Optimizing Routes for UVA's Facilities Management Fleet: Enhancing Sustainability and Pedestrian Safety

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract*—To enhance pedestrian safety and sustainability, UVA's Facilities Management (FM) fleet aims to reduce emissions and limit vehicle presence in high-foot-traffic areas. This supports UVA's goal of carbon neutrality by 2030 while creating a safer environment for pedestrians around Grounds. This project identifies optimal routes for FM vehicles traveling to reduce overall fuel consumption and minimize interactions with students in busy areas. Using vehicular telematics data available from the Geotab Platform, current routes were analyzed based on travel time, fuel usage, safety hazards, and proximity to popular student pathways. By looking at the most popular to and from locations of the FM fleet, we identified all reasonable route options and selected the best ones based on the above metrics. Recommended routes enhance efficiency and safety while also avoiding pedestrian-heavy areas like McCormick Road. We analyzed three high-frequency origin-destination pairs and assessed route options at different times of day, focusing on trip duration and peak pedestrian times like class changes. The final recommendations avoid McCormick Road during peak times or altogether while maintaining low trip durations and minimal safety concerns. These findings offer FM practical adjustments to support UVA's sustainability goals and pedestrian safety across grounds.

I. INTRODUCTION

The University of Virginia's (UVA) Facilities Management (FM) fleet is committed to ensuring pedestrian and student safety and sustainability. The primary goal of this research is to provide route recommendations to FM leadership that reduce interactions between FM vehicles and the student population in high-traffic areas, and decrease travel times for certain routes, leading to lower emissions and cost savings. As with most fleet systems, efficiency is a top priority. Many factors go into ensuring a fleet's efficiency, including optimized routes, maintenance, and travel time. Keeping track of a fleet's efficiency can have both monetary and safety benefits, allowing the operations to happen at a smoother pace.

One of UVA's goals, which the FM fleet is a part of, is to be carbon neutral by 2030, and fossil fuel-free by 2050 [1]. With these goals, the FM fleet should use metrics to measure efficiency to help UVA work towards these goals. Currently, the Geotab platform is used to collect and store data on vehicle speeds, paths, trips, fuel consumption, travel time, and safety infractions [2]. This platform has been useful in morphing FM's metrics for efficiency towards achieving UVA's sustainability goals. Currently, the FM team has a requirement for drivers to avoid traveling on McCormick road, which passes through the center of UVA grounds, unless it is absolutely necessary to reach a work site. Through this paper, we align the route optimization of the FM fleet at UVA with the time efficiency and sustainability metrics that UVA hopes to reach. The study at hand was organized to ultimately provide route recommendations as follows: (1) defining route optimization metrics; (2) data collection through geofencing; (3) data analysis and recommendations.

II. BACKGROUND

The FM fleet at the University of Virginia consists of approximately 300 vehicles that are essential for maintenance and operations around Grounds. These vehicles support a variety of tasks, from routine building upkeep to facilitating active construction projects. However, the frequent presence of FM vehicles on roads throughout Grounds introduces challenges related to both safety and operational efficiency, especially in areas with high student traffic. One such area is McCormick Road, which serves as a central corridor for student movement. It connects residential areas such as the Corner and first-year dormitories to key academic and campus hubs, including Shannon, Clemons, and Brown Libraries, as well as the Engineering School, Batten School, and College of Arts & Sciences. Student foot traffic along McCormick Road peaks during class change periods between 9:00 am and 5:00 pm, with transitions occurring every 50 or 75 minutes. Given the volume of pedestrian and vehicular traffic, McCormick Road is especially prone to safety incidents. According to 2023 crash reports from Virginia State and UVA FM, 10.64% of the 94 reported crashes occurred on McCormick Road [3]. Of these, five crashes resulted in injuries reported by Virginia State, while three involved collisions without any injuries. These findings underscore the need to minimize FM vehicle usage on McCormick Road whenever possible to enhance safety and reduce the potential for crashes on Grounds.

III. LITERATURE REVIEW

This section discusses route optimization metrics like trip duration, safety infractions, and proximity to high-traffic areas which are relevant to producing alternative routes for UVA's Facilities Management vehicle fleet.

A. Route Optimization Metrics

Route optimization plays a crucial role in fleet management by improving efficiency, reducing fuel consumption, and minimizing operational costs. Karimiour and their team examined how advanced vehicle routing algorithms could enhance fleet operations while lowering environmental impact [4]. Their primary motivation behind this study was to reduce the fleet's carbon footprint and contribute to sustainability efforts by minimizing fuel consumption and emissions through optimized routing. The study employed optimization techniques to determine the most fuel-efficient routes for fleet vehicles in Sydney, considering factors such as traffic conditions, road networks, and delivery schedules. By integrating real-time data with routing algorithms, the researchers demonstrated how optimized paths can significantly reduce fuel consumption and emissions. The study highlighted key route optimization metrics, including total distance traveled, fuel efficiency, idle time reduction, and carbon emissions per trip. These metrics provide a quantitative basis for evaluating the effectiveness of different routing strategies.

In addition to fuel efficiency and emissions reduction, fleet management research has increasingly focused on advanced models and algorithms for route optimization. Bielli and their team provided a comprehensive overview of optimization techniques used in fleet logistics [5]. The researchers categorized these techniques into static and dynamic models, where static models optimize pre-planned routes based on historical data and dynamic models adjust in real time using GPS tracking and traffic conditions. Their work highlighted the growing importance of integrating machine learning and artificial intelligence in route optimization to enhance decision-making and adaptability in fleet management.

While Karimiour and their team focused on sustainability and carbon footprint reduction and Bielli and their team emphasized the growth of optimization models, our project applied route optimization instead to limit the UVA FM fleet's presence around key areas on UVA's Grounds. Instead of prioritizing fuel efficiency alone, we analyze vehicle movement patterns using geofencing to identify alternative routes that reduce fleet congestion in high-traffic zones. By using Geotab tracking data, we propose to optimize vehicle flow while maintaining operating efficiency, ensuring that FM vehicles can complete necessary trips with minimal disruption to pedestrian activity. Our approach aligns with the trends outlined by Bielli and their team as we utilize both past and present tracking data to dynamically assess and improve the fleet's routes.

IV. METHODS

A. Data Collection

This project utilized telematics data collected by Geotab GPS devices installed in all but one of FM vehicles to analyze the best routes available to the FM fleet in terms of safety and sustainability [2]. Geotab takes in individual vehicle GPS data, storing it into a database that allows for comprehensive fleet management, enabling data-driven decisions to enhance fleet efficiency and safety. These GPS devices continuously capture a variety of data points anytime a vehicle is turned on and running. For this project, we reviewed trip longitude/latitude coordinates, speed during different points of the trip, and time stamps set to report roughly every 15 seconds. We also reviewed exception events, which are addressed as "infractions" in this paper, that include harsh braking, speeding, and engine idling events. For each trip, when a vehicle's engine is turned on and off, total trip duration and total trip distance was also recorded. These data points are crucial for monitoring fleet operations and identifying where improvements can be made.

A significant focus of this study was McCormick Road, a major road known for its heavy pedestrian traffic, especially during class changes. Due to its frequent use by

FM vehicles and associated safety concerns, vehicle drivers have been instructed to avoid McCormick Road during peak times, particularly during class changes. FM management continues to prioritize monitoring this road to decrease FM presence, aiming to minimize student interactions and optimize route safety and efficiency. Concerns include not just traffic congestion but also behaviors that compromise safety, such as speeding, or efficiency issues like excessive engine idling, which contribute to higher emissions. In the summer of 2023, McCormick road was closed for about three months, providing an opportunity to analyze alternative routes taken by vehicles unable to use the road. This road closure offered a controlled environment to assess how FM vehicles adapted their routes and left room for analysis to see if there is evidence to definitively say there is a better route than using McCormick road. The data collection was segmented into three phases in 2023 to effectively capture the impact of this closure: Before Construction (April 15th - April 29th), During Construction (June 1st - June 14th), and After Construction (October 15th - October 29th).

B. Analysis of Heatmap Data and Use of McCormick Road

Following the data collection, a detailed analysis was done to understand common trip routes of the FM fleet by analyzing the starting and ending coordinates of trips taken over the 6-week period. To ensure the relevance of the data analyzed, trips shorter than 0.1 km (approximately 330 feet) were excluded because engine starts without significant travel could skew route analysis and falsely indicate popular areas. To visually analyze and determine the most common trip destinations and starting points, a heatmap was generated using the coordinates of trips that exceeded the 0.1 km threshold. Over the 6-week period, roughly 60,000 trips starting and ending points were plotted on a heatmap with clustering applied to group points that were within 200 feet of each other. This clustering helped to identify high-traffic areas that serve as common starting points and destinations in the daily operations of the FM fleet. Further insights were provided by FM leaders, who discussed common daily routes, helping validate and prioritize busy traveled to areas.

Based on the heatmap and FM insights, six specific areas on the map were identified as significant points of interest due to their heavy traffic, operational importance, and potential use of McCormick road to get to the area (Figure 1). These areas were clearly defined using Google My Maps, where shaded zones were drawn to visually represent these key locations. The zones were digitally drawn based on the heatmap data, aiming to encompass as many relevant trip start and end points as possible to accurately reflect the travel patterns observed during the study. These areas included locations near Route 29, which accounted for 3% of the trips that started or ended in that area, John Paul Jones Arena (JPJ) with 5%, Culbreth Road at 2%, the hospital area with 9%, the area behind Clark Hall with 8%, and the FM headquarters, which was the most significant, accounting for 39% of trip starts and ends. These percentages are the proportion of trips within the 6-week data set that had either a start or an end point within the defined zones on Google My Maps (Figure 1). These zones were designed to capture trips likely following similar routes to these areas, helping to identify the most impactful areas for potential route optimizations.

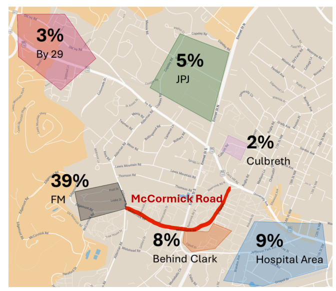

Figure 1. Start-Destination Hotspots

C. Identifying Areas for Specific Route Linking

After identifying the common start and end points of FM vehicle trips over the six-week period, these locations were analyzed to track trips traveling between various combinations of them. To accomplish this, Python code was written to systematically identify trips based on geofences drawn around six key regions. The code analyzed the GPS coordinate data to determine if a vehicle trip started and ended within these geo-fenced areas, classifying trips accordingly. Using this information, we generated a 6x6 matrix, displaying the number of trips traveling between each identified location. This provided movement patterns and trip frequency across the identified regions (Table 1). This table allowed us to identify the most frequently traveled to and from locations for further specific route analysis. In particular, we focused on choosing the to/from locations by analyzing whether there were routes that had the potential to utilize the heavily trafficked McCormick Road and exhibited a high trip frequency between origin-destination pairs.

Table 1. From/To Trip Count of Geofenced Areas

From/To	Geofenced Areas of Interest						
	JPJ	Culbreth	Hospital Area	By 29	Behind Clark	FM Area	Total
JPJ	182	9	133	34	39	497	894
Culbreth	7	117	45	25	**451**	151	796
Hospital Area	146	37	1581	145	154	**1118**	3181
By 29	29	16	123	237	42	553	1000
Behind Clark	38	**364**	167	38	564	**566**	1737
FM Area	505	145	**1241**	537	**612**	3493	6533
Total	907	688	3290	1016	1862	6378	14141

D. Linking Start and Destination Pairs to Specific Routes

Based on the the number of trips to/from each geofenced area in Table 1 and insight from Facilities Management leadership, we decided to analyze routes that connected the below geofenced areas (Figure 1):

1. FM to/from the Hospital Area (2,359 Trips Total)
2. Behind Clark to/from Culbreth (815 Trips Total)
3. FM to/from Behind Clark (1,178 Trips Total)

Because data was pulled from both a period of construction when part of McCormick road was closed, we assumed the data collected in the 6-week period encompassed all reasonable routes to analyze for McCormick Rd. avoidance.

V. RESULTS AND RECOMMENDATIONS

A. FM to UVA Hospital

From FM to the UVA Hospital hotspot area, we analyzed three routes from the FM yard to the University of Virginia (UVA) hospital (Figure 2). The first route took a left on Alderman road outside the FM parking lot and used Ivy road, University Avenue, and West Main Street to reach the hospital. Route 2 went through McCormick road on central grounds to University Avenue then to West Main Street to get to the hospital. Lastly, the third route took a right on Alderman road and used Whitehead Road to Jefferson Park Avenue to get to the UVA hospital. Only one out of these three routes traveled through McCormick road. Across the 6 week period analyzed, the majority of trips took place at 11:00 am, with peak trip duration occurring between the hours of 11:00 am and 1:00 pm, as well as 4:00 pm and 5:00 pm. Peak trip duration and trip count differ across the three routes.

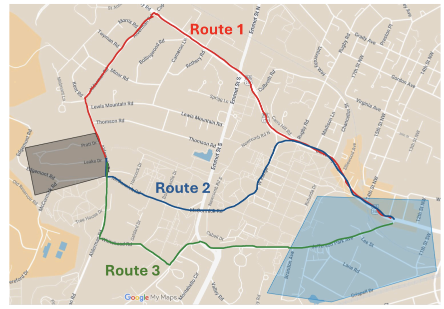

Figure 2. FM to/from the Hospital Area Routes

When traveling from the FM office to the UVA hospital, the three routes do not differ much in regards to average trip duration. Route 1 takes about 6.6 minutes, route 2 takes 6 minutes, and route 3 takes about 5.4 minutes. For time efficiency purposes, route 3 is seen as preferable as it is fastest and avoids McCormick road. However, despite the averages, times were broken down into increments for more targeted recommendations on when to take each route to reduce trip duration, as well as avoid heavy pedestrian traffic.

For route 1, the highest number of trips occurred at 12:15 pm. Moreover, peak travel duration time occurred at 12:15 pm, which is in the middle of a defined class change time period. The second travel duration peak occurred at 11:30 am. Based on this, we recommend FM avoids using route 1 to get to the hospital between the 11:45 am - 12:00 pm class change period, as well as 11:30 am-11:45 am.

Route 2 had peak trip durations at 10:45 am and 1:45 pm, both within class change periods, where pedestrian traffic is the highest on this route. Through this, the preferred suggestion is to avoid using route 2 entirely. If needed, route 2 should be avoided between 10:45 am - 11:00 am and 1:45 pm - 2:15 pm. Lastly, for route 3, there was a significantly more spread out variation of number of trips and trip durations. On average, the longest trip duration on this route occurs between 12:30 pm - 12:45 pm, during a class change period. Another significant spike in average trip duration occurs at 4:45 pm, another class change time and the beginning of rush hour. These peaks in average duration also match with significant increases in trip counts occurring. Through this, FM should avoid using route 3 between 12:30 pm - 12:45 pm, as well as at 4:45 pm. Overall, due to low average trip duration and avoidance of pedestrian-heavy paths like McCormick road, route 3 is the best path to travel from FM to the UVA hospital.

B. Clark to Culbreth

We analyzed three different routes connecting FM's Central Ground station behind Clark to the Culbreth parking garage where FM employees park their personal vehicles. The map below shows each route (Figure 3). Route 1 takes a left on McCormick Road onto Emmet Street and connects to Culbreth Road. Route 2 takes a right on McCormick Road to merge to University Avenue and take Culbreth Road. Route 3 takes a right on McCormick Road to connect to Rugby Road and eventually Culbreth Road.

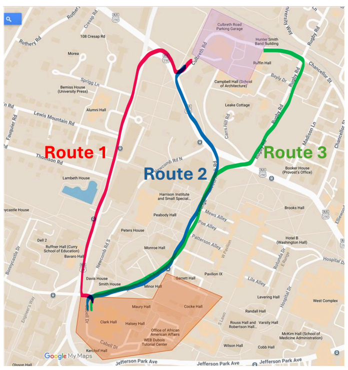

Figure 3. Behind Clark to/from Culbreth Routes

Breaking up Route 1 (McCormick to Emmet) by hour, we find a spike in travel time from 3:00 pm - 4:00 pm and 10:00 am - 11:00 am. It is also shown that FM seems to already travel less during 3:00 pm - 4:00 pm. Thus, looking from 10-11 am in 15 minute increments, we suggested FM limiting or avoiding traveling on Route 1. More specifically, from 10:30-11:00 am since that 30-minute period has a higher average trip duration than other intervals and has the most FM vehicles traveling at that time. It is also important to note that class change occurs at 10:45/50 am and adds students into the traffic.

Moving onto Route 2 (McCormick to University), we found that there was a spike in trip duration from 5-6 pm and 3-4 pm. Looking into 15-minute increments, we suggested avoiding traveling on Route 2 from 3-3:15 pm, 3:45-4 pm, and 5:30-6 pm with 3:45-4 pm (a class change) having a higher average trip duration and trip count.

As for Route 3 (McCormick to Rugby), we noticed a spike in trip duration from 2-3 pm and 12-1 pm, which FM already seems to avoid as there are fewer trips then. Thus we consider the next spikes which are from 4-5 pm and 10-11 am. Breaking those hours into 15-minute increments, we recommend FM avoids traveling on Route 3 from 10:45-11:00 am and 4:30-4:45 pm as those are class changes.

Next we looked at all routes during the busy time periods just listed to see which routes FM should take instead. If FM must drive during the recommended non-driving period during 3:45 pm, we suggest taking Route 2 (McCormick to University), during 10:30 am we suggest taking Route 3 (McCormick to Rugby), and during 10:45 am we suggest taking Route 2 (McCormick to University). Taking Route 1 was less efficient than the other routes in all cases.

C. FM and Behind Clark

The identified FM to Behind Clark route exhibits a significant presence of vehicles on McCormick Road when traveling to the destination because it's the only reasonable route option in terms of travel duration from FM (Figure 4). Therefore, we recommend avoiding it only during peak pedestrian periods rather than eliminating it entirely.

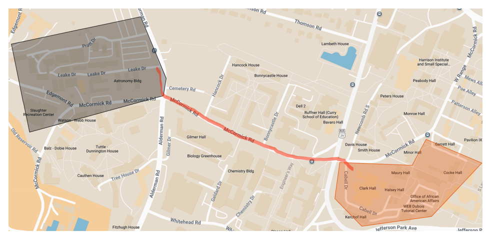

Figure 4. FM to/from Behind Clark Route

Over the six-week analysis period, two weeks of which fell during construction, when no vehicles traveled directly between FM and Clark through McCormick Road, a total of 386 vehicle trips were recorded. Five trips were removed as outliers due to their exceptionally long or short durations, as each represented a single, abnormal occurrence.To assess potential traffic congestion and identify periods of increased travel time, we analyzed trips by the hour within the designated time frame of interest (9:00 am – 5:00 pm), when pedestrian activity on McCormick Road is at its peak. This analysis revealed a notable increase in average trip duration between 2:00 pm and 3:59 pm. However, as restricting vehicle travel for the entire two-hour window was impractical, we conducted a more granular analysis using 15-minute increments.

Our findings indicate significant spikes in travel time specifically during the 2:45 pm – 3:00 pm and 3:45 pm – 4:00 pm periods, both of which conflict with major class change times (Figure 5). During the 2:45 pm – 3:00 pm window, average trip duration increased by 2 minutes and 20 seconds compared to the overall average of 5 minutes and 45 seconds. Similarly, during the 3:45 pm – 4:00 pm window, trip duration was 1 minute and 30 seconds longer than the overall average. These findings suggest that targeted travel restrictions during these periods could effectively reduce congestion and improve travel efficiency.

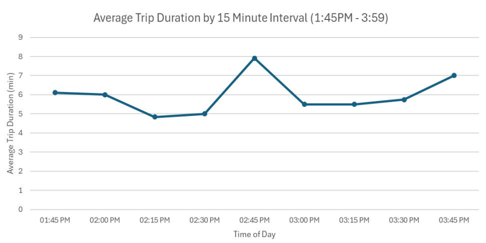

Figure 5. FM to/from Behind Clark McCormick Rd. Route: Average Trip Duration by 15 Minute Interval

Given that McCormick Road is a highly trafficked area, avoiding these two peak time frames not only minimizes travel delays but also enhances safety by reducing vehicle-pedestrian interactions during major class transition periods. By scheduling trips outside these windows, FM vehicles can maintain efficiency while mitigating potential conflicts with student foot traffic.

VI. CONCLUSION

This study provides data-driven recommendations to optimize UVA's Facilities Management (FM) fleet routes, reducing travel time, fuel consumption, and interactions with high-foot-traffic areas like McCormick Road. By analyzing telematics data, we identified peak congestion periods and proposed targeted travel adjustments to improve efficiency and safety. These recommendations align with UVA's sustainability goals, supporting carbon neutrality by 2030. While this study offers actionable insights, future research could incorporate additional sustainability metrics, more precise data collection, and safety infraction analysis to refine route optimization further. By implementing these adjustments, the FM fleet can operate more efficiently, reduce environmental impact, and enhance campus safety, contributing to a more sustainable and pedestrian-friendly UVA.

VII. LIMITATIONS AND FUTURE ANALYSIS

Despite the analysis and recommendations made, this study has several limitations. First, incorporating additional data fields such as vehicle engine idling time and emissions could improve the accuracy and alignment with UVA's sustainability goals. Vehicle engine idling can be detected within the Geotab interface, while vehicle emissions must be calculated using vehicle speed data in a different software, such as the Environmental Protection Agency's MOVES model. Another limitation is the 15-second interval at which data was reported and analyzed, which likely reduced accuracy compared to using the continuous data available in Geotab. Higher-frequency data could produce more specific measurements on average trip duration and trip count. Additionally, this study could not fully assess general safety infractions along routes to selected hotspots due to the limited amount of safety data recorded over the six-week period. Including this type of analysis in future work could help FM make more informed decisions regarding both efficiency and safety. Building on this research, future studies can use second-by-second vehicle speed data from Geotab in the MOVES model to assess emissions and identify opportunities to reduce FM's carbon footprint through improved trip planning, vehicle type selection, and engine idling reduction.

ACKNOWLEDGMENT

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