



Is Safe Driving More Economical?

Driver Safety and Fuel Consumption

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In efforts to reduce vehicle gas consumption and emissions, society has put heavy emphasis on government-imposed vehicle design standards and other vehicle-focused regulation. But what impact is our behavior behind the wheel having? This paper evaluates the correlation between actual driving behavior and fuel consumption and investigates the premise that safe driving is “eco- friendly” driving. The final analysis demonstrates that people who drive safely also benefit from improved fuel economy.

Current models for predicting fuel consumption typically take into account environmental conditions – the condition of the road, for example – and the physical attributes of the vehicle, such as horsepower. What these models are missing however is driver behavior and the influence that behind-the-wheel activities have on fuel consumption.

**Green drivers
realized a 7-10%
Fuel Savings over
Red or Yellow
drivers.**

The driving behavior inputs for this study were provided by GreenRoad™, an innovative driver decision system that measures driving behavior and incorporates real-time in-vehicle feedback and comprehensive visibility into those maneuvers which most impact safe driving, fuel efficiency and emissions.

The system uses advanced vehicle maneuver detection technology and real-time driver interaction to measure and effectively enforce safe driving. For the purpose of this study, direct comparisons are made between driving behavior measured in terms of risk and participant fuel consumption variables.

Drivers were categorized in terms of their behavior as Green, Yellow and Red drivers, based on the number of risky driving maneuvers executed and reported via GreenRoad Central™. ‘Green’ drivers, or those who made up to 20 risky maneuvers per 10 hours of driving, were considered low risk; ‘Red’ drivers were high risk and exhibited 100 or more risky maneuvers for each 10 hours behind the wheel. Driving behavior and fuel consumption was found directly correlated. The data showed that safe, Green drivers achieve MPG improvements of between 7% and 10% over their Red and Yellow counterparts.

Background

Fuel consumption and emissions are two critical aspects considered in the transportation planning process. Fuel consumption can represent more than 30% of corporate transportation budgets, and recent studies indicate that vehicle emissions contribute as much as 45% of total corporate pollutants. As a result, companies are seeking innovative methods to reduce fuel consumption and emissions.

The variables that influence fuel consumption and emission rates fall into six broad categories:

Travel: Distance, number of journeys and driving hours.

Weather: Temperature, humidity and wind effects

Vehicle: Engine size, the condition of the engine, whether the vehicle is equipped with a catalytic converter, whether the vehicle's air conditioning is functioning, etc.

Roadway: Roadway grade and surface roughness

Traffic: How congested are the highways, and how a vehicle is stopping, starting and idling

Driver Behavior: Attitudes manifested in terms of acceleration, braking, cornering, lane handling and speed handling

Current models estimate vehicle fuel consumption and emissions based on typical urban driving cycles, which are a series of data points representing the speed of a vehicle versus time. These models offer simplified mathematical expressions to compute fuel and emission rates based on average speeds without considering how driver behavior affects these rates. Moreover, most models use an aggregate modeling approach in which one vehicle type is used to represent all vehicles. While transportation planners to evaluate the impacts of network-wide highways on the environment have accepted this approach, it is insufficient to evaluate fuel consumption and environmental impacts. Rising fuel costs and a worldwide focus on the environment have generated an interest in the effect of driving behavior on fuel consumption and emissions.

Technical studies targeting the impact of driving behavior on fuel consumption estimated a ten percent variance in fuel consumption between drivers, illustrating the opportunity to reduce fuel consumption by changing driver behavior.

Influencing the
behavior of drivers
reduces fuel
consumption.

State-of-the-art emission models, such as MOBILE6, developed by the U.S. Environmental Protection Agency (EPA), and EMFAC7F, which was developed by the California Air Resources Board (CARB), attempt to account for other factors, including travel, weather and vehicle specifications. These models, however, fail to capture driver behavior influence on vehicle emissions.

Objectives and Methodology of this Study

This study is the first to evaluate at an academic level the correlation between safe driving (the independent variable) and “eco-friendly” driving (the dependent variable). This paper closes the research gap in two ways. First, it evaluates the relationship between driver behavior, which is captured in terms of a risk index, and two variables: fuel consumed [as measured in Miles Per Gallon (MPG)] and the number of fuel tank refills per hour of driving. Second, it categorizes drivers in terms of their fuel consumption and risk score.

Two analyses were conducted. The first evaluated the statistical correlation between driver risk, as computed by GreenRoad’s Safety Score, and fuel consumption. The second compared driver fuel consumption by risk index groupings. Both methods are described below:

Evaluation of the correlation between the Safety Score Risk Index and fuel consumption

A linear regression analysis was conducted on 55 individual driver scores comparing MPG and risk index. For each driver, the data was accumulated over an, average period of 3.4 months. This analysis takes into account the existence of differences between the drivers (i.e. driving time, vehicle type and journey routes) by introducing driver-specific dummy variables in order to standardize the effects. This method enabled researchers to isolate the effect of all driver characteristics other than the risk index.

Analysis of driving patterns and fuel consumption measures

To meet the second objective, the evaluation of how drivers can be grouped by their driving patterns and fuel consumption, a Two-Step Cluster Analysis was conducted. This method is designed to reveal natural groupings (or clusters) within a data set that would otherwise not be apparent.

Approximately 1200 fuel station visits were recorded and analyzed to extract the following variables: miles traveled, gallons and date of visit, days between visiting the fuel station and driving hours between fuel station visits. The Safety Score Risk Index was calculated for cumulative driving during the study.

Results

Evaluation of the statistical correlation between the Risk Index and the MPG Score:

Results of four linear models, presented in Table 1 below, demonstrate that safer drivers do in fact benefit from greater fuel efficiency as measured by MPG: Specifically, Green drivers average an additional 2 MPG over Red, riskier drivers.

MPG BY SAFETY CLASS			
	Green Driver (Risk Index = 20)	Yellow Driver (Risk Index = 50)	Red Driver (Risk Index = 100)
Model 1	28.33	27.30	25.80
Model 2	28.13	27.16	25.88
Model 3	27.73	26.65	25.88
Model 4	27.93	26.74	25.86

Table 1: Driver safety class and MPG

Green drivers' MPG scores were 7 to 11% higher than Red drivers' MPG in the four models that were developed, and Yellow driver's MPG scores exceeded those of Red drivers by 3% to 7% for the four models that were developed.

	MPG achieved Green vs. Red	MPG achieved Yellow vs. Red
Model 1	11%	7%
Model 2	10%	6%
Model 3	7%	3%
Model 4	8%	3%

Table 2: Percent difference in MPG achieved by Green and Yellow drivers over Red drivers

Conclusions

This analysis found a direct correlation between safe driving and fuel- efficient driving. The latent measure of safe driving was evaluated by the use of the GreenRoad Safety Score risk index, which previous studies have validated as an effective risk evaluator. The latent measure of eco-friendly driving was evaluated by two variables: MPG and the time between fuel station visits.

Several linear models were developed to assess the statistical correlation between those parameters. As for the MPG variable, four individual models demonstrated that the correlation is statistically negative and significant – where the risk index is low, the MPG is high – or, in other words, safe-driving leads to increased fuel efficiency. Green, or safe, drivers (those with risk index scores of 20 or lower) achieved between 2.04 and 3.41 MPG higher than Red drivers (those with risk index scores of 100 or higher).

For every mile driven,
Red drivers are a
higher crash risk, visit
fuel stations more
frequently and get
poorer MPG than their
Green counterparts.

Deeper investigation of the relationship between fuel consumption and driver behavior was achieved by conducting a cluster analysis to explore whether using the GreenRoad Safety Score risk index and the fuel consumption variables can create clusters.

An exploratory approach yielded clustering for two groups. The first group, Red drivers, had a higher average risk index score – they were riskier drivers – and achieved lower MPG. The second group, Green drivers, had a low average risk index score – they were safe drivers – and achieved greater fuel efficiency by an average of 2 MPG.

Analysis of driving patterns and fuel consumption:

Below, Table 3 and Figure 1 show the results of the cluster, or group analysis, comparing driving patterns to fuel consumption. There are two groups that emerged from the study: Red drivers and Green drivers.

The Red drivers' MPG scores are lower than the Green drivers' scores by about 2 MPG, again showing that Red drivers are less efficient than Green drivers. In addition, Red drivers visit the fuel station on an average of every 3 days, compared to a Green driver average of 5.1 days between fuel station visits. Finally, driving hours between fuel station visits also show that Red drivers visit fuel stations more frequently than Green drivers.

There is a direct correlation between driver safety and fuel efficiency.

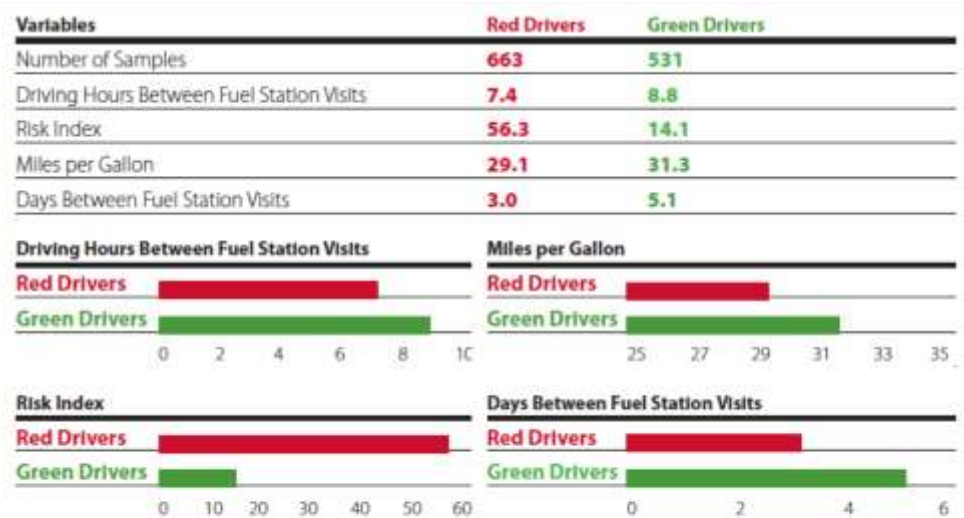


Table 3: Higher Risk Driving Negatively Impacts Fuel Consumption

About GreenRoad

GreenRoad is the leading innovator in driver safety and efficiency through real-time in-vehicle feedback and comprehensive visibility into those maneuvers which most impact safe driving, fuel efficiency and emissions. The GreenRoad 360™ service combines real-time driver coaching with Web-based applications that continuously rate driving skills for all types of vehicles, including trucks, busses, vans and cars. Fleet management and risk and safety professionals gain new insight into driving behavior and have the tools they need to help drivers achieve measurable safety and fuel-efficiency goals. For more information, visit www.greenroad.com.

About GreenRoad 360™

GreenRoad's flagship service for commercial fleets, GreenRoad 360™, takes a comprehensive approach to improving driving behavior.

GreenRoad Live™ real-time in-vehicle feedback continuously measures and analyzes risky driving maneuvers that most impact safe driving, fuel efficiency and emissions. GreenRoad Live measures G-forces impacting the vehicle as it is driven. Sensors analyze up to 120 separate driving events in five categories: speed handling, cornering, lane handling, braking, and acceleration. That data is transmitted in real-time to the red-yellow-green LED light display to provide the driver with immediate feedback that enables them to self-correct in the moment.

The GreenRoad Central™ Web portal reinforces real-time driver feedback and provides fleet management and risk and safety professionals complete visibility into drivers' performance as well as tools to measure and promote safety and fuel-efficiency goals. The GreenRoad Central Web portal enables managers and drivers to see results, analyze driving behaviors within the fleet and learn how specific habits can be improved. Managers can also configure and customize the service and dozens of reports according to fleet-specific policies. This ongoing and comprehensive approach empowers a driver to sustain driving improvement.

The GreenRoad Engage™ customer success program provides a step-by-step roadmap and project management methodology designed to engage drivers, managers, insurance partners and unions in the process of achieving measurable safety, fuel and cost improvements. GreenRoad continuously partners with its customers to sustain improvements by providing the latest fleet-proven best practices, implementation expertise, KPIs, employee recognition programs and co-branded marketing communications.

The GreenRoad Intersect™ partner program is an open multi-vendor platform for partners, including industry-leading technology, insurance, distribution, policy and research organizations, enabling fleets to create complete solutions based on best-of-breed products and services related to driving behavior.

References

1. Ahn, K., Rakha, H., Trani, A., Michel Van Aerde, M. (2002) Estimating Vehicle Fuel Consumption and Emissions based on Instantaneous Speed and Acceleration Levels. *J. Transp. Engrg.*, Volume 128, Issue 2, pp. 182-190 (March/April 2002)
2. Nader, J. "Measurement of the impact of driving technique on fuel consumption: Preliminary results", *Roads & Transportation*, Technical Note TN-172, 1991, pp. 1-6.
3. De Vlieger, L. "On-board emission and fuel consumption measurement campaign on fuel driven passenger cars", *Atmospheric Environment*, 31, 1997, pp. 3753-3761.
4. Ericsson, E. "Variability in exhaust emission and fuel consumption in urban driving", *Urban Transport Systems. Proceedings from the 2nd KFB-Research Conference*, Lund Institute of Technology, Department for Technology and Society, Bulletin 187. 1999, Lund 2000.
5. Fellendorf, M., Vortisch, P., (2000) Integrated Modeling of Transport Demand, Route Choice, Traffic Flow and Traffic Emissions presentation at the 79th Annual Meeting of the Transport Research Board
6. Johansson, H., Färnlund, J. & Engström, C. "Impact of EcoDriving on emissions and fuel consumption", *Vägverket: Publikation 165E*. 1999. [Swedish Road Administration: Publication 165E].
7. Lotan, T. and Toledo T. (2006) An in-vehicle data recorder for evaluation of driving behavior and safety. Preprints of the 85th Annual Transportation Research Board Annual Meeting.
8. Lotan, T. and Toledo T. (2005) Evaluating the safety implications and benefits of an in-vehicle data recorder. *Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*
9. *Mobile 5A User Guide* (1993). US Environmental Protection Agency (EPA), Ann Arbor, Michigan
10. National Research Council (1995). *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use*, National Academy Press, Washington, D.C.
11. Tong, H.Y. Hung, W.T. Cheung, C.S. (2000) On-Road Motor Vehicle Emissions and Fuel Consumption in Urban Driving Conditions. *Journal of the Air & Waste Management Association* (50) pp 543-554
12. *User's Guide to MOBILE6.1 and MOBILE6.2*. (2003) US Environmental Protection Agency (EPA) Report number: EPA420-R-03-010
13. Van de Burgwal, H. C., & Gense, N. L. "Interpretation of driving style tips", TNO Report 02.OR.VM.004.1/HVDB. TNO Automotive. 2002.
14. Wählberg, A. E. (2002). Fuel-efficient driving training -state of the art and quantification of effects. *Proceedings of Sordenne*.