# Investigation of the Link Between Macroscopic Traffic Flow Characteristics and Individual Vehicle Fuel Consumption

tech transfer summary

**Ambient temperature, traffic congestion, trip average speed, and driving behavior affect the energy consumption of gasoline-powered and electric vehicles.**

## Objective

The objective of this project was to investigate the impacts of several factors, including vehicle characteristics, ambient temperature, season, speed, driving behavior, and traffic flow, on individual vehicle energy consumption.

## Background and Problem Statement

Vehicle fuel consumption can be measured using on-board diagnostics II (OBD-II) loggers to capture data from a vehicle's controller area network (CAN) bus. For gasoline-powered vehicles, typical data collected include instantaneous speed, acceleration, engine revolutions, throttle position, air intake, and other parameters. For battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), OBD-II loggers can also be used to capture the battery's state of charge (SOC), current, and voltage from the vehicle's CAN bus. Moreover, CAN bus data can be used to characterize different types of driving behavior (from quiet to aggressive) based on the amount and type of braking, stopping, cruising, and acceleration.

Several hybrid linear regression models have been developed to relate these parameters and other factors, including road gradient, to energy consumption and vehicle emissions. For electric vehicles, models have also been developed based on vehicle specific power (VSP), which can be calculated from vehicle speed and acceleration. These VSP-based models can account for the impacts of regenerative braking, a feature of electric motors, on electricity consumption.

The relationship between macroscopic traffic flow characteristics, including traffic flow rate, speed, density, and individual vehicle energy consumption, has not been sufficiently explored.

## Research Description

A fleet of 18 vehicles, each driven by a separate driver, was monitored using OBD-II loggers. The 18 vehicles included 10 Iowa State University rental and 8 private vehicles. The fleet featured a variety of sizes, models, years, and powertrain configurations and included 16 gasoline-powered and 2 electric vehicles.

Seven of the private vehicles were driven mainly around Des Moines and Ames, Iowa, and one was primarily driven in Beaumont, Texas. The university rental vehicles were driven mostly in Iowa and sometimes in neighboring states.


MIDWEST TRANSPORTATION CENTER MTC

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**RESEARCH PROJECT TITLE**
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The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.





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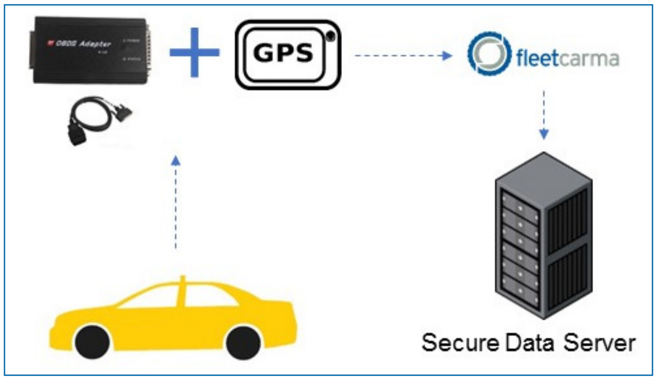


*Vehicle controller area network (CAN) bus data collection*

Each vehicle was monitored for approximately one year, with staggered start and end dates between August 2015 and September 2017.

The OBD-II loggers were linked to global positioning system (GPS) trackers and plugged into each vehicle's CAN bus to record vehicle location, speed, ambient temperature, and parameters related to energy consumption rate that were specific to either gasoline-powered or electric vehicles.

The data were uploaded via the cellular network to the data service provider, FleetCarma. Data and trip summary files detailing the travel distance and energy consumption of each trip were downloaded through a web data portal.

Traffic data were collected using Wavetronix detectors installed by the Iowa Department of Transportation (DOT) along Interstates and major highways in Iowa to monitor real-time traffic conditions. The detectors count vehicles, determine traffic speeds, and calculate occupancy by direction and by lane every 20 seconds. These data were provided by the Iowa DOT.

Vehicle data were matched with traffic data spatially and temporally using the timestamp and location information from the respective data sets.

Analyses were conducted to determine the impacts of vehicle characteristics, ambient temperature, season, trip average speed, driving behavior, and traffic characteristics on the study vehicles' energy efficiency. The analyses were carried out in miles per gallon (MPG) for gasoline vehicles and MPG equivalent (the amount of consumed electricity converted to the equivalent amount of gasoline) for electric vehicles.

The Virginia Tech microscopic energy and emission (VT-Micro) fuel consumption model was used to estimate the fuel consumption of the gasoline vehicles in this study. For the electric vehicles, a power-based electricity consumption model that considers VSP and ambient temperature was proposed and used. Both models were calibrated and assessed for accuracy.

## Key Findings

- The MPG of gasoline vehicles varies greatly by model, year, and engine technology, with compacts and sedans more fuel efficient than SUVs and pickup trucks. Electric vehicles have much higher MPG equivalent values than gasoline vehicles.
- Ambient temperature has a significant impact on fuel economy. MPG declines in cold temperatures and increases in warm temperatures. The optimal ambient temperature for vehicle energy efficiency is 60°F to 70°F. In hot weather (above 70°F), the use of air conditioning reduces vehicle energy efficiency.
- In general, vehicles consume more fuel at lower speeds. An optimal speed range exists for each vehicle that achieves the best fuel economy.
- For gasoline vehicles, driving behaviors featuring less variation in speeds, less hard acceleration, and less hard braking consume less fuel than aggressive driving behaviors. However, because electric vehicles feature regenerative braking, electricity consumption is lowest when 30 to 40 percent of braking events in a trip involve hard braking.
- When traffic density surpasses 26 vehicles per hour per lane, gasoline vehicle MPG decreases by 8 to 27 percent and electric vehicle MPG equivalent decreases by 10 percent.
- The calibrated VT-Micro fuel consumption models for the gasoline vehicles and the proposed power-based electricity consumption models for the electric vehicles were found to reliably estimate vehicle energy consumption.

## Implementation Readiness and Benefits

The research results show the impacts of vehicle characteristics, ambient temperature, season, trip average speed, driving behavior, and traffic characteristics on vehicle energy efficiency.

The energy consumption models for both the gasoline-powered and electric vehicles reliably estimate vehicle energy consumption.