The Flying Sidekick Travelling Salesman Problem with Integrated Pickup and Delivery (FSTSP-PD)

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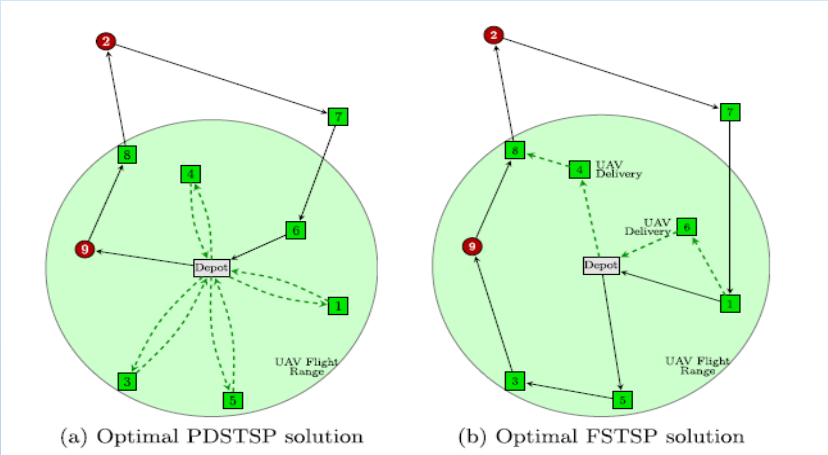
Introduction

Benefits of pickup function

- Increase utilization of drones
- Reduce inconvenience of returning goods
- Potentially serve more customers in a given area
- According to Steve Dennis (2017), e-commerce has a return rate between 25 - 40 percent

Introduction (Con't)

- This MILP formulation is based on The Flying Drone Sidekick Traveling Salesman Problem from Murray and Chu (2015)



- Adds constraints to allow a drone to collect parcels from the same or another customer after delivering parcels

Drone function

The drone operation for each trip can be either

- Delivery only
- Pickup only
- Delivery ***and*** Pickup

Assumptions

1. One truck and one drone.
2. Both truck and drone have constant speeds.
3. The drone can carry only one parcel at a time.
4. The drone cannot service all customers.
5. All customers must be served by either the drone or the truck.

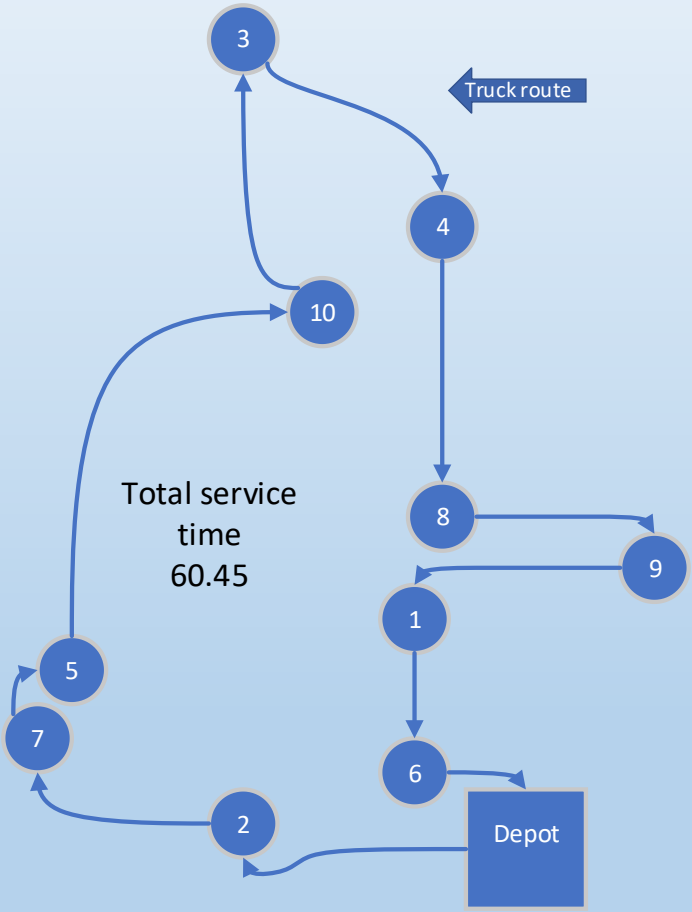
Assumptions (Con't)

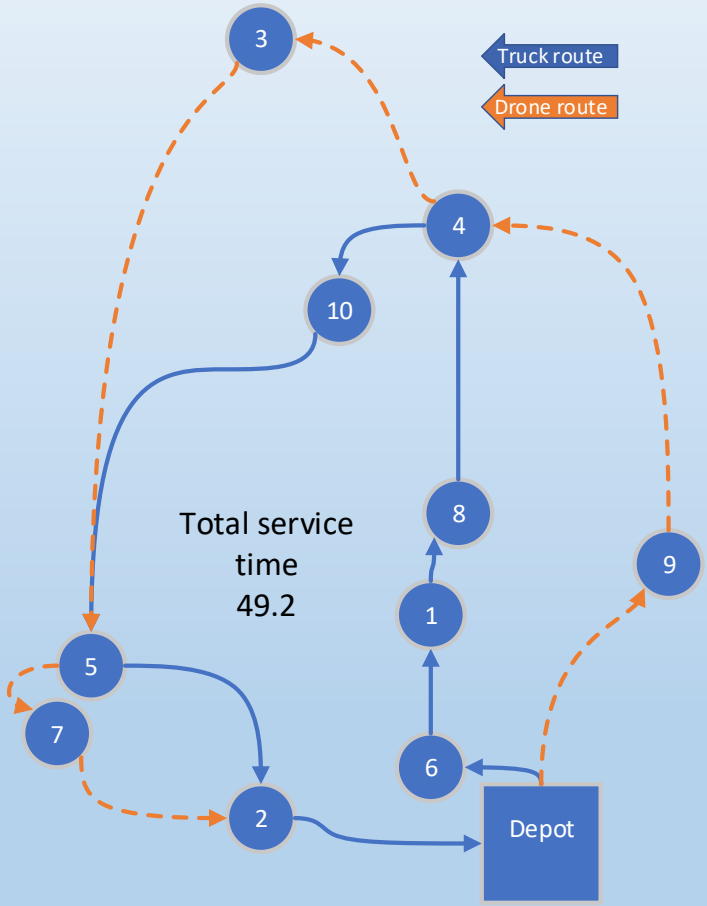
6. The drone can depart from the truck at any customer location or the depot.
7. The drone can rendezvous with the truck at any customer location or at the depot.
8. If the drone arrives at the rendezvous point before the truck, it must hover until the truck comes.

Assumptions (Con't)

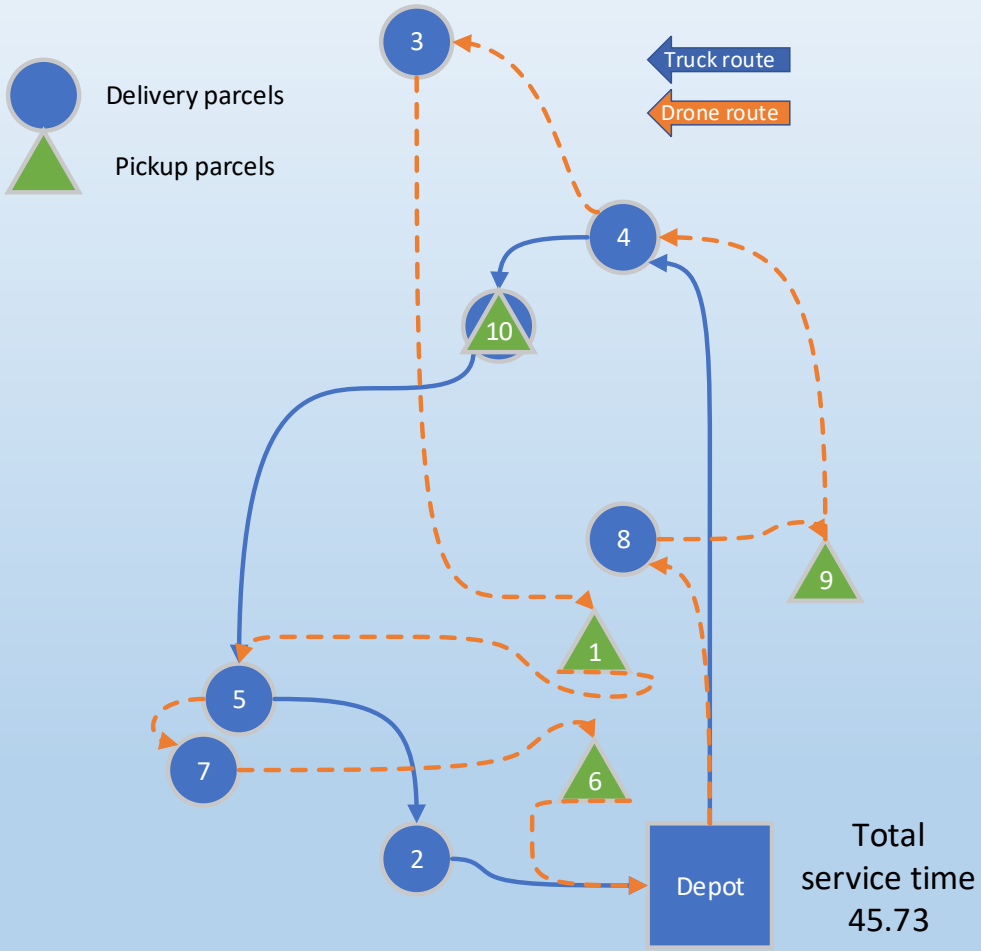
9. The drone uses the same amount of energy traveling or hovering.
10. The drone must leave customer locations immediately after picking up or delivering a parcel.
11. The drone has to leave before the truck leaves at any customer location but not at the depot.

Truck and Drone Routes





Truck and Drone Routes (Cont.)



Experiment

- Performance measurement: Total service time of FSTSP-PD vs. TSP or FSTSP.
- Parameters: the number of pickup customers, drone endurance, and speed of the drone.
- The proposed model is NP-hard; we limited the experiments to instances of 10 customers.
- Solved by CPLEX Python API.

Experiment (Con't)

	Factors	Levels
1	Number of pickup customers	0, 1, 2, 3, 4 customers
2	Drone endurance	20 and 40 minutes
3	Drone speed	35 and 45 miles per hour

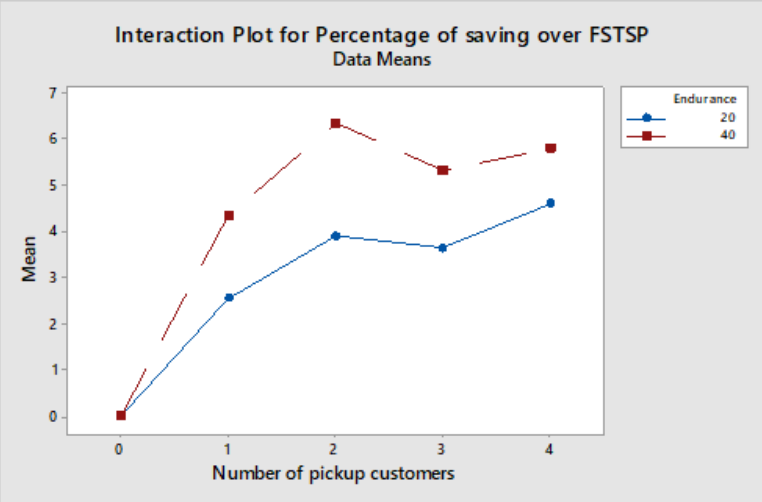
Experimental Results: Number of pickup customers

Number of pickup customers	Percentage of total service time savings of FSTSP-PD over			
	Standard TSP		FSTSP	
	Mean	Maximum	Mean	Maximum
0	16.23	34.94	0.00	0.00
1	18.07	42.34	2.54	11.37
2	19.11	43.70	3.89	13.45
3	18.92	43.70	3.63	13.45
4	19.62	43.70	4.59	20.82

Where drone endurance and drone speed are 20 and 35, respectively

Experimental Results: Drone Endurance

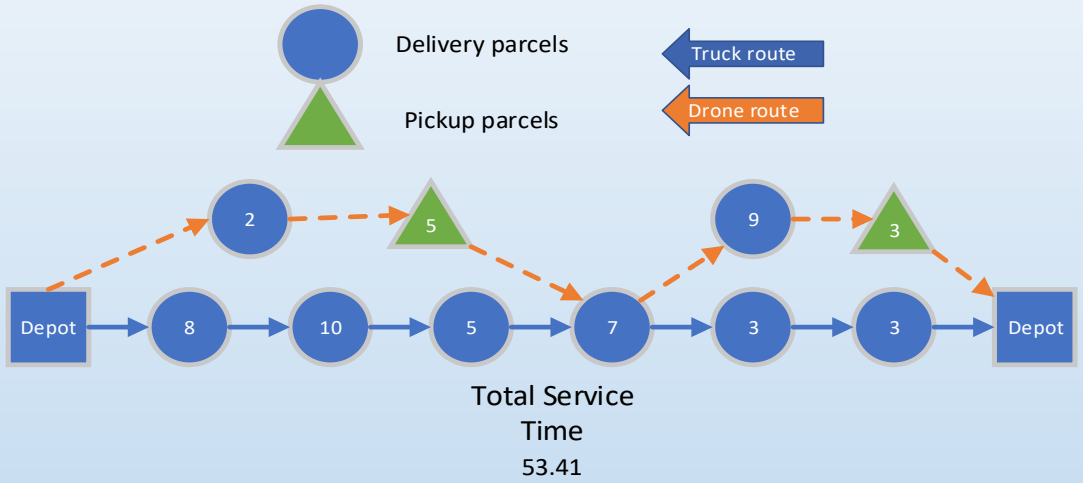
Number of pickup customers	Drone endurance (Minutes)	Percentage of total service time savings of FSTSP-PD over			
		Standard TSP		FSTSP	
		Mean	Maximum	Mean	Maximum
0	20	16.23	34.94	0.00	0.00
	40	19.48	34.95	0.00	0.00
1	20	18.07	42.34	2.54	11.37
	40	22.83	42.35	4.34	11.37
2	20	19.11	43.70	3.89	13.45
	40	24.42	43.70	6.34	13.46
3	20	18.92	43.70	3.63	13.45
	40	23.61	43.70	5.32	13.46
4	20	19.62	43.70	4.59	20.82
	40	23.87	43.70	5.78	22.59



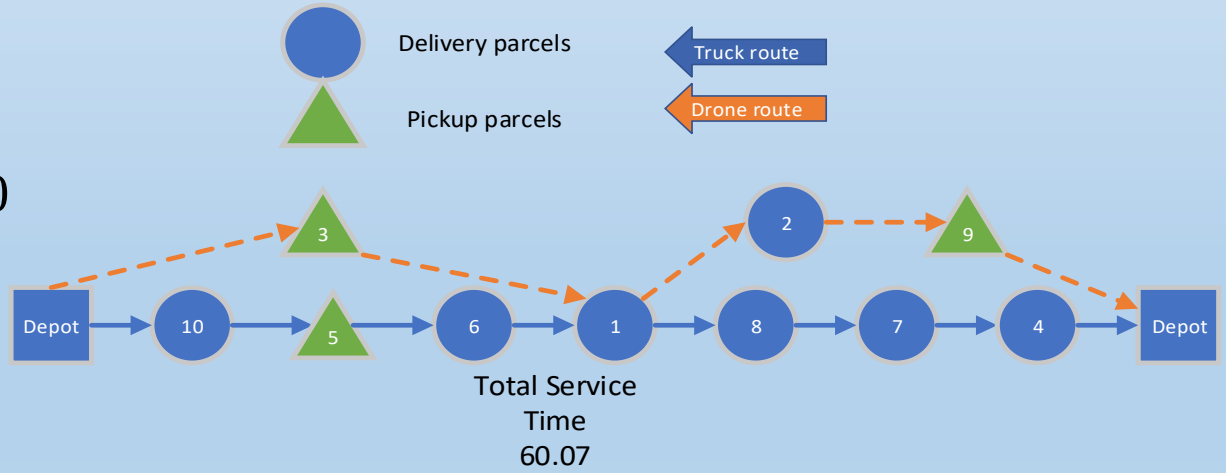
Where drone speed is 35 mph

Experimental Results

Number of Pickup Customers	Total Service Time (minutes)
0	60.7433
1	54.3950
2	53.4183
3	60.0737
4	60.0737

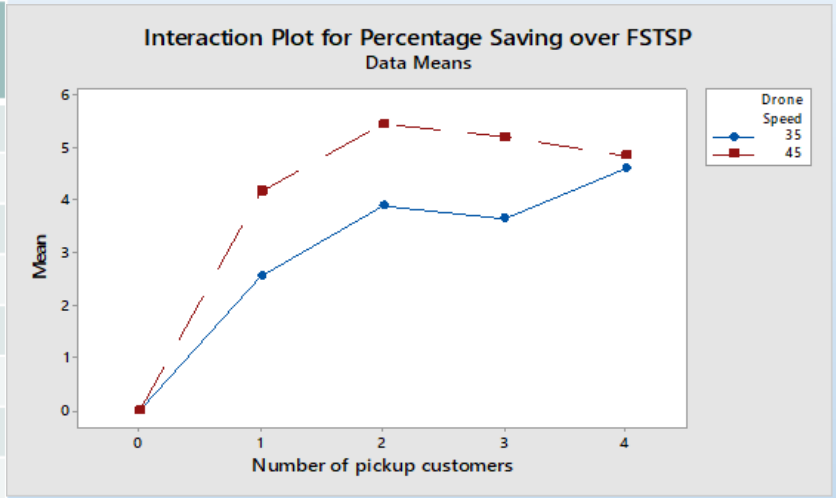


Where drone endurance: 40 and drone speed: 45



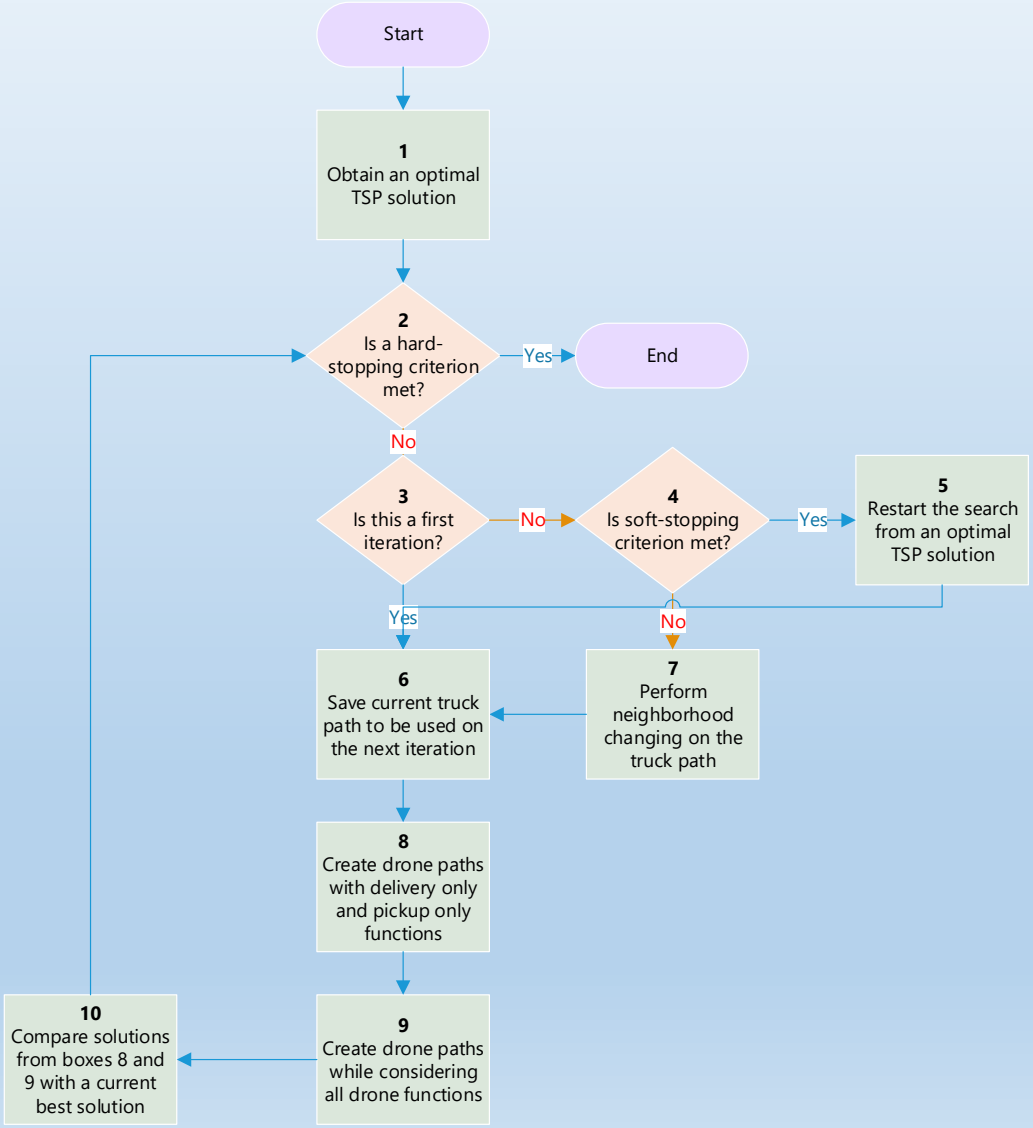
Experimental Results: Drone Speed

Number of pickup customers	Drone Speed (mph)	Percentage of total service time savings of FSTSP-PD over			
		Standard TSP (%)		FSTSP (%)	
		Mean	Maximum	Mean	Maximum
0	35	16.23	34.94	0.00	0.00
	45	20.26	39.57	0.00	0.00
1	35	18.07	42.34	2.54	11.37
	45	23.38	42.35	4.15	12.34
2	35	19.11	43.70	3.89	13.45
	45	24.36	43.70	5.43	12.34
3	35	18.92	43.70	3.63	13.45
	45	24.18	45.91	5.19	12.34
4	35	19.62	43.70	4.59	20.82
	45	23.79	45.91	4.84	18.38



Where drone endurance is 20 minutes

FSTSP-PD Heuristic



FSTSP-PD Heuristic (cont.)

Advantage of FSTSP-PD Heuristic

- Runs 96 times faster than MILP
- Achieves the average optimality gap of 1.7 percent
- Is very reliable regardless of instance and seed

Conclusions

- Total service time can be reduced up to 7 percent compared to the standard FSTSP.
- Only drone endurance and number of pickup customers impact reducing total service time.
- The most important factor is the number of pickup customers.
- Increasing the number of pickup customers might lead to poor total service time.

Upcoming Research

- Multiple trucks and drones
- Stronger heuristics
- Bi-objectives to include operation costs