Carnegie Mellon University
Tepper School of Business

412 FOOD RESCUE: OPTIMIZING DELIVERY PATHWAYS TO ENHANCE HOME DELIVERY

MS in Business Analytics Capstone Project

Team: Saahas Hari, Tina Arora, Yukta Butala, and Xiaohuan Wang
Advisor: Sai Harish Balijepalli
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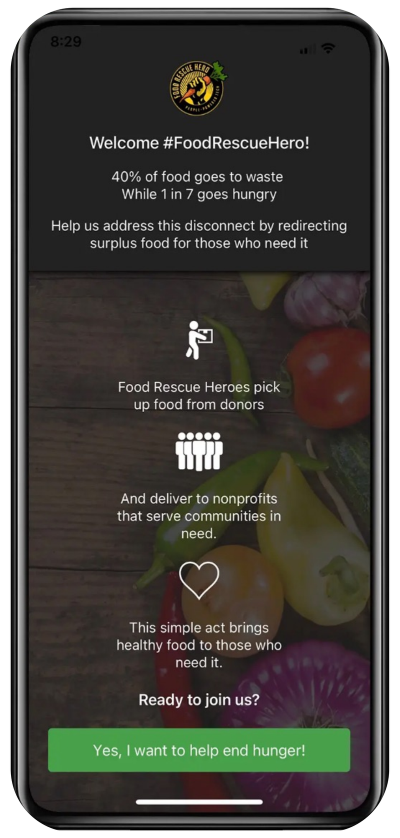
ABSTRACT

This project is a collaboration between Carnegie Mellon University Tepper School of Business and 412 Food Rescue with a focus on optimizing food delivery logistics. Home deliveries, which are crucial for food access, currently struggle with inefficient routes that often result in unclaimed food orders due to a process that is heavily reliant on manual adjustments to software-generated delivery routes.

Our objective is to boost distribution efficiency by identifying optimal hub locations for mobile delivery trucks using k-means clustering. We will analyze food delivery data to strategically establish distribution hubs near locations with frequent needs in an effort to reduce route planning complexity and delivery times. This streamlined and optimized approach aims to enhance route reliability, as well as attract more volunteers, to ensure timely and complete food deliveries to households in need.



INTRODUCTION

The primary challenge we addressed is that volunteers are not delivering the distributed food packages to their respective household assignment even after rescuing (claiming) them from donor locations. We identified two major causes which contributed to this problem: improper assignment of households to each of the volunteers and lack of convenience for the volunteers who were delivering food without getting incentivized for their efforts.

After careful deliberation with the Food Rescue team, we produced a creative recommendation: have mobile food storage & distribution hubs at locations that were in close proximity to clusters of households. Then, the next step was to determine where we should store the food? To solve this, we implementing machine learning algorithms and optimization techniques to address this challenge. We also generated a Tableau dashboard to help the Food Rescue team visually comprehend our solution.

After successful implementation of our solution, we predicted the average time taken to deliver the rescued food packages to each of the determined households would go down significantly. In addition, the probability of missing a home delivery was predicted to go down as well, hence maximizing the total number of households being fed every week.

Donor and Household Locations

METHODS AND MATERIALS

Model Development – Benchmark Setting: Using k-means clustering, we establish benchmarks to identify strategic hub locations for mobile delivery trucks, optimizing the k-value for precise grouping. This method incorporates constraints like donor-household affiliations, ensuring hubs serve high-frequency donor locations effectively.

Anomaly Detection and Constraint Integration: We apply anomaly detection to refine the delivery network, identifying irregularities in delivery patterns and standardizing them based on geographic and delivery frequency variables. This process also accounts for capacity and demand constraints due to donor-household affiliations.

Model Training and Validation – Data Segmentation and Toolset: We segment delivery data to include all relevant variables for accurate representation of donor-affiliated households. Development tools like Jupyter Notebooks support complex modeling, with Tableau providing visualization to optimize distribution efficiency within these constraints.

Dashboard Development and Geospatial Analysis: Engineered interactive Tableau dashboards to visualize and interpret complex datasets, enabling more intuitive insights into donor and household geographic correlations. Leveraged Tableau's advanced geospatial tools to map delivery routes, identify high-demand areas, and display donor-household relationships.

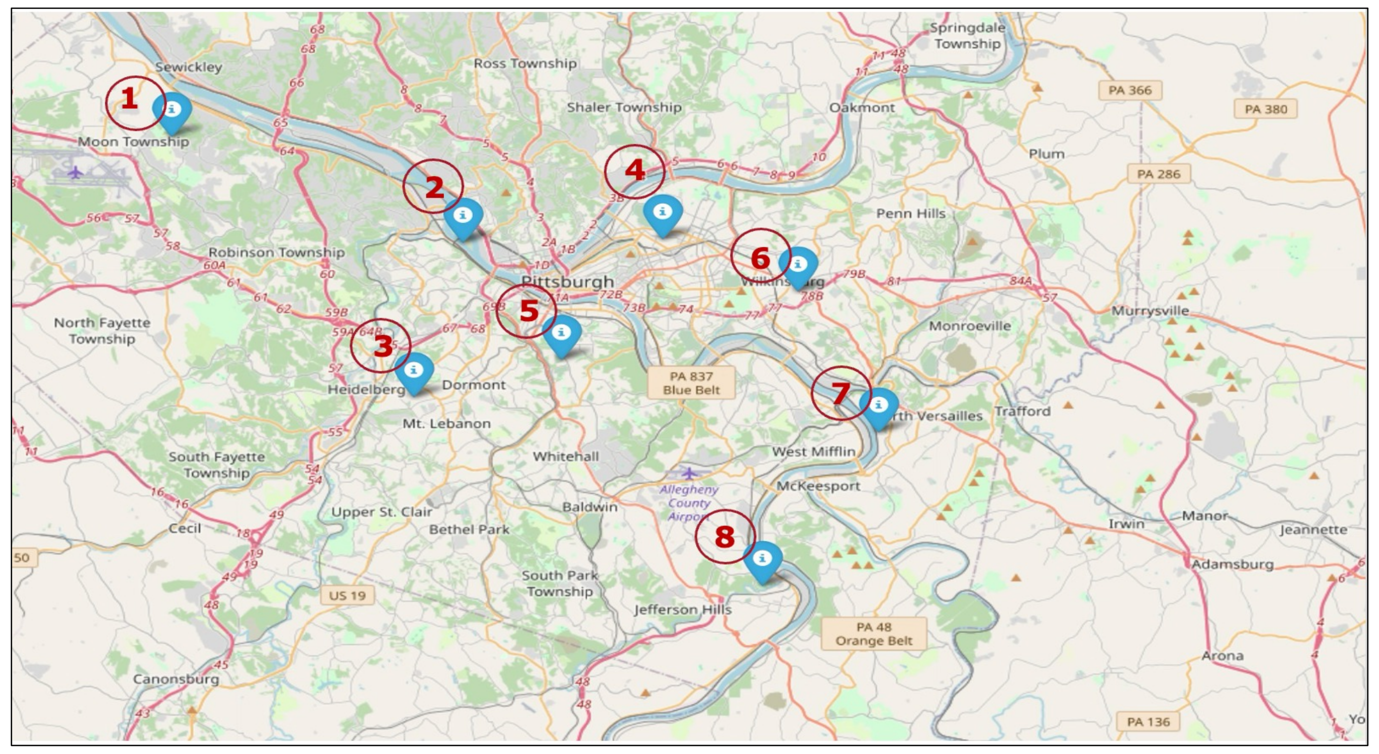
RESULTS

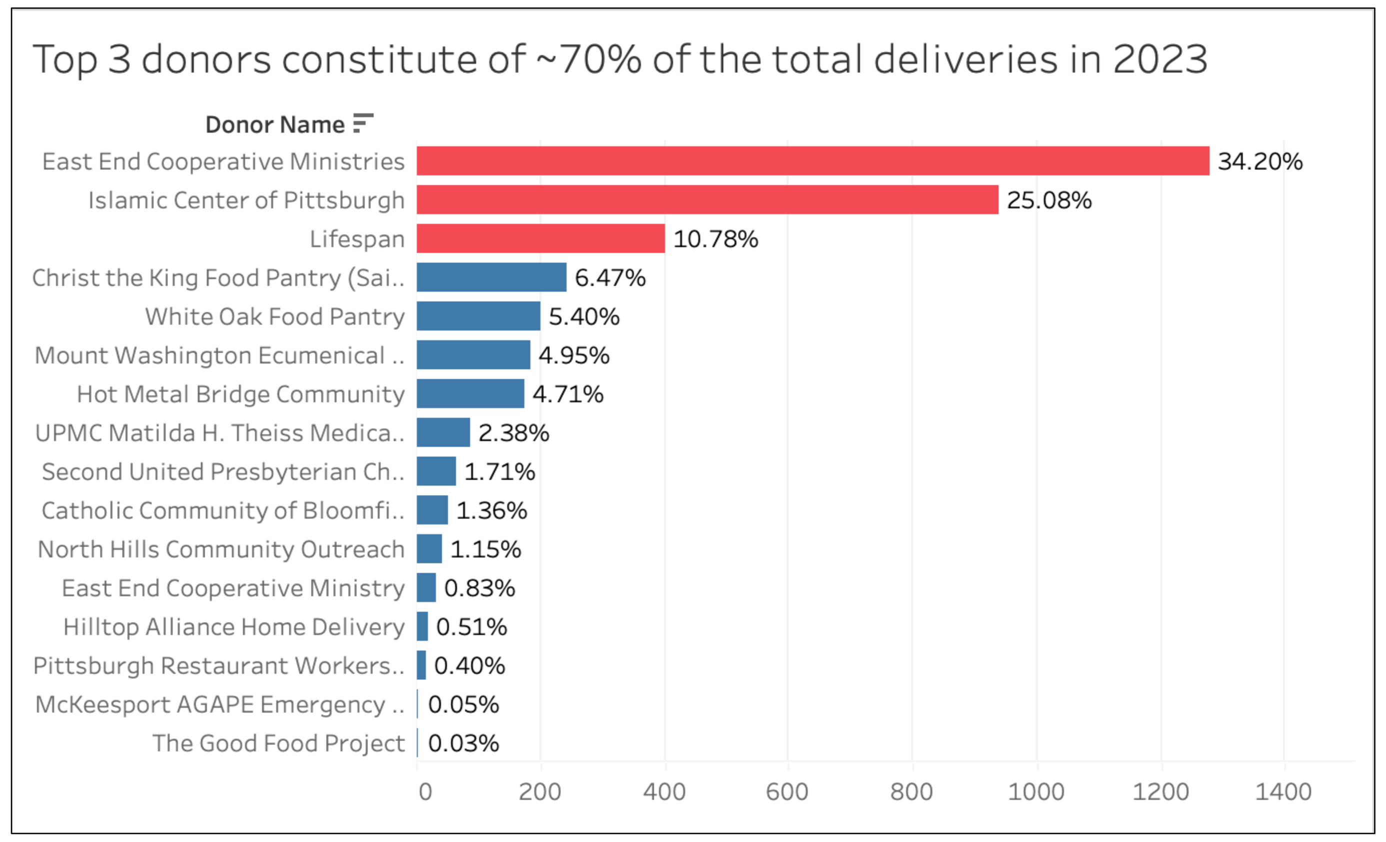
The data included **30 donor locations and over 9,000 households served weekly by 451 volunteers**. Since volunteers choose deliveries based on first come, first served, they have the flexibility to select their food rescue spots. However, delivering to multiple distant homes is challenging, so we propose centralized drop-off points.

After employing a clustering model, we identified **8 strategic mobile locations across Pittsburgh,** with two showcased in the graph below. These hubs will feature refrigerated storage for volunteers to collect and distribute food efficiently.

This approach addresses key issues:

1. Reduces pick-up points and brings them closer to delivery areas
2. Offers volunteers convenience in selecting locations and households
3. Significantly cuts delivery times





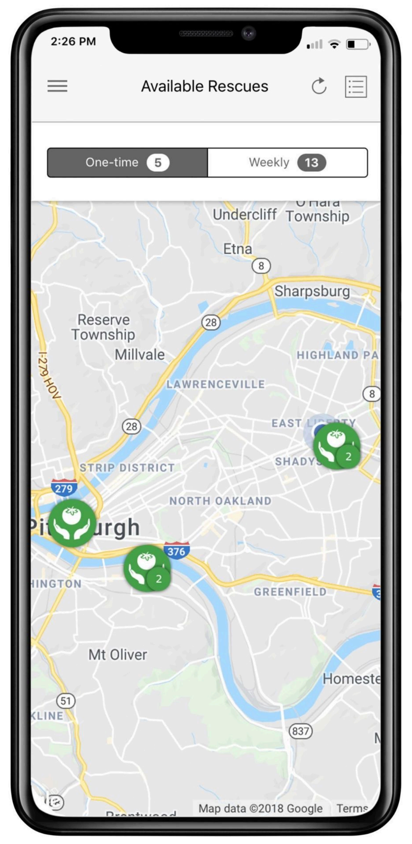
DISCUSSION

Challenges – More than 70% of donations came from the top 3 donors as can be seen in the above graph. While deciding the optimized locations of food storage we might also have to structure the capacity of storages accordingly. The recommendation is operation heavy, and Food Rescue will have to make significant changes in the current system, including adding infrastructure.

Alternatives - We initially built a model which restructured the route allocations to the volunteers. While that could have been one way forward, it did not impact our KPIs significantly as much as the current solution does.

Future Directions – Using the results of our k-means clustering geospatial model, we have identified an area of interest to better enhance route delivery between certain subsections of donor and household locations. By generating a list of shortest route paths between donor/hub locations and 3-5 optimally selected households, we can input this list into modern, cutting-edge route optimization software, such as Hybrid Genetic Search in Capacitated Vehicle Routing Problems, to seamlessly revolutionize the route planning system used by 412 Food Rescue.

CONCLUSIONS



By employing k-means clustering to optimize the placement of mobile food storage & distribution hubs, we have generated a creative solution that has led to a transformative improvement in food delivery logistics by effectively streamlined the routing process for home deliveries.

The implementation of machine learning algorithms and optimization techniques, as well as advanced data analytics, has allowed for a systematic identification of optimal hub locations that align closely with the geographical distribution of donor and household affiliations.

The predicted reduction in food delivery times and decrease in missed/incomplete deliveries highlights the project's potential to significantly increase the number of households served by 412 Food Rescue each week.

CONTACT

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REFERENCES

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2. Phillips, C.; Hoenigman, R.; and Higbee, B. (2011) *Food redistribution as optimization (2011). arXiv preprint arXiv:1108.5768*

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