Driving for Gas: Proposal for a Gas Station Decision Model

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1 Introduction

Drivers often encounter varying gas prices at different stations, and determining whether it is worth driving farther for cheaper fuel can be a tough decision. Our goal is to develop a model that allows drivers to input their car specifications, location, and gas prices at nearby stations to determine the most cost-effective choice. The model considers whether a user is stationary (e.g., at home or work) or traveling and in need of refueling before reaching their destination.

The app we propose will use inputs such as the car model, current fuel level, gas prices, and distance to the stations, taking into account real-time traffic conditions, and geographical restrictions such as tolls. This report outlines the model's components and how it makes decisions based on the data.

2 Problem Statement

Given a driver's location, vehicle specifications, and fuel prices, determine the optimal gas station to refuel at. The app needs to assess whether it is worth driving farther for cheaper gas considering various inputs. It must also take into account the specific needs of hybrid and electric vehicles (EVs), tolls, and road conditions that can affect fuel efficiency.

3 Assumptions

In developing this model, we make the following assumptions:

- **Accurate Real-Time Data:** Gas prices and traffic data retrieved from sources such as Plugshare, GasBuddy, or Google Maps are assumed to be accurate and up to date.
- **Constant Fuel Efficiency:** The vehicle's miles-per-gallon (MPG) rating remains constant throughout the trip, although in reality, MPG can vary depending on factors like acceleration, deceleration, and road conditions.

- **Round Trip:** The user will need to return to their starting location after refueling, meaning fuel consumption is calculated for both to and from the gas station.
- **No Extreme Weather Impact:** Weather conditions such as snow, rain, or extreme heat, which may affect fuel/battery efficiency, are not accounted for.
- **Minimal Traffic Fluctuation:** While real-time traffic data is considered, it's assumed that traffic conditions remain mostly consistent during the user's trip to the gas/charging station.
- **No Stops or Detours:** The user drives directly to and from the gas station without making additional stops or encountering unexpected detours.
- **EV Charging Stations Availability:** For electric vehicles, it is assumed that there will be a charging station available and operational at the chosen location.
- **Tolls and Road Conditions Known in Advance:** Tolls and road conditions (e.g., poor quality roads) are considered known in advance and factored into the cost calculations.
- **Driver Safety and Rule Following:** User will follow all traffic laws and will not deviate from the path as calculated by GPS. eg. The user will experience diminished fuel economy from speeding or from unsafe driving.

These assumptions simplify the model, while still providing a realistic and functional decision-making tool for drivers.

4 Model Overview

4.1 Scenario 1: Stationary (Not Traveling)

In this scenario, the user is not in immediate need of fuel, but wants to determine the best gas station to visit from a location such as home or work.

4.2 Scenario 2: On the road (traveling)

Here, the user is on the way to a destination and must refuel before running out of gas. The app considers the distance to gas stations along the way, ensuring that the user can reach their destination without running out of fuel.

5 Input Parameters

- **Make and Model of Vehicle** – Used to obtain MPG which varies by car model and fuel type (gasoline, hybrid, or EV). For EV's, we would factor in charging stations.

- **Fuel Remaining** – The amount of fuel left in the tank, determining how far the user can drive before needing to refuel.
- **Gas Tank Size and Fill Level** – The app needs to know how much gas the user needs to fill their tank (whether they need a full tank or just a partial refill).
- **Gas/Electric Prices** – Prices at nearby stations are pulled from APIs like GasBuddy or PlugShare.
- **Distance to Gas Stations** – Determined by the user's location, factored by GPS data or manual input.
- **Real-Time Traffic Data** – Integrated through Google Maps API to adjust driving times and fuel efficiency according to road conditions.
- **Geographical Restrictions** – Information on tolls, road conditions, and possible detours that might increase costs or decrease fuel efficiency.

6 Outputs

- **Recommended Gas Station or Charging Station**: The station with the lowest total cost, including driving distance, gas price, traffic, tolls, and vehicle type.
- **Driving Cost Calculation**: Estimates how much fuel or electricity will be used based on the distance and traffic conditions.
- **CO2 Emissions Impact (Optional)**: For environmentally conscious users, the app can suggest options that minimize emissions.

7 Algorithm and Calculations

7.1 Driving Cost

The app calculates the fuel or energy used to get to and from each gas station.

$$\text{Fuel Used} = \frac{\text{Distance to Station}}{\text{MPG}} + (\text{Traffic Impact Factor} \times \text{Idle Fuel Consumption Rate})$$

$$\text{Total Driving Cost} = \text{Fuel Used} \times \text{Gas Price at Current Location}$$

7.2 Total Refueling Cost

The cost of filling up the tank at each station, including the cost of driving there.

$$\text{Total Cost} = \text{Driving Cost} + (\text{Fuel Needed} \times \text{Price per Gallon at Station})$$

7.3 Station Comparison

The app compares the total costs for each station and selects the one with the lowest total cost.

7.4 Hybrid and Electric Vehicles

For hybrids, the algorithm adjusts the MPG values to account for battery and fuel efficiency under certain driving conditions. For electric vehicles, the app calculates charging costs based on distance to charging stations and estimated battery range. We could also take into account discounts if a user has a subscription through their car maker (eg. Tesla Supercharger Network)

Formula for EV Charging Costs:

$$\text{Charging Cost} = \text{Distance to Station} \times \text{Cost per kWh at Station}$$

7.5 Geographical Restrictions (Tolls and Road Conditions)

The app will adjust the total driving cost by adding toll fees or increasing fuel usage based on poor road conditions.

$$\text{Total Driving Cost with Tolls} = \text{Driving Cost} + \text{Toll Fees}$$

8 Decision Tree and Process

- **Step 1**: Collect all necessary inputs (MPG, fuel level, tank size, gas prices, traffic conditions, etc.).
- **Step 2**: Determine if the user would like to return to their current location or continue to an alternate destination after fueling.
- **Step 3**: Calculate driving costs to each nearby station, factoring in traffic delays and geographical constraints.
- **Step 4**: Calculate total costs (including the cost of driving and filling the tank) for each station.
- **Step 5**: Recommend the station with the lowest total cost.
- **Step 6**: For EVs or hybrids, adjust calculations based on battery life and the location of charging stations.

9 Example: Stationary Scenario

- **Car**: 25 MPG, gas tank size: 15 gallons, 3 gallons left.
- **Location**: 901 Burkemont Avenue, Morganton, NC.

- **Gas Station A**: 2 miles away, \$3.00/gallon.
- **Gas Station B**: 8 miles away, \$2.80/gallon.
- **Traffic Conditions**: Light traffic for Station A, moderate traffic for Station B (adds 5 minutes).

Station A:

$$\text{Fuel used for round trip} = \frac{4\,\text{miles}}{25\,\text{MPG}} = 0.16\,\text{gallons}$$

$$\text{Driving cost} = 0.16\,\text{gallons} \times 3.00 = \$0.48$$

$$\text{Total fuel cost} = 12\,\text{gallons} \times 3.00 = 36.00$$

$$\text{Total cost at Station A} = 36.00 + 0.48 = \$36.48$$

Station B:

$$\text{Fuel used for round trip} = \frac{16\,\text{miles}}{25\,\text{MPG}} = 0.64\,\text{gallons}$$

$$\text{Driving cost} = 0.64\,\text{gallons} \times 2.80 = \$1.79$$

$$\text{Total fuel cost} = 12\,\text{gallons} \times 2.80 = 33.60$$

$$\text{Total cost at Station B} = 33.60 + 1.79 = \$35.39$$

Decision: In this case, **Station B** is cheaper, even though it's farther away, due to the lower gas price.

10 Example: Moving Scenario

- **Car**: 25 MPG, gas tank size: 15 gallons, 2 gallons left.
- **Starting Location**: 901 Burkemont Avenue, Morganton, NC.
- **Destination**: Outer Banks, NC (392 miles from NCSSM - Morganton)
- **Distance Driven So Far**: 325 miles
- **Distance Left to Drive**: 67 miles
- **Traffic Conditions**: Light to moderate traffic for the majority of the road to the destination.
- **Station A**: There is a gas station 48 miles away, two miles less than you have gas left for, \$3.00 per gallon and on the way to the destination.
- **Station B**: There is a gas station 25 miles away, a safer option, \$3.50 per gallon, out of the way to the destination.

Station A:

$$\text{Fuel used} = \frac{48\,\text{miles}}{25\,\text{MPG}} = 1.92\,\text{gallons}$$

$$\text{Driving cost} = 1.92\,\text{gallons} \times 3.00 = \$5.76$$

$$\text{Total fuel cost} = 14.92\,\text{gallons} \times 3.00 = 44.76$$

$$\text{Total cost at Station A} = 44.76 + 1.92 = \$46.68$$

Station B:

$$\text{Fuel used} = \frac{25\,\text{miles}}{25\,\text{MPG}} = 1.00\,\text{gallons}$$

$$\text{Driving cost} = 1.00\,\text{gallons} \times 3.50 = \$3.50$$

$$\text{Total fuel cost} = 14\,\text{gallons} \times 3.50 = 49.00$$

$$\text{Total cost at Station B} = 49.00 + 3.50 = \$52.50$$

Decision: In this case, **Station A** is cheaper, even though it's farther away. Despite this, some range-conscious drivers would still choose the closer, more expensive station to ensure they have enough fuel at all times.

11 Analysis

Our model shows that small differences in fuel prices can have a sizable impact on the total fuel cost, and that the station with the cheapest fuel is not always the best value when accounting for the fuel burned to reach the station. The model highlights the importance of considering many factors in choosing a fuel station, especially the fuel economy of the vehicle and the amount of fuel the customer plans to purchase. The model proves that for the economical customer, analysis and reasoning are key to spending less on fuel.

12 Conclusion

This model proposes an app that uses a variety of data inputs to calculate the best gas station for the user to refuel. By incorporating real-time traffic data, geographical restrictions such as tolls, and accounting for different vehicle types, the model becomes robust and adaptable to various real-world conditions.