GREEN ROUTING FUEL-SAVING OPPORTUNITY ASSESSMENT: A CASE STUDY USING LARGE-SCALE, REAL-WORLD TRAVEL DATA

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Background and Problem Statement

- Emerging technologies such as connected and automated vehicles have attracted more attention because they can be implemented in the near term and have positive impacts on mobility, fuel consumption, and greenhouse gas emissions.
- One particular interest is guiding drivers or vehicles to choose more fuel-efficient routes—"green routing." The green routing fuel-saving potentials for a large-scale, real-world travel data set have to be assessed.
  - Green routing needs pre-trip fuel consumption estimation methods for any given driving route that has not yet been driven.
  - The green routing pathfinding service requires accurate real-world traffic and network data. Map service application programming interfaces (APIs) provide quality route information.
- The proposed evaluation framework for green routing fuel-saving opportunities uses a routing API and an enhanced pre-trip fuel consumption rate estimation method and applies them to a large-scale, real-world travel data set in California.

Methodology

- The green routing fuel-saving opportunity evaluation framework is shown in Figure 1.

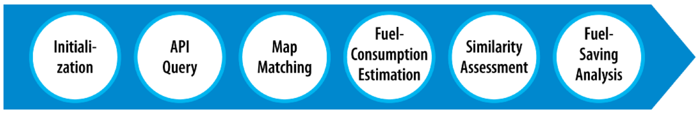
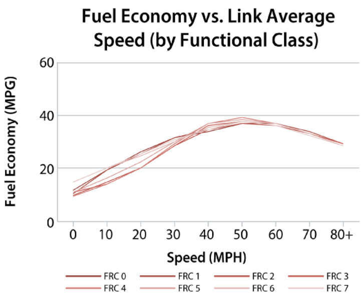


Figure 1: Workflow of green routing fuel-saving opportunity evaluation framework.

- Step A: **Initialization**. Prepare actual route GPS trajectory data and extract origin/destination (O/D) pairs.
- Step B: **API query**. Query directions API and obtain API routes for each O/D pair, including route topology and traffic data.
- Step C: **Map matching**. Map-match API routes and actual routes to a common road network and obtain link attributes, such as functional class and road grade.
- Step D: **Fuel-consumption estimation**. Estimate route-specific fuel consumption for API routes and actual routes.
- Step E: **Similarity assessment**. Determine if the actual route matches one of the API routes.
- Step F: **Fuel-saving analysis**. Analyze fuel consumption and travel time comparisons between greenest routes and actual routes.
- Enhanced pre-trip fuel consumption estimation method.
  - Use Future Automotive Systems Technology Simulator (FASTSim)-estimated fuel economy data as the ground truth fuel consumption for each actual route.
  - Estimate the fuel consumption rate of a driving segment by its average speed, functional class, and road grade.



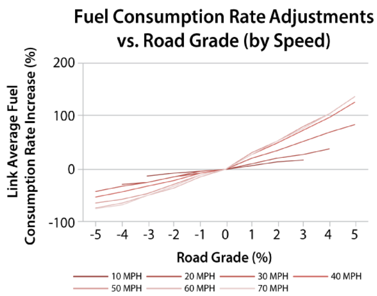


Figure 2: Fuel economy (in miles per gallon) as a function of link average speed and functional class. Figure 3: Fuel consumption rate correction percentages, as a function of road grade and link average speed.

Experiment and Results Discussion

- The data set has 44,805 O/D pairs and contains 4,265,064 global system positioning (GPS) points, which are extracted from 111,096 miles of actual driving routes in California.
- Google API then provides the API routes and their traffic information for each O/D pair, resulting in a total of 100,031 API-procured routes (an average of 2.2 API route options per O/D pair).

Results and Discussion

1. Overall Actual Route Ratio Distribution.
   - In Figure 4, 31% of actual routes (dark and light blue) have fuel-saving potential while 69% of actual routes (dark and light green) do not.
   - If an actual route matches one of the API routes, the actual route is more likely to be a green route. [No fuel savings versus fuel-savings potential (58% vs. 20%)].

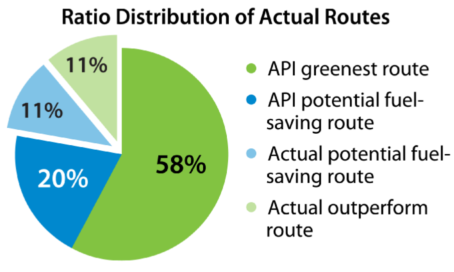


Figure 4: Ratio distribution of actual routes.

2. Fuel Consumption and Fuel Savings (Figure 5).
   - The red bar in the "actual" column represents the cumulative estimated fuel consumption (3,896 gallons) of potential fuel-saving actual routes. The red bar in the "green" column illustrates the cumulative fuel consumption (3,420 gallons) of the greenest routes corresponding to the potential fuel-saving actual routes.
   - The blue bar in the "actual" column represents the cumulative fuel usage of actual routes that are already the least fuel-consuming route options (6,718 gallons, which are identical).
   - The potential fuel saved is 476 gallons (3,896 – 3,420 gallons), 12% of the cumulative fuel consumption from actual routes that showed fuel-saving potential (left red bar), equals roughly 4.5% of the total.

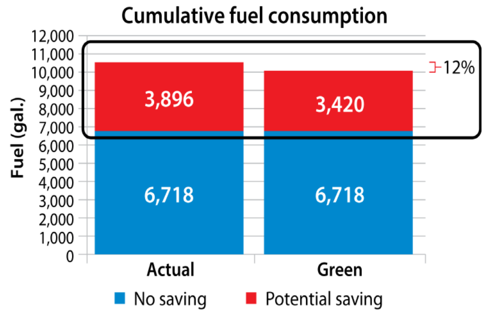


Figure 5: Cumulative fuel-consumption bar chart for actual routes compared to the least fuel-consuming green route options.

3. Trade-Offs between Fuel Savings and Travel Time.
   - The green routes sometimes provide time penalties and sometimes offer time savings. Potential travel time impacts have to be considered if switching to the green routes.
   - **Time difference**: Actual route duration minus the greenest route duration.
   - **Most desirable routes**: Both time and fuel savings (above the dashed black zero time difference line). About 49% of actual routes with fuel-saving potential and about 66% of total fuel savings in gallons.
   - Least desirable routes (close to the negative y-axis in Figure 6) require significant time penalties to achieve relatively little fuel savings.

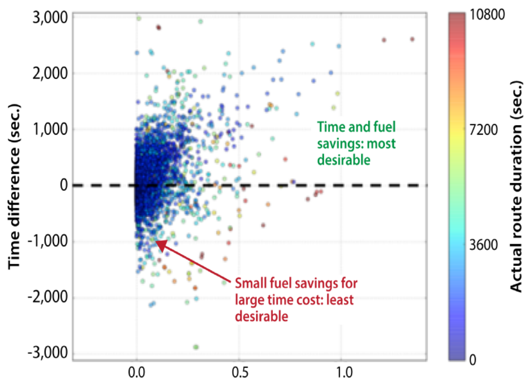


Figure 6: Fuel saving vs. time difference for potential fuel-saving actual routes.

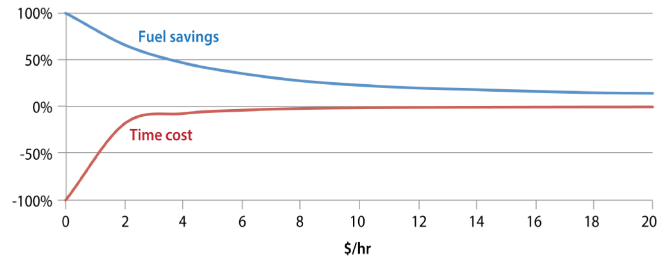


Figure 7: Value-of-time threshold impacts on the cumulative fuel savings and time penalties for the subset of green routes that require longer travel time.

- For the least desirable routes.
  - The values for gallons saved are converted into dollars by assuming $2.50/gallon. The red and blue curves in Figure 7 indicate the percentage of the cumulative time penalties (time cost) and fuel savings that remain for this green routing subset where fuel savings and increased travel time must be traded off.
  - At a threshold of $0/hour: The cumulative fuel savings and travel time increase remain at 100% of the values (161 gallons and 263 hours).

Conclusions

- The proposed framework for evaluating green routing fuel-savings opportunities provides a feasible way to assess potential fuel savings for a large-scale, real-world travel data set.
- From a sample data set with 44,805 O/D pairs, 31% of actual routes show an opportunity for fuel savings through green routing. The corresponding cumulative fuel-savings estimate is 12% of the total fuel consumption for the routes that show a potential fuel-saving benefit, or 4.5% of that for the entire set of actual routes.
- Notably, two-thirds of the green routing savings come from routes estimated to save time as well as fuel relative to the original actual route.
- The framework is transferable and can be developed as an application tool for any location having real-world travel data.

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