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Routing Strategies for Efficient Deployment of Alternative Fuel Vehicles for Freight Delivery

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Author

Dessouky, Maged

Publication Date

2017-02-01



Routing Strategies for Efficient Deployment of Alternative Fuel Vehicles for Freight Delivery

Maged Dessouky
Daniel J. Epstein Department of Industrial & Systems Engineering
University of Southern California, Los Angeles

For more information, contact:
Maged Dessouky
maged@usc.edu

RESEARCH BRIEF

Project Objective

With the increased emphasis on sustainability, several logistics companies have purchased alternative fuel vehicles, like Compressed Natural Gas (CNG) trucks, to support their delivery operations. However, CNG trucks face several challenges on their way to replacing traditional diesel trucks such as limited mile range and small load capacity. Without effective deployment strategies for fueling stations it is not clear that these initiatives will result in net savings in emissions. Many of the local freight delivery operations are performed by independent truckers who are too small to manage their own fueling station, while the public fueling stations are limited. This research develops efficient deployment strategies for these carriers.

Problem Statement

This research solves the vehicle routing problem for a distributor that employs a fleet of CNG trucks to daily deliver products to customers. Customers are widely distributed in a region and demands from customers are known ahead of time. The distributor's depot does not own private fueling stations by itself and the sparsely distributed public ones are the only options.

The main objective for this problem is to minimize the total cost, while keeping the fleet size as small as possible. The total cost mainly comes from two sources. One is the traveling cost, which is directly proportional to the fleet's daily traveling distance. The other is the fixed refueling cost from the fueling process. It occurs every time when the truck goes to a fueling

station. This fixed fueling cost could be the waiting time for the availability of the pump and setting up time for fueling. The motivation for the fixed fueling cost comes from the real world. A survey shows users may wait for hours in long queues to get their trucks refueled at CNG fueling stations. Meanwhile the fixed fueling cost can have a large influence on the solution method. A fueling station with a shorter detour may not lead to a better solution. The model needs to balance the detour and the frequency of visiting fueling stations.

Research Methodology

Both an exact algorithm and heuristic solution method are given in this research. For the exact algorithm, a Mixed Integer Programming (MIP) model with preprocessing and valid inequalities is developed to solve the problem optimally. The preprocessing and valid inequalities do not influence the optimality of the problem, but accelerate the searching speed of the optimal solutions.

In order to solve a large problem instance of realistic size, a heuristic solution method, Adaptive Large Neighborhood Search (ALNS) with a local search and MIP model, is proposed. ALNS is a widely used method to solve various vehicle routing problems. A classical ALNS includes a construction of initial feasible routes followed by iterations of destroy and repair operations to improve the initial routes. Based on the ALNS, a local search is adopted to enhance the efficiency of a single ALNS iteration and a MIP model is uniquely designed to handle the selection of fueling stations.

Results

In this research, test cases with estimation of daily goods delivery data for the Ports of Los Angeles and Long Beach are solved by the proposed ALNS. The data is from the report “SCAG Regional Travel Demand Model and 2008 Model Validation,” which was conducted by the Southern California Association of Governments (SCAG) in 2012. The locations of CNG fueling stations are collected from the Alternative Fuels Data Center under the U.S. Department of Energy. In total the Southern California region is divided into 4,109 blocks, 85 of which have CNG fueling stations.

In order to analyze the influence of the tank capacity, the model assumes a light-duty CNG truck is identical with its diesel version except for the tank capacity. Since diesel fueling stations are easily accessible in the urban area and the refueling process can be finished in a short time, diesel trucks are not significantly restricted by their tank capacity for local delivery. Figure 1 shows the total daily traveling distance for CNG trucks with different tank capacities. By using the ALNS, the total daily traveling distance for CNG trucks can be reduced significantly when the tank capacity increases from 275 miles to 300 miles, and finally be very close to the benchmark from diesel trucks, which is 10,677.6

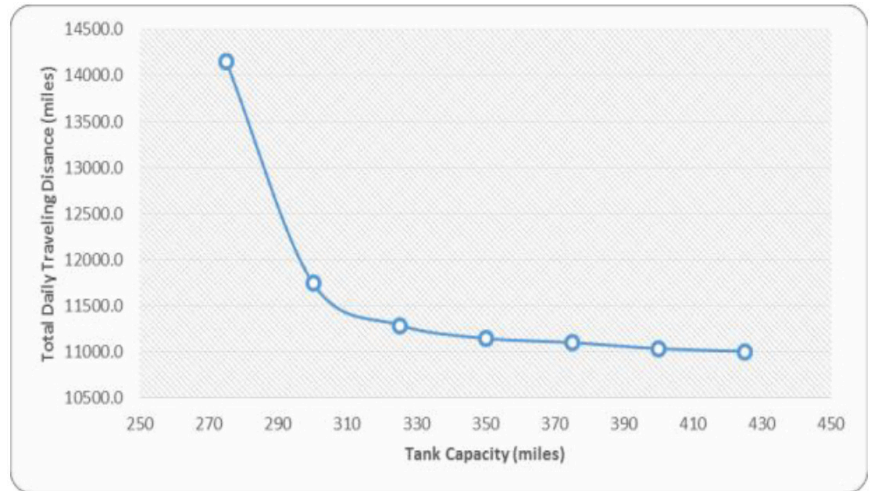


Figure 1. Total daily traveling distance with different tank capacities

miles. Figure 2 shows the relationship between load capacity and total daily traveling distance. In this set of experiments, the tank capacity for CNG truck is fixed at 300 miles (e.g., Chevrolet 2014 Express 3500 model) and the load capacity changes from 50% to 100% of that of diesel trucks. Compared with the total daily traveling distance of 10,677.6 miles for light-duty diesel trucks, the load capacity for CNG trucks is an important factor.

The above computational results illustrate that with the proposed deployment strategies, the influence of the tank capacity from CNG trucks can be reduced to a low level under the current availability of the public CNG fueling stations in the Southern California area. However, the load capacity is a main source for the increase of total daily traveling distance.

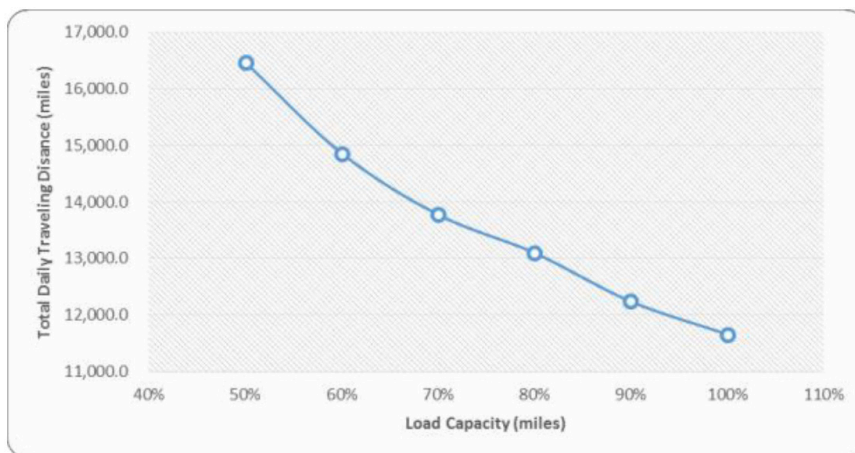


Figure 2. Total daily traveling distance with different load capacities

Further Reading

This research brief is based on “Routing Strategies for Efficient Deployment of Alternative Fuel Vehicles for Freight Delivery,” a report from the National Center for Sustainable Transportation, prepared by Maged Dessouky and Yihuan (Ethan) Shao, of the University of Southern California. To download the report, visit: <https://ncst.ucdavis.edu/project/usc-dot-05/>

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