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Modelling driver acceptance of driver support systems

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ABSTRACT

Driver support systems are intended to enhance driver performance and improve transportation safety. Even though these systems afford safety advantages, they challenge the traditional role of drivers in operating vehicles. Driver acceptance, therefore, is essential for the adoption of new in-vehicle technologies into the transportation system. In this study, a model of driver acceptance of driver support systems was developed. A conceptual driver acceptance model, including several components, was proposed based on a review of current literature. An empirical study was subsequently carried out using an online survey approach. The study collected data on participants' perceptions of two driver support systems (a fatigue monitoring system and an adaptive cruise control system combined with a lane-keeping system) in terms of attitude, perceived usefulness, and other components of driver acceptance. Results identified five components of driver acceptance (*attitude*, *perceived usefulness*, *endorsement*, *compatibility*, and *affordability*). The results also confirmed several mediating effects. The developed model was able to explain 85% of the variability in driver acceptance. The model provides an improved understanding how driver acceptance is formed, including which factors affect driver acceptance and how they affect it. The model can also help automakers and researchers to assess the design and estimate the potential use of a driver support system. The model could also be highly beneficial in developing a questionnaire to assess driver acceptance.

1. Introduction

Driver support systems are technologies that are intended to enhance driver performance and improve transportation safety. There are mainly three types of driver support systems available in the market: information/warning systems, semi-autonomous driving systems, and autonomous driving systems. Information/warning systems do not actively intervene in the driving task, but rather assist drivers with information and/or warnings (e.g., lane departure warning systems, navigation systems, etc.). Semi-autonomous driving systems assist the driver by providing active support for lateral and/or longitudinal control with or without warning, but do not completely take over the driving task; thus responsibility always remains with the driver (e.g., RESPONSE 3, 2009). These systems are also called advanced driver assistance systems (e.g., adaptive cruise control, intersection assistant, etc.). Autonomous driving systems completely take over the operation of the vehicle under certain traffic conditions. Great progress has been seen with the invention and implementation of new driver support systems in the last decade, with the aims of improving safety (reduction in number of crashes), enhancing driver comfort and convenience, and decreasing environmental and economic impact (Fagnant and Kockelman, 2015; Kusano and Gabler, 2012). The introduction of these new vehicle technologies is causing the driver's task to slowly evolve from controlling the vehicle to supervising the driver support system. However, this role change may not be readily accepted by all drivers. Some drivers may not trust such automated systems and/or may not be willing to release vehicle control, even in situations where the system may afford safety advantages.

There is a general agreement among researchers about the potential positive impact of driver support systems in improving transportation safety, and many researchers have estimated significant reductions in the number of accidents. Jermakian (2011) studied crash records extracted from the General Estimates System of the National Automotive Sampling System and the Fatality Analysis Reporting System to estimate the crash avoidance potential of side view assist, forward collision warning/mitigation, lane departure warning/prevention, and adaptive

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headlights. The results of their analysis estimated that a combination of these four technologies could prevent or mitigate more than 1.8 million crashes each year, including more than ten thousand fatal crashes. Kusano and Gabler (2012) also estimated safety benefits of forward collision warning, brake assist, and autonomous braking systems in terms of reduction in the number and severity of rear-end crashes. In their estimation of the safety potential of these devices, these researchers assumed that every vehicle on the road was equipped with the technologies in consideration and that the technologies were highly effective in preventing crashes. In addition to these estimates, Cicchino (2017, 2018) provided some actual crash reduction statistics for forward collision and lane departure warning systems. Cicchino (2017) analyzed police reported crash involvement for several vehicle models from 22 US states during 2010-2014. Comparison was made between vehicles that had a forward collision warning (FCW) system, a low-speed autonomous emergency braking (AEB) system, or a combined FCW and AEB system and vehicles that did not have the technology installed. The results revealed that the technologies (FCW, AEB, and the combined system) were able to reduce front-to-rear crash rates by 27%, 43%, and 50%, respectively. Using a similar approach, Cicchino (2018) reported that vehicles with lane departure warning systems had a significantly lower involvement in crashes of all severities (18%), in injury crashes (24%), and in fatal crashes (86%). Nevertheless, even though these numbers promise great safety benefits, in-vehicle technologies cannot achieve their potential if they are not accepted or used in a sustainable and appropriate manner by drivers. Studies have reported that many drivers (as much as 50% of the drivers, for some technologies) frequently turn off crash avoidance technologies while driving (Reagan et al., 2018; Reagan and McCartt, 2016; Flannagan et al., 2016). It is therefore necessary to study driver acceptance to ensure the appropriate use of driver support systems.

Driver acceptance studies are important both from the perspective of the manufacturer and from the perspective of the driver. Manufacturers do not want to invest in technologies for which there is no demand in the market. Therefore, such studies can help to increase driver interest as well as manufacturer awareness of end users' needs. Driver acceptance studies may also identify features of a driver support system which annoy and/or interfere with a driver's (preferred) driving style. In addition, a driver would likely expect an assistance system to be highly reliable and effective. The study of acceptance will assess a driver support system to identify the issues that affect perceived usefulness and usability of the system and eventually help designers to build a better system. The goal of studying acceptance is to ensure the use of these technologies, and assessment of driver acceptance provides a means to estimate drivers' willingness to purchase and use such systems (Najm et al., 2006). Without addressing driver acceptance, adoption of driver support systems may progress more slowly, with the additional unfortunate result that potentially avoidable crashes will continue to occur.

1.1. *Definition of driver acceptance*

Acceptance has been defined in many ways with both different and overlapping characteristics. A good review of definitions of acceptance in the literature can be found in Adell et al. (2014) and Adell (2009). Adell (2009) classified the definitions of acceptance found in the literature into five categories. Category 1 used the word 'accept' and Category 2 emphasized the 'usefulness of the system' to define acceptance. Categories 3 and 4 focused on the attitudes towards, or the behavioral intention to use, a system whereas Category 5 defined acceptance through actual use. This categorization suggests that acceptance is a multifaceted concept and researchers have tended to focus on selected aspects, limiting the scope of each definition. Other researchers have distinguished between acceptance formed before or after experiencing the technology, referred to by Schade and Schlag (2003) as "acceptability" and "acceptance," respectively. Pianelli et al. (2007) have drawn a similar distinction, naming the two types as a priori acceptability and a posteriori acceptability. Given the various definitions of acceptance, it is important that studies provide a clear operational definition of acceptance, along with the measure being used to assess it. For this study, we adopt the definition provided by Adell (2009). Adell (2009), in her definition of acceptance, covered both the behavioral intention and the actual use aspects of acceptance. The author defined acceptance as "the degree to which an individual incorporates the system in his/her driving, or, if the system is not available, intends to use it" (p. 31). A similar approach of defining and measuring acceptance by focusing on both actual use and behavioral intention is adopted in studying technology acceptance in general (to be discussed in the next section). However, measuring acceptance with behavioral intention is comparably more convenient and applicable throughout the entire process of development and implementation of driver support systems.

1.2. *Related works in modelling driver acceptance*

Among the models/theories used to understand acceptance of driver support systems, the Technology Acceptance Model (Davis, 1985, 1989), Theory of Planned Behavior (Ajzen, 1991), and Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) are the most popular. In general, these theories propose that *actual use* of a technological system is influenced by *behavioral intention* of the user and *behavioral intention* is influenced by several factors. These theories have proposed unique, as well as overlapping, factors. In addition to adopting the factors proposed by these theories, some researchers have proposed new factors that are specific to the driver support systems. In the following sections, both approaches to model driver acceptance are discussed.

1.2.1. *Theories of technology acceptance*

The Technology Acceptance Model (TAM) was developed to explain user acceptance of information technology (Davis, 1985). TAM proposes two predictors of *behavioral intention*: *attitude* toward using a technology and *perceived usefulness* (see Table 1 for the definitions). According to TAM, a positive *attitude* toward a driver support system and positive *perceived usefulness* would lead to a positive *behavioral intention* to use the driver support system. In a later article, Davis (1989) proposed *perceived usefulness* and *perceived ease of use* (Table 1) as the predictors of *behavioral intention*, removing *attitude* from the model.

The Theory of Planned Behavior (TPB), developed by Ajzen (1991) to explain human behavior in general, proposed three components of *behavioral intention*: *attitude* toward a behavior, *subjective norm*, and *perceived behavioral control* (Table 1). This theory has been adopted by many researchers to explain acceptance and usage of information technology (cited in Legris et al., 2003; Venkatesh et al., 2003).

A more recent theory of technology acceptance is the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT considered three key components of *behavioral intention* (*performance expectancy*, *effort expectancy*, and *social influence;* Table 1) and four moderating factors (gender, age, experience, and voluntariness of use). UTAUT was developed based on several models of technology acceptance and human behavior including TAM and TPB.

There have been relatively few studies done to test these models on the acceptance of driver support systems, despite the theoretical framework provided. Among the above-mentioned technology acceptance theories, TAM appears to be the most widely adopted theory for modelling driver acceptance. Xu et al. (2010) considered two TAM factors, *perceived usefulness* and *perceived ease of use*, with four other system specific factors to model acceptance of an advanced traveler information system. In a similar attempt, Roberts et al. (2012) augmented the TAM model with a third factor, *unobtrusiveness*, which measures driver distraction or annoyance due to warnings generated by a warning system. Reagan et al. (2017) and Kidd and Reagan (2018) explored