# Greener Pastures: Reducing Small-Business Emissions Through Route Optimization

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## Abstract

This work investigates decreasing carbon emissions from delivery vehicles by optimizing delivery routes algorithmically. The main work focuses on a case study of a small-business florist shop on a large delivery day (Mother's Day). The algorithm utilized is the Vehicle Routing Open-source Optimization Machine (VROOM-project) (1), which is designed to employ algorithms to optimize complex vehicle routing problems. This is coupled with the Open-source Routing Machine (OSRM) project (2), which can be queried to calculate distances and times between geographic locations. The algorithmic approaches were compared to the manual approach with multiple evaluation metrics, including carbon emissions, distance, time, and cost. The VROOM algorithmic approach was found to save 89 minutes, 66.8 miles, 4 delivery trips, 512.36 dollars, and 73.62 $pdCO_2eq$. Thus, we conclude that algorithmic routing, in this case, is more efficient and generates a marked reduction in carbon emissions.

## 1 Introduction

One of the biggest contributors to climate change is the excessive emissions caused by transportation. This research aims 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.

Previous literature has touched on the topic of route optimization for carbon emission reduction. Apaydin and Gonullu (2008) (6) determined a decrease in $CO_2$ emissions as well as $NOx, HC, CO, PM$ emissions when employing route optimization for solid waste collection. Qin et al. (2019) (7) found that route optimization could decrease carbon emissions while maintaining customer satisfaction for cold chain logistic companies. To the best of my knowledge, there has been no previous literature directly studying the impact on carbon emissions through route optimization within the floral industry.

While this project is not computationally intensive, the importance lies in focusing on the real-world aspect 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.

## 2 Data

The data was collected directly from a local flower shop in Pennsylvania, called Media Florist. This flower shop takes orders from their personal website, online Florists' Transworld Delivery (FTD), and through phone calls. The orders are all manually entered into a computer system, which houses the computerized tickets. The tickets include the location of the delivery, personal information about the individual who placed the order, and specifications for the floral arrangement.

For the purposes of this study, delivery locations were recorded as street addresses. Deliveries occurring on Mother's Day 2025 were selected, as this date represents a period of exceptionally high demand for floral delivery services. To supplement these data, the delivery process was reconstructed by working backward to identify the individual trips undertaken by delivery drivers and the specific routes traveled on May 11. From this reconstruction, key operational metrics, including the number of stops, number of trips, total distance traveled, and total delivery time, were computed based on the recorded time of delivery by the driver as well as supplemental data from Google Maps (8).

The total number of deliveries was 100 stops. This number is due to the limitations of VROOM, which caps queries at 100 deliveries per algorithmic pass. The delivery addresses are in the following neighborhoods in Pennsylvania: Media, Wallingford, Swarthmore, Rutledge, Springfield, Clifton Heights, Newtown Square, Morton, Havertown, Drexel Hill, Rose Valley, Philadelphia, and Glen Mills. The locations consist of residential, businesses, nursing homes, and hospitals.

## 3 Methodology

To determine the optimal route for the deliveries, the VROOM-project (1) was utilized, which is an open source-route optimization coding algorithm, publicly available through GitHub. This project is an optimization engine meant to solve complex vehicle routing problems. To supplement VROOM, the Open-source Routing Machine project (OSRM) (3) was downloaded and run on Docker in the background. OSRM is an open-source routing machine that will be queried by VROOM to provide distance and time measurements between locations. With these queries, the VROOM algorithm calculated the optimal route plan based on minimizing time and distance.

Once both engines were up and running, the VROOM algorithm would receive the same list of deliveries as the manual version as input in the form of a JSON file, as well as the number of vehicles, and the number of max deliveries per vehicle. In addition, the algorithm is told the address of Media Florist and accounts for it being the start and end destination for each delivery route. VROOM then queries OSRM for distances and time measures between all combinations of delivery locations. With these queries, the VROOM algorithm then calculated the optimized route plans to meet the requirements and complete the deliveries. This output was converted to an Excel format for ease of reading.

Again, the total mileage for delivery completion, the number of trips taken, the number of stops, and the total time taken were calculated. These calculations were completed using Google Maps directions capabilities (8). While the algorithm was running, the carbon emissions from the computation were calculated utilizing Code Carbon (4). The location of the server was documented to understand how the carbon footprint can differ by location.

An average estimate of the carbon emissions per mile for the fleet of cars was created based on MIT's online Carbon Counter (5), which provided the lifecycle emissions for a specific vehicle based on vehicle production, fuel production, and fuel use. The fuel usage emission value for some of the utilized cars was isolated, and the average emissions among these cars was calculated, creating a rough estimate of the emissions per mile of driving and emissions per minute of idling for the vehicles in the delivery fleet.

## 4 Evaluation

To evaluate the algorithmic routing compared to the manual routing, a series of equations was employed to assess its overall feasibility and benefits (or disadvantages). These equations calculate the emissions from each method, the cost of fuel, the cost of labor, and compare the time, trips, distance, emissions, and cost.

Firstly, the total emissions for each routing method were calculated. For both the manual and algorithmic methods, the calculation accounted 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:

Manual Routing:

$$\text{TotEmit}_{\text{manual}} = \sum_{i=1}^{n} \left[ (EPM_i \cdot \text{Miles}_i) + (EF_i \cdot \text{Stops}_i \cdot \bar{d}) \right] \tag{1}$$

where

$$\begin{aligned} n &: \text{ total number of trips,} \\ EPM_i &: \text{ emissions per mile on trip } i, \\ \text{Miles}_i &: \text{ total miles traveled on trip } i, \\ EF_i &: \text{ emissions per minute while idling on trip } i, \\ \text{Stops}_i &: \text{ number of stops on trip } i, \\ d &: \text{ average dwell time (minutes) at each stop.} \end{aligned}$$

Algorithmic Routing:

$$\text{TotEmit}_{\text{algo}} = \sum_{i=1}^{n} \left[ (EPM_i \cdot \text{Miles}_i) + (EF_i \cdot \text{Stops}_i \cdot \bar{d}) + \text{compute\_emissions} \right] \tag{2}$$

where

$$\text{compute\_emissions} : \text{ carbon emissions from algorithmic computation process}$$

The two calculations are then compared to determine if the algorithmic routing yields a smaller emissions total, thus indicating a reduction in emissions, and confirming the feasibility of the algorithm.

$$\text{Reduction}_{\text{emissions}} = \text{TotEmit}_{\text{manual}} - \text{TotEmit}_{\text{algo}} \tag{3}$$

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

$$\text{FuelCost} = \text{P}_{\text{fuel}} \cdot \sum_{i=1}^{n} \frac{\text{Miles}_i}{\text{MPG}_i} \tag{4}$$

$$\text{LaborCost} = \text{w} \cdot \sum_{i=1}^{n} \text{T}_i \tag{5}$$

$$\text{TotalCost}_{\text{manual}} = \text{FuelCost} + \text{LaborCost} \tag{6}$$

$$\text{TotalCost}_{\text{algo}} = \text{FuelCost} + \text{LaborCost} + \text{AlgoCost} \tag{7}$$

Similarly, the two calculations were compared to determine if the algorithmic routing yields a change in operational costs. Two outcomes are possible: 1) The algorithmic routing will yield incurred costs, and thus the florist will have to determine whether the environmental gains outweigh the financial loss, or 2) The algorithmic efficiency will decrease operational costs and will increase incentive for being more anti-carbon.

$$\text{Reduction}_{\text{cost}} = \text{TotalCost}_{\text{manual}} - \text{totalCost}_{\text{algo}} \tag{8}$$

where

$$\begin{aligned}
n &: \text{ number of trips,}\\
\text{P}_{\text{fuel}} &: \text{ price per gallon gas,}\\
\text{MPG}_i &: \text{ miles per gallon on trip } i,\\
\text{w} &: \text{ dollars per hour for drive wage ,}\\
\text{T}_i &: \text{ worker time for driver in hours ,}\\
\text{AlgoCost} &: \text{ cost to run algorithm if subscription is needed.}
\end{aligned}$$

## 5 Results

Two different configurations of the VROOM algorithm were created and tested, one with 10 maximal deliveries per vehicle and one with 8 maximal deliveries per vehicle. For reference, the absolute maximum deliveries per vehicle is around 13 for minivans, while a normal-sized car averages 7-8 deliveries.

The results of the manual routing, and algorithm 1 (10 max) and algorithm 2 (8 max) are shown in the table below in Table 1. The calculated time, distance, trips, emissions, and cost are displayed for each of the two algorithmic routing methods as well as the manual version.

Table 1: Routing performance metrics

| Routing | Time (mins) | Distance (mi) | Trips | Emit ($pdCO_2eq$) | Cost ($) |
|---|---|---|---|---|---|
| Manual | 583 | 230.2 | 14 | 319.89 | 2686.746 |
| VROOM 1 | 494 | 163.4 | 13 | 246.27 | 2174.382 |
| VROOM 2 | 515 | 173.5 | 10 | 257.39 | 2277.005 |

As seen in Table 1, VROOM produced two optimized route plans that proved to be more efficient than the manual version. Most importantly, the routes were logical and completely possible in terms of the physical driving route, which was verified with Google Maps (8).

The algorithms both improved upon the mileage, the number of trips, the total time elapsed for a day of delivering, the estimated carbon emissions (even when considering computational emissions), and overall costs from labor and gas.

Table 2: Routing performance compared to manual baseline

| Routing | $\Delta$ Time | $\Delta$ Dist | $\Delta$ Trips | $\Delta$ Emit | $\Delta$ Cost |
|---|---|---|---|---|---|
| VROOM 1 | -89 | -66.8 | -1 | -73.62 | -512.37 |
| VROOM 2 | -68 | -56.7 | -4 | -62.50 | -409.74 |

Table 2 displays the differences in the evaluation metrics between each of the algorithmic routing methods and the manual method. Each metric is negative, indicating that the algorithms were able to improve the efficiency across the board. Most importantly, we see that VROOM algorithm 1 saw a 73.62 $pdCO_2eq$ decrease in emissions as compared to the manual routing, and VROOM algorithm 2 saw a 62.50 $pdCO_2eq$ decrease in emissions as compared to the manual routing. Furthermore, there was a $512.37 and $409.74 decrease in cost, respectively, indicating that not only is there no incurred costs from using the algorithm, but in fact, there is a financial incentive to use the algorithm to improve delivery efficiency.

Table 2 also shows that the VROOM algorithm using 10 deliveries max per vehicle (VROOM 1) outperformed both manual and the 8 max algorithm (VROOM 2), achieving the best results in each evaluation metric. This algorithm was able to save 1h29, 66.8 mi, 4 trips, 73.62 pd CO2eq, and $512.36.

# 6 Discussion

Overall, the algorithm achieves its environmental goal in that it decreases carbon emissions from delivery route transportation. In addition, the algorithm is able to generate a decrease in delivery time and overall costs incurred.

It should be noted that algorithmic planning will also generate a decrease in manual labor in terms of physically planning the routes. Manually planning 100-plus deliveries is a time-intensive job and requires specific domain knowledge of the delivery area. The algorithm, on the other hand, stands in for this necessary knowledge and is less demanding. For a florist to utilize the algorithm, they would simply need to extract a list of their delivery addresses in the form of an Excel spreadsheet, clone the GitHub repository, download and unzip the OSRM data files, upload the address Excel sheet, and run the provided script file. The elapsed time for this process will certainly vary based on familiarity with GitHub and script files, however, it should take no more than approximately 30 minutes to obtain the necessary materials and no more than 5 minutes to run the entire script pipeline. The manual version, on the other hand, could take up to a few hours to obtain the delivery list, sort by neighborhood or common area, design multiple delivery routes, and manually verify them through Google Maps. This metric is not explicitly mentioned in the results section because it is difficult to precisely measure and depends heavily on the expertise of the scheduler; however, it is reasonable to conclude that the algorithm will be less labor-intensive to utilize.

We also conclude that the algorithm, while beneficial for major holidays or exceptionally heavy delivery days, is not suitable for smaller, more normal delivery days. For most small to medium-sized florists, most days consist of somewhere between 1 and 15 deliveries, while the major floral holidays, being Christmas, Valentine's Day, and Mother's Day, can reach upwards of 250 deliveries. For these smaller off days, using the algorithm for only a few deliveries may be more labor-intensive than simply manually routing them by hand. In addition, a smaller delivery day is more likely to have deliveries with time stipulations (ie, special events that need to be delivered by 11am) and orders that are placed in the middle of the day. At this point, the algorithm is not capable of factoring in time constraints, and if deliveries are added in the middle of the day, the algorithm will re-run all addresses and might change the delivery routes. Simply put, without large quantities, the algorithm loses its efficiency to a well-trained, road-knowledgable florist. So, in conclusion, for Mother's Day, Christmas, and Valentine's Day, this algorithm could save time, money, and emissions, but for the rest of the days, a manual method is more feasible.

## 6.1 Limitations

The main limitation of this work is the lack of adjustability of the algorithm. The initial work set out to test the route optimization using a variety of different real-world delivery scenarios, including specifying when an order must be delivered by, specifying more fine-grained limits for each specific vehicle to account for vehicle sizes and larger floral arrangements, and assigning specific routes to specific cars. Instead, the algorithm works with the number of cars and provides that number of optimized routes, only providing one route for each car. In theory, this can be tuned by looking at this number instead as the number of delivery routes and hyperparameter tuning to find the optimized number of routes, and then, in the real scenario, dividing these routes among the drivers; however, this adds an additional layer of complexity to the calculation and more computational emissions.

## 6.2 Future Work

In terms of future work, the main priority would be making a front-end version of this project pipeline that would allow florists to forgo any code handling. This could be through the creation of a publicly-hosted website or an extension specifically for the computerized ticket housing system.

In addition, there are other avenues to investigate in terms of making a florist shop greener. Firstly, calculating the total electricity consumption of the industrial coolers and researching the installation of portable solar panels for the coolers. Secondly, 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. The cost differences between the flower suppliers would also be included.

# 7 Conclusion

In conclusion, delivery route optimization was able to decrease carbon emissions for a local florist while maintaining practicality and avoiding additional costs. The algorithm is proven feasible for large floral holidays and extends upon current research in the field of route optimization for climate science.

This particular algorithm could be utilized in a real-world scenario for other similar-sized floral shops. In addition, it is transferable to other small to medium-sized local delivery businesses.

When one small business optimizes its delivery routes, it makes a merely imperceptible change in carbon emissions, but when many small businesses follow suit, there is potential for a real change in emissions for the transportation sector.

## 7.1 Carbon Cost

Overall, Code Carbon estimated 0.000010 kg for each run of the VROOM optimization algorithm. During the process of coding and tweaking the algorithm and full setup, I ran the full pipeline about 20 times. In addition, I ran smaller versions about 10 times. This equates to about 0.3 grams of CO2 equivalent.

In addition, during the process I estimated about 10 queries to Chat GPT, which each produce 3 grams of CO2. This translates to 30 grams of CO2.

Finally, utilizing a laptop emits 10g CO2eq per hour, and, by my estimates, this project in its entirety took about 40 hours, for a total of 400 gCO2eq.

The final rough estimate is about 430.3 gCO2eq from start to finish.


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