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 (IoV). 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 IT 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, 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). Actually, the definition of fuel efficiency may differ in different literature. It can be fuel consumption per unit time (L/h) or per unit distance (L/100 km) (Vaezipour et al. 2015; Wang et al. 2008). And 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 defined by the amount of fuel consumed per unit distance (L/km) in this paper.

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).

2.2.1 average driving speed

When it comes to specific eco-driving behavior and fuel efficiency, prior research indicated that the relationship between driving speed and fuel consumption or emissions is quite complex (Haworth and Symmons 2001a). Many built the calculations and models of fuel efficiency due to driving speed. Commonly, fuel consumption per unit distance (i.e. fuel efficiency) firstly decreases with the increase of engine speed due to reduced heat losses, reaches the optimal point and then increases at high speed, overpasses the starting value mainly due to increased friction losses (Eo et al. 2018; Luo et al. 2017; Pulkrabek 2004; Wang et al. 2008). As a result, the fuel consumption-driving speed curve shows a U-shape. However, the turning point of their U-shapes may indicate quite a difference because of different measurements and various vehicle types (Luo et al. 2017). Besides, although the relationship between fuel efficiency and driving speed has been widely discussed, few investigates the fuel efficiency due to average driving speed. Obviously, more work needs to be done.

Given that average driving speed represents the long-term operating condition of the vehicle and reflects the long-term driving performance of a driver, even though different speeds will result in different fuel consumption per unit distance (i.e. fuel efficiency), average driving speed is chose in this study. In other words, we will be concerned about the IT effects on eco-driving behaviors, especially average driving speed and its quantitative change relationship with fuel efficiency.

2.2.2 speed change

A general rule of eco-driving is to change the aggressive driving style, which mainly refers to hard acceleration and deceleration, to a smoother one (Huang et al. 2018). The function of acceleration/deceleration is to increase/reduce the driving speed or to start/stop the vehicle. However, there are always more or less efficient ways to do that, and the strategies vary and have no consensus (Larsson and Ericsson 2009; Sanguinetti et al. 2017). Most eco-driving programs recommend smooth driving and minimising the use of accelerator and brake pedals (Ericsson 2001; Huang et al. 2018).

However, a few studies (Saerens and Van den Bulck 2013; Xia et al. 2013) reported that more aggressive to the target speed would save fuel in certain situations. A Swedish eco-driving training program suggested bus drivers accelerate more strongly and start acceleration earlier (Af Wåhlberg 2006). Thus, this study will also test the effect of speed change (mainly hard acceleration and deceleration) on fuel efficiency in the context of our empirical research.

In summary, when discussing IT in the context of IOV, we are meant to measure its effects with drivers’ behavior changes, especially paying attention to drivers’ eco-driving behaviors, including average driving speed, accelerantion and deceleration, and we are to discover how those changes could contribute to 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.

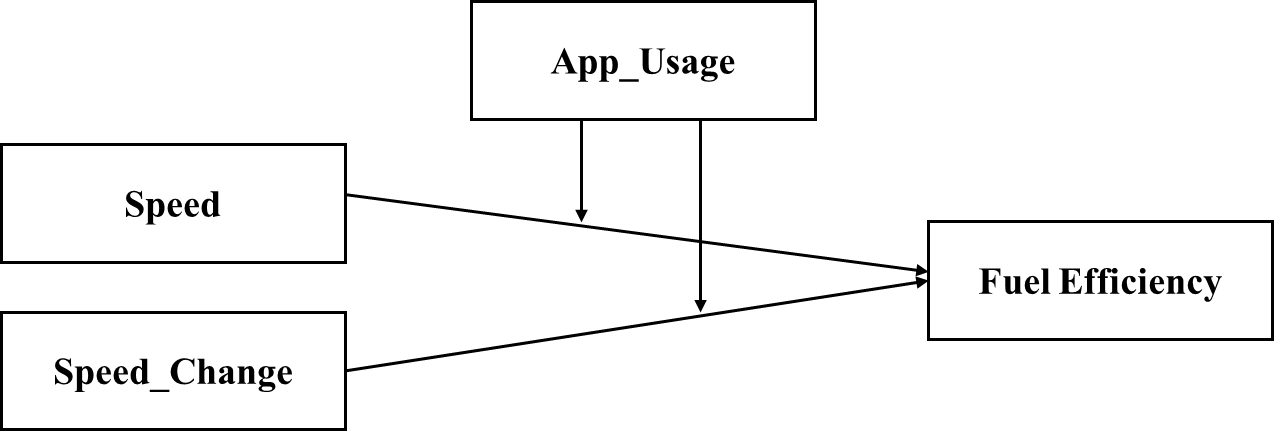
Other researchers explore cognitive discrepancy and behavior. Westphal and Bednar (Westphal and Bednar 2008) reasoned that fund managers experienced dissonance when received ingratiation from the CEO for their actions conflicted with the CEO’s preferences. As what is suggested by the Cognitive Dissonance 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.



As reviewed before, researchers would always take average driving speed and the number of speed change (e.g. hard accelertion and deceleration) during a time period into consideration when modeling the relationship between driving behavior and fuel efficiency (Andre 1996; Fomunung et al. 1999; Kuhler and Karstens 1978; Wang et al. 2008). Following previous studies, our model considers them as important and typical factors as well.

Despite of the fuel consumption-driving speed curve shows a U-shape, the fuel efficiency due to average driving speed has not been determined. Since many literature on internal combustion engines explains that the friction losses would increase significantly with the increase of engine speed and then decrease the fuel efficiency (Eo et al. 2018; Kepsu et al. 2021), we hypothesize:

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

Generally, a smooth driving style reduces fuel consumption and increases safety compared to aggressive driving, while being more aggressive in certain situations could save fuel instead. Considering there are a number of studies have been carried out to investigate the negative effect of aggressive speed change on fuel consumption and emissions (Berry 2010; Chen et al. 2007; El-Shawarby et al. 2005; Wang et al. 2011), we hypothesize:

H2: Speed changes are positively related to fuel consumption.

While factors such as speed and speed change directly influence fuel efficiency (Ross 1997; Wang et al. 2014), other factors like different forms of intervention (e.g. educational intervention and the intervention of IT) are also worth studying on their indirectly effects on fuel efficiency (Vaezipour 2018; Vaezipour et al. 2015). As the literature shows that IT can change individual behavior and eco-driving behaviors help improve fuel efficiency, if the drivers’ behaviors are successfully intervented by our app, their proper eco-driving behaviors will effectively reduce fuel consumption. Thus, we hypothesize:

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

H3b: App usage weakens the relationship between speed change 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

Fuel efficiency is defined differently in different scenes. Vaezipour et al. define fuel efficiency as ratio of the work or energy output of an engine to the work or energy input (Haworth and Symmons 2001b; Vaezipour et al. 2015). It can be defined as fuel consumption per unit time (L/h) or per unit distance (L/100 km) (Wang et al. 2008). Fuel efficiency can also be based on a vehicle’s miles per gallon (Carson 1980; McCarthy and Tay 1998). Considering all definitions, fuel efficiency is measured by the amount of fuel consumed per unit distance (L/km) in this paper. Thus, we choose Fuel Consumption as dependent variable, and the more the fuel is consumed per unit distance, 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. | | | | | | | | | | | | | |

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| --- |
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|  |  |  |
| --- | --- | --- |
| 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

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