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# The Effect of Eco-Driving System Towards Sustainable Driving Behavior

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**Abstract**

In this paper, we explore the use of an Eco-Driving System [1] to see how the system promotes greener driving behavior. We conducted both an online survey (N=60) and a user test (N=14) to study the Eco-Driving System. Based on participant responses, we found that the current Eco-Driving System shows minor benefits in gas mileage due to different driving behaviors and also increased task loads for our participants. Therefore, we suggest a new research direction for the Eco-Driving System for further study.

**Keywords**

Sustainability, Eco-Driving System, Behavior, Design

**ACM Classification Keywords**

H.5.2. Information Interfaces and Presentation: User Interfaces, Evaluation/Methodology.

**General Terms**

Design

**Introduction**

The world's dependence on limited fossil fuels that have significant environmental impacts creates a need for alternative solutions to prevent an environmental crisis. Fossil fuels are well known for their effect on global

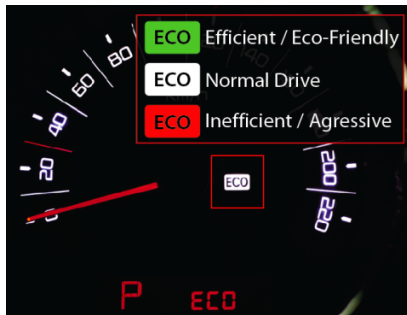


figure 1. Eco-Driving System indicator

warming and are blamed for producing the high CO<sub>2</sub> emissions. The Republic of Korea is the 9<sup>th</sup> largest CO<sub>2</sub> producer in the world where 97% of the energy depends on imports [7]. This tells us that development of alternative energy sources or innovative ways of conserving energy is crucial.

The greatest CO<sub>2</sub> contributor in the average Korean household is personal transportation [7]. Therefore, KIA [5] has integrated a system called Eco-Driving System for the first time in Korea to all their product line-ups since 2008. Since KIA is the leader in Eco-Driving Systems in Korea and advertises that the system is proven to save gas, we wanted to see how effective the system was. The Eco-Driving System is a function that allows the users to see how energy efficient they are driving through an indicator which is placed in the middle of the dashboard. The system changes its color to green (environmentally friendly & energy efficient driving), to white (normal driving), and to red (environmentally unfriendly & aggressive driving) depending on the users' driving behavior (figure 1). We studied this system using both an online survey and a user test to see how the system affected the users' driving behaviors. We also wanted to see if the systems task load was acceptable for the users to adapt to it.



figure 2. KIA Soul

### Studies of Eco-Driving System

We conducted two formative studies- an online survey and a user test. In the survey we explored the respondents' Eco-Driving System usage, how much gas they saved, users' satisfaction rate, reasons for the use, and possible ways to improve the current Eco-Driving System. We then describe the results of a user test of the KIA Soul's (figure 2) Eco-Driving System to see how effective the systems were when the system is on

and off. We also conducted a user task load test [4] to see what factors increased the user's task load when using the system.

### Online Survey

The online survey was conducted to see how KIA Soul drivers used the Eco-Driving System and to get feedback on their thoughts.

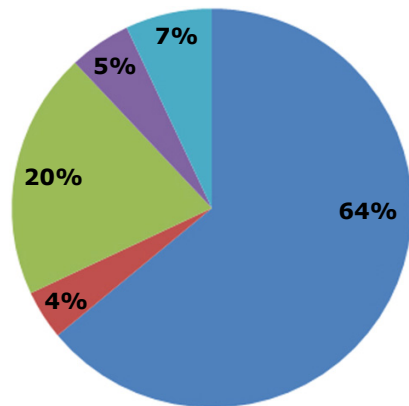
The survey was conducted using Google Spreadsheets on a popular online KIA Soul community [6]. The survey was titled "Survey on KIA Soul Eco-Driving System" and the study was explained that it will be used "to find out if they use it(or not), why they use it(or not), how often they use it, how much they are aware of it while driving, how much gas they think it saves, how satisfied they are, and ideas on how to improve it."

A total of 60 respondents (male: 83% female: 17%) completed the online survey between December 1<sup>st</sup> to 16<sup>th</sup> 2009. All respondents were KIA Soul drivers in the Republic of Korea with an average age of 30.9 years, average of 7.8 years of driving experience, and an average of 4.4 months of owning a KIA Soul.

### Online Survey Results

The online survey helped us understand how respondents use the Eco-Driving System and their thoughts on it. It helped us realize the problems and gave us insights to improve the current system. The results of the survey are discussed in turns.

*Using the Eco-Driving System:* From the 60 respondents, 78% answered that they have used the Eco-Driving System and from the respondents who



Save Gas & Money: 64%  
 Safety / Changing Driving Behavior: 20%  
 Maintenance: 7%  
 Environment: 4%  
 Etc: 5%

**figure 3.** Reason for Using Eco-Driving System

used the system, 91% answered they use the system on a daily basis. On a 5 point Likert scale, 87% said they were highly aware of the system while they were driving. 78% were positive that it was saving them gas and also 87% were satisfied with using the system. When asked about the reasons why they use the system 64% said it saves fuel and money, 20% said it changes their driving behavior to become safer, 7% said for maintenance, 4% said for environmental reasons, and 5% responded with miscellaneous answers (figure 3). 13% of the users who did not use the system thought the system did not save them gas and constantly checking the Eco-Driving indicator distracted them, leading to unsafe driving behavior. Our results suggest that the usage of Eco-Driving System and the satisfaction rate was positive. It also showed that the system seemed to change the drivers' behavior into a safer and more economical way. But, it also indicated that current users lacked environmental awareness to promote greener behavior.

*Ideas to Improve Eco-Driving System:* The ideas on improving the system were classified into 4 categories; Measurement, Visibility, Function, and Reliability. The categories are discussed in turns.

**Measurement:** Respondents said that they wanted to see the precise gas mileage difference when using and not using the system to evaluate the effectiveness of the system. This indicates that lack of information could discourage or question the users' to use the system. By displaying the data regarding fuel savings, this could motivate them to become more fuel efficient. Also, displaying the environmental impacts [3,8] they make while driving could motivate them to become

aware of the environment, which will result in better gas mileage.

**Visibility:** Most respondents said that the position of the indicator needed to be changed since the current indicator is small in size and also positioned in the dashboard. The awkward position made it hard to check while driving- risking safety. 25% of the respondents said that it would be appropriate to keep them informed by sound [8]. This indicates that an alternative interaction method for the indicator is needed to improve safety and also better driving behavior [3,8].

**Function:** Respondents thought the current system was too simple and since the setting for the system was fixed by the factory, it did not take into consideration other factors that affect gas mileage, such as road conditions and driving behavior. This indicates that the system could be set to individual users depending on their driving behaviors. This can help users' gradually generate green behaviors over time.

**Reliability:** Respondents said that simple light change for the indicator and lack of precise data for gas mileage questioned the system's performance. They wanted a simple, but a more interactive system. This complaint again questions the performance of the system that could discourage the driver to use the system. The system should give the driver more feedback [8] than a simple indicator light.

In our online survey many of the users said they were using the Eco-Driving System frequently and believed it saved them gas, but they also said they wanted to see the precise amount of gas they were saving, which is



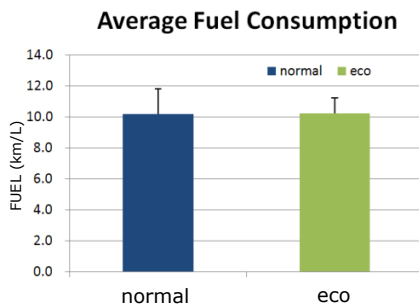
**figure 4.** KIA Soul trip computer, which indicates the overall driving time (top), driving distance (middle), and average fuel consumption (bottom)

not shown in the system. This tells us that users assumed they were saving gas without clear confidence, because the system was indicating that they were.

#### User Test

After the online survey, we ran a user test to see whether the users saved fuel by activating or deactivating the Eco-Driving System. We wanted to see if the user test results were consistent with the results from the online survey, and to see what factors effected the users to change their driving behaviors. A total of 14 participants from Korea Advance Institute of Science and Technology (KAIST) were chosen to participate in a half hour driving test session.

Participants who were selected all commuted to school by car, were familiar with the assigned driving course, had an average of 29.9 years of age and an average of 7.5 years of driving experience, which was similar to the demographic profile of the online survey respondents. Also the chosen participants did not have prior experience with the system, which could clearly show the effectiveness of the system and show what factors differed from diving without it.



**figure 5.** Average fuel consumption form user test results

For the driving test, a 2010 KIA Soul equipped with the Eco-Driving System was used. The driving test was conducted in the KAIST campus for consistency of traffic flow and safety reasons. Also, one of our observers was present with the participants during the driving test for observation and safety reasons. The driving course was 5.2km which took approximately 9 to 13 minutes to complete depending on the use of Eco-Driving System. There were 52 speed bumps and 4 stop signs within the driving course that was used to trigger the participants to come to a sudden stop and make quick starts, which is known for inefficient driving

behaviors that lead to bad gas mileage. Driving with these obstacles represent the driving experience in Korea, where driving in heavy traffic is common especially in the capital city Seoul (1/4 of the population lives in Seoul).

The driving test was conducted in daylight before and after lunch hours to maintain clear visibility and open traffic. The participants were asked to drive the KIA Soul around the assigned driving course twice. They were asked to drive the KIA Soul without activating the ECO-Driving System to see how much gas they consumed. They were encouraged to drive the KIA Soul as they would normally drive their own car. Afterwards, they were asked to drive the KIA Soul with the Eco-Driving System deactivated to see if there was a difference in gas mileage and also to see if it changed their driving behaviors. The order of activating the Eco-Driving System during sessions was reversed between each user to minimize the confounding variables that might impact the final fuel usage results.

Before they started the actual test, participants were asked to freely drive the KIA Soul for a few minutes to get familiarized themselves with the accelerator and brakes. After each session the KIA Soul's trip computer (figure 4), which indicates the overall driving time, driving distance, and average fuel consumption was recorded (the trip computer was rested to 0 before each session). Also to find what factors affected them a NASA Task Load Index (TLX) [4] was conducted after each driving session. The TLX is a multidimensional rating procedure that provides an overall workload score based on the weighted average of six subscales; Mental Demands (MD), Physical Demands(PD), Temporal Demands(TD), Own Performance(PR),

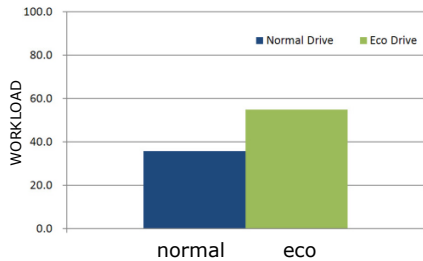


figure 6. Overall workload of normal and eco drive

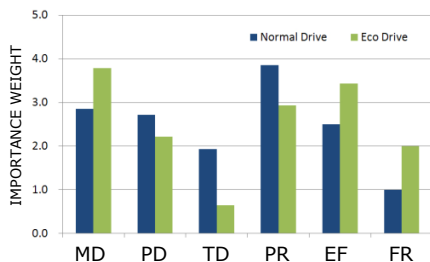


figure 7. Workload weight of each factor during normal and eco drive

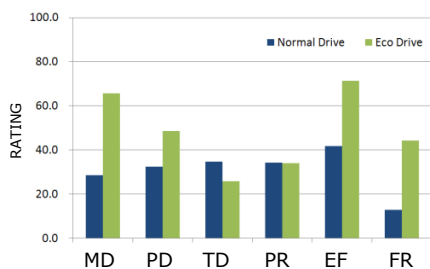


figure 8. Workload magnitude on each selected factor during normal and eco drive

Effort(EF) and Frustration(FR) [4]. By evaluating the six factors we were able to see which factor contributed to the specific workload the most.

**User Test Results**

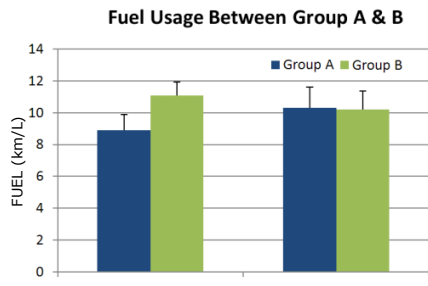
Based on the user test results, we found out that the overall fuel consumption did not differ when the Eco-Driving System was activated or deactivated, which refuted the assumption that the system would save fuel and promote greener behavior. An average of 10.2 km/L was calculated between the two sessions (figure5), which showed no significant difference. The driving time with the Eco-Driving System activated showed an average of 12 minutes to complete the driving course whereas driving with the Eco-Driving System deactivated took 11 minutes to complete (t=1.883, df=13, p=0.041, one-tailed). This suggests that the Eco-Driving System has problems to be further explored.

From further analysis, with the TLX we found out that there was a significant difference among the workload between normal drive and eco drive (t=4.512, df=13, p=0.0005, one-tailed) (figure 6). The Eco- Driving Function required more task load for the users, which resulted in inefficient gas usage. By analyzing the task load differences between normal drive (Deactivating Eco-Driving System) and Eco Drive (Activating Eco-Driving System) we were able to see what factors affect them the most while they were driving. During normal drive, the importance weight (Factors that contributed more to the workload of that task) in order was PR (3.9) > MD(2.9) > PD(2.7) > EF(2.5) > TD(1.9) > FR(1) while in Eco Drive was MD(3.8) > EF(3.4) > PR(2.9) > PD(2.2) > FR(2.0) > TD(0.6) (figure 7). This shows us that Eco Drive requires more mental demand (31%

increase), effort (36% increase), and accompanies more frustration (100% increase) than normal drive. The second part of the TLX was to rate the task load magnitude on each selected factor. During normal driving, the task load magnitude order was EF(41.8) > TD(34.6) > PR (34.3) > PD(32.5) > MD(28.6) > FR (12.9) while Eco Drive was EF(71.4) > MD(65.7) > PD (48.6) > FR (44.3) > PR (33.9) > TD(25.7) (figure 8). This shows us that Eco-Driving System requires more mental demand(128% increase), physical demand(49% increase), effort(71% increase), and accompanies more frustration(243% increase).

Our TLX results suggest that mental demand, effort and frustration were the main factors that affected the driver when using the Eco-Driving System. We were able to see that users were constantly thinking, deciding, and calculating not only on driving the car, but on driving efficiently- increasing mental demand. Also, all the hard work of maintaining the green light made the participants exert too much effort while driving. Due to these factors, most of the participants’ results showed that they felt insecure and stressed while driving on with the system activated. These results indicate that the system should unconsciously aware the users of their driving status so they can easily adapt to the system and change their behavior

In our user test, we also noticed that there were users who saved gas (N=6) and those who did not (N=8). Even though the sample size was small, we thought it would be interesting to see how the driving behaviors differed in the two groups. The group that saved gas(Group A) during the sessions had an average age of 29.1 years and 6.2 years of driving experience, whereas the group that did not save gas (Group B) had



**figure 9.** Fuel usage between Group A & B

an average age of 30.5 years and 8.6 years of driving experience. We first wanted to see if the age and driving experience affected gas mileage between the two groups. In normal drive, our result showed that Group A had an average of 8.9km/l while Group B had an average of 11.1km/L, which tells us that older users with more driving experience had greener driving behavior even without the system (figure 9). With the system activated, our test results showed that Group A had an average of 10.3km/L (15.7% increase) while Group B had an average of 10.2km/L (8.8% decrease). This result tells us drivers who are younger and have less driving experience were more able to adapt to the system easier than the ones who were older and more experienced. Although Group B saved more gas than Group A, their prior driving experience made it hard to change their current driving behaviors. This happened because the green light will still be on even when they exceeded their normal eco driving standards. Having the green light on made them assume they were driving efficiently. This tells us that the current system setting for indicating the green light is set higher than the Group B driving standards. After the user test, some of the participants in Group B said they did not need the system indicator to save fuel because they could tell the gas usage by hearing the engine or the sound of the gears changing. We suggest that the Eco-Driving System should be set to meet the users' current driving behaviors and slowly persuade [2] them to change their driving behaviors.

### Conclusion and Further study

In this paper we discovered that the increased cognitive load using Eco-Driving System brings negative effects on gas mileage. Also the drivers' age and driving experience may be a factor which could affect the gas

mileage as well. So how can we design a system where the users can unconsciously interact and also benefit all type of users? We hereby propose a new system that can evaluate the users' current driving behavior and slowly persuade [2] them to change into a more economic and sustainable way. Ultimately, we will conduct more research by creating prototypes from the results and feedback from current research, testing them over a period of time. This will allow us to explore how to generate greener behavior through applications, which could be implemented to other areas.

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