

# Providing eco-driving feedback to corporate car drivers: what impact does a smartphone application have on their fuel efficiency?

**Johannes Tulusan**

Institute of Technology Management  
St. Gallen University  
St. Gallen, Switzerland  
{johannes.tulusan}@unisg.ch

**Thorsten Staake, Elgar Fleisch**

Bits to Energy Lab  
ETH Zurich  
Zurich, Switzerland  
{tstaake, efleisch}@ethz.ch

## ABSTRACT

The personal transport sector constitutes an important target of energy conservation and emission reduction programs. In this context, eco-feedback technologies that provide information on the driving behavior have shown to be an effective means to stimulate changes in driving in favor of both, reduced costs and environmental impact. This study extends the literature on eco-feedback technologies as it demonstrates that a smartphone application can improve fuel efficiency even under conditions where monetary incentives are *not* given, i.e. where the drivers do not pay for fuel. The field test, which took place with 50 corporate car drivers, demonstrates an improvement in the overall fuel efficiency by 3.23%. The theoretical contribution underlines the assumption that context-related feedback can favorably influence behavior even without direct financial benefits for the agent. Given the large share of corporate cars, findings are also of high practical importance and motivate future research on eco-driving feedback technologies.

## Author Keywords

Eco-Feedback Technology, Eco-driving, Sustainability

## ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## General Terms

Context aware computing, sustainability, user studies

## INTRODUCTION

Eco-driving presents an economical approach to reducing fuel consumption that can be utilized regardless of the vehicle type. The underlying ethos of eco-driving trainings is to impart positive driving attributes into the individual's

daily driving habits, potentially leading to an average reduction in fuel consumption of up to 15%. Moreover, respective programs can foster energy savings and emission reductions without the need to buy a new car with the latest in-vehicle technologies. Current studies have demonstrated that financial rewards (i.e. cash bonuses) or economical savings influence private car drivers to act more sustainably or to use public transportation systems.

One potential lever to effectively modify driving behavior that builds upon eco-driving concepts is to use feedback technologies. Respective applications help to identify when drivers should change gear or pinpoint energy intense driving maneuvers. In a pioneering study, an improvement in fuel efficiency of 1% on highways and 6% on city streets was shown with 20 drivers in the US who tested an on-board eco-driving feedback device [1]. Thus far, initiatives to drive more efficiently have mainly targeted private car or truck drivers; few address corporate car drivers. Corporate car drivers often use their company car for both business and private driving occupations, and are estimated to travel on average 21,500 miles per year, compared with 8500 miles for private car users. Hence, the potential savings for companies with a large car fleet could be immense if drivers improved their fuel efficiency by adapting a more sustainable driving style, especially if no new in-vehicle technologies have to be purchased. Corporate car drivers, however, mostly use their car under a very special financial regime: They often do not have to pay for fuel, such that an economical and environmentally friendly driving style does not directly translate into financial rewards for themselves. Therefore, it is questionable if feedback on driving style unfolds its beneficial effects for corporate car drivers.

In the study at hand, we investigate the effects of feedback for this specific case based on an opt-in experiment with a total of 50 corporate car drivers, 25 in the control group (CG) and 25 in the treatment group (TG), making over 800 journeys over eight weeks. The application used in the experiment provided feedback about driving style in form of a score and acceleration, braking, and average speed figures. The analysis bases on real fuel

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consumption from sales data provided by the petrol credit cards from the corporate car drivers. The findings indicate that eco-efficient persuasive feedback technologies can significantly improve corporate car drivers' fuel efficiency by providing context specific eco-driving feedback, even when financial rewards are not present as an incentive.

## RELATED WORK

### Automotive Eco-feedback Technologies

Numerous studies have been conducted in which car manufacturers such as Fiat, Ford, Toyota, and Nissan tested feedback technologies using on-board systems to enforce a sustainable driving behavior. These technologies fall into the category of persuasive technologies. In [2], the authors characterized eco-feedback technologies as a *'technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact'*. Academic studies by [1,3,4] have evaluated eco-driving feedback systems. An obvious link between financial benefits and individual's motivation to reduce their fuel consumption was highlighted. In [4], the authors applied feedback interventions to urge postal-workers in the Dutch Postal Service to promote eco-friendly driving by providing them with instant feedback via an installed tachometer in their delivery trucks and agreeing on a goal defined and monitored by the management of reducing fuel consumption by 5%. Results revealed a 7.3% reduction which was maintained six months thereafter.

Given these findings, persuasive feedback technologies *'seem to be a promising approach to be researched in automotive environments, when it comes to fostering a more fuel-efficient driving behavior'* [3]. As smartphones are becoming increasingly available, several applications have been created to use the phone's internal technologies, such as GPS and accelerometer, to deliver context related feedback to drivers. Examples of these applications are: DriveGain, EcoDrive, greenMeter, Fuel Saver, Green Driver, BlissTrek, iEcoMeter, Green Gas Saver. However, compared to other available eco-driving technologies (i.e. in-vehicle -, on-board -, or navigation systems), eco-efficient smartphone technologies seem, at present, underutilized.

### Overview of the Eco-Driving Smartphone Application

An eco-driving application called DriveGain, a product of DriveGain Ltd., UK, was used for the purpose of this study. After extensive evaluation of the aforementioned products, this application was chosen due to the quality of the feedback and the access to the data collected by the application from the drivers participating in the field test. The application provides feedback related to the eco-driving concepts, such as correct gear change during acceleration and braking, and most efficient average speed depending on the vehicle type. Similar feedback types were also tested by [5]; there, authors showed that drivers were able to reduce their fuel consumption by 16% when using the support tool; it is important to acknowledge that the test was confined to a driving simulator. Feedback types

identified to reduce fuel consumption were: correct gear changing during acceleration and smooth acceleration. These feedback types were also implemented within the DriveGain application as illustrated in Figure 1.

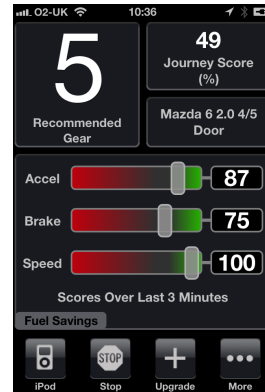


Figure 1. Application interface (DriveGain Ltd., 2012)

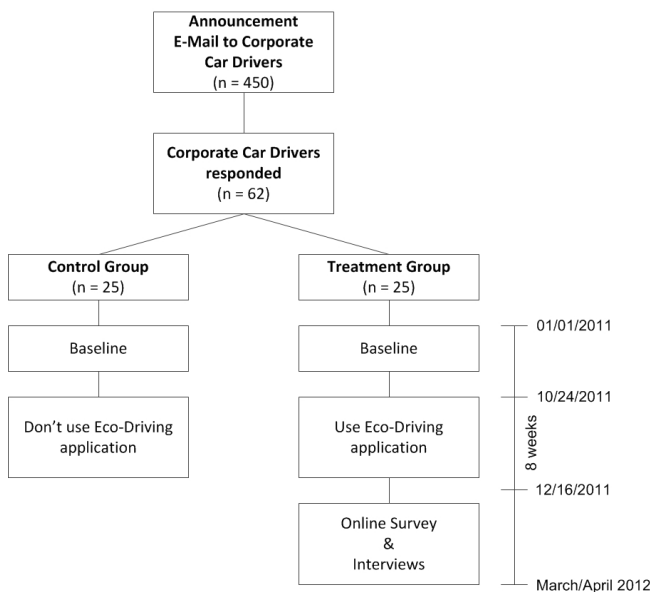
The top third of the interface screen illustrates: optimal gear change (recommended gear), journey score, and type of vehicle. Feedback meters are located in the central third of the screen and below this, functions to: activate music, reset the journey scores, upgrade with new feedback meters and settings of the application reside. Once the application has been started, the car type chosen and a GPS signal received, it will log and monitor the driving behavior. The feedback meter called 'Fuel Savings' provides feedback regarding the average figures for acceleration, braking and vehicle speed at a frequency of three-minute intervals. Acceleration, braking, and vehicle speed is measured by the accelerometer sensor and GPS receiver. All three feedback types are displayed on a scale categorized red to green (green being most ecological), as well as a numerical score from 0 (being least ecological) to 100 (representing most ecological). Values on these scales change in response to how efficiently the driver has been accelerating, braking, and speed variance during the last few minutes. The journey score, visible on the top right corner of the screen, is calculated using data taken from each section of the journey and represents acceleration, braking, and speed values with respect to each car-type selected from the driver for this journey. A higher score indicates greater efficiency, i.e. less harsh braking and moderate average journey speed thus far. A score above 70 is a good, above 80 very good and above 90 is excellent sustainable driving behavior.

Depending on the car-type, acceleration / braking, and current speed, the recommended gear feature advises drivers with a manual gearbox when to shift up or down for maximum efficiency. For example, shifting up faster to the highest gear once the targeted speed has been reached. Only two gears, 'P' for parking and 'N' for driving, will be represented for cars with automatic gearboxes. Additionally, the following data relevant for this study is collected from the application: 1. Journey start and end location (measured by the GPS receiver); 2. When and duration application was used in seconds; 3. Distance

travelled in meters per journey; 4. Duration each type of feedback meter was used in seconds; 5. Values for acceleration, braking and vehicle speed.

### EXPERIMENTAL SETTING

The study design was between subject, using an independent samples t-test for comparing the means of fuel efficiency between control group CG (without use of smartphone application) and treatment group TG (with use of smartphone application). The following hypothesis was defined: Corporate car drivers who use an eco-driving smartphone application improve their average overall fuel efficiency, with  $\mu_1$  representing the liters of petrol per 100 kilometer without and  $\mu_2$  with eco-driving feedback. Therefore,  $H_0 = \mu_1 \leq \mu_2$ ;  $H_1 = \mu_1 > \mu_2$ .



**Figure 2. Between-subjects experimental design**

For the study, sixty-two out of 450 corporate car drivers from the same company based in Switzerland responded to the announcement email (see Fig. 2). Tank-refill data of all drivers were available prior to and during the introduction of the field test for each driver. This made possible the calculation of the drivers' average baseline fuel efficiency from January to October 2011 (prior to implementing the experimental condition). Five drivers were identified as outliers using the Grubb's test due to very low or excessively high baseline consumption and thus were removed from the sample. Thereafter, the normality of the distribution was met, as shown by the Shapiro-Wilk test for normality (with  $P > .05$ , skeweness =  $-0.579$  and kurtosis =  $1.739$ ). Due to technical requirements, ownership of an iPhone model 3G, 3Gs, 4 or 4s was essential, as we had indicated in the recruitment email. Therefore, seven drivers with other phones had to be removed from the sample. The remaining fifty drivers were then randomly assigned to the two experiment groups (CG = 25 and TG = 25). Participants in the TG used the eco-driving application for a duration of eight weeks from 24<sup>th</sup> of October to 16<sup>th</sup> of

December 2011. As it would be in a non-study environment, it was left to the drivers in TG to decide how often and when the application would be used; however, they were informed that the application should be used on a regular weekly basis within the designated eight weeks. Data collected from the application were transmitted directly from the smartphone to the DriveGain Ltd. server after each recorded route. This made it possible to verify frequency-use of the application by each driver.

Drivers' monthly tank-refill details were collected from petrol credit cards provided by the company. For each tank-refill, the total number of km driven and volume of petrol were recorded during the payment process as a normal prerequisite to get permission to refuel on the company account (a measure to prevent drivers from refueling other cars on the cost of the company). Tank-refill data were sent to the company through a mobility operator. This allowed the researcher to calculate and compare the fuel efficiency per tank-refill more objectively, as drivers only had to record the total number of km shown on their in-vehicle system at the time of payment. The total liters, required to calculate the fuel efficiency, were automatically reported by the system from the petrol station, thus, eliminating the need for further self-reported input from drivers.

### RESULTS

It was evident that the application was used mainly during the week and at daytime. Furthermore, an average distance per route of 21 miles was travelled with an average usage of the application of 28 minutes per route. The total average journey score rating of 75 indicates a good ecological driving behavior. As each participant's data reflecting each tank filling from the beginning of the year were available, and to control for seasonal effects, the fuel efficiency of each driver was calculated for each tank filling from the start of January 2011 until the treatment started, and during the treatment phase. Once the average fuel efficiency was calculated for these two timeframes and the changes in percentage calculated, a paired samples t-test comparison between participants' (CG vs. TG) changes in fuel efficiency was made. Before the t-test was conducted three outliers in the CG and two outliers in the TG in terms of untypical changes of consumption, due to false entries of kilometers driven during the experiment phase, were identified using Grubb's outlier procedure. Three additional data sets were removed in the TG to control for periods where the application was not used. A total of CG = 22 and TG = 20 were used for the t-test. The outcome showed that all participants' fuel efficiency changed positively or negatively; the maximum improvement in the CG was  $-4.94\%$ , and  $-12.15\%$  in the TG. The minimum change in the CG was  $8.40\%$  and  $1.92\%$  in the TG. On average the corporate car drivers in the TG had improved their overall fuel efficiency by the end of the treatment phase ( $M = -2.2$ ,  $SE = 0.87$ ) compared with the CG ( $M = 1.03$ ,  $SE = 0.70$ ). This difference of  $3.23\%$  was statistically significant  $p <$

0.01 with  $t(40) = 3.23$ ,  $P = 0.006$ . As the Levene's test was not significant ( $P = 0.459$ ), the equality of variances can be assumed and the  $H_0$  rejected in favor of the  $H_1$ .

## DISCUSSION

Comparing the improvement in fuel efficiency of 3.23% with existing studies referred to in this paper strengthens the underlying assumption that persuasive feedback technologies can have a positive impact in promoting eco-driving behavior. Studies with greater improvements in fuel efficiency where either conducted in a driving simulator [5] or with companies who set their target fuel reduction rate at 5% and given that an important stakeholder (i.e. the management) monitored achievements [4], which was not the case in our study. Existing studies did not evaluate improvements in corporate car drivers' fuel efficiency where monetary incentives are absent. The data recorded by this application provides important insights into driving behavior and, in line with the body of knowledge, showed that acceleration contributes strongly to fuel consumption, which supports the findings of the experiment conducted in the driving simulator by [5].

## LIMITATIONS AND FUTURE RESEARCH

Due to the small sample size it may not be feasible to generalize these findings to other companies. Nevertheless, existing studies within this field were conducted using an even smaller sample size of drivers ( $n < 20$ ), and field tests using a larger sample size (mainly conducted with truck drivers) did not evaluate an eco-driving smartphone application, rather a fixed installed system. A second shortcoming is the opt-in experimental setting, which may have attracted individuals who already had a pro-environmental attitude. Nevertheless, the findings should be applicable to corporate car drivers who have an interest to use an eco-driving smartphone application. It is also possible to control this by analyzing their environmental beliefs using a post-survey (currently underway). Regardless of these limitations, the unique data set from corporate car drivers, the objective measurement of their fuel efficiency collected via the data received from their petrol credit cards, and the field test duration of eight weeks, is a good starting point through which to attain further insights in this promising research domain. More than 800 journeys were recorded within these eight weeks and as future evaluation of these data it would be of interest to evaluate how the usage of the eco-driving smartphone application changes over time, and if there is a correlation between frequency of usage and overall improvement in fuel efficiency.

## CONCLUSION

This paper examined how feedback affects fuel consumption when monetary incentives are absent. The findings highlight how feedback technologies, which provide context related eco-driving feedback during driving, improve corporate car drivers' fuel efficiency. An existing smartphone application available on the market,

with eco-driving functionalities, was selected and tested in an experimental setting with one company's pool of drivers. The improvement in fuel efficiency demonstrates that ubiquitous computing technologies can play an important role in reducing a company's overall CO<sub>2</sub> emission and petrol costs. Moreover, given a high penetration rate of smartphones, the savings come at very little additional cost. This endorses literature finding as the participants of this study were not awarded any monetary incentives to motivate their behavioral modification. Drivers used the eco-driving application mainly for business related travel, and smooth acceleration appeared to have a stronger influence on driving compared with braking and average speed. All participants used their car every day and drove, on average, more than 21,500 miles per year, which conforms to the corporate car driver's criteria. Since corporate car fleets are constantly increasing, for instance  $\frac{1}{4}$  of the total of 3 Mio new registered cars in Germany in 2011 were corporate cars (a total increase of 7.1%), corporations are certainly eager to acquire a better understanding of how to reduce energy consumption by improving the driving behavior of their employees through means of eco-feedback technologies as well as minimal financial investments. Future challenges include implementing incentives that lead to a persistent use of such feedback technologies to ensure ongoing savings.

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