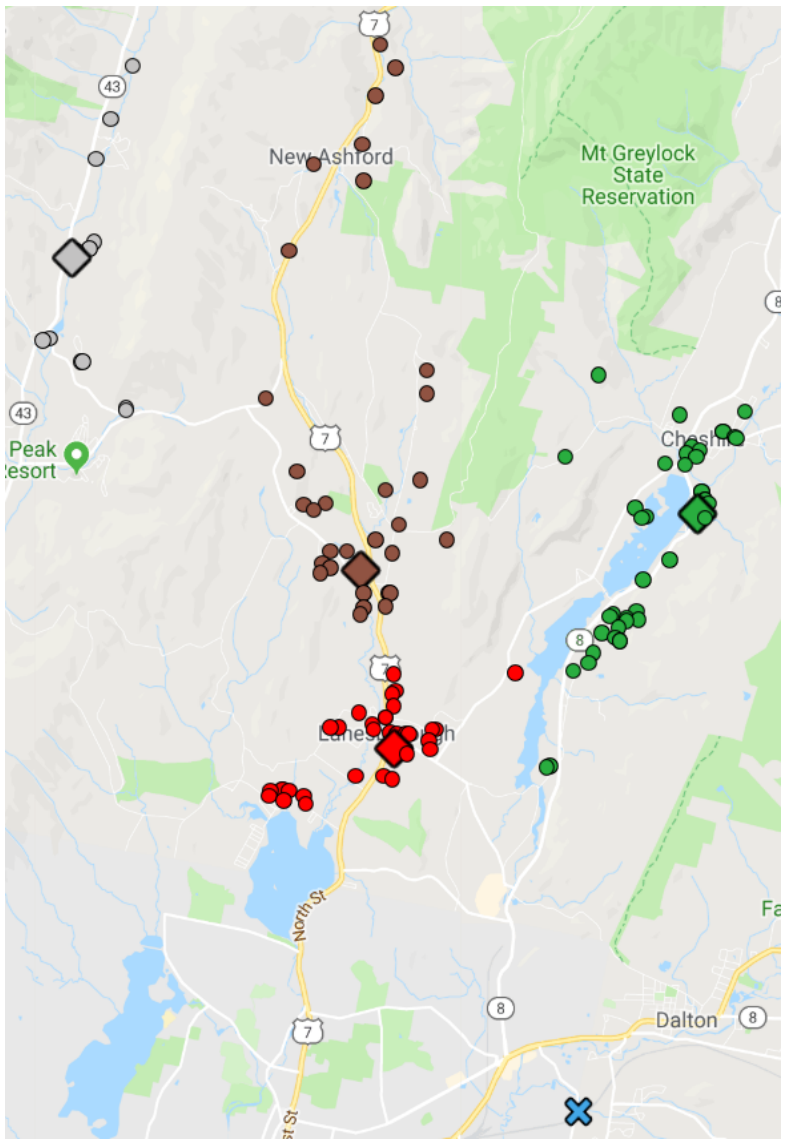


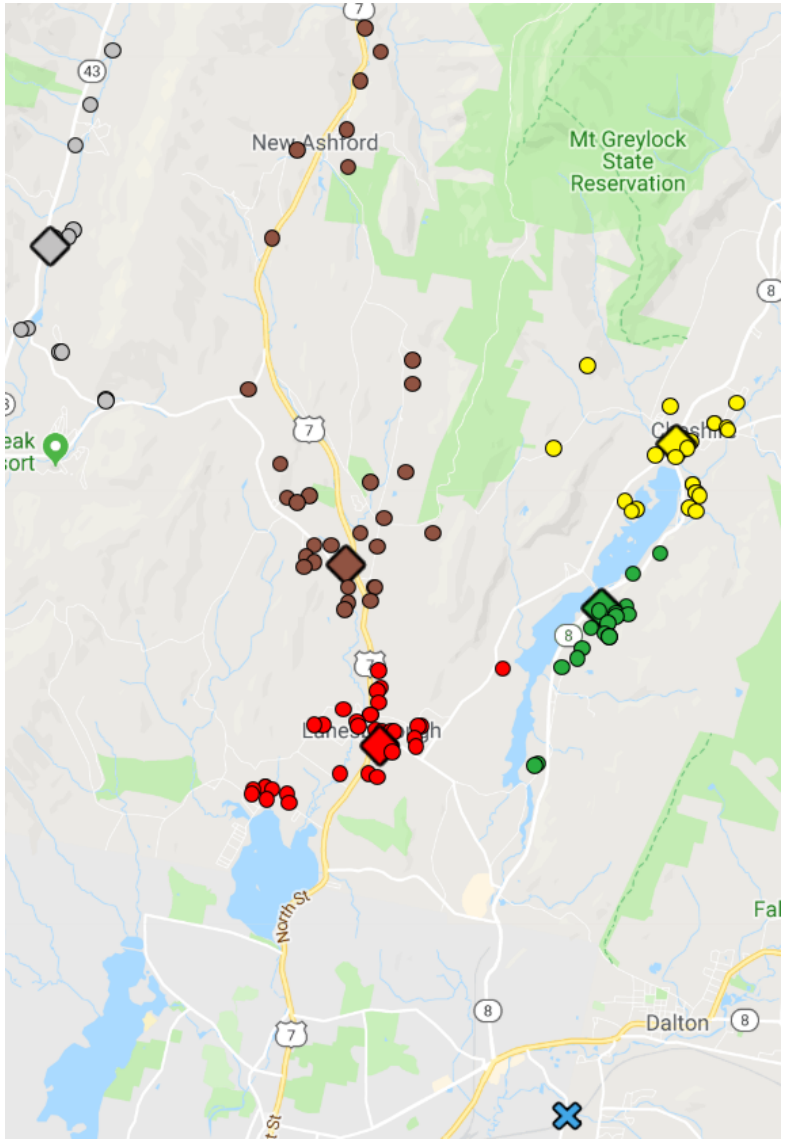




Pittsfield: 3, 4, and 5 Transshipment Points







Transshipment Point Optimization

$$Minimize \sum_i \sum_j x_{ij} \times (t_{ij} + \alpha \times t'_j)$$

$$\sum_j x_{ij} = 1 \qquad \forall i$$

$$\sum_j y_j = \beta$$

$$\sum_i x_{ij} \leq N \times y_j \qquad \forall j$$

$$x_{ij}, y_j \in \{0,1\}$$

Notation	Description
i	Index representing all customer locations.
j	Index representing all potential transshipment point locations.
α	Weighting for drone travel time compared to truck travel time.
β	Number of transshipment points in a scenario.
x	Decision variable for a transshipment point to a customer.
y	Decision variable for the number of transshipment point locations opened.
N	Total number of customers.
t	Time for a truck to drive from a transshipment point to a customer delivery address.
t’	Time for the drone to travel from the DC to a transshipment point.