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Greener Pastures: Reducing Small-Business Emissions Through Route Optimization

Problem Definition

One of the biggest contributors to climate change is the excessive emissions caused by transportation. For this project, I aim to tackle the problem of emissions in a small real-world example. This entails making a flower shop 'greener' by attempting to optimize delivery routes for the local small business. The goal will be to determine if utilizing route optimization algorithms is a viable solution to unnecessary emissions from inefficient delivery routes. While this project is not computationally heavy, the importance is focusing on the real world aspect of and the scalability to other similar small and medium sized businesses, which together could make a measured difference in emissions and operating costs from the delivery portion of the transportation sector.

Data collection and refinement

The data will be collected directly from a local flower shop in Pennsylvania, Media Florist. This flower shop takes orders from their personal website, online FTD, and through phone calls. The orders are all manually inputted into a computer system, which houses the computerized tickets that include the location of delivery, personal information about the individual who placed the order, and specifications for the floral arrangement. For the purposes of this research, I will just be utilizing the delivery location in the form of a street address. I will select deliveries from either previous Mother's Day or Valentine's Day, which are both particularly busy days. To supplement this data I will then have the owner of Media Florist, the person usually scheduling these delivery routes, plan out the route that would hypothetically be taken. I will then calculate the total miles traveled, the total time taken, the make and model of each vehicle that will be used in this delivery rotation, and the miles travelled for each individual vehicle. The second portion of the data will come from outputs of the below defined machine learning algorithm.

Implementation

To determine the optimal route for the deliveries I will utilize one of the two following open source route optimization coding algorithms. The first is the VROOM-project (https://github.com/VROOM-Project/vroom?utm_source=chatgpt.com) and the second is openrouteservice-py (https://github.com/GIScience/openrouteservice-py). Both are publicly available through Github.

I will work with both of these, adjusting the code slightly to meet my specific needs of number of total deliveries, number of vehicles, and maximum number of deliveries per vehicle. I will move forward with whichever algorithm better fits these requirements.

Once the algorithm is up and running, I will feed it the list of delivery addresses, as well as the number of vehicles, and the number of max deliveries per vehicle. The algorithm will provide me optimized route plans to meet the requirements and complete the deliveries. I will calculate, again, the total mileage for delivery completion, the miles driven by an individual vehicle, and the total time taken.

While the algorithm is running, I will also measure the carbon emissions from the computation utilizing Code Carbon (https://codecarbon.io/). I will document the location of the server as well as test with multiple server locations to get a comprehensive view of the carbon footprint.

I will also create estimates of the carbon emissions per mile for each car based on the make and model of the car. To do this, I will leverage MIT's online Carbon Counter (https://www.carboncounter.com/#!/explore?cars=36794), which provides the lifecycle emissions for a specific vehicle based on vehicle production, fuel production, and fuel use. I will isolate the fuel usage emission value and divide by the average lifecycle miles for the specific car, creating a rough estimate of the emissions per mile for each vehicle in the delivery fleet.

Evaluation

In order to evaluate whether the route optimization is feasible and results in a measurable decrease in carbon emissions, I will first calculate the total emissions for each routing method. For both the manual and algorithmic methods, the calculation will look at each individual route and account for both the emissions produced while vehicles are moving between delivery locations and the emissions generated while vehicles are idling at each stop. The algorithmic routing method will also include emissions produced by running the optimization algorithm itself:

1. Manual Routing:

$$tot\_emit_{manual} = \sum_{i=1}^{n} [(EPM_{v_i} \times Miles_i) + (EF_{v_i} \times Stops_i \times \overline{d})]$$

where

- n = is the number of total trips
- v_i = vehicle used on trip i
- EPM_{v_i} = emissions per mile for vehicle used on trip i
- $Miles_i$ = total number of miles travelled on trip i
- EF_{v_i} = emissions per minute while idling for vehicle used on trip i

- $Stops_i$ = number of stops made on trip i
- $\overline{d}$ = average number of dwell minutes at each stop

2. Algorithmic Routing:

$$tot\_emit_{algo} = \sum_{i=1}^{n} ((EPM_{v(i)} \times Miles_i) + (EF_{v(i)} \times Stops_i \times \overline{d})) + compute\_emissions$$

where

- $compute\_emissions$ = carbon emissions from the algorithmic computation process

I will then compare the two calculations, determining if the algorithmic routing yields a smaller emissions total, thus, indicating a reduction in emissions, and confirming the feasibility of the algorithm.

$$reduction_{emissions} = tot\_emit_{manual} - tot\_emit_{algo}$$

In addition to calculating emissions, I will estimate the total cost associated with each routing method to evaluate financial feasibility. The analysis will include three components: fuel expense, cost of algorithmic implementation, and driver labor costs.

$$FuelCost = P_{fuel} \times \sum_{i=1}^{n} \frac{Miles_i}{MPG_i}$$

$$LaborCost = w \times \sum_{i=1}^{n} T_i$$

$$TotalCost_{manual} = FuelCost + LaborCost$$

$$TotalCost_{algo} = FuelCost + LaborCost + AlgoCost$$

$$reduction_{cost} = TotalCost_{manual} - TotalCost_{algo}$$

where

- n = number of trips
- P_{fuel} = price per gallon gas
- MPG_i = vehicle miles per gallon on trip i
- w = dollars per hour for driver wage
- T_i = worker time for driver in hours
- $AlgoCost$ = cost to run algorithm if subscription is needed

The results will then be subject to robustness checks to determine whether the decrease in carbon emissions is applicable to different delivery specifications. These specifications will include utilizing days that are less busy (smaller number of deliveries), situations when orders are taken in the middle of the day, situations where orders are expected by a specific time, not just by end-of-day, and different parameters of the maximum number of deliveries per vehicle (ie when only small compact cars can be used instead of delivery vans).

Further Work:

Time permitting, I will investigate other avenues of making the flower shop 'greener'. Firstly, calculating the total electricity consumption of the industrial coolers and researching the installation of portable solar panels for the coolers. Secondly, I will estimate the transportation emissions associated with flowers sourced from South America and assess the feasibility of sourcing all flowers locally from Amish growers instead. This analysis would determine whether Amish growers can supply the full variety of flowers needed while reducing emissions from overseas transport. I will also factor in the cost differences between the flower suppliers.