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Geospatial Analysis and Optimization of Fleet Logistics to Exploit Alternative Fuels and Advanced Transportation Technologies

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Geospatial Analysis and Optimization of Fleet Logistics to Exploit Alternative Fuels and Advanced Transportation Technologies

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ABSTRACT

Today's fleet managers are faced with new challenges posed by government mandates and private-sector goals that include reducing petroleum use, reducing greenhouse gas (GHG) emissions, and—for federal and other government fleets—complying with alternative-fuel mandates. Choosing the right technologies to reach these goals is a complex process that requires an understanding of the technological landscape in addition to the makeup and operational requirements of each fleet. Funded by the U.S. Department of Energy's Federal Energy Management Program (FEMP) and Vehicle Technologies Program, the National Renewable Energy Laboratory (NREL) is developing geographical information system (GIS) tools to evaluate alternative fuel availability in relation to garage locations and to perform automated fleet-wide optimization to determine where to deploy alternative fuel and advanced technology vehicles and fueling infrastructure.

Keywords: fleet, alternative fuel, GIS, optimization, transportation

1 IMPETUS

The United States Energy Policy Act of 2005 and resulting regulations require federal fleets to fuel their alternative fuel vehicles with alternative fuel if suitable fuel is available within five miles of the vehicle's garage location. [1]. This requirement led to the development of a geospatial analysis capability to determine, using the Department of Energy's database of alternative fueling stations [2], which federal vehicles are subject to the requirement.

In addition, Executive Order 13514 directs federal agencies to prepare a mult-year plan for reducing carbon emissions. This goal is another factor motivating fleets to maximize the use of alternative fuels and advanced vehicle technologies.

Both federal and private fleets are pursuing goals that can be addressed using alternative fueling and advanced vehicle technologies. These goals include reducing petroleum consumption to reduce costs or promote U.S. energy security and reducing fleet greenhouse gas emissions.

Unlike gasoline and diesel fuel, alternative fuels such as biodiesel, ethanol, natural gas, and electricity are not available universally. Before investing in alternative fuel vehicles, a fleet must establish that either a source for an alternative fuel exists or that sufficient fuel will be used to justify the installation of fueling infrastructure. This analysis is inherently spatial, and the easiest way for a fleet manager to understand the situation is to examine the data on a map.

2 GIS ANALYSIS

Fleet Atlas is a Web-based application developed by NREL that helps users visualize their garage locations and nearby alternative fueling stations on a map. The application is based on a largely open-source software stack. Data are housed in an Oracle database that includes Oracle Locator [3], a subset of Oracle Spatial. MapServer [4], Tilecache [5], and Feature Server [6] are used to serve map data to the client Web application. The client is written using ExtJS [7] and OpenLayers [8]. The application supports basic features found in GIS, including pan, zoom, find location, query, and custom styling of data layers.

After fleet location data have been imported into the database, the application automatically generates data layers showing garage locations as well as those alternative fueling stations located within five miles of a garage location. The alternative fueling station layers are separated by fuel type, which includes E85 ethanol, biodiesel, compressed natural gas, liquefied natural gas, liquefied propane gas, hydrogen, and electricity. This information can be used to answer questions such as:

- Which garages have access to which alternative fuel? This answer can be used to identify locations where alternative fuel vehicles should be added to the fleet and which fuels those vehicles should utilize.
- Which garages do not have access to alternative fuel? This answer identifies where not to place alternative fuel vehicles and where to consider

utilizing other technologies, such as hybrid vehicles, or installing infrastructure.

If users agree to share their data with other fleet users, the tool can be used to identify opportunities for collaboration. For example, if several fleets have garage locations near a single point, it might be possible to justify the installation of fueling infrastructure based on the aggregate number of vehicles among all fleets, but an individual fleet might not have enough vehicles to justify the investment.

The tool also provides data layers depicting flex-fuel, diesel, and hybrid-electric vehicle densities in the overall U.S. vehicle fleet. When fleet managers are deciding whether to install fueling infrastructure, these data indicate the number of potential customers outside their fleet.

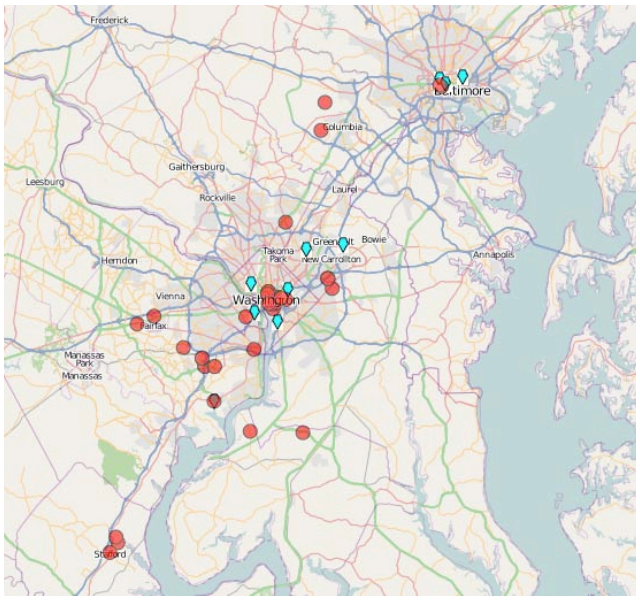

Figure 1: Fleet Atlas showing an example fleet with nearby E85 fueling stations

2.1 Data Quality

The biggest hurdle to overcome is the quality of the input data. For large fleets, it is sometimes difficult to gather all the data for the garage locations with accuracy—particularly to the address level—and store them in a single data repository. Federal fleets, for example, often have garage locations to the ZIP-code level. Performing a GIS analysis with ZIP-code-level accuracy implicitly assumes the garage is located at the geographic center of the ZIP code. While this can provide a reasonable approximation, there will be cases in which this assumption introduces errors.

2.2 Future Enhancements

Potential enhancements to the tool include:

- Customizing the search radius for nearby stations. This will allow the user to perform custom analysis using a driving radius from the garage location to the fueling station location appropriate to that fleet's situation.
- Filtering garage locations to show only those garages where alternative fuel is not available nearby. This will facilitate an analysis of where to place advanced technology vehicles that rely on a traditional fuel (such as hybrids), and where to consider adding fueling infrastructure.
- Downloading tabular reports. This feature is necessary to fulfill certain government reporting requirements and provides the ability to export data to perform further analysis.

3 OPTIMIZATION

Federal agency fleets have aggressive targets for reducing petroleum consumption and greenhouse gas emissions. NREL, funded by FEMP, is working with federal fleet managers to develop an optimization application as a decision-support tool that will allow managers to compile fleet descriptive data, apply mandated and situational constraints, and solve for optimal solutions. Fleet managers will be able to test multiple strategies for both positive and negative ramifications, which will allow for informed decision-making as they strive to meet their energy goals.

3.1 Software

The optimization tool is being developed in the FICO Xpress Optimization Suite [9] that runs the Mosel optimization coding language. It is primarily an integer-optimization program constructed of a system of linear equations defining all fleet constraints in terms of the decision variables to be optimized. The optimizer returns the best-possible value for the decision variables given the constraints. The software is valuable in solving over large samples. In this case, the model handles thousands of vehicle combinations spread over thousands of possible locations.

3.2 Primary Challenge

The optimization tool will primarily benefit fleet managers during the fleet-acquisition process when new vehicles are sited across diverse locations. At this time, managers deal with a myriad of challenges or constraints.

New vehicles must meet the needs of the assigned mission. Typically, an acquired vehicle is replacing another from the fleet inventory. Currently, the new vehicle must be of a similar type as the out-going vehicle to ensure meeting mission requirements. Provided that vehicle use data were available, the optimization tool could be enhanced to identify opportunities for fuel efficiency gains through right-sizing, the substitution of a smaller vehicle that still meets operational requirements.

Fleets are subject to a large number of statutory mandates and executive order requirements. For example:

- A portion of newly acquired vehicles must be alternative fuel vehicles (AFVs).
- These AFVs must be fueled by alternative fuel, or if none is available, the fleet must apply for a waiver to fuel the vehicle with conventional petroleum fuel.
- Fleets must increase the use of alternative fuel and decrease the use of petroleum.

In addition to the constraints of meeting mission needs and mandates, fleet managers operate with budgetary constraints.

3.3 Fleet Goals

Fleet managers approach the vehicle-acquisition process with different strategies for reaching targets related to reducing petroleum consumption and GHG emissions. One option is to increase the use of AFVs, but there are challenges to the strategy. Mission needs or fuel availability might seem to prevent the possibility of aggressive alternative fuel use. Aside from alternative fuel goals, conflicting management priorities and a limited budget complicate decision-making. For instance, fleets might have a need to invest in vehicle maintenance capabilities, fueling infrastructure, or special-use vehicles, such as fire trucks or large busses that fall outside the typical acquisition cycle.

Given these site-specific needs, some AFV-related strategies a fleet manager might wish to investigate include:

- Maximizing the acquisition of AFVs
- Maximizing access of AFVs to alternative fuel
- Minimizing cost while complying with all requirements
- Optimally locating new alternative fuel pumps.

3.4 Optimization Example

The situation of a typical example federal fleet in 2005 illustrates the capabilities of the optimization tool:

- Roughly 2,200 vehicles were due for replacement.
- 59 different vehicle types were being replaced.
- 41 different AFVs were available as replacements for each out-going vehicle.
- Vehicles were garaged in roughly 900 different locations.
- The fleet had a $1.2M incremental budget to purchase AFVs.
- The Energy Policy Act of 1992 (EPAct) requires that 75% of vehicles acquired in Metropolitan Statistical Areas (MSAs) be AFVs. Fleets receive EPAct credits for the AFVs they acquire, and the fleet required over 1,200 credits.
- As an internal challenge, the fleet was in need of funding for fire trucks at $400,000 per truck.

Table 1 summarizes five strategies developed in prior fleet modeling efforts [10] that could have been provided to the fleet manager to support decision-making. In addition to the high-level summary output, the fleet manager would receive the detailed listing of specific vehicle replacements.

3.5 Strategy 1: Actual Results

The first scenario depicts the actual fleet acquisitions that were decided without the aid of an optimization tool. Historically, the AFV-acquisition requirement has driven agencies to acquire as many AFVs as possible regardless of the availability of alternative fuel. This example is no exception. The fleet spent the entire $1.2M budget while acquiring many more AFVs than mandated, and only 10.6% of the vehicles were sited to allow for access to alternative fuel.

3.6 Strategy 2: Max EPAct

The goal of the "Max EPAct" scenario is to maximize the number of AFV EPAct credits acquired. As can be seen, the actual fleet acquisitions came very close to the optimized maximum. Nearly double the number of mandated AFV credits would be acquired, and the budget would be fully exhausted with a marginal increase in the number of AFVs with access to alternative fuel.

Strategy	Cost $	EPAct Credits Acquired	EPAct %	# of Alternative Fuel Pumps Built	% Acquired AFVs with Access to AF
1. Actual Results	$1.2M	2,161	>100%	0	10.6%
2. Max EPAct	$1.2M	2,182	134%	0	13.1%
3. Min Cost	$281K	1,239	75%	0	12.5%
4. Max AF Use	$409K	1,232	75%	0	23.1%
5. Max AF Use, Infrastructure Allowed	$822K	1,231	75%	9	41.3%

Table 1: Example fleet optimization output

3.7 Strategy 3: Min Cost

"Min Cost" represents a scenario where the fleet would attempt to meet the minimum 75% AFV-acquisition requirement while minimizing the budget impact. The 75% mandate would indeed be met, but less than a quarter of the budget would be spent to meet this goal.

3.8 Strategy 4: Max AF Use

The "Max AF Use" scenario has a goal of meeting the 75% requirement, minimizing cost, and maximizing the number of AFVs with access to alternative fuel by optimizing the placement of newly acquired AFVs in locations with access to alternative fuel. The results show the fleet could have spent a small fraction of the budget, met the AFV-acquisition mandate, and more than doubled the percentage of acquired AFVs with access to alternative fuel.

3.9 Strategy 5: Max AF Use, Infrastructure Allowed

The "Max AF Use, Infrastructure Allowed" scenario is similar to the previous but includes the option of the fleet funding the construction of new alternative fuel infrastructure located where the maximum number of AFVs would have access to the fuel. The results show that the agency could have met the AFV-acquisition mandate, constructed nine alternative fuel pumps, and quadrupled the percentage of acquired AFVs with access to alternative fuel. Even under this aggressive approach, the organization would have sufficient funds remaining to purchase a new fire truck.

While the gains for these scenarios appear significant for a single year, the real benefits come year after year as fleets apply similar analysis and continue to optimize the use of funds and maximize alternative fuel use.

3.10 Ongoing Development

The initial benefit of the described model is that it allows a fleet manager to see the cross-cutting impacts of the various strategies. Further development of the optimization tool will include analyses of the following:

- How can a fleet efficiently transfer AFVs within the fleet to locations where alternative fuel is available?
- How can a fleet downsize by optimally selecting the appropriate vehicles to remove?
- How can a fleet best meet the overarching goals of reducing petroleum consumption and greenhouse gas emissions?

With the basic structure of the model in place, the optimization tool is highly flexible and able to handle new constraints or goals. New vehicle and fueling technologies are expected to continue to be developed. These technologies include plug-in hybrid electric vehicles, electric vehicles, and new fuel alternatives. The optimization tool will be able to support fleet managers acquiring these new technologies as they deploy them in their fleets.

Both the optimization tool and the GIS analysis tool are currently under development at NREL. The tools are being used to provide analytical support within FEMP with the intention of eventual public release.

4 CONCLUSION

The use of GIS and optimization tools and techniques can help fleet managers meet the petroleum and greenhouse gas emissions reduction goals that are increasingly part of efforts to move toward sustainable communities, while staying within budget and ensuring that the vehicle fleet continues to meet mission requirements.

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15. SUBJECT TERMS
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