Fuel Efficiency and IT : The Moderating Effect App Usage in Driving

Abstract

Information technology (IT) is playing an increasingly important role in the Internet of Vehicle. 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 and fuel consumption through impacting individual driving behavior. Based on Cognitive Dissonance Theory, this study investigates whether a driving-assistant app help improve fuel efficiency by helping individuals to improve their driving behavior and attempts to explore the reasons for the phenomenon. A natural experiment has been designed to collect personal app usage and driving data from XXX drivers over a one-year period. The results of the study will contribute to sustainable development and further enrich the IT application scenario.

Empirical investigation

Keywords:

Introduction

With the massive growth of people's needs and the advancement of communication and computation technology, information technology (IT) is widely used in various fields, and it is no exception in the field of Internet of Vehicle (IoV). It has made a big difference in autonomous driving, communication quality of IoV networks and environmental detection (Guo et al. 2017; Xu et al. 2021; Yu et al. 2018), and it has the potential to make a big difference in improving road safety and fuel efficiency (Vaezipour et al. 2015).

Since fuel efficiency has been a crucial topic, for the constantly rising GHGs emissions from road transport raises special concern (Gorham 2002), we mainly pay our attention to this in the paper. As pointed out by prior studies, fuel efficiency from road transport is a result of five major categories of influential factors, including the built environment (both roadway and roadside environment), driver characteristics, 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. 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). 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).

There have been a large amount of papers exploring the relationship between IT and human behavior, the relationship between driving behavior and fuel efficiency, whereas research that examined the IT impacts on driving behavior and fuel efficiency is still immature yet (Vaezipour 2018; Vaezipour et al. 2015). In order to disentangle the relationships among different variables, we carried out a natural experiment, meant to measure the direct or indirect effects between the use of IT and fuel efficiency while testing the intermediate effects of IT on driving behavior.

--研究问题

In order to disentangle the relationships among different variables, we applied the SEM technique to measure the direct and indirect effects between street environments and fuel efficiency while testing the intermediate effects of driving behavior on fuel efficiency.

Literature Review

1 The Impacts of IT

--IT在发展，人也被影响着

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). As we develop IT and optimize information systems, they are also influencing our habits and performance at the same time. IT has been used as external stimulation to assist in changing people's behavior to exercise and break properly and 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).

--IT的正面影响 —side effects darkside负面影响

However, while all these developments will bring many benefits, they also carry risks. 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. Impaired reading and writing impairs learning and memory (Spitzer 2014). IT even leads to decreased student learning because of increased distraction (Bowman et al. 2010; Fried 2008). Finally, IT can cause IT-addiction (Chen 2020; Leung and Lee 2012; OReilly 1996). Moreover, 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). Every click, every browse we make on the Web depends on millions of physical servers in data centers around the world. These data centers are connected to numerous cables, switches and routers, requiring a lot of energy to run, most of which comes from fossil fuels. The burning of these fuels results in significant carbon emissions.

We can find 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 fuel efficiency/fuel consumption and eco-driving behavior

--温室气体引发关注

Since greenhouse gas (GHG) emissions, especially CO2 emissions, are considered to be the main causes of global warming (Letcher 2019; Soytas et al. 2007), the most important measure to control global warming is to control the GHGs emissions. 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).

--解决办法有很多，其中eco-driving出现了

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”. In fact, eco-driving is a new approach to driving style developed since the mid '90s (Alessandrini et al. 2012; Barkenbus 2010) and is an initiative that has been adopted and explored worldwide over the last decade (Alam and McNabola 2014).

--eco-driving定义很多，但是我们的定义是xxxxx。为什么。

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), we narrow eco-driving to the driving behaviors or the driver's control of the vehicle during a journey. 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

--定义是什么

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).

--以前有哪些应用场景

Although the original conception of Cognitive Dissonance Theory was intended to apply to a wide range of psychological phenomena, later research focused more on 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 few studies to examine the permanency of attitude change following dissonance, Boswell et al. (Boswell et al. 2005) found that after leaving one job for another, employees adjusted job satisfaction to favor the new job, while the satisfaction rose just in the short term and eventually declined, suggesting such discrepancy reduction wears off over time.

Others explore cognitive discrepancy and behavior. Westphal and Bednar (Westphal and Bednar 2008) reasoned that CEO ingratiation of fund managers would produce cognitive dissonance for fund managers when their actions conflicted with the CEO’s preferences. Cognitive Dissonance Theory suggests that the fund managers aligned their actions with CEO preferences to avoid the dissonance that defying the CEO would create. Similarly, Westphal and Deephouse (Westphal and Deephouse 2011) found that journalists were less likely to write a negative article about a CEO if that CEO had ingratiated 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.

--在我们的场景下一样可以用，为什么

(以“心里想有好的表现，但是做出来的行为却是不好的”为例——如果偏向于这样解释这个理论的话，我们可能还需要在最后强调一下，我们依据这个人是否签到来判断他当天是否有意愿使用APP。

其实“签到”这个动作也不完全可靠，也许我们的论文可以把这个解释成：只有他主动打开了APP，APP的功能才会开启，并且自动记录“签到”。P.S.后续要是这个APP真能设计成这样，我觉得会好很多？)

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) and help individual be conscious of their own behavior (e.g. the alert), we will use Cognitive Dissonance Theory to explain the results.

In summary, this research explores the relationship between IT, fuel efficiency and driver behavior in the context of IOV, and examines the possible positive and negative impacts of IT, considering driver characteristics, vehicle types, and environmental influences.

↑在IOV的语境下，探究IT与驾驶员行为的关系，研究IT的正面和负面影响，并考虑驾驶员特征、汽车特征和环境影响。

**后面部分的一些段落仅仅是先mark一下，不是正式的文章**

Hypotheses

Drivng speed 和speed change

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).

Methodology and Data

在methodology和data当中描述一下这个APP。

--时间长了之后教育的效果就会减弱

Though promising, as an external intervention, IT’s positive effects could be limited. As stated in lots of studies in the field of eco-driving, people’s behaviors can improve obviously immediately after an external training (Larue et al. 2014; Rolim et al. 2014; Rutty et al. 2013), while long-term studies showed that the training impact faded over time (af Wåhlberg 2007; Barla et al. 2017). This was because the habits developed through many years of practice were engrained and thus hard to change in short training time (Huang et al. 2018). It should be noted that many factors could influence the ‘training’ results -- behaviors. So in this paper, we consider a variety of factors relevant to drivers’ driving behaviors too.

Measurement

The variables used to define driving style are related to speed and acceleration or deceleration. According to the most common approach, for the characterization of the driving profile, it is examined whether a driver accelerates or decelerates harshly, how often and, of course, whether he drives at high speed or not, far, near or even above the corresponding speed limit. Specifically, the above quantities for each route are summarized using statistical metrics, such as mean, variance, maximum and minimum, and frequency (for acceleration and deceleration) and are considered adequate to describe a driver’s driving style [20]. （来源于文章Eco-Driving and Its Impacts on Fuel Efficiency: An Overview of Technologies and Data-Driven Methods）

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。

实证研究（empirical study）的通病,可能在读文献的过程中，发现自己和前人结果一致或不一致都是可能的，甚至和自己的预期不符、发现自己是错的，但是都是正常的，只要能解释即可。要圆回来。

Experiment (field, natural)

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