MUSA FINAL PROJECT OUTLINE

Atharva Ranade (atharvar@design.upenn.edu) ,

Suryakiran Prabhakaran (suryajp@design.upenn.edu)

GITHUB PAGES: https://suryajps.github.io/Spatial-Analysis-for-Drone-vs-Truck-Deliveries-/

Spatial Analysis of Drone vs Truck Deliveries to compare CO_2 Emissions

Introduction

The project is drawn from a research paper published by author, Anne et al. at the University of Washington, titled-- *"Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing CO2 emissions in the delivery service industry".* The paper studies CO2 emissions caused by mid-size delivery trucks for deliveries between warehouses and households, contrasts the findings with average energy required (translated to emissions) if replaced with drone deliveries. The study draws out scenarios based on proximity to deliveries within incremental radius from one point.

Our final project seeks to conduct a similar analysis on two sites, Manhattan NYC was chosen as a dense urban condition and Yonker's county was chosen for studying a suburban condition. The project seeks to establish connections, correlations and premise for further research. Although there are various limitations to the scope of this study, we have tried to match the spatial scenarios to realistic conditions. We also did not get access to a dataset which provided actual delivery information on the number of deliveries made or distances traveled by UPS trucks. Hence the analysis is limited by many assumptions.

The questions we hoped to answer before the study were;
Can drones effectively reduce carbon emissions when compared to trucks for delivery of packages?
How does carbon emissions of drones (UAV) and trucks vary in suburban vs urban conditions?
How can we visualize CO2 emissions which determines the emissions spatially?

Methodology:

Spatial Analysis – Truck travel and Drone Travel – Calculate CO2 Emissions

Datasets

Firstly, we utilized the UPS warehouses locations within the chosen city and suburb limits. UPS stores categorized as "UPS Customer Centers" are the primary hubs of freight and "UPS

Stores” are located more frequently within the city or a suburb. Our second main data source was the street networks graphs from Open Street Maps to map shortest path of travel between the UPS Warehouses and UPS Stores, and households to measure travel miles for a mid-size delivery truck.

Clustering

There were 48 UPS customer center and UPS store facilities in the Manhattan Area, of which we assume that not all facilities would provide delivery service since they are located in close proximity. We used DBSCAN un-supervised clustering algorithm to determine 3 clusters for further analysis. Each cluster has a varying number of UPS stores with figures 04, 05, and 21 UPS stores clustered for a particular label. The fourth cluster was chosen from noise samples to account for UPS Stores at farther locations.

Buffer Radii

Urban and suburban areas were categorized into zones (buffer radii or optimized polygon) for each UPS store. The radii for each buffer is determined to ensure minimum overlap. Each buffer zone serves as a bounding radius for the maximum travel path of trucks and drones.

Urban buffer radius was considered to be 1.5km while suburban radius was estimated to be 4km radius.

Origin Point

The origin point is located at the center of the buffer polygon. The nearest open-street-map(OSM) node is also calculated

Destination Points

The number of destination points in each zone are determined based on the size of the clusters and therefore the density of the neighborhood. For example, the noise cluster is assumed to have the least number of destination points while the cluster with size 21 is assumed to have most destination points.

As a result, 8, 20, 35 and 45 random samples (delivery recipients) were identified for the Manhattan cluster-zones.

30, 45 random samples (destination recipients) were identified for the suburban cluster zones.

Selection of a number of sample points was based on the machine learning clusters. These points can always be increased incrementally to provide more accurate results.

Truck Delivery Path

A continuous travel path for the delivery truck was mapped using street networks from origin (UPS facility) to destination points (destination recipients) for each cluster. A road network route shows a delivery truck leaving a UPS Store and delivering in each household before it returns to the UPS store. CO_2 emissions for the truck will be calculated based on its total miles traveled and weight of truck. Subsequently, 4 parallel street network maps will be plotted for individual scenarios studied for the urban and suburban condition.

Drone Delivery Path

The same scenarios will be tested for drone deliveries which require straight travel paths between UPS Store and households assuming drones fly over and around buildings. Total emissions for drones will be calculated based on operational carbon emissions.

Automation

An automated script will run the truck-cases and drone-cases for each buffer polygons and varying destination points.

Plotting

Finally, interactive folium maps and geo-pandas static plots visualize multiple test case scenarios of using only trucks vs only drones. These plots will be both geo-spatial and quantitative Seaborn heatmap plots displaying a comparison of overall CO_2 emissions in urban and suburban conditions. The plots are meant to emphasize and highlight the key outcomes of using drones vs trucks based on distance travelled, number of deliveries and average energy requirement of drones in service delivery industry, this analysis is derived from the methodology used by Anne et al.

Methodology - Emissions:

CO_2 emission calculations for trucks are based on distance traveled. Carbon emission for drones cannot be accounted solely based on its miles traveled as delivery-drones do not have tailpipe emissions. Hence, AER which is the average energy requirement of the drone in Wh per mile was factored in to normalize energy expended by truck and drones in order to compare. Three sub scenarios were created with AER of 30Wh/mile, 60Wh/mile and 90Wh/mile. The final Seaborn plot shows a heatmap of CO_2 emission differences between drone and truck deliveries with varying drone energy requirements for urban (Manhattan) and sub-urban (Yonkers) area. Cells with negative values indicate that drone emit less CO_2 than Trucks.Cells with negative values indicate that drone emit less CO_2 than Trucks. In our condition, where all values are negative, little inferences can be made from the results.

Results:

· Since the scope of analysis is limited to a 1 mile radius, the emissions of drones had negligible differences with varying energy requirements in all conditions.

· We could infer that a higher difference in CO_2 emissions was due to larger distances (number of points in the case of urban condition) leading to trucks emitting more CO_2 than drones.

· In order to study a scenario where drones emit more CO_2, a larger radius may have to be considered and studied.

· We see a similar scenario in sub-urban conditions as well with truck emissions exceeding drone emissions resulting in higher differences.

· However, a valid comparison between urban and sub-urban conditions cannot be established given that UPS stores are scarcely located, number of deliveries and times of delivery is uncertain.

Final Remarks

The research narrative considers multiple variables to be constant such as UPS truck stop-time(idle) and drive(time), speed of truck and drone, and time of the day. Moreover, the shortest path can be further optimized to create minimum overlap of routes between multiple destination points. In an ideal case scenario, the destination stops would be a much larger number with incremental buffer radii which should provide a more robust and accurate estimation. Current estimated values are a multiplier factor of a real-world scenario. The analysis has a potential to expand for different cities, suburbs, and a larger number of destination points.