Drone Delivery in last-mile distribution

**Motivation / Background**

Drone has emerged as an innovative and viable business solution for commercial last-mile distribution due to lower cost structure (~80% cost reduction), reduced delivery time, farther reach in poor infrastructure areas and less CO2 emission.

Drone delivery is relevant for e-commerce as ~80% of packages delivered by e-commerce weigh less than 5 lbs. Over the past 5 years, major logistic and e-commerce companies have been experimenting with drones as last-mile delivery system. Major companies that tested drone as last mile delivery:

- 2013 Dec
- 2015 Mar
- 2015 Mar
- 2016 Apr
- 2016 Nov
- 2016 Nov
- 2017 Dec
- 2017 Dec

**Key Question / Hypothesis**

Problem statement resembles classic routing problem: “Find the optimal set of routes for a fleet of trucks and drones to serve a set of customers”

Drone routing problem is more complicated than classical Vehicle Routing Problem (VRP) due to drone-specific constraints, such as drone operational limit (e.g. distance covered, drone endurance, payload) and unique technical characteristics of drone delivery (e.g. one package per trip, no pick-up, no night-time operation).

**Relevant Literature**

- Ham A. 2018. Integrated scheduling of m-truck, m-drone and m-depot constrained by time-window, drop-pickup, and m-visit using constraint programming. Transportation research part C 91 (2018) 1-14

**Methodology**

Our project will evaluate the optimal design and operational performance of four different drone delivery models, using real-life last-mile truck delivery data.

A Memetic Algorithm, an extension of Genetic Algorithm, is developed and used to optimize delivery routes of drones and trucks in all the four models.

3 different objective functions (e.g. minimize return time, last customer wait time and total waiting time) and different operating parameters (e.g. drone range, # of drones/trucks) are run to identify the optimum routes.

**Sensitivity analysis**

Sensitivity analyses based on Memetic Algorithm for 4 different drone delivery models with different objective functions

**Exected Contribution**

Reference framework for drone application in last-mile delivery.

Initial Analyses and Results

Initial analyses were run on a reduced dataset to minimize return time to depot, based on different # of drones and flight endurance. Baseline scenario: 2 drones, 1 truck & 30 mins flight endurance.

Sensitivity analysis

**Table: Initial Analyses and Results**

<table>
<thead>
<tr>
<th>Model</th>
<th>Customers served, %</th>
<th>Number of drones</th>
<th>Flight endurance, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>100%</td>
<td>2 drones</td>
<td>20 mins</td>
</tr>
<tr>
<td>Model 2</td>
<td>50%</td>
<td>3 drones</td>
<td>30 mins</td>
</tr>
<tr>
<td>Model 3</td>
<td>100%</td>
<td>4 drones</td>
<td>40 mins</td>
</tr>
<tr>
<td>Model 4</td>
<td>100%</td>
<td>5 drones</td>
<td>50 mins</td>
</tr>
</tbody>
</table>

Reference framework for drone application in last-mile delivery.

**Diagram: Initial Analyses and Results**

- Number of drones
- Flight endurance
- Return time to depot

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