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CS 6630: Visualization for Data Science

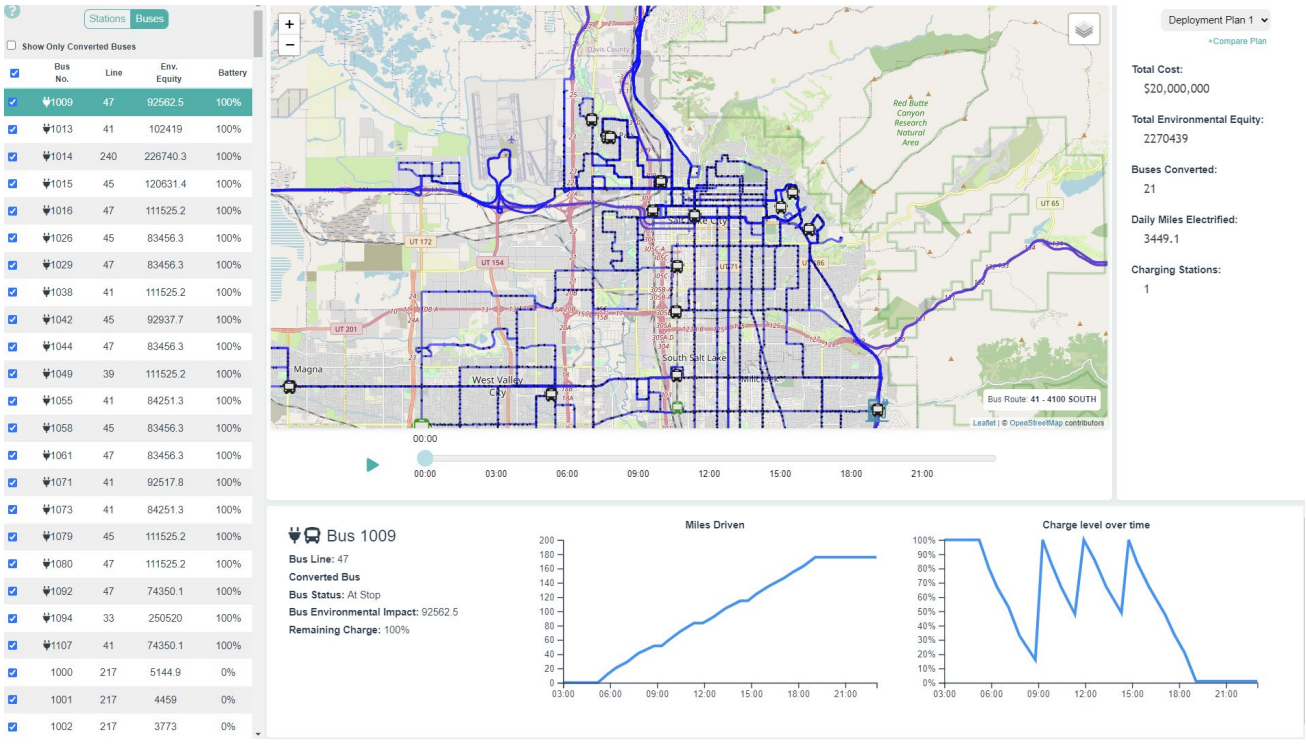
Project Process Book

Overview & Motivation

This project is an extension of my research on the Seed2Soil project headed by Dr. Bei Wang Phillips and Dr. Cathy Liu. The aim of this project is to provide a visualization tool for performance analysis of service fleet vehicles at the University of Utah. This tool will visualize telematic and operational data from University of Utah vehicles to allow for analysis of the performance of fleet operation. I hope that that this tool will allow for the development of strategic solutions for more cost effective and energy efficient fleet service management.

Related Work

In the fall of 2021 I took Dr. Bei Wang Phillips' Advanced Data Visualization class where I built a visualization tool for the deployment of electric busses in Salt Lake City. For this visualization I visualized the locations of busses under this plan according to their routes and the charging stations associated with them. I also added an extra panel to visualize data about selected busses and charging stations. After I completed that class, I continued to work on the visualization with Dr. Bei Wang Phillips and Dr. Cathy Liu for a paper on the efficient deployment of electric busses. This visualization was a starting point for this project and I am using its overall layout and application structure for this project. This is a screenshot of that visualization:



Questions

For the Seed2Soil project we are working closely with the administration to tailor our research towards their needs. The primary questions that they hope to answer with our project and visualization are:

How can we optimize the utilization of vehicles between departments to consolidate our fleet?

Can we reduce the number of trips taken by vehicles by consolidating similar routes?

Can we reduce vehicle idle time?

Can we increase driving efficiency by analyzing driver behavior?

By answering these questions, we hope that we will be able to reduce costs and emissions from fleet vehicles at the University of Utah.

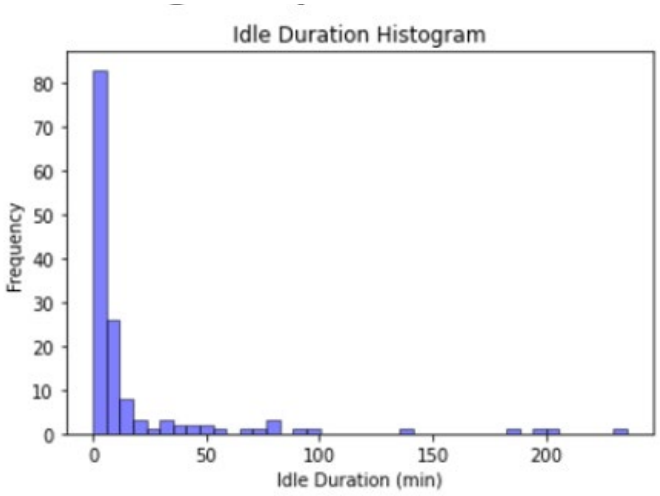
Data

The data that I have been using for the project so far has been from a platform called GeoTab which the University of Utah currently uses to house data on their fleet. On this platform are two main pieces of data that we are analyzing, descriptions of the fleet vehicles, and descriptions of the trips that these vehicles make. The data on the fleet vehicles themselves is in csv format and includes the vehicle's ID, make, model, year, class, department, and VIN. The trips data is also in csv format where each row corresponds to a stop made on the trip. Each stop includes the vehicle that made the stop, the department of the vehicle, the time the stop started, the time the stop ends, the duration of the stop, the duration of idle time during the stop, the distance traveled since the last stop, and the address of the stop location.

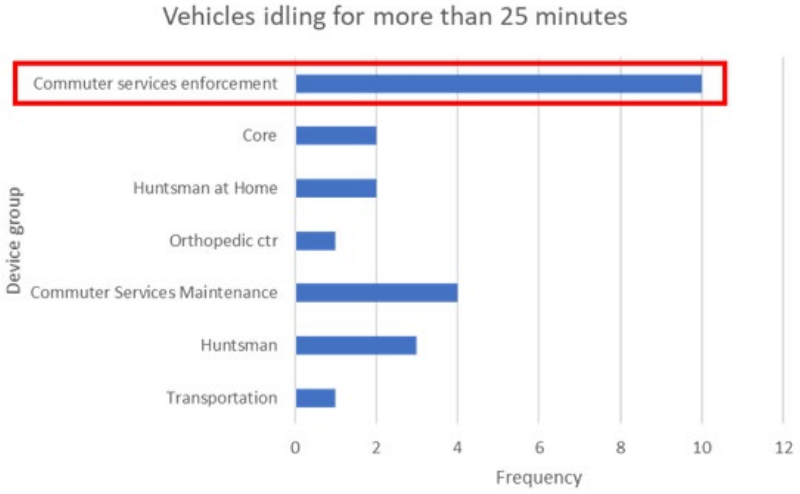
For the data processing I created three 4 distinct objects: departments, vehicles, trips, and stops. Each object contains the information related to that type of object. Each department is associated with the vehicles in that department, each vehicle is associated with the trips that vehicle made and the department it belongs to, each trip is associated with the individual stops on the trip, and the stops are associated with the vehicle and the trip that it was a part of. The greatest challenge of the data processing stage was that each stop only included the address, not the actual coordinates of the stop which are necessary for plotting on a map. To overcome this I used the ArcGIS API to go through each address and convert it into readable format. I then converted this coordinate into a GeoJson point feature to be plotted. I performed all of the initial data processing using python and then saved the arrays of objects to JSON files which I then read in my application.

Exploratory Data Analysis:

Before completing the data extraction I described above for the application, I created some preliminary visualizations to explore what we want to include in the overall visualization. Firstly, I looked into the idling time since that was a point of interest for the University of Utah and came up with the following visualizations:

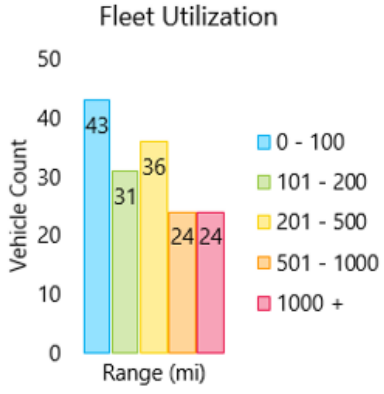


This histogram displays the frequency of idle durations across stops made. From this we can see that most of the time, vehicles are not idling although there are some major outliers. From this I figured that it would be important to include more fine grain analysis of these outlying idle times.

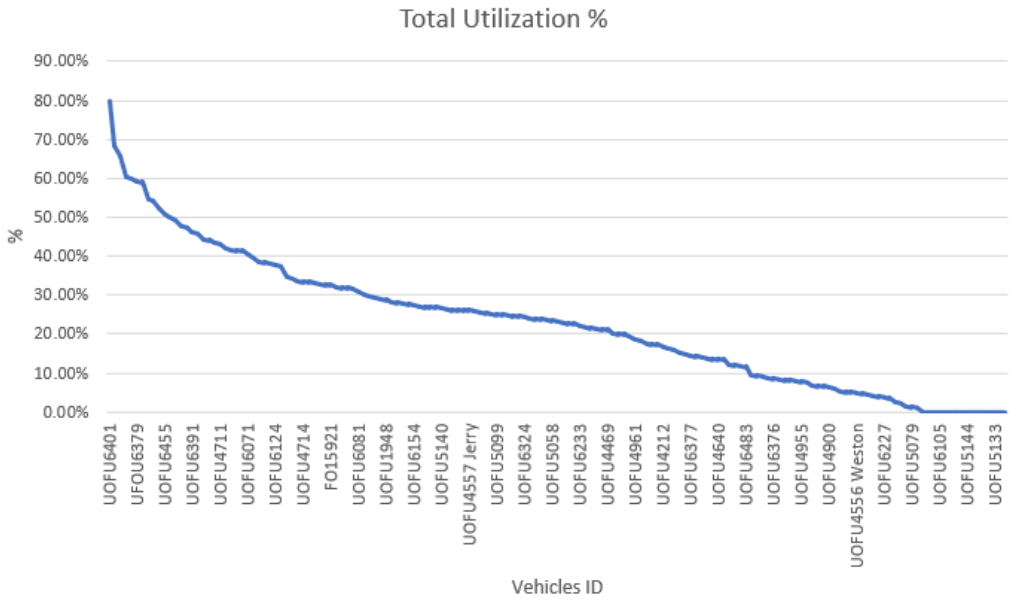


This visualization displays the frequency of long idle times across departments. In order to help the university discover where they can improve their fleet efficiency, we want to include analysis of idle time by department in the application.

After doing some preliminary analysis of idle times, I also began exploring how we can visualize fleet utilization in the application.



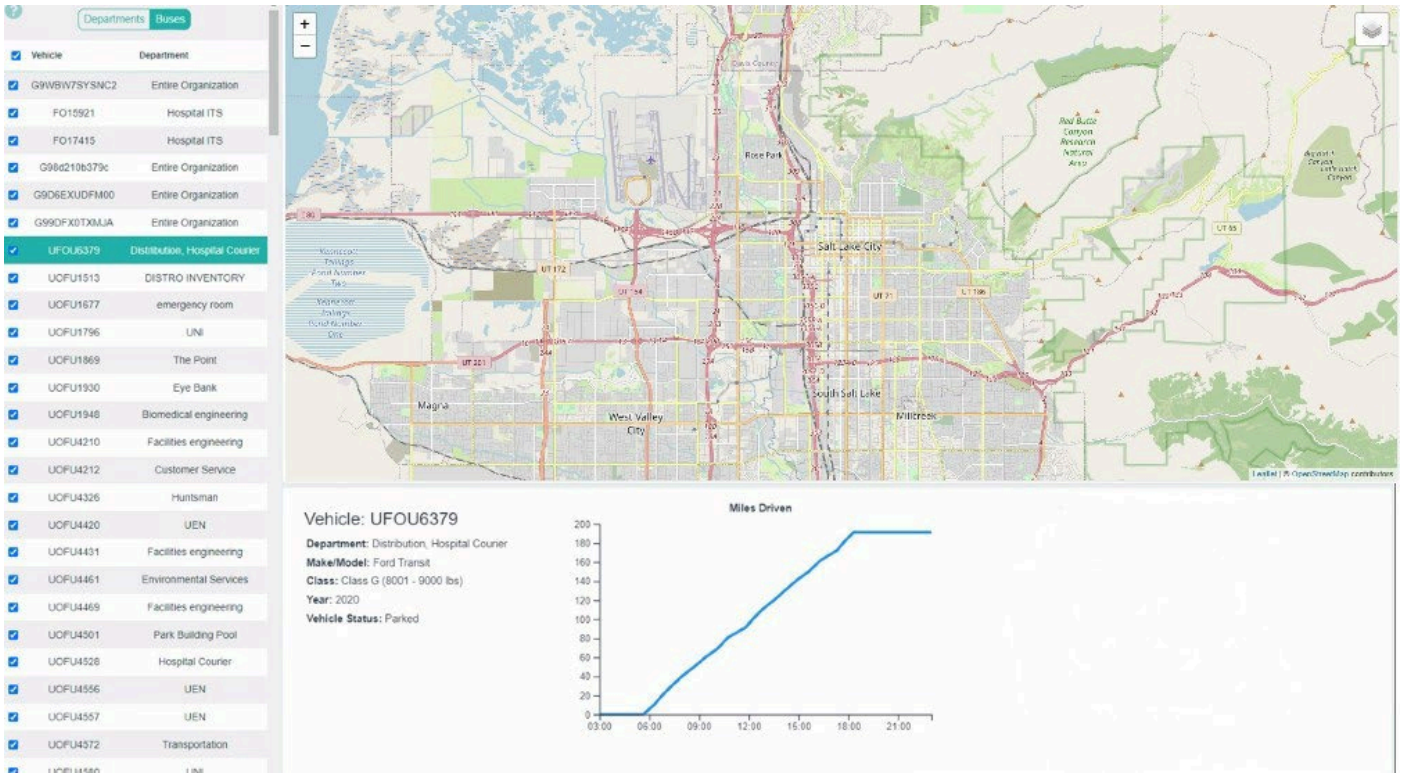
This visualization shows the frequency of high and low usage among university vehicles. From this we can see that the most vehicles are not used very much with 43 traveling between 0 and 100 miles in a one-month span. From I figured it would be important to provide comparisons of usage across vehicles in the application.



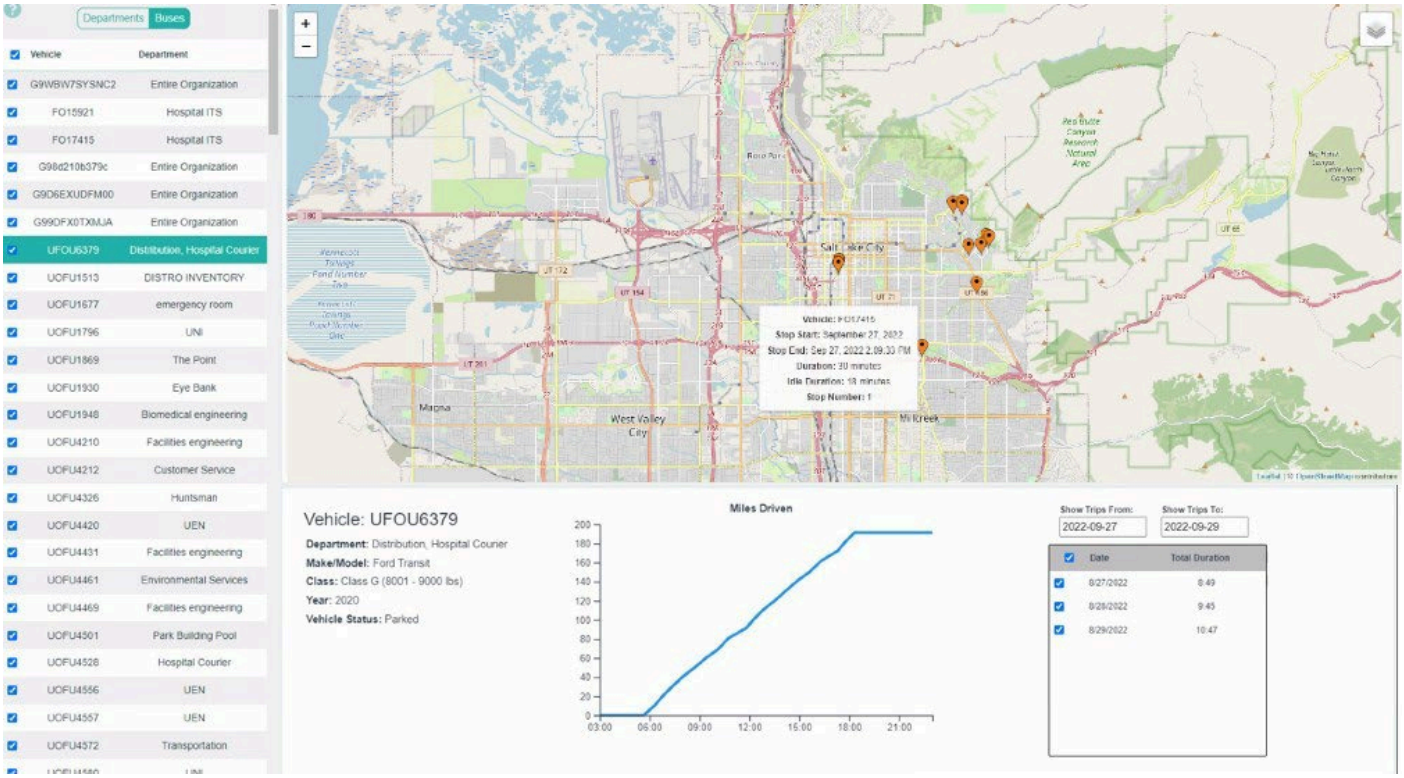
This visualization displays the usage of individual university vehicles, from most utilized to least utilized. I calculated utilization by the number of days with a trip divided by the total number of days in a one month span. I believe that visualizing a utilization metric like this will be important in the final application.

Design Evolution & Implementation:

The starting point of the design for this visualization was the previous project for which I displayed a screenshot in the related work section. In that design, the left panel displays the different deployment plans for electric busses. This was pretty specific to that project so I first decided to cut that out and expand the map section. Next, after processing the data I added all of the vehicles to the list on the left side and made them selectable such that on selecting, information about the vehicle is displayed on the bottom panel. Here is how the application looks in this stage. As of this point the visualization chart in the bottom panel is just a placeholder and is not showing any useful information.



In the next stage I expanded the visualizations for vehicles. Firstly, I wanted to display where the vehicle was on the map by placing markers at each stop location for each of a vehicle's trips. This resulted in a significant amount of clutter on the map so I also included a time varying component so that you can visualize stops that a vehicle made within a specific period of time. I also wanted the user to be able to view specific trips that a vehicle has made, so on the bottom panel, I included a list of all of the trips made by the vehicle within the specified time range. When you uncheck a trip in this list, the stops for that trip will not be displayed on the map. When you check the checkbox on the top of the list, all of the trips for that vehicle will once again be checked and all of the trips will be displayed on the map. Also, to increase the interactivity of the visualization, I added a tooltip for each of the markers which displays the vehicle associated with the stop, the start and stop time of the stop, the idle duration of the stop, and the stop number on the trip. This is a view of the application in this stage:

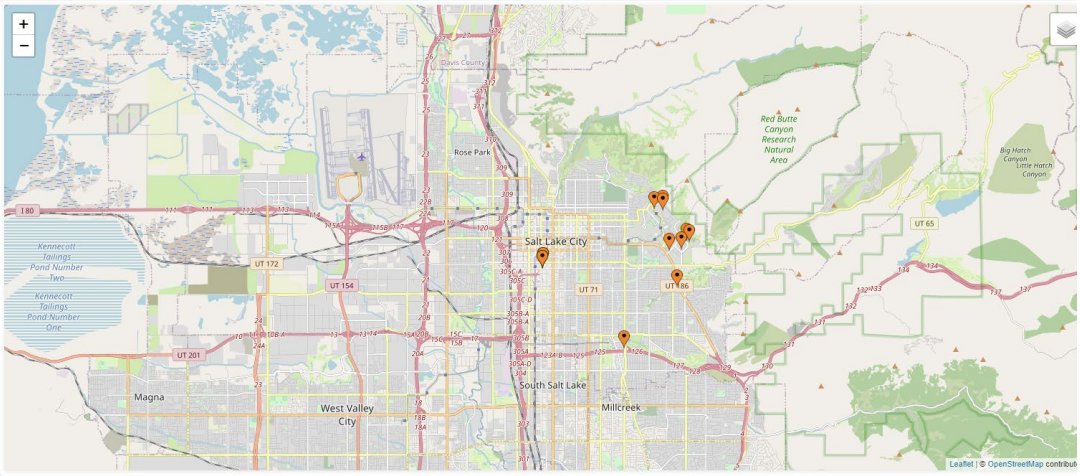


In this next stage I wanted to add two important pieces to the visualization, a view for visualizing department wide statistics, and changing the placeholder chart to visualize real information. For the visualization for a single vehicle, I decided to visualize its driving time across the selected dates. To do this I added a bar chart where the dates in the selected range are on the x axis and the driving duration on a particular day is on the y axis. In the future I will add more selectable visualizations for other pieces of the data like idle duration, but felt that this was the most important so I added it first. Also, on the vehicle information panel, I made the department name of the vehicle to be a button where upon clicking, the department view of the vehicle's department will be displayed.

I added the department view because the administrators at the U want to be able to analyze the performance of department wide statistics. To do this I first added the functionality to the top left toggle so that when it is switched, the list on the left panel displays all of the departments rather than vehicles. Upon selecting a department, the view on the bottom panel will display information on that specific department. I also wanted to make it so that from this view you could view and select the vehicles in that department. I implemented this similarly to how I implemented the trips list on the vehicle panel view, and by selecting a vehicle on this list, the information for that vehicle will be displayed on the bottom panel. For the visualization on the department view I wanted to show the usage of the entire department's vehicles. I thought it would be important to know which vehicles were being used so rather than a normal bar chart like in the vehicle information panel, I added a stacked bar chart where each section in the bar is color coded to represent the usage of a specific vehicle in the department. Moving forward, I intend to add a legend for this visualization as well as a tooltip where upon hovering over a specific piece of the bar, you can see which vehicle that piece of the bar is representing.

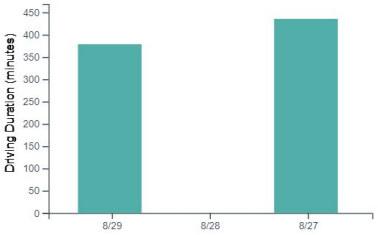
Departments | Vehicles

Vehicle	Department
G9WBW7SYSNC2	Entire Organization
FO15921	Hospital ITS
FO17415	Hospital ITS
G98d210b379c	Entire Organization
G9D6EXUDFM00	Entire Organization
G99DFX0TXMJA	Entire Organization
UFOU6379	Distribution, Hospital Courier
UOFU1513	DISTRO INVENTORY
UOFU1677	emergency room
UOFU1796	UNI
UOFU1869	The Point
UOFU1930	Eye Bank
UOFU1948	Biomedical engineering
UOFU4210	Facilities engineering
UOFU4212	Customer Service
UOFU4326	Huntsman
UOFU4420	UEN
UOFU4431	Facilities engineering
UOFU4461	Environmental Services
UOFU4469	Facilities engineering
UOFU4501	Park Building Pool
UOFU4528	Hospital Courier
UOFU4556	UEN
UOFU4557	UEN
UOFU4572	Transportation
UOFU4580	UNI



Vehicle: FO17415

Department: Hospital ITS
Make/Model: Ford Transit
Class: Class G (8001 - 9000 lbs)
Year: 2016
Vehicle Status: Parked

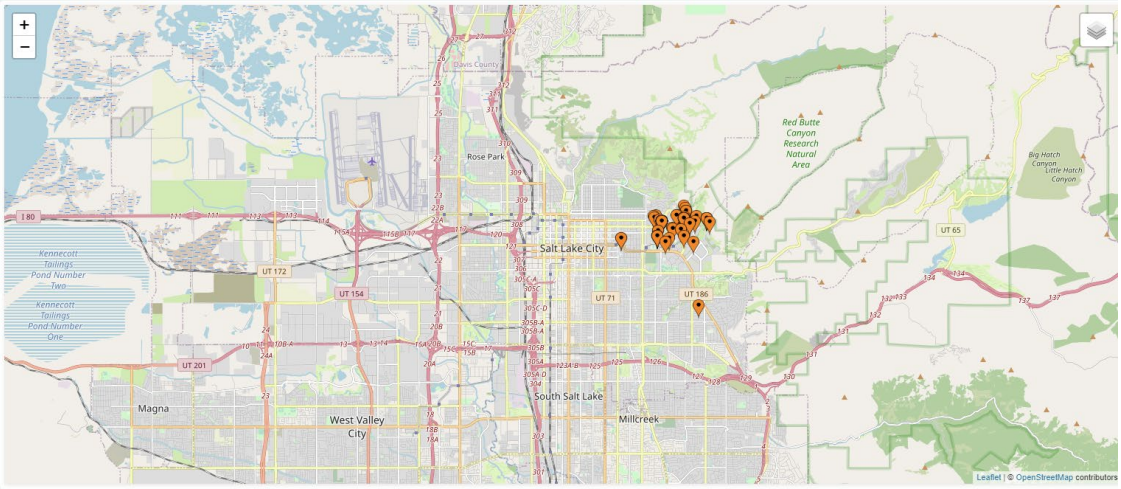


Show Trips From: 2022-09-27
Show Trips To: 2022-09-29

Date	Total Duration
8/27/2022	7:49
8/29/2022	6:52

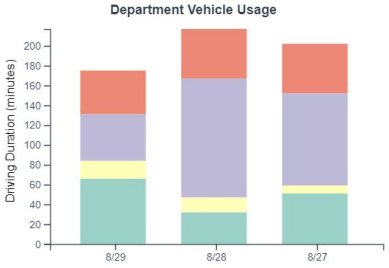
Departments | Vehicles

Department	Num Vehicles
Academic District	1
Air Med	2
Auxiliary Services	1
Biomedical engineering	3
CPD Pool	2
Cardio	2
Carpenter shop	5
Commuter Services	1
Commuter Services Maintenance	5
Commuter services enforcement	11
Construction	4
Core	7
Customer Service	1
DISTRO INVENTORY	2
Distribution, Hospital Courier	1
Electronics	1
Emergency Services	2
Engineering District	3
Entire Organization	6
Environmental Services	1
Eye Bank	1
Facilities engineering	11
Geology	1
Grounds	1



Carpenter shop

Number of Vehicles: 5



Show Trips From: 2022-09-27
Show Trips To: 2022-09-29

Vehicle Id	Year
UOFU5119	2017
UOFU5120	2017
UOFU6171	2019
UOFU6172	2019
UOFU6311	2020

Evaluation:

At this point in the project, I believe that there are a few things that can be learned about the data using this visualization. First, we can inspect each vehicle closely and understand where it is making its trips on the map, the duration and idle duration during these trips (using the tooltip) and get an idea of the vehicle's usage over a set period of time. I believe this could be useful if you wanted to see if a vehicle could be better used in a different department, you could inspect the vehicle to see if its usage is low, and more specifically on what days the usage is low. The department view could also be useful in that by selecting a department you can quickly see which of its vehicles are being underused and could be re allocated.

Overall, I feel like the interactivity of the application is quick and intuitive. Setting the date range that you wish to visualize data is easily accessible and usable, you can quickly switch between vehicle and department views, and the tooltips on the map provide an easy way to get more information on stops that specific vehicles are making.

At this stage there are a few things that I would like to add to better answer the questions I set out to answer. Firstly I would like to add more visualizations to the bottom panel views, most notably for idle time data. I also would like to reduce the clutter on the map when there are many stops by clustering points together. Another important feature will be to add a way to directly compare statistics between different departments and vehicles. Lastly, I think that it will be useful to add a way to visualize overall fleet statistics, like ordering most used to least used vehicles, and usage across all departments.