



Comparative Analysis of Two-Wheeled Mobility Options and Suitability for the U.S. Park Police

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1 National Laboratory of the Rockies

2 United States Park Police

The National Laboratory of the Rockies is a national laboratory of the U.S. Department of Energy, Office of Critical Minerals and Energy Innovation, operated under Contract No. DE-AC36-08GO28308.

Technical Report
NLR/TP-5400-99289
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List of Acronyms

MODE	Mobility Optimization and Deployment Engine
NLR	National Laboratory of the Rockies
NPS	National Park Service
POI	Point of Interest
PuLP	Python Linear Programming
USPP	United States Park Police

Executive Summary

This report provides a framework for analyzing the operational effectiveness and resource efficiency of micromobility and e-mobility—henceforth collectively referred as two-wheeled mobility—operations for the U.S. Park Police fleet in the Washington D.C. metropolitan area. Micromobility refers to small, lightweight transportation modes—such as bikes, and e-bikes—designed for short-distance urban travel and first and last-mile connectivity. E-mobility refers to electrified vehicles such as electric motorcycles. The Park Police currently have an inventory of bikes, e-bikes, e-motorcycles, UTVs, and cars which they use to patrol National Monuments and points of interest in the capital region. They want to understand how they can patrol these locations by using new and existing two-wheeled mobility options.

The authors conducted a comprehensive analysis of the U.S. Park Police’s patrol operations by assessing their patrol patterns, rapid response, and community-engagement scenarios. Using this data, the authors developed application criteria to guide optimal deployment, maintenance scheduling, and future acquisition decisions of micromobility and e-mobility options to maximize operational effectiveness and resource efficiency. These criteria were organized around an optimization framework to support allocating mobility options to different stations based on their inventory, usage pattern, and officers deployed.

The Mobility Optimization and Deployment Engine (MODE) model developed in this report could be used to explore other micromobility and macromobility (long-distance, higher capacity transportation) options for fleets across the country.

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1 Introduction

The United States Park Police (USPP) is a federal police force tasked with patrolling and maintaining law and order in and around the National Monuments in the Washington D.C. metropolitan area. In the many pedestrian areas that cannot be patrolled by cars, the Park Police must choose between the different two-wheeled mobility options available to them.

The USPP already have a fleet of bikes, electric bikes (e-bikes) and electric motorcycles (e-motorcycles) that they acquired in 2017, 2024 and 2019 respectively. The fleet is currently satisfying the needs of USPP, although some vehicles are due for replacement. The USPP is also expecting a period of rapid growth in their operation between FY25 and FY26, almost doubling their officer count. This increase in officers and responsibilities is expected to result in a need to buy newer and more advanced micromobility and e-mobility vehicles. Researchers from the National Laboratory of the Rockies (NLR) were asked to develop a framework to identify optimal two-wheeled mobility options for USPP's patrolling duties considering both operational needs and efficient use of resources.

To provide a solid framework of deployment options for the USPP, NLR analyzed the current fleet and points of interest (POIs) that officers patrol, and explored the various two wheeled mobility options that are currently available in the market. The authors then developed a travel optimization algorithm to pair the most well-suited mobility options with the patrol duties using the Mobility Optimization and Deployment Engine (MODE) model.

2 Overview of USPP Fleet Operations

The USPP currently has an inventory of bikes, e-bikes, motorcycles (both gas and electric), and cars that they use to patrol National Monuments and POIs in the capital region. Since many of these areas are not accessible by motorcycle or car and are walk/bike only, they also use different micromobility options available to them. The USPP has five stations in the Washington, D.C. metropolitan area from which they patrol these locations (USPP 2025). Each station has specific patrol locations assigned to them based on proximity and officer count.

The USPP currently operates between 24 and 29 bikes and 12-15 e-bikes across five stations in the D.C. metropolitan area. They also maintain a fleet of over 30 bikes as a training fleet for initial police bike classes that are necessary to train officers for their bike certifications. They have 8 e-motorcycles out of the District 1 station in downtown D.C. Additionally, they have 2 electric Polaris Ranger UTVs as well: one is assigned to the District 1 station, and one is assigned to USPP headquarters. The bikes in the patrol fleet are roughly five to nine years old as of this report. The training fleet is mostly over ten years old. The e-bikes are two years old, and the e-motorcycles are seven years old. Based on fleet reporting, there are patrol cars available at each of these police stations as well. However, the authors focused exclusively on two wheeled mobility options for this study.

The five district stations and the equipment allocated to them are shown in Table 1 and Figure 1.

Table 1. U.S. Park Police District Offices in DC Metropolitan Area and Transportation Assets

Station	Address	Bikes	E-bikes	E-motor-cycles
District 1	1200 Ohio Drive SW, Washington DC	18	10-12	8
District 2	700 George Washington Memorial Parkway, McLean VA	2-4		
District 3	5701 Beach Drive NW, Washington DC	2-4		
District 4	6501 Greenbelt Road, Greenbelt MD		1-2	
District 5	1901 Anacostia Drive SE, Washington DC	2-3	1	

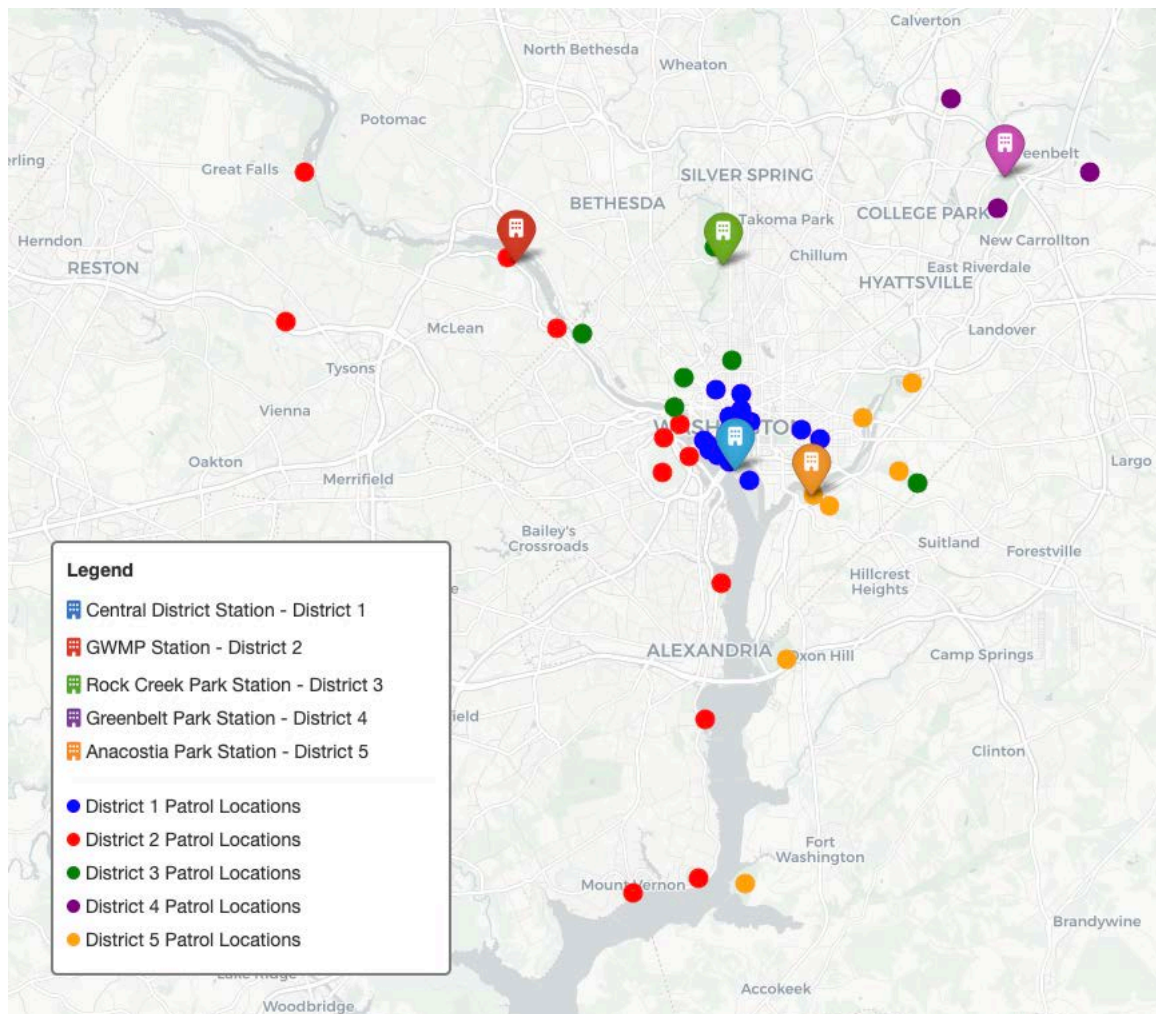


Figure 1. Map of the Washington DC metropolitan area identifying USPP stations and patrol locations

3 Two-wheeled mobility Options

The USPP wants to utilize the micromobility options at its disposal to patrol some non-motorized traffic areas, such as the National Mall and the Lincoln Memorial. To that extent, they already have a fleet of bikes, and e-bikes. Additionally, USPP has concerns that some of their current two-wheeled mobility fleet is under-utilized and that their e-motorcycles have taken a long time to get repaired when maintenance issues arise. Our market research hence started with finding reliable mobility options that can withstand the usage patterns of USPP.

Of all the current options in the market, bikes and e-bikes stood out for their reliability, popularity, and suitability to USPP operations. Additionally, there are police-specific options available in the market, which reduces the costs of accessorizing and modifying them compared to any other mobility option. E-bikes are one of the faster options in the micromobility space. Bikes are one of the most economical forms of mobility available with a long police force history. The patrol officers need to be certified before they operate any micromobility options; owing to a long history of usage, it is easier for bike certification compared to other options like scooters and one-wheels.

Manufacturer recommendations for maintenance are similar across bike types but return to operation from maintenance has varied significantly in USPP operations. Bikes and e-bikes typically require routine maintenance that is available at dozens of area shops, including replacement of damaged parts such as brake pads and chains as well as greasing and gear tuning. The e-motorcycles procured by USPP need to be fixed in specialty shops certified by their manufacturer. There are few of these in the D.C. metropolitan area, and sometimes the turnaround from these shops can take months. The USPP believes that with a greater market share, the e-motorcycles may eventually yield maintenance savings compared to gasoline motorcycles because they have fewer moving parts and fluids to replace.

Table 2 details some of the micromobility and e-mobility options that are currently available in the market. The USPP currently operates Code 2 and Code 3 bikes (Police Bike Store 2026), Recon Police Interceptor e-bikes (Recon Interceptor 2026), and Zero DSR (Zero Motorcycles 2025), all of which are police specific models. Livewire e-motorcycles – whose parent company Harley Davidson has a long history with the police force – are a new option in the e-motorcycle space (LiveWire Motorcycles 2026).

Table 2. Mobility Options, Example Makes and Models, Ranges, and Maintenance Periods

Mobility Type	Make	Model	Unit Cost	Range	Maintenance Cost Per Year	Maintenance Period per Mobility Type
Bikes	Code	2	\$1,000	15-20 miles per shift	\$100	1 year
	Code	3	\$1,200	15-20 miles per shift	\$100	
E-bikes	Recon	Interceptor	\$4,000	60+ miles per battery	\$200 (Volcanic Bikes 2026)	1 year/1,000 miles
	Recon	Stryker	\$4,000	50+ miles per battery	\$200	
E-motorcycles	Livewire	S2 Del Mar	\$12,000	113 miles per battery	\$500 (Happy Run 2025)	1 year/5,000 miles
	Livewire	S2 Alpinista	\$13,000	120 miles per battery	\$500	
	Zero	FX	\$12,500	102 miles per battery	\$500	1 year
	Zero	DSR/X	\$20,000	179 miles per battery	\$600	

The largest advantage of bikes is their low cost. Even the top-of-the-line fully kitted police bike is roughly 1/3 the cost of the e-bikes. They are also very maneuverable, excellent among crowds, and easy to teach officers to ride and use properly.

E-bikes can cover short and long distances at speed, and officers arrive physically able to respond to a call for service or emergency. Traveling any real distance on a bike to an emergency leaves officers at a disadvantage physically. The capabilities of e-bikes are not equivalent to a gas or electric motorcycle for covering large distances. However, for smaller geographical areas and congested areas where low speeds are required, officers view e-bikes as an equally capable tool. While the lights on the bikes function sufficiently, the e-bikes use the same top-tier lights as emergency vehicles, the emergency lighting on the e-bikes is very good which is another advantage of e-bikes.

E-motorcycles can cover farther distances at a greater speed with very little physical exertion when compared with bikes and e-bikes, though they are restricted to motor vehicle routes. They can carry more equipment throughout the day compared to micromobility options. The compact vehicle size allows officers to ride more comfortably and safely in and around traffic. The quietness of the e-motorcycles avoids disturbing visitors or notifying bad actors.

With increasing market share, the service and spare part availability of e-motorcycles have also improved significantly since 2019 when the USPP first purchased the Zero DSR e-motorcycles. Newer models with more efficiency and longer range have since been introduced, successfully addressing range and efficiency concerns among the officers. With less moving parts, e-motorcycles are easier to service and have a longer time between services compared to traditional motorcycles. With many of the new models supporting fast charging, and with easier access to charging stations, e-motorcycles present a strong case financially and operationally.

Using a combination of two-wheeled mobility options helps maximize the advantages and minimize the disadvantages of the various technologies, while balancing maintenance, cost, and range requirements.

With a variety of micromobility and e-mobility options potentially at their disposal, the USPP wants to re-think how to deploy their officers for patrolling duties. Each station in the D.C. metropolitan area has specific POIs assigned to them. In addition to the mobility options and service timelines, NLR was also tasked to prepare an optimum patrolling schedule and framework. Therefore, the authors utilized an optimization tool to achieve realistic schedules and mobility options for the service.

4 Framework for Deploying Micromobility in U.S. Park Police Operations

NLR developed an optimization framework called the Mobility Optimization and Deployment Engine (MODE) to account for vehicle purchase cost, maintenance cost, vehicle range, and patrol requirements to prioritize different mobility options based on the patrol radius and the stopover time at each site. The framework utilizes an algorithm to optimize vehicle selection using the number of officers and the numbers of places they have to patrol based on the transportation options each station has and constraints described below.

To optimize the patrolling schedules and fleet allocation, MODE treats the patrol assignment as a resource allocation problem. It looks at the mobility options available at each station, their travel times, and their weighted cost factors. This section outlines the data parametrization, the mathematical formulation of the optimization model, and the various constraints NLR utilized in solving the problem.

First, an objective function is defined. In this case, the primary objective involves balancing two sets of transportation constraints: travel time and the weighted cost factor attached to each mode of transport. This optimizes for mobility efficiency. The weighted cost factor is dependent on the price to acquire and maintain that mode of transport. Maintenance price includes the service costs, spare parts cost and the cost to charge the vehicles. By utilizing the cost to acquire and maintain these mobility options over a period of five years and by using the price data from Table 2, NLR was able to calculate weighted cost factors for each mobility option. From foot patrols to e-motorcycles, the cost factor rises steadily as their price increases. The final weighted cost factors for each mode of mobility are detailed in Table 3.

Table 3. Weighted Cost Factor for Each Transportation Mode

Mode of Transportation	Weighted Cost Factor
Foot	1
Bike	2.5
E-bike	4
E-motorcycle	16

Additionally, the algorithm also supports a secondary objective to maximize utilization by minimizing unused shift time such that routes are assigned in such a way that every officer's time is utilized for the maximum possible duration.

In addition to the transportation constraints mentioned above, a few more operational constraints are important to the functioning of the optimization algorithm:

1. **Complete Coverage Constraint:** Every POI must be visited exactly once. Each POI is visited by only a single officer.
2. **Station Matching Constraint:** Every patrol officer only patrols the POI location that belongs to the officer's station.

3. **Time Capacity Constraint:** Total time spent by an officer patrolling should not extend their shift time.
4. **Officer Schedule Constraint:** An officer can patrol only one location at a time and once they are assigned a schedule, they are not assigned any more schedules.
5. **Mode Compatibility:** Our dataset has an “allowed modes” column which checks whether a particular POI allows for a particular mode of transport or not. For example, the solver wouldn’t allow an e-motorcycle borne officer to ride up to the Washington Monument since that POI would not allow an e-motorcycle.
6. **Shift Integrity:** The total duty time (travel time + service time + lunch break) should not exceed eight hours of shift time.
7. **Service Requirements:** Each POI is assigned a mandatory service time, representing the time an officer must be onsite for investigation or presence.
8. **Flow Conservation:** Every officer must start at their respective station, visit the POIs in their schedule, and return to their origin station.

This approach generates a time-constrained heterogeneous vehicle routing solution, which includes three main aspects:

1. **Heterogeneity:** The routing problem accounts for mixed modes of transportation, but each daily schedule uses a single mode per officer.
2. **Decision Variables:** MODE uses both binary decision variables (x_{ijk}) and continuous time variables (t_{ijk}) to determine if officer k travels from location i to location j .
3. **Optimization Engine:** For optimizing our routing, NLR utilizes a Mixed-Integer Linear Programming optimization package called PuLP (Mitchell et al. 2011) in Python.

With the constraints and algorithm defined, NLR used the geospatial intelligence and routing APIs to arrive at a solution. OpenRouteService (HeiGIT gGmbH 2025) is utilized to fetch live routing matrices between the stations and POIs. These matrices are different for different modes of transport. If the API failed to fetch the data, MODE could use Haversine distances to calculate these matrices, but that was not needed for the USPP patrol routes in Washington, D.C. Each value in these matrices signifies the time it takes (in minutes) to cover the distance between each POI and the stations.

Once these matrices are obtained, the MODE solver starts the optimizing process of assigning different modes of transport to different POIs. It uses these matrices and the above-mentioned transportation constraints to build multiple trip chains depending on the number of officers available at each station and the number of POIs to be patrolled with each trip starting and ending at the same station. Once the model evaluates the possible combination of POIs in the form of a trip by cross checking with our specified operational constraints it then generates the routes for each officer to travel from stations to cover each of the POIs with the lowest total weighted cost accounting for transportation constraints.

5 Results

MODE was able to successfully find optimal transport modes and trip chains for officers to cover all 45 POIs across 5 stations. By using OpenRouteService, NLR was able to obtain accurate travel times for all the micromobility modes. The authors then developed complete travel time matrices, and the model was able to build a valid patrol itinerary for officers in all 5 stations.

Table 4 details the final itinerary assigned to officers from each station and a mix of 4 modes of mobility. All trips start and end at the station noted in the first column of the table, and therefore the table does not show the start and end points in the “Trip Chain” column. Each of the 45 POIs was successfully assigned to a patrol officer. The solver’s prioritization of mode was heavily influenced by distance to POIs and accessibility for different modes of transportation. MODE users could change their requirements, available fleet options, and the other constraints described in Section 4 to develop different trip scenarios.

Table 4. Final Patrol Routes

Station	Mode	Trip chain	Total travel time (min)	Total travel distance (mi)	Total service time (min)
District 1	Foot	FDR Memorial → Jefferson Memorial → East Potomac Park	47	3.3	360
	Bike	Lincoln Memorial → Korean and Vietnam Veterans Memorial → West Potomac Park	14	3.3	360
	Bike	National Mall → Washington Monument → Lafayette Square	17	4.5	360
	E-bike	Stanton Park → Lincoln Park	19	7.2	240
	E-bike	Ford's Theater → Petersen House → Ellipse Ground South	15	4.7	360
	Bike	Dupont Circle → Mary McLeod Bethune House → Franklin Park	28	6.8	360
District 2	Foot	Turkey Run	11	1.1	120
	E-motorcycle	Belle Haven Marina → Washington Sailing → Columbia Island	60	43.3	360
	E-motorcycle	Theodore Roosevelt Island → Iwo Jima → Arlington National Cemetery	46	28.1	360
	E-motorcycle	Fort Marcy → Great Falls → Wolf Trap Performing Arts	62	36.9	360
	E-motorcycle	Fort Hunt → Mount Vernon	61	62.9	240
District 3	Foot	Rock Creek Park	26	2.7	120
	E-motorcycle	Capital Crescent Trail → Waterfront Park → Montrose Park	34	15.8	360
	E-motorcycle	Fort Circle → Meridian Hill Park	50	22	240
District 4	Bike	Agricultural Research Center → Goddard Space Flight Center	61	14.3	240
	Bike	Greenbelt Park	10	3.7	120
District 5	Bike	Langston Golf Course → Kenilworth Aquatic Gardens → Fort Dupont Park	64	14.2	360
	Bike	Anacostia Park → Frederic Douglas House	7	2.3	240
	E-motorcycle	Fort Washington Park → Oxon Hill Farm	50	31.5	240

To patrol all 45 POIs using different modes of mobility, it would take approximately 11hrs in total by 19 officers. The maximum number of POIs covered by a single officer is 3 while the minimum number is 1. Since the authors assumed a service interval time of 120 minutes per POI,

a 30-minute break per officer and an 8-hr working day, the maximum number of serviceable POIs in a single day is capped at 3 per officer by time constraints. The longest trip time is 63.9 minutes while the shortest is 6.9 minutes, both on bikes. The distribution of the sum of total travel times by different modes is summarized in Table 5, and the recommended mobility options are summarized in Table 6.

Table 5. Mode Utilization

Mode	Total travel time (min)	Percentage of total time (%)
Foot	83.4	12.3
Bike	200	29.4
E-bike	33.4	5
E-motorcycle	362.9	53.3

Table 6. Recommended Mobility Options for Each Station

Station	Address	Foot	Bikes	E-bikes	E-motor-cycles
District 1	1200 Ohio Drive SW Washington DC	1	3	2	
District 2	700 George Washington Memorial Parkway McLean VA	1			4
District 3	5701 Beach Drive NW Washington DC	1			2
District 4	6501 Greenbelt Road, Greenbelt MD		2		
District 5	1901 Anacostia Drive SE Washington DC		2		1

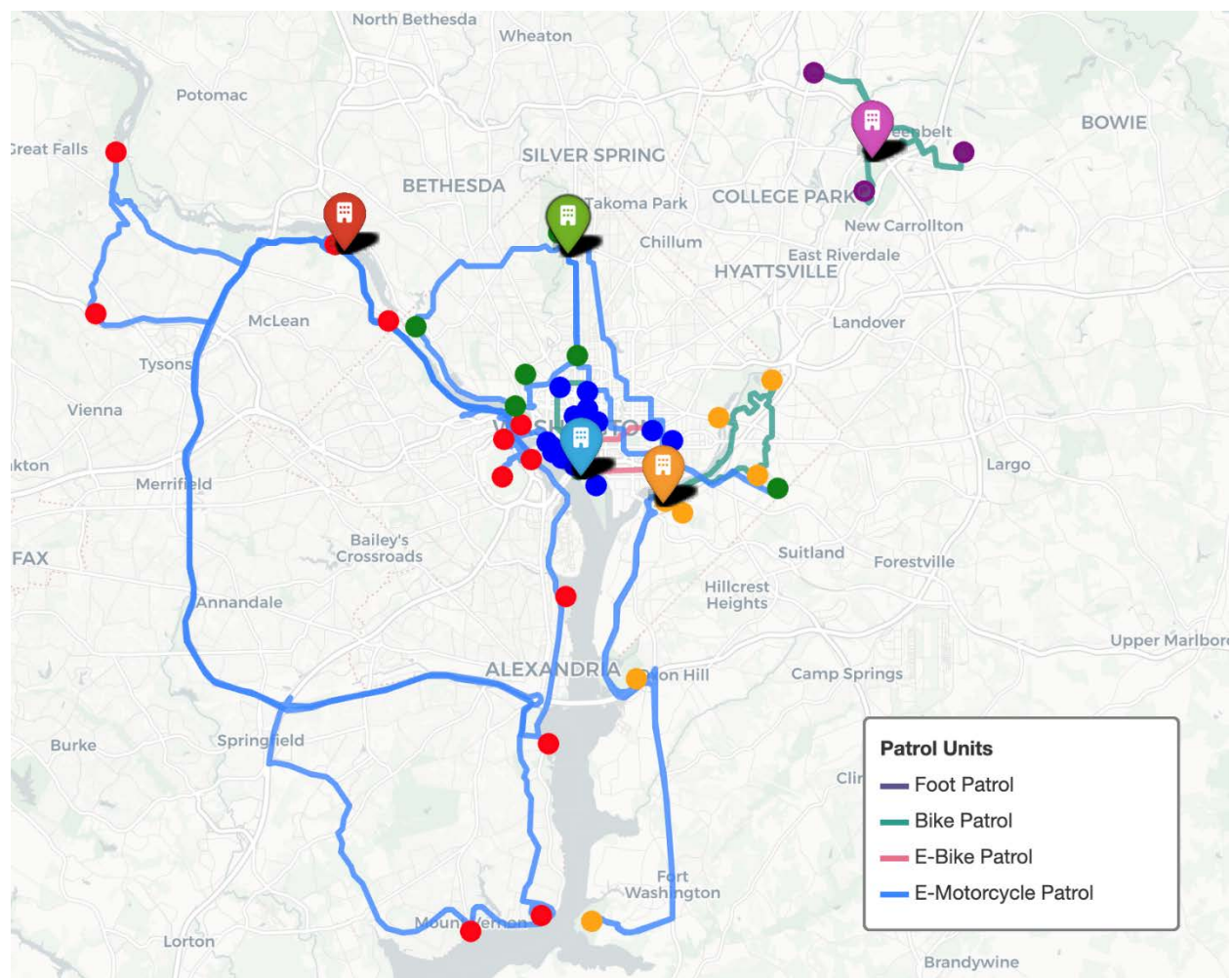


Figure 2. Overview of final patrol routes of all modes

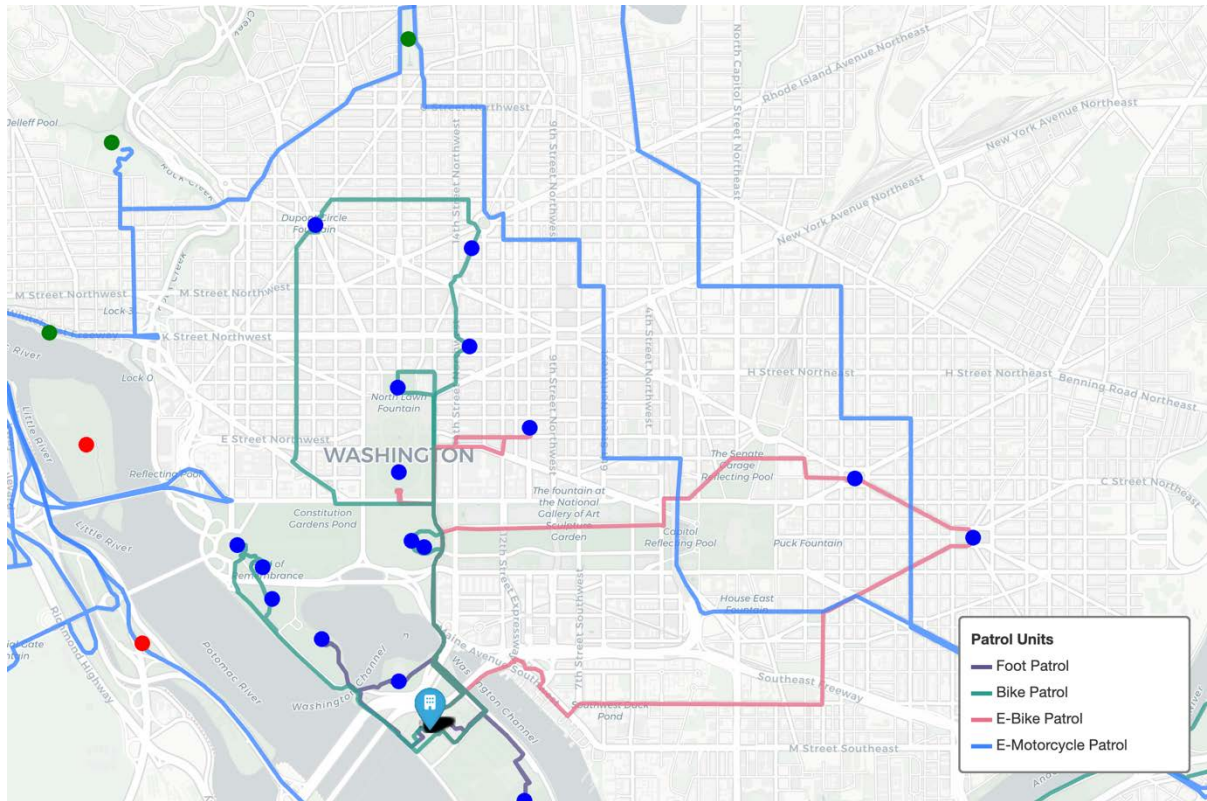


Figure 3. Zoomed in view of USPP foot, bike and e-bike patrols in central Washington DC

The results showcased how a diversity of micromobility options can serve a wider variety of routes. In many cases, e-bikes were only slightly faster than bikes but with a cost factor of 4 to 2.5, respectively, thus lowering the cost-benefit factor of e-bikes over bikes. One factor NLR did not include in the model was rider fatigue, which was higher in the case of bikes and hence stations could prioritize e-bikes to avoid fatigue in some situations.

The solver prioritized e-motorcycles when it calculated the costs associated with the e-motorcycle making up for the distance covered for a particular trip. Instead of splitting up the distance travelled by an e-motorcycle into multiple e-bike or bike trips which led to more officer usage, the solver chose to prioritize e-motorcycles.

Patrols in the dense, POI-heavy areas of central D.C. were assigned to foot and bike modes while patrols done by the District 2 (GWMP) station were geographically dispersed and assigned to e-motorcycle modes.

The model provides a baseline for USPP to allocate mobility assets to each district station as well as feasible patrol routes for the officers. However, other factors, like weather and tourist seasonality, could impact those schedules. Additionally, charging time and other associated logistics were not included in the study but could be factored in as additional constraints. Given that the trip distances analyzed for both e-bikes and e-motorcycles are well within their respective operational ranges, mid-trip charging was not considered in this study. Instead, all vehicles are assumed to be fully charged before starting the trip.

6 Conclusion

This report recommends transportation assignments for USPP officers, aiming to minimize both travel time and total transportation costs. NLR’s model developed for this study, MODE, generated logistically feasible schedules that organized routes and assigned a single patrol schedule to a single transportation mode. Table 7 shows how MODE aligned the fleet distribution with actual usage patterns and operational demand across stations. This efficient allocation reduces downtime and improves asset utilization thereby helping in managing capital and maintenance costs. This approach could provide USPP a more efficient and cost-effective fleet mix for the future; however, USPP fleet administrators will need to verify whether there are other considerations for asset assignment not considered in this analysis. For example, training needs, weather, or peak events like Independence Day celebrations might require additional assets.

Table 7. USPP Existing Asset Distribution Compared to MODE Recommended Asset Distribution

Station	Existing Asset Distribution			Recommended Asset Distribution			
	Bikes	E-bikes	E-motor-cycles	Foot	Bikes	E-bikes	E-motor-cycles
District 1	18	10-12	8	1	3	2	
District 2	2-4			1			4
District 3	2-4			1			2
District 4	1-2				2		
District 5	2-3	1			2		1

MODE, the model developed as part of this report effort, is highly adaptable. It can be tuned for different locations (such as National Parks), types of fleets (e.g., trail maintenance or shuttles), and different transportation assets (including cars and buses). With the use of tested and proven open-source services like OpenRouteService, MODE ensures a robust solution is generated every time.

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