IT and Eco-driving: The Moderating Effect of App Usage on Behavior Changing

Abstract

Information technology (IT) is playing an increasingly important role in the Internet of Vehicles. While there is a substantial body of literature that examines factors resulting in fuel consumption and greenhouse gas emissions, including driving behavior, few studies have focused on the impacts of IT on fuel efficiency. The purpose of this study is to examine whether and how much the use of IT could influence the fuel efficiency through impacting individual driving behavior. Based on Cognitive Dissonance Theory, this study investigates whether a mobile app help improve fuel efficiency by helping individuals to improve their driving behavior and attempts to explore the reasons for the phenomenon. An Empirical investigation has been designed to collect drivers’ app usage data and driving data from XXX drivers over a 16-month period. The results of the study will contribute to sustainable development and further enrich the IT application scenario.

Keywords: app usage; behavior; eco-driving; fuel consumption/efficiency

1 Introduction

The continuous development of information technology (IT) has created new and immensely complex environments. The world we live in is greatly influenced by these developments, and the use of information technology is gradually penetrating all aspects of life (Stolterman and Fors 2004). Researchers explore from the acceptance to influence of IT (Dede 2000; Lee et al. 2005; Moon and Kim 2001; Wang et al. 2015b), and recently intend to positively directing people's behavior using IT. In the last decade, IT has been proved to be effective in assisting in changing people's behavior, such as advising individuals to exercise and break properly and successfully helping increase work efficiency (Consolvo et al. 2006; Hughes et al. 2010; Kamal et al. 2016; Lin et al. 2006; Short et al. 2014; Sundaram et al. 2007).

In fact, information technology (IT) is widely used for good in various fields, and it is no exception in the field of driving and Internet of Vehicles (IoV). IT has already made a big difference in autonomous driving, improving communication quality of IoV networks and optimizing environmental detection (Guo et al. 2017; Xu et al. 2021; Yu et al. 2018). To date, as the constantly rising green house gases (GHGs) emissions from road transport raises special concern (Gorham 2002), sustainability is being discussed more often and fuel efficiency has become a crucial topic in the fields around driving sustainability (Allison et al. 2022; Barth and Boriboonsomsin 2009; Hua et al. 2022; Huang et al. 2018; Jazairy et al.).

Prior studies indicated that fuel efficiency from road transport will be influenced by several factors, such as driving environment (e.g., roadway and roadside environment), demographic information, driving style, weather, and vehicle/fuel types (Ewing et al. 1997; Fafoutellis et al. 2021; Sivak and Tsimhoni 2009; Wang et al. 2014).

In order to improve fuel efficiency and reduce fuel consumption, several measures have come out. The most popular ones are investing in new vehicle technologies (like advanced engines) and fuels, and promoting a fuel-efficient driving style, i.e. eco-driving (Alam and McNabola 2014; Zhou et al. 2016). Among them, eco-driving can be significantly lower-cost and more immediate. Eco-driving is a new way of driving that has been developed since the mid-1990s and is now a climate change initiative that cannot be ignored (Alessandrini et al. 2012; Barkenbus 2010). It is a multidimensional concept and has different definitions or scope in the literature. The exact descriptions of the definition may vary, nevertheless, the purpose of introducing the concept of eco-driving in this field is to improve fuel efficiency and driver’s driving behavior (Fafoutellis et al. 2021). Thus, in this paper, eco-driving is defined as the adoption of a driving behavior (or a driving style) that aims at saving fuel and reducing harmful emissions of greenhouse gases (GHG) (Andrieu and Saint Pierre 2012b).

In the field of eco-driving, there is the presence of IT as well. IT is often used to collect data and give feedbacks on drivers’ driving behavior (Stillwater et al. 2017; Young et al. 2011). In addition, many studies claim that IT has the potential to improve road safety and fuel efficiency through providing eco-driving advice and in-vehicle feedback to drivers (Andrieu and Saint Pierre 2012a; Barla et al. 2017; Fafoutellis et al. 2021; Gao et al. 2021; Vaezipour et al. 2015). According to Hebden et al., those kinds of IT are a novel technology that can be used to deliver behavior change interventions directly to individuals and have the potential to make a difference (Hebden et al. 2012). However, the effect of IT on specific eco-driving behaviors such as drivng speed, deceleration and acceleration has not been fully explored (Fafoutellis et al. 2021; Vaezipour 2018; Vaezipour et al. 2015).

Thus, to explore the mechanisms of how IT could influence eco-driving behaviors to improve fuel efficiency, this research carries out an empirical investigation, builds regression model based on naturalistic driving data collected using smartphones and on-board devices (OBD).

The rest of the manuscript is organized as follows: In Section 2 the impacts of IT and the notion of eco-driving is presented in detail and in Section 3 theoretical explanations are discussed. In Section 4 research model and hypotheses are presented and, in Section 5, the methodology is elaborated. Section 6 includes a thorough discussion about the relationship between IT and eco-driving behavior. In Section 7 the main conclusions are presented and future research directions are discussed.

2 Literature Review

2.1 The Impacts of IT

As we develop information technology and optimize information systems, they are also influencing our habits and performance at the same time.

If managed well, they have the potential to give rise to innovation that will drive growth and social impact. For example, people use IT in health care to reduce the frequency and consequences of errors (Bates et al. 2001; Bates and Gawande 2003); in the field of education, using advanced IT helps learning and add value to management education (Alavi and Gallupe 2003; Alavi et al. 1997); IT also has dramatically transformed travel and tourism (Buhalis and Law 2008; Werthner and Klein 1999); IT has been widely adopted in business not only as a supporting player within the overall strategy of the firm to, but can used to create new needs, cause new product development, and command new procedures as well (Chan 2000; Gunasekaran and Nath 1997); and, IT has a great potential to be a global greenhouse gas emission game-changer by monitoring the waste remotely (Imasiku et al. 2019; Liu et al. 2020a; Sun and Zhang 2020).

IT can definitely bring some risks with its benefits. Aside from some common problems like the rising threat of cyberattacks, privacy issues, and the polarizing effects of technologies on labor markets could derail these benefits (Baller et al. 2016), the down-side of IT can be manifested in different areas. For instance, in education, studies show that typing could impair reading and writing, which results in impaired learning and memory (Spitzer 2014). IT also decreases students’ learning by increasing distraction (Bowman et al. 2010; Fried 2008). In behavioral psychology, IT can cause IT-addiction (Chen 2020; Leung and Lee 2012; OReilly 1996) that has been shown to lead to consequences such as failing school, family, and relationship problems (Ng and Wiemer-Hastings 2005; Vaghefi and Lapointe 2014). Moreover, in environmental science, although IT could be used to promote low-carbon environmental protection, they themselves contribute to carbon emissions in their operation (Gelenbe and Caseau 2015; Zhou et al. 2019), for the Web runs on millions of physical servers requiring a lot of energy, most of which comes from fossil fuels. The burning of these fuels results in significant carbon emissions.

There is a large body of research has explored IT usage in diverse areas. Recently, IT in the Internet of Vehicles (IOV) has become an emerging topic. In this area, researchers always put stress on the connection between vehicles, vehicle and road, vehicle and cloud, vehicle and infrastructure, etc., and take note to self-driving, automotive revolution (Guo et al. 2017; Kadhim and Seno 2018; Liu et al. 2019; Liu et al. 2020b; Wu and Horng 2017). However, few studies the relationship between vehicle and driver. This paper is interested in the relationship between vehicles and drivers, and explores the effects of IT on drivers: whether they have positive impacts or bad ones, or there would be some side effects while influencing drivers.

2.2 Eco-driving behavior

Since greenhouse gas (GHG) emissions, especially CO2 emissions, are considered to be the main causes of global warming (Letcher 2019; Soytas et al. 2007). As was stated by researchers, it is human activity that exerts extra pressure on what is otherwise a self-balancing Earth system(Xi-Liu and Qing-Xian 2018), and the human emissions of GHG such as CO2 mainly comes from burning fossil fuels (Ritchie and Roser 2020).

Reducing dependence on fossil fuels has been recognized as an urgent social need that should be addressed through scientific and technological research and industrial developments. Research on improving fuel efficiency is growing. Investigators identified six groups of factors affecting fuel consumption, namely travel-, weather-, vehicle-, roadway-, traffic- and driver-related factors (Zhou et al. 2016). Correspondingly, a wide range of measures have been taken to make driving more environmentally friendly and safer. In addition to targeted policies, the most popularly known practice is about personal transportation: people can buy more fuel-efficient vehicles; they can purchase vehicles that utilize low-carbon fuels (e.g. electricity and renewable energy) (Saber and Venayagamoorthy 2010); they can reduce their vehicle miles travelled through such actions as carpooling and using public transportation; and, they can operate their current vehicles more efficiently (Alessandrini et al. 2012; Barkenbus 2010).

Among those measures, investments in new vehicle technologies and fuels are usually large and long-term. The potential efficiency improvements of advanced engine and vehicle technologies were estimated to be around 4-10% and 2-8% respectively (Zhou et al. 2016). However, the improvement of driving behavior is relatively low-cost and has an immediate effect, as fuel efficiency can be improved by up to 45% (Huang et al. 2018; Sivak and Schoettle 2012). Usually, researchers called the driving style aiming to achieve cleaner travelling “eco-driving”.

Eco-driving involves a number of factors and has different definitions or scope in the literature (Sanguinetti et al. 2017; Sivak and Schoettle 2012; Zhou et al. 2016). Based on the concept of behavioral functions, Sanguinetti et al. identified six classes of eco-driving behavior including driving, cabin comfort, trip planning, load management, fueling and maintenance. The driving behavior was further divided into accelerating, cruising, decelerating, waiting, driving mode selection and parking (Sanguinetti et al. 2017). Broadly speaking, eco-driving also involved public education, driving feedback devices, regulation, fiscal incentives and social norm reinforcement (Barkenbus 2010). In this study, referring to Huang et al. (Huang et al. 2018), Andrieu and Saint Pierre (Andrieu and Saint Pierre 2012b) we narrow eco-driving to the driving behaviors or the driver's control of the vehicle during a journey, i.e. the adoption of a driving behavior (or a driving style) that aims at saving fuel and reducing harmful emissions of greenhouse gases.These factors include driving speed, acceleration, deceleration, and vehicle accessories (other factors). This is not only because they are the most common and useful eco-driving skills that every driver can implement in practice every day, but also because their improvement can lead to significantly higher reductions in fuel consumption and emissions than other behaviors such as the aforementioned better vehicle technologies (Alam and McNabola 2014; Ericsson 2001; Xu et al. 2018; Yao et al. 2020; Zhou et al. 2016).

Thus, when discussing the effects of IT in the context of IOV, we are meant to pay attention to its direct effects on drivers’ eco-driving behavior, and we are also concerned about IT’s side effects on fuel consumption and fuel efficiency as well.

3 Cognitive Dissonance Theory/ theoretical foundation

The theoretical foundation for this study comes from Festinger's book Theory of Cognitive Dissonance (Festinger 1957). According to the Cognitive Dissonance Theory, individuals seek to maintain consistency among multiple cognitions (e.g., thoughts, behaviors, attitudes, or beliefs). Inconsistency (or dissonance) would lead to individual’s psychological discomfort and motivate the person to actively change one or more cognitions to restore consistency with other cognitions. In the past decades, the theory has been proved by various experiments (Brehm and Cohen 1962) and revolutionized thinking about psychological processes (Harmon-Jones and Harmon-Jones 2007).

Although the Cognitive Dissonance Theory was originally introduced to explain a wide range of psychological phenomena, later research extends its application to attitudes and behaviors (Miller and Jehle 2007). For example, a qualitative study of employees with dirty (i.e., stigmatized) jobs applying Cognitive Dissonance Theory to explain why employees adjusted their job attitudes by reframing their view to make it more favorable (e.g. personal injury attorneys deal with the taint associated with their work by asserting that they help to hold manufacturers accountable) (E. Ashforth et al. 2007). And in one of the studies to examine the permanency of attitude change following dissonance, Boswell et al. (Boswell et al. 2005) found that employees adjusted job satisfaction to favor the new job after leaving one job for another, while the satisfaction rose just in the short term and eventually declined, suggesting such discrepancy reduction wears off over time.

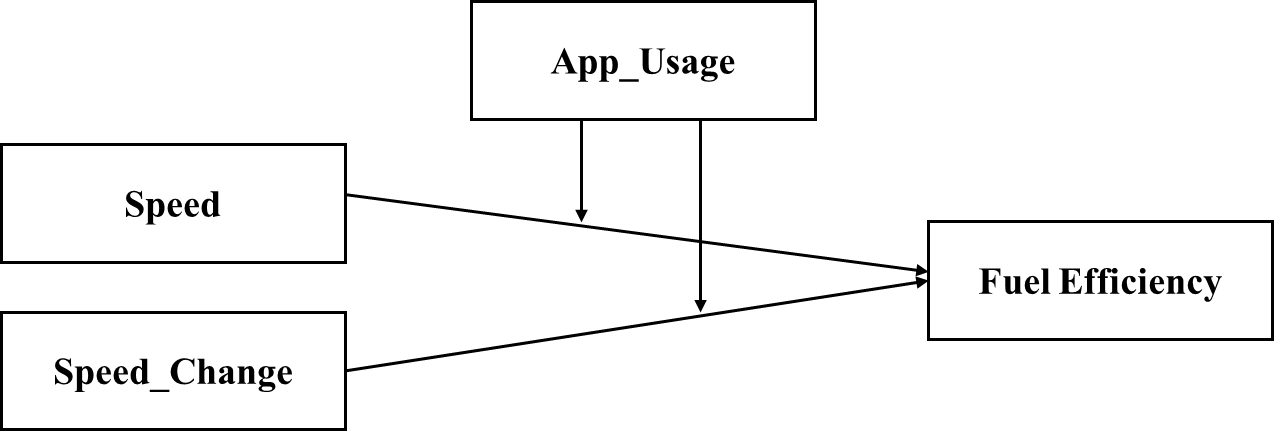
Other researchers explore cognitive discrepancy and behavior. Westphal and Bednar (Westphal and Bednar 2008) reasoned that fund managers experienced dissonance when received ingratiation from the CEO for their actions conflicted with the CEO’s preferences. As what is suggested by the Cognitive Dissonance Theory, in order to avoid the dissonance that defying the CEO would create, the fund managers tended to align their actions with CEO preferences. Similarly, Westphal and Deephouse (Westphal and Deephouse 2011) found that a journalist would be less likely to write a negative article about a CEO if that CEO was on good terms with them.

Cognitive Dissonance Theory has also been referred to design persuasive technology strategies to encourage behavior change, helping individuals change their behavior to match their attitudes (Consolvo et al. 2009). As was stated by Consolvo et al., for instance, the technology should help the person stay focused on their commitment to change and the associated patterns of behavior. The awareness provided by the technique must be consistently available and easily accessible, yet subtle enough to support the need for occasional information/avoidance of situations.

In our research, there is just such an app which will record and show users all kinds of driving data (e.g. the app usage history, driving speed, fuel consumption, travel mileage and so on) and will send alerts to them when it detects risky driving behavior. Considering that these functions of the driving-assistant app could reflect the person’s attitude towards improving driving style (the app usage history), create psychological discomfort and help individual be conscious of their own behavior (e.g. the alert), this study will use Cognitive Dissonance Theory to explain the results.

4 Research model and hypotheses development

Extending cognitive dissonance theory into the context of Internet of Vehicles and driving, we propose a comprehensive research model in Figure 1 to elaborate the moderating effect of IT on driving behavior. Meanwhile, the direct effects of driving behavior on fuel efficiency will also be investigated.



Cognitive Dissonance Theory suggests that a persuasive technology to encourage lifestyle behavior change should address whichever factors may prevent the individual from incorporating the change into her everyday life (i.e., by helping her change her behavior to match her attitudes).

Fuel consumption rate firstly decreases with the increase of engine speed due to reduced heat losses, reaches the optimal point and then increases at high speed due to increased friction losses (Pulkrabek 2004).

H1: Average driving speed is positively related to fuel consumption.

H2: Speed changes are positively related to fuel consumption.

while factors such as speed and speed change(or acceleration and deceleration) directly influence fuel efficiency (Ross 1997; Wang et al. 2014), other factors like different forms of intervention (e.g. educational and the intervention of IT) are considered as worth studying effects on fuel efficiency and fuel consumption indirectly through driving behaviors (Vaezipour 2018; Vaezipour et al. 2015).

H3a: App usage weakens the relationship between average driving speed and fuel consumption.

H3b: App usage weakens the relationship between speed changes and fuel consumption.

5 Methodology

Data collection

This research observed 400 different taxi drivers using a driving-assistant app named “hujiabao” over 16 months. Drivers were asked to register demographic information such as age, gender, permanent address and types of their cars. Their usage behaviors were recorded once they open the app in a given day. Data sets for driving behaviors were collected using on-board devices (OBD). The OBD system is designed to capture detailed driving information such as vehicle speed, engine rpm, engine coolant temperature, diagnostic trouble codes, fuel consumption, etc. (Bian et al. 2018), and it starts to be used in research recently (Chen et al. 2015; Yang et al. 2016). Then observations with a 0 mile driven record on the day are excluded. After merging data sets of app usage behavior and individual driving behavior, we winsorized the quantity of fuel consumed at the 1 percent level (Tukey 1962) to alleviate potential bias caused by outliers in the following regression analysis. Then because there are 35% missing values in drivers’ demographic information, especially in age and gender, we use the mode of the non-missing values to impute the missing values (Lakshminarayan et al. 1999). The final sample dataset consists of 11187 observations.

Measurement

Independent variables

Following Huang et al.’s and Wang et al.’s study (Huang et al. 2018; Wang et al. 2014), this research characterized eco-driving behaviors using two most important driving behavior variables: average speed and speed change, to reduce the complexity of the model. In this study, average speed is collected from the app data, named as Speed\_KMH and Speed\_Change refers to aggressive speed changing behavior. Speed\_Change is measured by the total number of hard acceleration and deceleration.

Moderator variable

Regarding the driving assistant app works automatically when the user has opened it, the check-in records reflect an individual’s usage status. We define App\_Usage as whether a driver uses the app and whether the app runs effectively during a day (Taylor and Levin 2014). It is measured by the drivers’ check-in status (used or not used) in a given day.

Dependent variable

Vaezipour et al. distinguishes the term fuel consumption rate with fuel efficiency. Their research defines fuel consumption rate as total quantity of fuel consumed by a vehicle per unit distance (commonly expressed in liters/100kilometers) (Vaezipour et al. 2015), while fuel efficiency as ratio of the work or energy output of an engine to the work or energy input (Haworth and Symmons 2001). But according to some other literature, fuel efficiency is based on a vehicle’s miles per gallon (Carson 1980; McCarthy and Tay 1998). Considering both definitions, fuel efficiency is measured by the amount of fuel consumed per unit distance (liters/kilometer) in this paper. Thus, we choose Fuel Consumption as dependent variable, and the more the fuel is consumed, the less efficient is it.

Control variables

Control variables are considered to ensure the model robustness. Apart from driving styles and driving skills, other objective factors can affect driving behavior. For example, driving experience, time pressure, driving environment (weather condition, road condition, traffic congestion, etc.) and vehicle states (Bone and Mowen 2006; Cai et al. 2016; Drobot et al. 2007; Ma et al. 2019; Shi et al. 2019; Wang et al. 2015a; Zheng et al. 2014). Thus, we controlled driving time period, vehicle types (Car\_Type\_n), and drivers’ driving experience. Specifically, we categorized the driving time period by weekay or weekend and day or night, generating two control variables: Day\_n and Isnight. Besides, driving experience (Totalm) is measured by the total distance a driver had ever travelled before. According to the definition of fuel efficiency above-mentioned, we controlled the continuous driving time (Time) in the model. We controlled demographic information of drivers, such as Age, Gender and permanent address as well. We also controlled geographical location-related variables such as the country where the participants driving in. All the drivers comes from Anhui province in China and drive cars in Anhui.

6 Statistical Results

As the dependent variable Fuel Consumption is a continuous quantitative variable obeying normal distribution, linear regression is considered as an appropriate method (Su et al. 2012). App\_Usage is a dichotomous variable that we code as 1 for records with use and 0 for records without use; other nominal control variables like gender (0 for female and 1 for male), car\_style\_n (encoded with integers from 1 to 32), isnight (0 for day and 1 for night driving) and day\_n (1 for weekdays and 2 for weekends) are encoded into numeric data. Given that moderating effects of app usage on driving behaviors will be tested, relevant variables including are mean-centered before generating the interaction value to mitigate potential multicollinearity (Daniel and Stewart 2016). Analyses are conducted with StataSE 15. Descriptive statistics and correlations are displayed in Table 1. The majority of correlations are neither too large nor too small. We have also estimated variance inflation factors with a mean value of 1.76, which is below the threshold level of 10, further demonstrating multicollinearity is not a big concern.

Table 2 shows regression results for hypotheses testing. The model includes all variables aforementioned. The coefficients of Speed\_Change (β=0.010, p<0.01) and Speed\_KMH (β=0.195, p<0.01) are positive and significant. Therefore, H1 and H2 are supported. The moderating effect of App\_Usage has been tested in the model. The negative and significant relationship between Fuel Consumption and App\_SC (β=-0.002, p<0.01) indicates H3a is supported. The model also reveals the significantly negative influence of App\_Speed (β=-0.081, p<0.01), which means App\_Usage weakens the positive influence of Speed\_KMH. Thus, H3b is supported.

Table 1 Decriptive Statistics

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean | SD | Correlations | | | | | | | | | | |
| Variables |  |  | Fuel Consumption | Speed\_Change | Speed\_KMH | time | totalm | age | gender | car\_style\_n | day\_n | night |
| Fuel Consumption | 28.68 | 20.72 | 1 |  |  |  |  |  |  |  |  |  |
| Speed\_Change | 206 | 217 | 0.714\*\*\* | 1 |  |  |  |  |  |  |  |  |
| Speed\_KMH | 22.91 | 8.917 | 0.381\*\*\* | 0.292\*\*\* | 1 |  |  |  |  |  |  |  |
| time | 8.833 | 6.137 | 0.957\*\*\* | 0.695\*\*\* | 0.325\*\*\* | 1 |  |  |  |  |  |  |
| totalm | 28162 | 26307 | 0.466\*\*\* | 0.313\*\*\* | 0.260\*\*\* | 0.461\*\*\* | 1 |  |  |  |  |  |
| age | 42.35 | 6.819 | 0.107\*\*\* | 0.103\*\*\* | -0.021\*\* | 0.124\*\*\* | 0.137\*\*\* | 1 |  |  |  |  |
| gender | 0.923 | 0.267 | -0.277\*\*\* | -0.098\*\*\* | -0.080\*\*\* | -0.239\*\*\* | -0.152\*\*\* | 0.185\*\*\* | 1 |  |  |  |
| car\_style\_n | 17.39 | 5.089 | -0.171\*\*\* | -0.076\*\*\* | -0.032\*\*\* | -0.180\*\*\* | -0.086\*\*\* | -0.040\*\*\* | 0.022\*\* | 1 |  |  |
| day\_n | 1.283 | 0.45 | -0.020\*\* | -0.01 | -0.008 | -0.018\* | 0.006 | 0.004 | 0 | -0.01 | 1 |  |
| night | 0.776 | 0.417 | 0.468\*\*\* | 0.317\*\*\* | 0.149\*\*\* | 0.469\*\*\* | 0.235\*\*\* | 0.028\*\*\* | -0.097\*\*\* | -0.102\*\*\* | -0.028\*\*\* | 1 |
| Notes: n=11187. \*Significant at 10 percent level, \*\*significant at 5 percent level, \*\*\*significant at 1 percent level. | | | | | | | | | | | | | |

|  |
| --- |
|  |

|  |  |  |
| --- | --- | --- |
| Variable | VIF | 1/VIF |
|  |  |  |
| Speed\_Change | 3.25 | 0.307237 |
| time | 2.74 | 0.365346 |
| App\_SC | 2.46 | 0.407065 |
| App\_Speed | 2.04 | 0.489658 |
| Speed\_KMH | 1.95 | 0.51283 |
| totalm | 1.32 | 0.757821 |
| night | 1.31 | 0.762958 |
| gender | 1.13 | 0.882343 |
| age | 1.12 | 0.893646 |
| car\_style\_n | 1.07 | 0.936271 |
| day\_n | 1 | 0.998556 |
|  |  |  |
| Mean VIF | 1.76 |  |

**Table 2 Linear regression**

**Linear regression**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fuel Consumption | Coef. | | St.Err. | t-value | | p-value | [95% Conf | | Interval] | | Sig |
| Speed\_Change | 0.010 | | 0.000 | 23.29 | | 0.000 | 0.009 | | 0.011 | | \*\*\* |
| App\_SC | -0.002 | | 0.001 | -3.47 | | 0.001 | -0.003 | | -0.001 | | \*\*\* |
| Speed\_KMH | 0.195 | | 0.008 | 23.90 | | 0.000 | 0.179 | | 0.211 | | \*\*\* |
| App\_Speed | -0.081 | | 0.013 | -6.43 | | 0.000 | -0.106 | | -0.057 | | \*\*\* |
| time | 2.815 | | 0.014 | 200.82 | | 0.000 | 2.787 | | 2.842 | | \*\*\* |
| car\_style\_n | -0.019 | | 0.011 | -1.79 | | 0.074 | -0.040 | | 0.002 | | \* |
| day\_n | -0.140 | | 0.116 | -1.21 | | 0.226 | -0.366 | | 0.087 | |  |
| totalm | 1.62e-05 | | 2.27e-06 | 7.13 | | 0.000 | 1.17e-05 | | 2.06e-05 | | \*\*\* |
| age | 0.006 | | 0.008 | 0.76 | | 0.448 | -0.010 | | 0.022 | |  |
| gender | -4.497 | | 0.207 | -21.69 | | 0.000 | -4.903 | | -4.091 | | \*\*\* |
| night | 1.179 | | 0.143 | 8.25 | | 0.000 | 0.899 | | 1.459 | | \*\*\* |
| Constant | 0.306 | | 0.479 | 0.64 | | 0.523 | -0.634 | | 1.245 | |  |
|  | | | | | | | | | | | |
| Mean dependent var | | 28.681 | | | SD dependent var | | | 20.721 | |
| R-squared | | 0.930 | | | Number of obs | | | 11187 | |
| F-test | | 13422.983 | | | Prob > F | | | 0.000 | |
| Akaike crit. (AIC) | | 69896.824 | | | Bayesian crit. (BIC) | | | 69984.694 | |
| *\*\*\* p<.01, \*\* p<.05, \* p<.1* | | | | | | | | | | | |
|  | | | | | | | | | | | |

7 Conclusion（future work）

Driving Speed 作用及各主要变量作用的解释

Future work，我们目前把APP直接当做一个整体（包含其警告、反馈、社交属性、主动使用意愿等等），01变量即我们有没有这个APP。我们可以解释我们的APP当中有alert这种的警示提醒项，但是我们这次不单独看。未来我们可能会细化研究这个APP的功能对应产生的效果。contains various functions, such as risk warning, daily driving behavior feedbacks, driving records, even driver exchange groups

Alam, M. S., and McNabola, A. 2014. "A Critical Review and Assessment of Eco-Driving Policy & Technology: Benefits & Limitations," *Transport Policy* (35), pp. 42-49.

Alavi, M., and Gallupe, R. B. 2003. "Using Information Technology in Learning: Case Studies in Business and Management Education Programs," *Academy of Management Learning & Education* (2:2), pp. 139-153.

Alavi, M., Yoo, Y., and Vogel, D. R. 1997. "Using Information Technology to Add Value to Management Education," *Academy of management Journal* (40:6), pp. 1310-1333.

Alessandrini, A., Cattivera, A., Filippi, F., and Ortenzi, F. 2012. "Driving Style Influence on Car Co2 Emissions," *2012 international emission inventory conference*.

Allison, C., Stanton, N., Fleming, J., Yan, X., and Lot, R. 2022. "How Does Eco-Driving Make Us Feel?: Considering the Psychological Effects of Eco-Driving," *Applied Ergonomics*).

Andrieu, C., and Saint Pierre, G. 2012a. "Comparing Effects of Eco-Driving Training and Simple Advices on Driving Behavior," *Procedia-Social and Behavioral Sciences* (54), pp. 211-220.

Andrieu, C., and Saint Pierre, G. 2012b. "Using Statistical Models to Characterize Eco-Driving Style with an Aggregated Indicator," *2012 IEEE Intelligent Vehicles Symposium*: IEEE, pp. 63-68.

Baller, S., Dutta, S., and Lanvin, B. 2016. *Global Information Technology Report 2016*. Ouranos Geneva.

Barkenbus, J. N. 2010. "Eco-Driving: An Overlooked Climate Change Initiative," *Energy policy* (38:2), pp. 762-769.

Barla, P., Gilbert-Gonthier, M., Castro, M. A. L., and Miranda-Moreno, L. 2017. "Eco-Driving Training and Fuel Consumption: Impact, Heterogeneity and Sustainability," *Energy Economics* (62), pp. 187-194.

Barth, M., and Boriboonsomsin, K. 2009. "Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System," *Transportation Research Part D: Transport and Environment* (14:6), pp. 400-410.

Bates, D. W., Cohen, M., Leape, L. L., Overhage, J. M., Shabot, M. M., and Sheridan, T. 2001. "Reducing the Frequency of Errors in Medicine Using Information Technology," *Journal of the American Medical Informatics Association* (8:4), pp. 299-308.

Bates, D. W., and Gawande, A. A. 2003. "Improving Safety with Information Technology," *New England journal of medicine* (348:25), pp. 2526-2534.

Bian, Y., Yang, C., Zhao, J. L., and Liang, L. 2018. "Good Drivers Pay Less: A Study of Usage-Based Vehicle Insurance Models," *Transportation research part A: policy and practice* (107), pp. 20-34.

Bone, S. A., and Mowen, J. C. 2006. "Identifying the Traits of Aggressive and Distracted Drivers: A Hierarchical Trait Model Approach," *Journal of Consumer Behaviour: an International Research Review* (5:5), pp. 454-464.

Boswell, W. R., Boudreau, J. W., and Tichy, J. 2005. "The Relationship between Employee Job Change and Job Satisfaction: The Honeymoon-Hangover Effect," *Journal of applied psychology* (90:5), p. 882.

Bowman, L. L., Levine, L. E., Waite, B. M., and Gendron, M. 2010. "Can Students Really Multitask? An Experimental Study of Instant Messaging While Reading," *Computers & Education* (54:4), pp. 927-931.

Brehm, J. W., and Cohen, A. R. 1962. "Explorations in Cognitive Dissonance,").

Buhalis, D., and Law, R. 2008. "Progress in Information Technology and Tourism Management: 20 Years on and 10 Years after the Internet—the State of Etourism Research," *Tourism management* (29:4), pp. 609-623.

Cai, X., Wang, C., Chen, S., and Lu, J. 2016. "Model Development for Risk Assessment of Driving on Freeway under Rainy Weather Conditions," *PLoS one* (11:2), p. e0149442.

Carson, B. 1980. "Fuel Efficiency of Small Aircraft," *Aircraft Systems Meeting*, p. 1847.

Chan, S. L. 2000. "Information Technology in Business Processes," *Business Process Management Journal*).

Chen, C.-Y. 2020. "Smartphone Addiction: Psychological and Social Factors Predict the Use and Abuse of a Social Mobile Application," *Information, Communication & Society* (23:3), pp. 454-467.

Chen, S.-H., Pan, J.-S., and Lu, K. 2015. "Driving Behavior Analysis Based on Vehicle Obd Information and Adaboost Algorithms," *Proceedings of the international multiconference of engineers and computer scientists*, pp. 18-20.

Consolvo, S., Everitt, K., Smith, I., and Landay, J. A. 2006. "Design Requirements for Technologies That Encourage Physical Activity," *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pp. 457-466.

Consolvo, S., McDonald, D. W., and Landay, J. A. 2009. "Theory-Driven Design Strategies for Technologies That Support Behavior Change in Everyday Life," *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 405-414.

Daniel, S., and Stewart, K. 2016. "Open Source Project Success: Resource Access, Flow, and Integration," *The Journal of strategic information systems* (25:3), pp. 159-176.

Dede, C. 2000. "Emerging Influences of Information Technology on School Curriculum," *Journal of Curriculum Studies* (32:2), pp. 281-303.

Drobot, S. D., Benight, C., and Gruntfest, E. 2007. "Risk Factors for Driving into Flooded Roads," *Environmental Hazards* (7:3), pp. 227-234.

E. Ashforth, B., E. Kreiner, G., A. Clark, M., and Fugate, M. 2007. "Normalizing Dirty Work: Managerial Tactics for Countering Occupational Taint," *Academy of Management Journal* (50:1), pp. 149-174.

Ericsson, E. 2001. "Independent Driving Pattern Factors and Their Influence on Fuel-Use and Exhaust Emission Factors," *Transportation Research Part D: Transport and Environment* (6:5), pp. 325-345.

Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., Chen, D., McCann, B., and Goldberg, D. 1997. "Growing Cooler: The Evidence on Urban Development and Climate Change,").

Fafoutellis, P., Mantouka, E. G., and Vlahogianni, E. I. 2021. "Eco-Driving and Its Impacts on Fuel Efficiency: An Overview of Technologies and Data-Driven Methods," *Sustainability* (13:1), p. 226.

Festinger, L. 1957. *A Theory of Cognitive Dissonance*. Stanford university press.

Fried, C. B. 2008. "In-Class Laptop Use and Its Effects on Student Learning," *Computers & Education* (50:3), pp. 906-914.

Gao, J., Chen, H., Liu, Y., Li, Y., Li, T., Tu, R., Liang, B., and Ma, C. 2021. "The Effect of after-Treatment Techniques on the Correlations between Driving Behaviours and Nox Emissions of Passenger Cars," *Journal of Cleaner Production* (288), p. 125647.

Gelenbe, E., and Caseau, Y. 2015. "The Impact of Information Technology on Energy Consumption and Carbon Emissions," *Ubiquity* (2015:June), pp. 1-15.

Gorham, R. 2002. "Air Pollution from Ground Transportation," *An Assessment of Causes, Strategies and Tactics, and Proposed Actions for the International Community. New York: United Nations, Division of Sustainable Development, Department of Economic and Social Affairs*).

Gunasekaran, A., and Nath, B. 1997. "The Role of Information Technology in Business Process Reengineering," *International journal of production economics* (50:2-3), pp. 91-104.

Guo, L., Dong, M., Ota, K., Li, Q., Ye, T., Wu, J., and Li, J. 2017. "A Secure Mechanism for Big Data Collection in Large Scale Internet of Vehicle," *IEEE Internet of Things Journal* (4:2), pp. 601-610.

Harmon-Jones, E., and Harmon-Jones, C. 2007. "Cognitive Dissonance Theory after 50 Years of Development," *Zeitschrift für Sozialpsychologie* (38:1), pp. 7-16.

Haworth, N., and Symmons, M. 2001. "The Relationship between Fuel Economy and Safety Outcomes,").

Hebden, L., Cook, A., Van Der Ploeg, H. P., and Allman-Farinelli, M. 2012. "Development of Smartphone Applications for Nutrition and Physical Activity Behavior Change," *JMIR research protocols* (1:2), p. e9.

Hua, Y., Sevegnani, M., Yi, D., Birnie, A., and Mcaslan, S. 2022. "Fine-Grained Rnn with Transfer Learning for Energy Consumption Estimation on Evs," *IEEE Transactions on Industrial Informatics*).

Huang, Y., Ng, E. C., Zhou, J. L., Surawski, N. C., Chan, E. F., and Hong, G. 2018. "Eco-Driving Technology for Sustainable Road Transport: A Review," *Renewable and Sustainable Energy Reviews* (93), pp. 596-609.

Hughes, D. C., Andrew, A., Denning, T., Hurvitz, P., Lester, J., Beresford, S., Borriello, G., Bruemmer, B., Moudon, A. V., and Duncan, G. E. 2010. "Balance (Bioengineering Approaches for Lifestyle Activity and Nutrition Continuous Engagement): Developing New Technology for Monitoring Energy Balance in Real Time," *Journal of diabetes science and technology* (4:2), pp. 429-434.

Imasiku, K., Thomas, V., and Ntagwirumugara, E. 2019. "Unraveling Green Information Technology Systems as a Global Greenhouse Gas Emission Game-Changer," *Administrative Sciences* (9:2), p. 43.

Jazairy, A., Pohjosenperä, T., Sassali, J., Juga, J., and von Haartman, R. "Truck Drivers’ Motivations to Eco-Drive and Observed Eco-Driving Behavior: A Case Study," *Available at SSRN 3996757*).

Kadhim, A. J., and Seno, S. A. H. 2018. "Maximizing the Utilization of Fog Computing in Internet of Vehicle Using Sdn," *IEEE Communications Letters* (23:1), pp. 140-143.

Kamal, A. K., Muqeet, A., Farhat, K., Khalid, W., Jamil, A., Gowani, A., Muhammad, A. A., Zaidi, F., Khan, D., and Elahi, T. 2016. "Using a Tailored Health Information Technology-Driven Intervention to Improve Health Literacy and Medication Adherence in a Pakistani Population with Vascular Disease (Talking Rx)–Study Protocol for a Randomized Controlled Trial," *Trials* (17:1), pp. 1-13.

Lakshminarayan, K., Harp, S. A., and Samad, T. 1999. "Imputation of Missing Data in Industrial Databases," *Applied intelligence* (11:3), pp. 259-275.

Lee, M. K., Cheung, C. M., and Chen, Z. 2005. "Acceptance of Internet-Based Learning Medium: The Role of Extrinsic and Intrinsic Motivation," *Information & management* (42:8), pp. 1095-1104.

Letcher, T. M. 2019. "Why Do We Have Global Warming?," in *Managing Global Warming*. Elsevier, pp. 3-15.

Leung, L., and Lee, P. S. 2012. "The Influences of Information Literacy, Internet Addiction and Parenting Styles on Internet Risks," *New media & society* (14:1), pp. 117-136.

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. B. 2006. "Fish’n’steps: Encouraging Physical Activity with an Interactive Computer Game," *International conference on ubiquitous computing*: Springer, pp. 261-278.

Liu, G., Chen, R., Xu, P., Fu, Y., Mao, C., and Hong, J. 2020a. "Real-Time Carbon Emission Monitoring in Prefabricated Construction," *Automation in Construction* (110), p. 102945.

Liu, M., Teng, Y., Yu, F. R., Leung, V. C., and Song, M. 2019. "Deep Reinforcement Learning Based Performance Optimization in Blockchain-Enabled Internet of Vehicle," *ICC 2019-2019 IEEE International Conference on Communications (ICC)*: IEEE, pp. 1-6.

Liu, Y., Dai, H.-N., Wang, Q., Shukla, M. K., and Imran, M. 2020b. "Unmanned Aerial Vehicle for Internet of Everything: Opportunities and Challenges," *Computer communications* (155), pp. 66-83.

Ma, Y., Qi, S., Fan, L., Lu, W., Chan, C.-Y., and Zhang, Y. 2019. "Dynamic Bayesian Network Approach to Evaluate Vehicle Driving Risk Based on on-Road Experiment Driving Data," *IEEE Access* (7), pp. 135050-135062.

McCarthy, P. S., and Tay, R. S. 1998. "New Vehicle Consumption and Fuel Efficiency: A Nested Logit Approach," *Transportation Research Part E: Logistics and Transportation Review* (34:1), pp. 39-51.

Miller, M. K., and Jehle, A. 2007. "Cognitive Dissonance Theory (Fessinger)," *The Blackwell encyclopedia of sociology*).

Moon, J.-W., and Kim, Y.-G. 2001. "Extending the Tam for a World-Wide-Web Context," *Information & management* (38:4), pp. 217-230.

Ng, B. D., and Wiemer-Hastings, P. 2005. "Addiction to the Internet and Online Gaming," *Cyberpsychology & behavior* (8:2), pp. 110-113.

OReilly, M. 1996. "Internet Addiction: A New Disorder Enters the Medical Lexicon," *CMAJ: Canadian Medical Association journal* (154:12), p. 1882.

Pulkrabek, W. W. 2004. "Engineering Fundamentals of the Internal Combustion Engine."

Ritchie, H., and Roser, M. 2020. "Co₂ and Greenhouse Gas Emissions," *Our world in data*).

Ross, M. 1997. "Fuel Efficiency and the Physics of Automobiles," *Contemporary Physics* (38:6), pp. 381-394.

Saber, A. Y., and Venayagamoorthy, G. K. 2010. "Plug-in Vehicles and Renewable Energy Sources for Cost and Emission Reductions," *IEEE Transactions on Industrial electronics* (58:4), pp. 1229-1238.

Sanguinetti, A., Kurani, K., and Davies, J. 2017. "The Many Reasons Your Mileage May Vary: Toward a Unifying Typology of Eco-Driving Behaviors," *Transportation Research Part D: Transport and Environment* (52), pp. 73-84.

Shi, X., Wong, Y. D., Li, M. Z.-F., Palanisamy, C., and Chai, C. 2019. "A Feature Learning Approach Based on Xgboost for Driving Assessment and Risk Prediction," *Accident Analysis & Prevention* (129), pp. 170-179.

Short, C. E., Vandelanotte, C., Dixon, M. W., Rosenkranz, R., Caperchione, C., Hooker, C., Karunanithi, M., Kolt, G. S., Maeder, A., and Ding, H. 2014. "Examining Participant Engagement in an Information Technology-Based Physical Activity and Nutrition Intervention for Men: The Manup Randomized Controlled Trial," *JMIR research protocols* (3:1), p. e2776.

Sivak, M., and Schoettle, B. 2012. "Eco-Driving: Strategic, Tactical, and Operational Decisions of the Driver That Influence Vehicle Fuel Economy," *Transport Policy* (22), pp. 96-99.

Sivak, M., and Tsimhoni, O. 2009. "Fuel Efficiency of Vehicles on Us Roads: 1923–2006," *Energy Policy* (37:8), pp. 3168-3170.

Soytas, U., Sari, R., and Ewing, B. T. 2007. "Energy Consumption, Income, and Carbon Emissions in the United States," *Ecological Economics* (62:3-4), pp. 482-489.

Spitzer, M. 2014. "Information Technology in Education: Risks and Side Effects," *Trends in Neuroscience and Education* (3:3-4), pp. 81-85.

Stillwater, T., Kurani, K. S., and Mokhtarian, P. L. 2017. "The Combined Effects of Driver Attitudes and in-Vehicle Feedback on Fuel Economy," *Transportation Research Part D: Transport and Environment* (52), pp. 277-288.

Stolterman, E., and Fors, A. C. 2004. "Information Technology and the Good Life," in *Information Systems Research*. Springer, pp. 687-692.

Su, X., Yan, X., and Tsai, C. L. 2012. "Linear Regression," *Wiley Interdisciplinary Reviews: Computational Statistics* (4:3), pp. 275-294.

Sun, M., and Zhang, J. 2020. "Research on the Application of Block Chain Big Data Platform in the Construction of New Smart City for Low Carbon Emission and Green Environment," *Computer Communications* (149), pp. 332-342.

Sundaram, S., Schwarz, A., Jones, E., and Chin, W. W. 2007. "Technology Use on the Front Line: How Information Technology Enhances Individual Performance," *Journal of the Academy of Marketing Science* (35:1), pp. 101-112.

Taylor, D. G., and Levin, M. 2014. "Predicting Mobile App Usage for Purchasing and Information-Sharing," *International Journal of Retail & Distribution Management*).

Tukey, J. W. 1962. "The Future of Data Analysis," *The annals of mathematical statistics* (33:1), pp. 1-67.

Vaezipour, A. 2018. "Design and Development of an in-Vehicle Human Machine Interface for Eco-Safe Driving." Queensland University of Technology.

Vaezipour, A., Rakotonirainy, A., and Haworth, N. 2015. "Reviewing in-Vehicle Systems to Improve Fuel Efficiency and Road Safety," *Procedia Manufacturing* (3), pp. 3192-3199.

Vaghefi, I., and Lapointe, L. 2014. "When Too Much Usage Is Too Much: Exploring the Process of It Addiction," *2014 47th Hawaii International Conference on System Sciences*: IEEE, pp. 4494-4503.

Wang, J., Zheng, Y., Li, X., Yu, C., Kodaka, K., and Li, K. 2015a. "Driving Risk Assessment Using near-Crash Database through Data Mining of Tree-Based Model," *Accident Analysis & Prevention* (84), pp. 54-64.

Wang, X., Liu, C., Kostyniuk, L., Shen, Q., and Bao, S. 2014. "The Influence of Street Environments on Fuel Efficiency: Insights from Naturalistic Driving," *International Journal of Environmental Science and Technology* (11:8), pp. 2291-2306.

Wang, Y., Chen, Y., and Benitez-Amado, J. 2015b. "How Information Technology Influences Environmental Performance: Empirical Evidence from China," *International Journal of Information Management* (35:2), pp. 160-170.

Werthner, H., and Klein, S. 1999. *Information Technology and Tourism: A Challenging Ralationship*. Springer-Verlag Wien.

Westphal, J. D., and Bednar, M. K. 2008. "The Pacification of Institutional Investors," *Administrative Science Quarterly* (53:1), pp. 29-72.

Westphal, J. D., and Deephouse, D. L. 2011. "Avoiding Bad Press: Interpersonal Influence in Relations between Ceos and Journalists and the Consequences for Press Reporting About Firms and Their Leadership," *Organization Science* (22:4), pp. 1061-1086.

Wu, H.-T., and Horng, G.-J. 2017. "Establishing an Intelligent Transportation System with a Network Security Mechanism in an Internet of Vehicle Environment," *Ieee Access* (5), pp. 19239-19247.

Xi-Liu, Y., and Qing-Xian, G. 2018. "Contributions of Natural Systems and Human Activity to Greenhouse Gas Emissions," *Advances in Climate Change Research* (9:4), pp. 243-252.

Xu, L., Zhou, X., Khan, M. A., Li, X., Menon, V. G., and Yu, X. 2021. "Communication Quality Prediction for Internet of Vehicle (Iov) Networks: An Elman Approach," *IEEE Transactions on Intelligent Transportation Systems*).

Xu, Z., Wei, T., Easa, S., Zhao, X., and Qu, X. 2018. "Modeling Relationship between Truck Fuel Consumption and Driving Behavior Using Data from Internet of Vehicles," *Computer‐Aided Civil and Infrastructure Engineering* (33:3), pp. 209-219.

Yang, L., Zhang, S., Wu, Y., Chen, Q., Niu, T., Huang, X., Zhang, S., Zhang, L., Zhou, Y., and Hao, J. 2016. "Evaluating Real-World Co2 and Nox Emissions for Public Transit Buses Using a Remote Wireless on-Board Diagnostic (Obd) Approach," *Environmental pollution* (218), pp. 453-462.

Yao, Y., Zhao, X., Zhang, Y., Chen, C., and Rong, J. 2020. "Modeling of Individual Vehicle Safety and Fuel Consumption under Comprehensive External Conditions," *Transportation research part D: transport and environment* (79), p. 102224.

Young, M. S., Birrell, S. A., and Stanton, N. A. 2011. "Safe Driving in a Green World: A Review of Driver Performance Benchmarks and Technologies to Support ‘Smart’driving," *Applied ergonomics* (42:4), pp. 533-539.

Yu, C., Lin, B., Guo, P., Zhang, W., Li, S., and He, R. 2018. "Deployment and Dimensioning of Fog Computing-Based Internet of Vehicle Infrastructure for Autonomous Driving," *IEEE Internet of Things Journal* (6:1), pp. 149-160.

Zheng, Y., Wang, J., Li, X., Yu, C., Kodaka, K., and Li, K. 2014. "Driving Risk Assessment Using Cluster Analysis Based on Naturalistic Driving Data," *17th International IEEE Conference on Intelligent Transportation Systems (ITSC)*: IEEE, pp. 2584-2589.

Zhou, M., Jin, H., and Wang, W. 2016. "A Review of Vehicle Fuel Consumption Models to Evaluate Eco-Driving and Eco-Routing," *Transportation Research Part D: Transport and Environment* (49), pp. 203-218.

Zhou, X., Zhou, D., Wang, Q., and Su, B. 2019. "How Information and Communication Technology Drives Carbon Emissions: A Sector-Level Analysis for China," *Energy Economics* (81), pp. 380-392.