Drone Delivery Systems Optimization Algorithm

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Outline

1. Problem
2. Methodology
3. Solution
4. Sensitivity Analysis
5. Summary of Results

1. Problem

TSP class problems for last-mile delivery

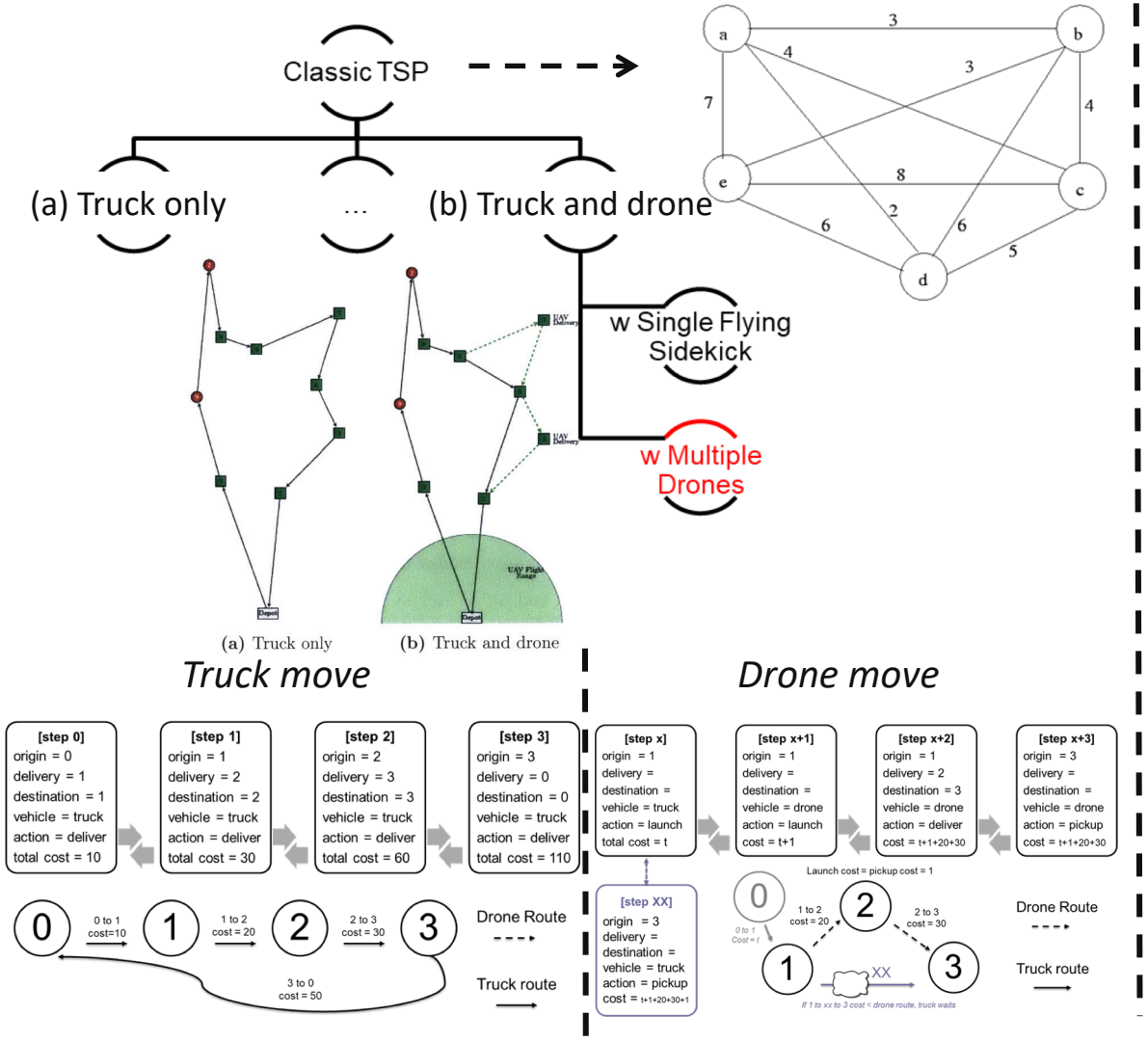
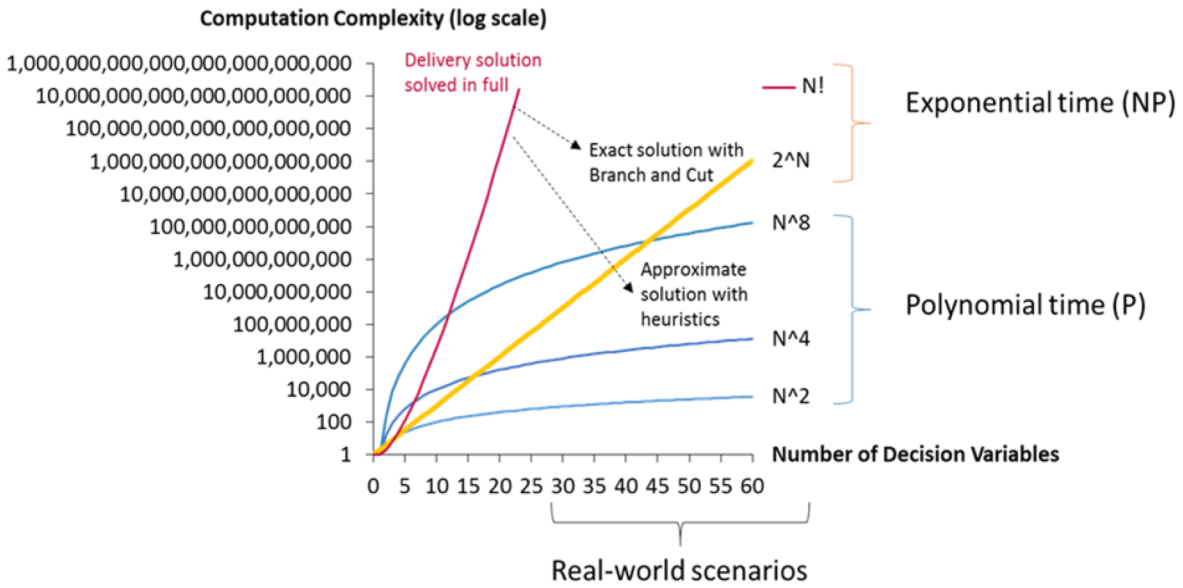


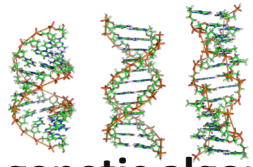
Illustration of NP computation complexity



Motivating questions

- What is the benefit of truck and drone delivery over truck alone?
- How sensitive is benefit to drone flying range?
- How sensitive is benefit to number of drones?
- How sensitive is benefit to drone/truck speed differential?
- How sensitive is benefit to customer location distribution?

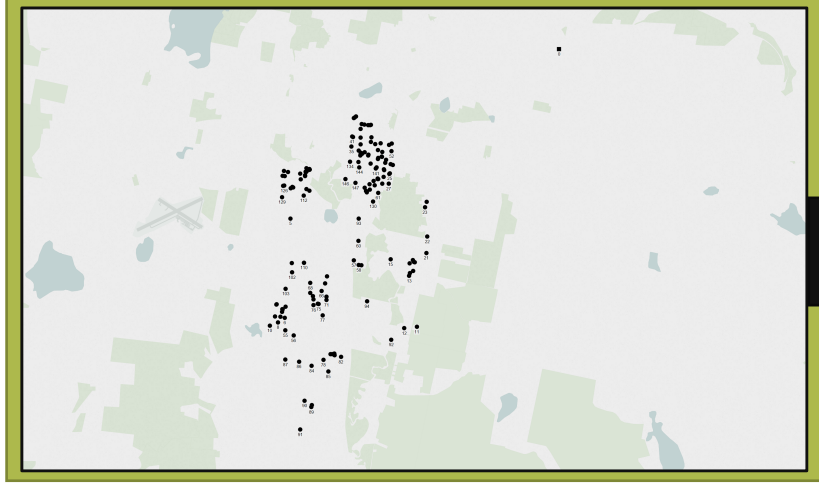
2. Methodology



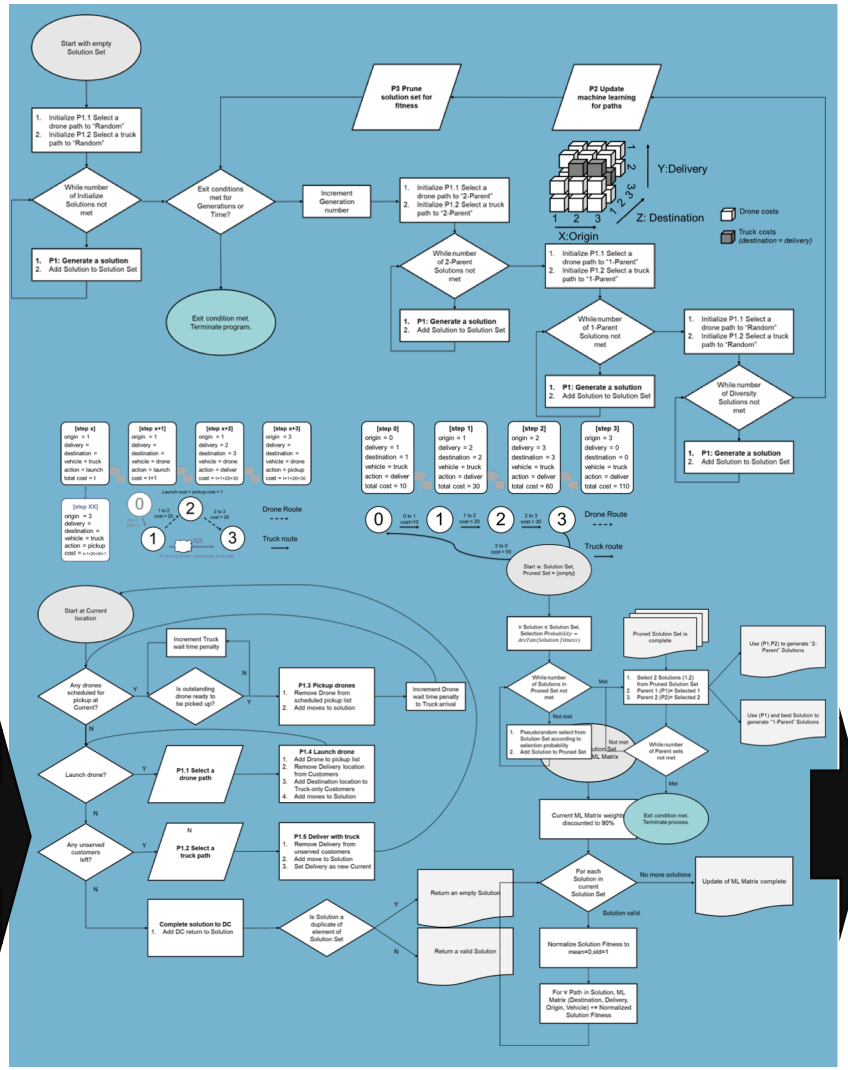
Wide variation of problems

Customer instance:
Map: Megacity Logistics Lab (MLL) map 9
Density: Urban – 3.32 km between customers
Customers: 158
DC: 1

Problem parameters:
Truck: 1
Drones: 4
Truck speed: 40 km/hr
Drone speed: 60 km/hr
Drone range: 45 mins

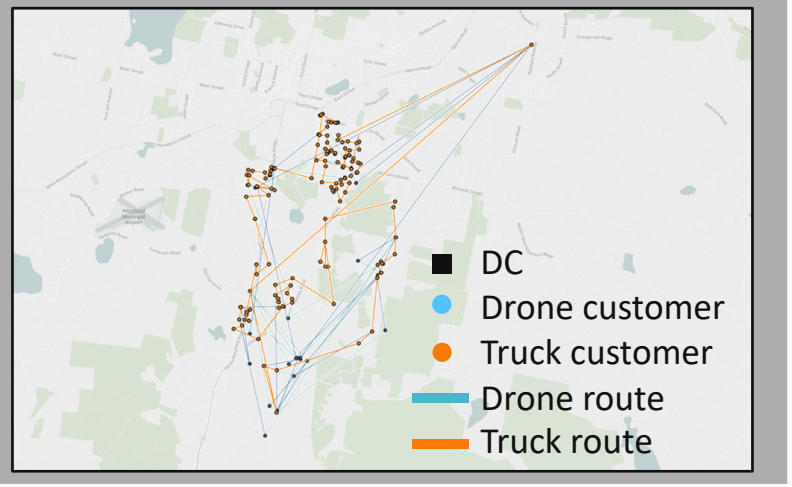


Single complicated genetic algorithm



"Good enough" solution

				Vehicle			
				Travel		Wait	
Step	From	To	Action	drone	truck	drone	truck
0	0	158	deliver		6.81		0.00
3	158	16	deliver	0.00		0.00	
4	16	51	pickup	6.47		0.00	
5	158	157	deliver		0.02		0.00
8	157	72	deliver	0.00		0.00	
9	72	112	pickup	8.72		0.00	
10	157	47	deliver		0.24		0.00
11	47	46	deliver		0.19		0.00
14	46	139	deliver	0.00		0.00	
15	139	96	pickup	2.85		0.00	
16	46	156	deliver		0.31		0.00
19	156	86	deliver	0.00		0.00	
20	86	95	pickup	12.32		0.00	
21	156	155	deliver		0.04		0.00
22	155	140	deliver		0.34		0.00
23	140	141	deliver		0.05		0.00



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3. Solution

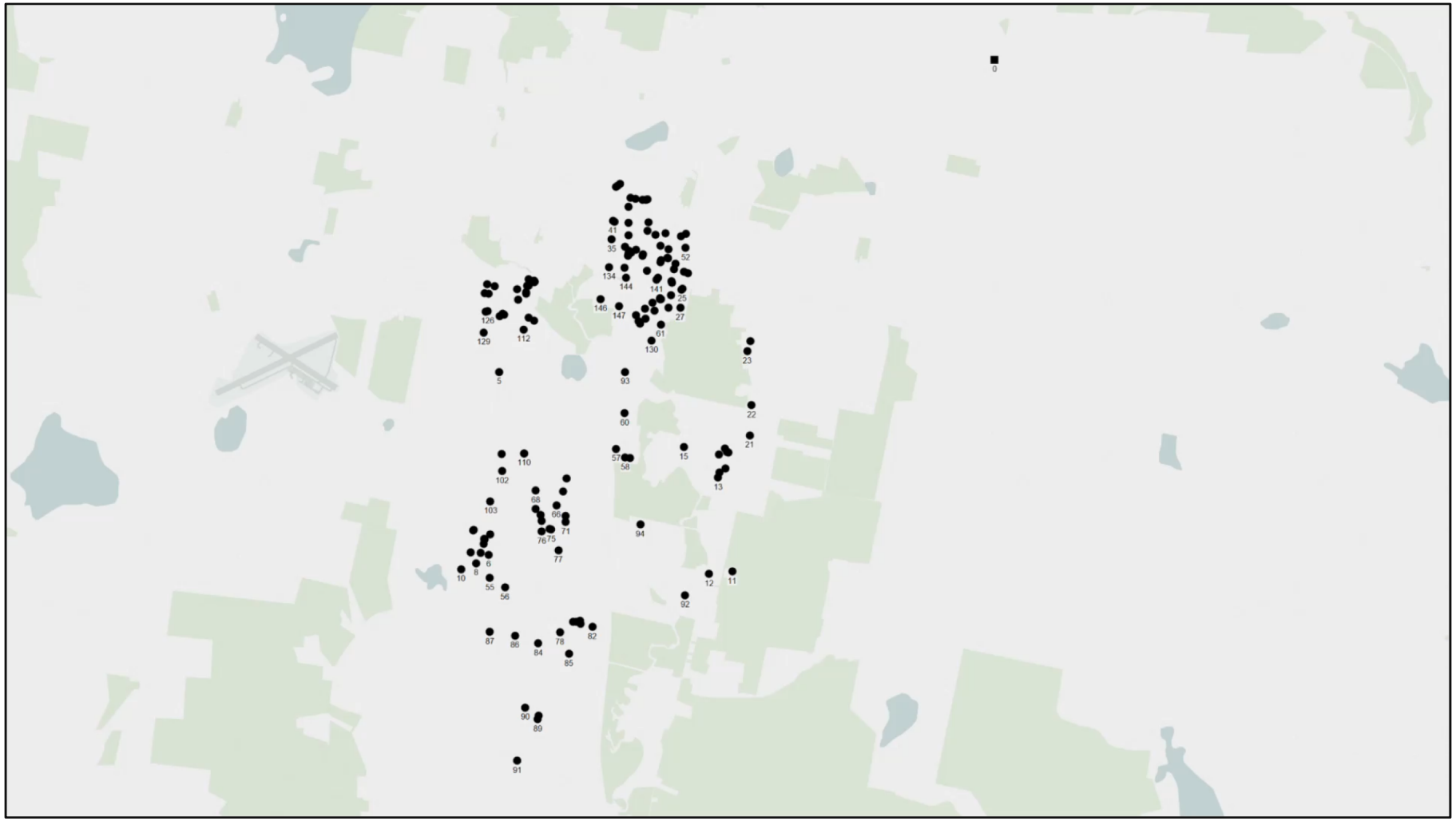
Optimization of MLL map 9 at 48 minutes of CPU execution

Key

- DC
- Drone customer
- Truck customer
- Drone route
- Truck route

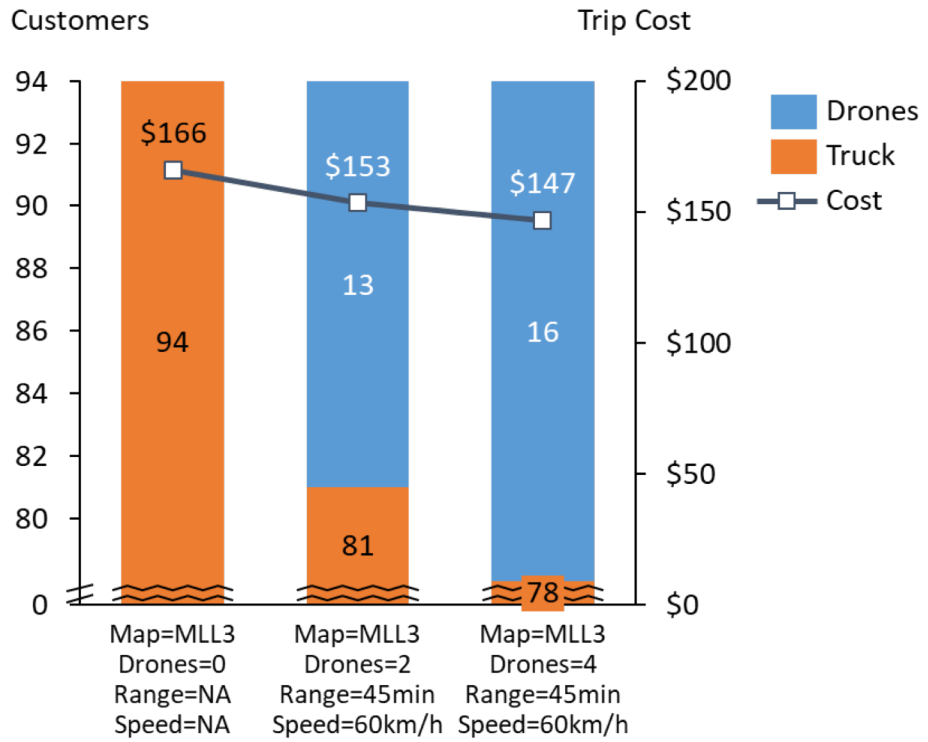
Customer instance:
Map: MLL map 9
Density: Urban
Customers: 158
DC: 1

Problem parameters:
Truck: 1
Drones: 4
Truck speed: 40 km/hr
Drone speed: 60 km/hr
Drone range: 45 mins
Drone movement: Road
Truck travel: $0.542/min
Truck idle: $0.124/min
Drone travel: $0.002/min

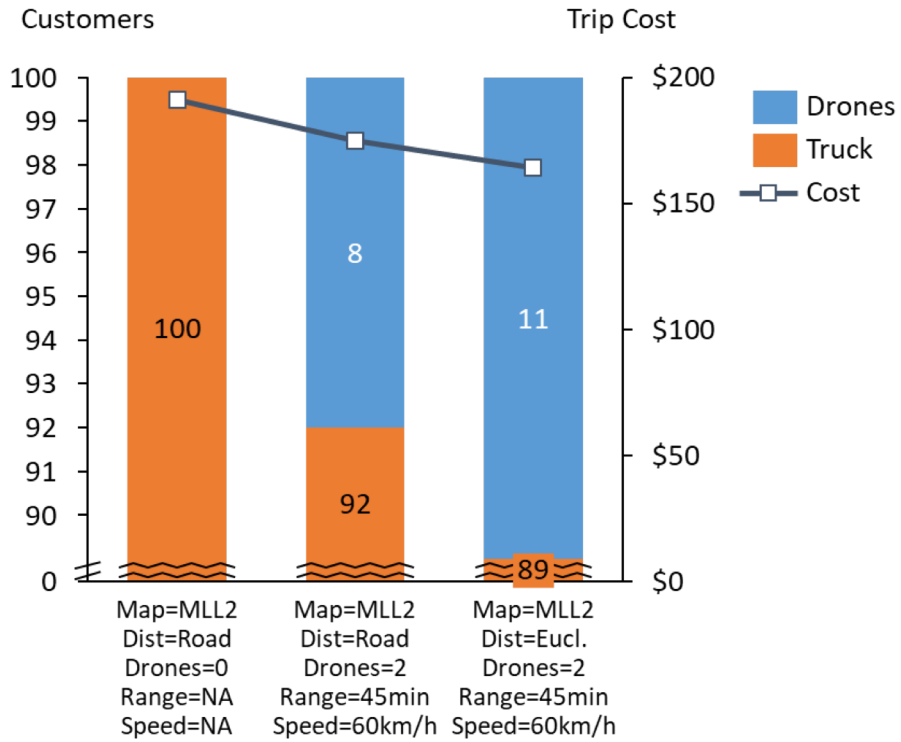


4. Sensitivity Analysis (1 of 2) – capacity and method

Drone availability analysis for MLL Map 3

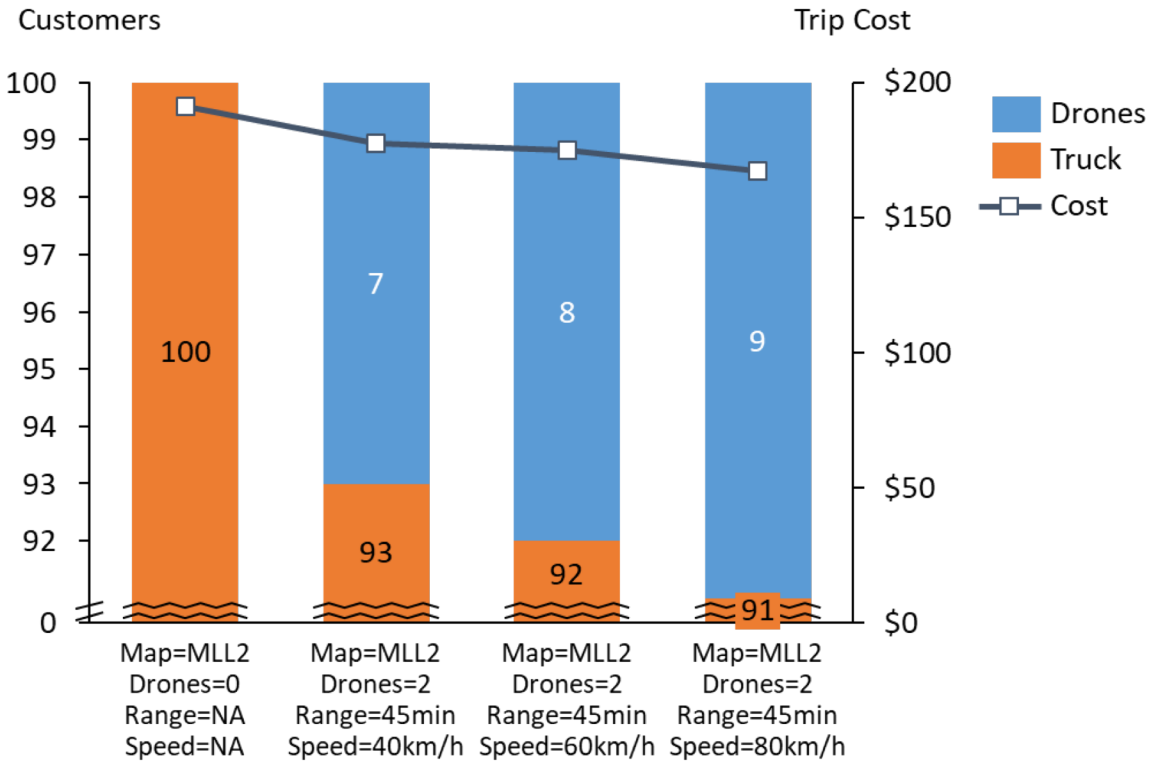


Mode of movement analysis for MLL Map 2

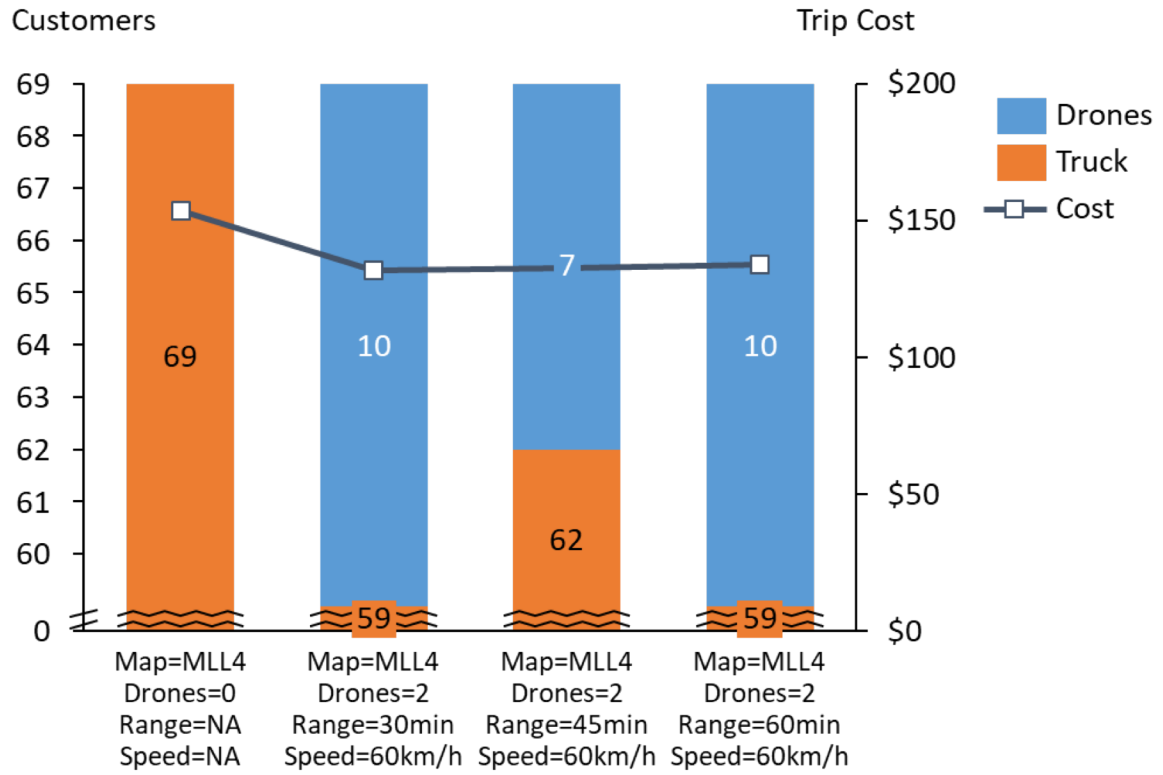


4. Sensitivity Analysis (2 of 2) – speed and range

Drone speed analysis for MLL Map 2



Drone range analysis for MLL Map 4



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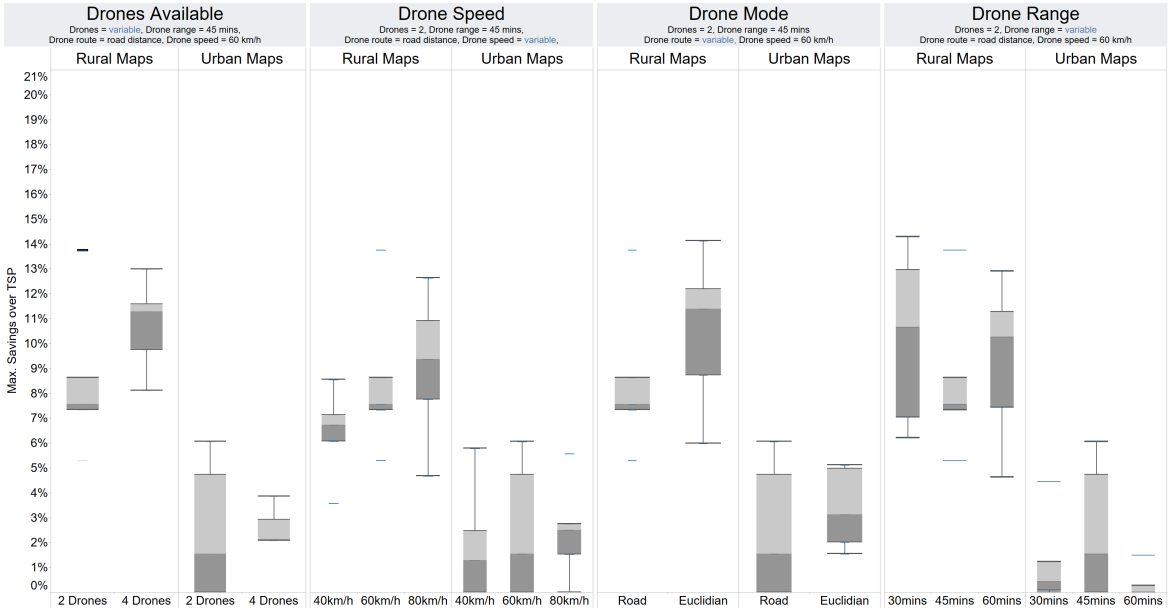
5. Summary of Results

Summary of parameters tested

Parameters	Truck capacity (drones)	Drone range (mins)	Truck speed (km/h)	Drone speed (km/h)	Drone travel method
Speed	2	45	40	40/60/80	Road route
Endurance	2	30/45/60	40	60	Road route
Availability	0/2/4	45	40	60	Road route
Drone Mode	2	45	40	60	Road/Euclidean

Summary of analysis of results



Key observations:

- A truck efficiently working in conjunction with drones will typically be better than truck alone
- Being able to travel directly in Euclidean distances is a large opportunity for drones
- Faster drones are generally better; increasing returns
- More drones are generally better but quickly sees diminishing returns
- Difficult to realize savings when dense (urban) and drone launch/retrieval operations are slow