Technology acceptance comparison between on-road dynamic message sign and on-board human machine interface for connected vehicle-based variable speed limit in fog area

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Abstract

Purpose – Connected vehicle-based variable speed limit (CV-VSL) systems in fog area use multi-source detection data to indicate drivers to make uniform change in speed when low visibility conditions suddenly occur. The purpose of the speed limit is to make the driver's driving behavior more consistent, so as to improve traffic safety and relieve traffic congestion. The on-road dynamic message sign (DMS) and on-board human–machine interface (HMI) are two types of warning technologies for CV-VSL systems. This study aims to analyze drivers' acceptance of the two types of warning technologies in fog area and its influencing factors.

Design/methodology/approach – This study developed DMS and on-board HMI for the CV-VSL system in fog area on a driving simulator. The DMS and on-board HMI provided the driver with weather and speed limit information. In all, 38 participants participated in the experiment and completed questionnaires on drivers' basic information, perceived usefulness and ease of use of the CV-VSL systems. Technology acceptance model (TAM) was developed to evaluate the drivers' acceptance of CV-VSL systems. A variance analysis method was used to study the influencing factors of drivers' acceptance including drivers' characteristics, technology types and fog density.

Findings – The results showed that drivers' acceptance of on-road DMS was significantly higher than that of on-board HMI. The fog density had no significant effect on drivers' acceptance of on-road DMS or on-board HMI. Drivers' gender, age, driving year and driving personality were associated with the acceptance of the two CV-VSL technologies differently. This study is beneficial to the functional improvement of on-road DMS, on-board HMI and their market prospects.

Originality/value – Previous studies have been conducted to evaluate the effectiveness of CV-VSL systems. However, there were rare studies focused on the drivers' attitude toward using which was also called as acceptance of the CV-VSL systems. Therefore, this research calculated the drivers' acceptance of two normally used CV-VSL systems including on-road DMS and on-board HMI using TAM. Furthermore, variance analysis was conducted to explore whether the factors such as drivers' characteristics (gender, age, driving year and driving personality), technology types and fog density affected the drivers' acceptance of the CV-VSL systems.

Keywords Technology acceptance model (TAM), Connected vehicle (CV), Dynamic message sign (DMS), Human machine interface (HMI), Variable speed limit (VSL)

Paper type Research paper

1. Introduction

Fog reduces visibility on roads which is a critical factor in drivers' perceptions of the driving environment. Crashes are always possible in fog area because of drivers' failure to maintain safe following distances under adverse weather conditions according to the World Health Organization (2016). Fog is likely to have played a role in 20,159 police-reported fatal crashes that occurred in China in 2017 by the Ministry of Public Security Traffic Management Bureau (2017).

Several measures have been made to reduce traffic crash frequency in fog area such as fog detection and warning systems, low visibility driving safety campaigns, and driver training. Some studies have further attempted to address the issue of fog and its impact on highway safety with connected vehicle technologies (Boyle and Mannering, 2004). Nowadays, the fog warning system using connected vehicle technology is

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widely used. All countries in the world have taken measures to improve the driving safety of highway in foggy days by fog warning system. Connected vehicle used advanced wireless communication and a new generation of internet technology, implemented vehicle and road dynamic real-time information interaction all around, allowed vehicles to talk to one another, to transportation infrastructure, to pedestrians, cyclists and passengers in a cooperative manner, and carried out vehicle active safety control and road collaborative management on the basis of the whole space-time dynamic traffic information collection and integration, fully realized the effective coordination of human, vehicle and road to form a safe, efficient and environmentally friendly road traffic system (McGurrin *et al.*, 2012).

Speed control is a primary method to change drivers' behavior. This has been studied extensively and described in the literature, and various connected vehicle system approaches have been introduced to capture the underlying processes of drivers' speed control (Khondaker and Kattan, 2015; Wu *et al.*, 2018). Notably, variable speed limit (VSL) systems are speed control system solutions that enable dynamic changes of posted speed limits in response to prevailing traffic, incidents, and/or weather conditions. Connected vehicle-based variable speed limit (CV-VSL) systems use traffic speed, volume detection, and road weather information systems to determine the appropriate speed at which drivers are expected to be traveling, given the current traffic and road conditions. Changes in posted speed limits are indicated by displays on overhead or roadside variable message signs, or displays on a vehicle's human–machine interface (HMI) (Chang *et al.*, 2019; Zhao *et al.*, 2019). In the connected vehicle condition, dynamic message signs (DMS) on the road and on-board HMI displays are two types of information transmission technologies (Louw *et al.*, 2015; Louw *et al.*, 2017).

On-road DMS in fog area refers to the establishment of variable speed limit signs at certain intervals on the road section, instructing the drivers to achieve uniform speed change, to avoid the sudden speed mutation of the vehicle at low visibility. It is an infrastructure for real-time display of information sent by management center and usually located in front of the fog zone and helps the drivers adjust to the driver performance as they enter the fog zone (Goodwin and Pisano, 2003; Pisano and Goodwin, 2004; Xu, 2007). In the United States, UT (Goodwin and Pisano, 2003), WA (Pisano and Goodwin, 2004), Carolina (Xu, 2007) have the fog warning systems, where DMS and speed limit signs are installed on the road side to reduce the speed of vehicles under adverse weather conditions to reduce the accident rates. In Australia, DMS is used to carry out the warning measures in foggy days on the freeway. Moreover, the reduction of vehicle speed and the difference of speed after the implementation of the measures is analyzed, which verifies the effectiveness of the facilities (Xu, 2007).

In recent decades, some researchers put forward from HMI design research from the psychological point of view. Laboratory led by Negroponte did a large number of researches on the multi-channel user interface through the visual, auditory, tactile and other sensory organs of human–computer interaction to reduce the visual pressure of users (Shneiderman, 1992). On-board HMI is a key device for information transmission between driver and vehicle, and the interaction of on-board systems with the outside world based on connected vehicle and big data technology will become more powerful (Li *et al.*, 2008). For complex human-machine interaction scenarios, information needs to be intuitive, precise and clear, with the goal of assisting driving, ensuring driving safety and reducing the driving burden (Zhang, 2014).

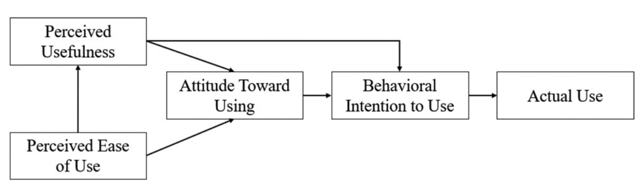
On-road DMS and on-board HMI are two types of warning technologies for CV-VSL systems, however, drivers' acceptance of these two technologies are rarely analyzed. The purpose of this study is to:

1 analyze the drivers' acceptance of the CV-VSL systems including on-road DMS and on-board HMI; and
2 explore factors affecting drivers' acceptance of the warning technologies.

Among various methods, the technology acceptance model (TAM) has been frequently and widely used in information technology adoption studies. TAM was based on the theory of reasoned action (TRA) (Fishbein and Ajzen, 1975) and theory of planned behavior (TPB) (Ajzen, 1991) which suggested that social behavior was motivated by an individual's attitude. According to Davis (1989), the TAM consists of four determining factors to accept information technologies, namely perceived usefulness (PU) and perceived ease of use (PEOU), attitude toward using (ATT) and behavioral intention to use (BIN) as shown in Figure 1. The impacts of both determining factors on attitude towards the information technology are assumed to be positive. That is when users' perceptions of usefulness and ease of use to one information technology increase, the users' positive attitude towards adopting that information technology is more likely. Furthermore, perceived ease of us is assumed to have a positive, direct effect on perceived usefulness while both attitude and perceived usefulness has positive, direct effects on behavioral intention. The TAM has been applied to predict and explain a variety of information technologies and the hypothetical relationships have been widely supported (Chen and Chen, 2011; Rahman *et al.*, 2017; Scherer *et al.*, 2019; Taherdoost, 2018).

The objective of this research was to quantify the drivers' acceptance of the CV-VSL system and its influencing factors through driving simulator experiment and its post surveys. The CV-VSL systems including on-road DMS and on-board HMI were both realized through a connected vehicle testing platform based on a driving simulator. According to the TAM, two factors, namely perceived usefulness and PEOU associated with DMS and on-board HMI are assumed to affect consumers' acceptance of the CV-VSL systems in this study. The influence of driver characteristics (gender, age, driving

Figure 1 Technology acceptance model



Source: Davis (1989)

year and driving personality), technical type (on-road DMS or on-board HMI) and fog density (heavy or light fog) on driver's acceptance of CV-VSL systems were considered. The research results are conducive to better popularizing the use of the CV-VSL systems and giving full play to its positive role in traffic safety.

2. Experiment design

2.1 Connected vehicle testing platform

The research constructed a CV-VSL test platform based on driving simulator. The fixed-base driving simulator located in the Key Laboratory of Traffic Engineering of Beijing University of Technology consists of a real car, computers, videos, and audio equipment. The road scenario was projected onto three big screens, providing a 130-degree field of view. The screen resolution of the driving simulator was 1920 × 1080. The simulator recorded operating data (e.g. braking force, acceleration, speed, lateral placement, lane numbers, and turning angle of the steering wheel) 30 times per s. The simulator adopted an application programming interface (API), which allowed users to design driving tasks according to their needs.

The virtual visibility sensor and distance sensor collect data by the roadside unit to driving simulator system (DSS) through the API corresponding to the data collection in the actual system. When visibility is less than 10,000 m, the information will pass to the management center. The management center compares the visibility information with the threshold value of the classification standard related to fog level to determine the level of fog: light fog and heavy fog.

We structure the interconnection between driving simulator and DSS through interface. DSS and management center synchronously transmits through the user datagram protocol corresponding to visibility and distance perception in the actual system. Management center send the final display information to the roadside or user terminal. The information interaction process was shown in Figure 2.

This study chose the CV-VSL system in foggy conditions as a case study based on the connected vehicle testing platform. The results revealed that the majority of drivers agreed with the validity of this platform. The validity of this platform has been determined in our previous research using an assessment method (Shechtman *et al.*, 2009).

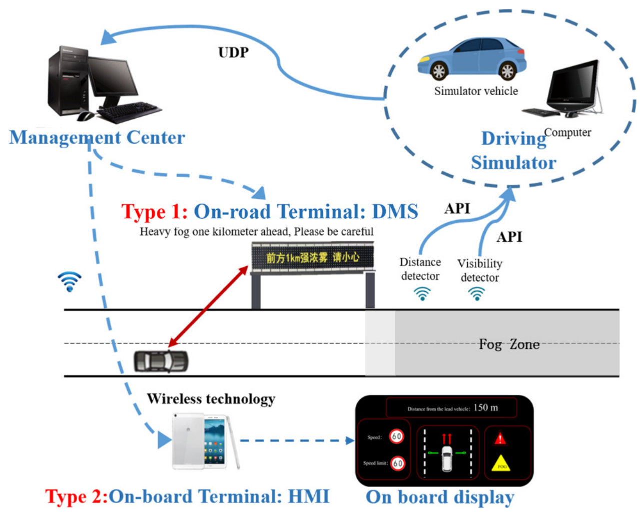
2.2 Warning information interaction modes – on-road dynamic message sign and on-board human–machine interface

Two types of terminals including on-road DMS and on-board HMI were designed in this study. The CV-VSL system warning appeared when the vehicle neared the 2 km range of the fog. There were 5 warning points in the clear zone, each at an interval of 500 m. The technical details of the implementation are described as follows.

2.2.1 Dynamic message sign design

The DMS displayed the fog warning and variable speed limit information on the road infrastructure as shown in Figure 3. In order to enhance the effect of forecast, multiple DMS should be set up. The advance distance of DMS to the driver should be considered to ensure that the driver can see each DMS. Yellow

Figure 2 Connected vehicle testing platform construction



is chosen as the color of DMS text since it means warning in traffic sign. Traffic signs are set up in columns type (both single and double), cantilevered type, attached type and doorframe type according to the Institute of highway science, ministry of communications (2009). The DMS on the freeway adopts the doorframe type through communication with traffic management department because the doorframe sign is more striking than the roadside sign. The size of DMS is shown in Figure 1 (Take two lanes for example, the lane width is 3.75 m).

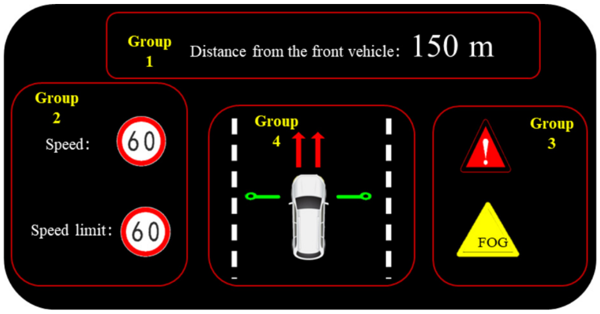
2.2.2 Human–machine interface design

The on-board display uses a PAD that receives fog warning and variable speed limit information in real time at a rate of 5 times per s through wireless as shown in Figure 4. The HMI was divided into four groups as shown in Figure 4:

1. Group 1 showed the distance between a vehicle and its lead vehicle;
2. Group 2 showed the speed warning to the drivers; "Speed" showed the current speed of the vehicle, and "Speed limit" showed the current speed limit of the road. The speed limit was 120 km/h in a no fog or light fog

Figure 3 Design of DMS

Figure 4 Symbol display of HMI



situation, and 60 km/h in a heavy fog situation *(30)*. A continuous voice warning (you have been speeding, please slow down) alerted drivers of danger whenever the driver's speed exceeded the speed limit.

3 Group 3 showed imminent dangerous vehicle surroundings. The red exclamation mark appeared with a continuous alarm to alert drivers of an imminent collision whenever time to collision (TTC) with the lead vehicle was below a 2-s threshold *(31)*. The fog symbol appeared with a voice warning (you are close to the fog area) when the vehicle neared the 2-km range of the fog. The voice played once every 500 meters, and the fog symbol was continuous.

4 Group 4 showed the traffic situation surrounding a vehicle. The arrow symbol was solid green when the distance between a vehicle and its surrounding vehicles was over 200 m, flashing yellow when the distance was less than the 200 meters, and flashing red whenever the TTC was below a 2-s threshold.

2.3 Experimental design and data collection

Experiments were conducted to analyze the drivers' acceptance of the CV-VSL systems and its influencing factors.

2.3.1 Scenario design.

The experimental road in this study was based on the northbound sections on the Xingyan freeway (a freeway with a total width of 18.8 m (lane width = 3.75 m, median (green belt) width = 0.8 m and shoulder width = 1.50 m) in the north of Beijing. The selected segments were located in a relatively foggy area. The Xingyan freeway is a four-lane divided freeway with 120 km/h speed limit, while in heavy fog area the speed limit is 60 km/h. For each road segment, the total length was about 6 km, consisting of three zones:

1 a clear zone (3.5 km);
2 a transition zone (0.5 km); and
3 a fog zone (2 km) (Figure 3).

The length of the clear zone was determined to ensure sufficient distance for allocating multiple CV-VSL systems; the distance (1.5 km) before the warning was to ensure drivers could reach the normal speed. The transition zone was designed with gradually reduced visibility to avoid a sudden visibility change, and the visibility changes to the fog zone's level when the drivers arrive to fog zone. It was assumed that drivers could get used to the reduced visibility within the 0.5 km distance. In addition, drivers were expected to drive in the fog zone for a 2 km distance. As shown in Figure 5, the visibility in the different fog level scenarios was no fog, light fog (visibility = 725m) and heavy fog (visibility = 125 m), respectively (Standardization Administration of the People's Republic of China, 2012). Each driver would drive twice along the freeway using on-road DMS and on-board HMI, respectively.

2.3.2 Participants

A total of 43 healthy participants (age: Mean = 35 years, Standard Deviation (SD) = 11.88), including 27 males and 16 females, were recruited from universities and social organizations to participate in the experiment. The participants were required to have at least 20/20 (normal or corrected, self-reported) vision and no hearing problems (self-reported). A self-administered questionnaire was designed to collect the empirical data for this study. All participants provided informed written consent and demographic data (Table I) before joining the experiment. Driver's basic information includes gender, age, driving year, driving personality, etc. To clarify, the homogeneous sample of subjects was selected in order to minimize any bias attributable to sample heterogeneity. After excluding 5 invalid questionnaires, 38 sample data were used in this study.

2.4 Technology acceptance model

The driver's questionnaire on technology acceptance was based on the study of Son *et al.* (2015) and Venkatesh and Davis (2000) to make used of the TAM to study the degree of driver's acceptance of one technology. Besides of the basic information of the drivers, the questionnaire also included 3 questions measuring respondents' perceptions about usefulness, ease of use for the CV-VSL system. The average score for questions "rationality of the warning content", "safety of the technology" was used to calculate the perceived usefulness (PU) and the

Figure 5 Layout of the experimental road

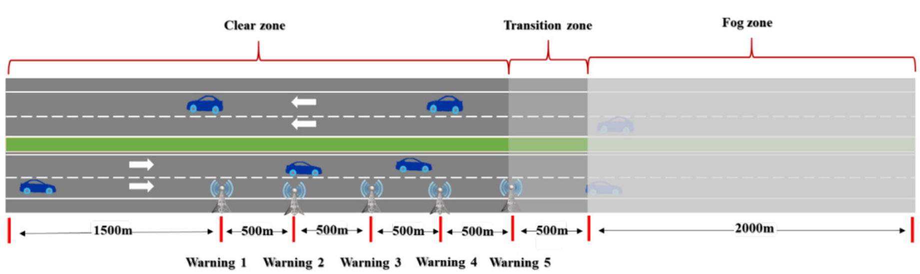


Table I Descriptive statistics

Variables	Mean (SD) statistics	% statistics	Data description
Gender	1.42 (0.49)	1:57 2:43	1: male; 2: female
Age (years)	35 (18)	1:40 2:60	1: age < = 30; 2: age > 30
Driving years	14.9 (9.8)	1:47% 2:53%	1: driving years <10; 2: driving years > = 10
Driving personality	1.39 (0.49)	1:60% 2:40%	1: conservative; 2: aggressive
Average driving mileage (km/per year)	15450 (4372.15)	–	–

score for question "negative interference of the technology" was used to calculate the PEOU.

All questions were measured with a five-point Likert-type scale ranging from "strongly disagree (=1)" to "strong agree (=5)". All the 3 questions have been asked for DMS, DMS in light fog, DMS in heavy fog, on-board HMI, on-board HMI in light fog, on-board HMI in heavy fog separately. TAM uses the drivers' attitude that is sum of PU and PEOU to quantify the acceptance of computer-related technologies. The driver's acceptance of the technology is calculated as follows (Davis, 1989):

$$A = \left((PU + PEOU)/(2 * C) \right) * 100\% \quad (1)$$

In the formula: A is the driver's acceptance of DMS or on-board HMI; PU is the perceived usefulness, PEOU is PEOU, C is the subjective scale rating, that is, 5 points.

3. Results

3.1 Drivers' acceptance of on-road dynamic message sign and on-board human–machine interface

The driver's acceptance of DMS and on-board HMI for CV-VSL system can be defined as the reaction when they come into contact with the warning technology, as well as the intention to adopt the technology while driving (Rahman *et al.*, 2017). Table II shows the acceptance of DMS and on-board HMI by drivers of different gender, age, driving year and driving personality, as well as the acceptance of the two technology types in light and heavy fog areas.

The results showed that the average acceptance of DMS was approximately equal for drivers of different gender, 74 per cent for male and 71 per cent for female. The average acceptance of on-board HMI is 65 per cent for male and 62 per cent for females. In heavy fog, the acceptance of DMS was 70 per cent for male and 65 per cent for female; while in light fog, the acceptance of DMS was 64 per cent for both male and female. In heavy fog, the acceptance of HMI was 61 per cent for male and 59 per cent for female; while in light fog, the acceptance of HMI was 63 per cent for male and 54 per cent for female. The results indicated that there was no larger difference for the drivers' technology acceptance between male and female.

The acceptance of DMS by young and middle-aged drivers was 71 per cent and 74 per cent respectively, and the acceptance of the on-board HMI was 60 per cent and 67 per cent respectively for young and middle-aged drivers. In heavy fog, the acceptance of DMS was 63 per cent for young and 71 per cent for middle-aged; and they were 59 per cent and 69 per cent respectively. In heavy fog, the acceptance of HMI was 59 per cent for young and 60 per cent for middle-aged; while in light fog, the acceptance of HMI was 51 per cent for young and 63 per cent for middle-aged. The results showed that the middle-aged drivers' acceptance is higher than young drivers.

The acceptance of DMS was 72 per cent for drivers with longer driving year (more than 10 years) and 73 per cent for drivers with shorter driving year (less than 10 years), and the acceptance of HMI was 62 per cent for drivers with more than 10 driving years and 65 per cent for drivers with less than 10 driving years respectively. The acceptance of DMS in heavy fog was 65 per cent and 70 per cent for drivers with different driving years, and was 60 per cent and 67 per cent in light fog. The acceptance of HMI in heavy fog was 61 per cent and 59 per cent for drivers with different driving years, and was 53 per cent and 64 per cent in light fog. The results showed that the experienced drivers' acceptance is lower than inexperienced drivers in most cases.

The acceptance of DMS for conservative and aggressive drivers was 72 and 73 per cent and 60 and 67 per cent for HMI. In heavy fog, the acceptance of DMS was 68 per cent for conservative and aggressive drivers, while in light fog, they were 64 per cent and 63 per cent respectively. In heavy fog, the acceptance of HMI was 56 per cent for conservative drivers and 63 per cent for aggressive drivers, while in light fog, the acceptance values were 61 and 57 per cent. The results showed that there were no consistent rules for the drivers' acceptance of technologies between different driving personalities.

From another perspective, no matter what type the drivers are, the drivers' acceptance of DMS is higher than that of on-board HMI. In most cases, the drivers' acceptance of both of the two types of technologies in light fog is lower than that in heavy fog.

3.2 The effect of technology types and fog density on technology acceptance of fog waring system

In order to study the effect of technology types and fog densities on drivers' acceptance, the variance analysis was carried out with technology types for CV-VSL and fog densities as factors. The results in Table III showed that the technology types had a significant effect on drivers' acceptance, while the fog density had no significant effect on drivers' acceptance.

The results showed that the drivers' acceptance of DMS (73 per cent) was obviously higher than that for on-board HMI (64 per cent) which could be seen in Figure 6. The results showed that drivers were significantly easier to accept DMS than on-board HMI for the CV-VSL systems. It also indicated that the more complex CV-VSL system such as on-board HMI design did not mean the higher acceptance of drivers. The information transmission to driver should pay more attention to the simplicity and directness instead of the gorgeous design.

Although the results in Table II indicated that for most cases the acceptance of the technologies in light fog was lower than that in

Table II Descriptive statistics results of driver's acceptance

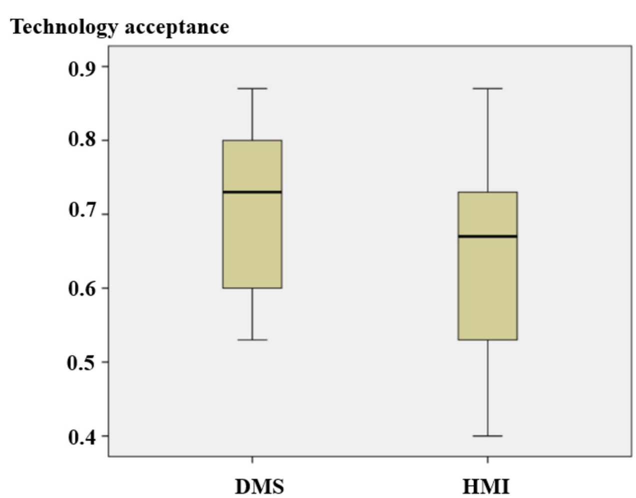
Variables	DMS	HMI	DMS light fog	DMS heavy fog	HMI light fog	HMI heavy fog
Gender						
Male						
Mean/(%)	74	65	64	70	63	61
SD	0.11	0.111	0.155	0.1	0.184	0.176
Female						
Mean/(%)	71	62	64	65	54	59
SD	0.094	0.099	0.145	0.15	0.117	0.132
Age						
Youth						
Mean/(%)	71	60	59	63	51	59
SD	0.089	0.084	0.166	0.141	0.15	0.119
Middle age						
Mean/(%)	74	67	69	71	63	60
SD	0.115	0.112	0.115	0.1	0.167	0.185
Driving years						
Experienced						
Mean/(%)	72	62	60	65	53	61
SD	0.094	0.105	0.178	0.145	0.14	0.126
Inexperienced						
Mean/(%)	73	65	67	70	64	59
SD	0.115	0.099	0.112	0.099	0.18	0.189
Driving personality						
Conservative						
Mean/(%)	72	60	64	68	61	56
SD	0.12	0.093	0.131	0.122	0.154	0.182
Aggressive						
Mean/(%)	73	67	63	68	57	63
SD	0.092	0.108	0.163	0.128	0.17	0.136
Total						
Mean	73	64	64	68	58	60
SD	0.104	0.101	0.146	0.123	0.158	0.155

Note: Total means all the 43 participants

Table III Analysis results of the effect of technology types and fog density on drivers' acceptance of CV-VSL systems

	Mean(SD)	*F*	Df	*p*
DMS VS on-board HMI		12.623	1	0.001
DMS	73% (0.10)			
On-board HMI	64% (0.10)			
DMS				
Heavy fog VS light fog		1.694	1	0.197
Light fog	64% (0.15)			
Heavy fog	68% (0.12)			
HMI				
Heavy fog VS light fog		0.078	1	0.781
Light fog	59% (0.17)			
Heavy fog	60% (0.16)			

Figure 6 Acceptance of different technology types for CV-VSL system



heavy fog, the variance analysis in Table III showed that the fog density was not associated with the drivers' acceptance significantly.

3.3 The effect of gender, age, driving year and driving personality on technology acceptance

In order to further study the influence of driver's gender, age, driving year, and driving personality on technology acceptance of DMS and on-board HMI for CV-VSL, variance analysis was carried out with the driver's gender, age, driving year and driving personality as factors, as shown in Table IV.

The variance analysis results in Table IV showed gender was not associated with the acceptance of any technology for the CV-VSL system. Driver's age was associated with the acceptance of HMI, DMS in heavy fog, and DMS in light fog significantly. It could be seen from Table II that the acceptance of drivers above 30 years old is higher than that for younger drivers. Driving year was significantly associated with the acceptance of HMI in light fog. It could be seen from Table II that the acceptance of HMI in light fog for drivers with more than 10 driving years is lower than that for drivers with less than 10 years, which could be understood as fresh drivers are more able to accept new technologies while experienced drivers get used to the traditional driving environment. Driving personality is also significantly associated with the acceptance of HMI. It could be seen from Table II that the acceptance of HMI for aggressive drivers is higher than that for conservative drivers.

4. Discussion and conclusion

Driving in fog area is a potentially dangerous activity, especially when fog appears suddenly. CV-VSL systems can deliver warning messages to drivers and help them improve their decisions in conditions of reduced visibility. Previous studies have been conducted to evaluate the effectiveness of CV-VSL systems. However, there were rare studies focused on the drivers' attitude toward using which was also called as acceptance of the CV-VSL systems. Therefore, this research calculated the drivers' acceptance of two normally used CV-VSL systems including DMS and on-board HMI using TAM. Furthermore, variance analysis was conducted to explore whether the factors such as drivers' characteristics (gender, age, driving year, and driving personality), technology types, and fog density affected the drivers' acceptance of the CV-VSL systems. The data in this study were collected by the questionnaires after the drivers' experiment on a driving simulator.

The analysis results showed that:

- The technology type (DMS or on-board HMI) of CV-VSL systems in fog area has a significant impact on drivers' acceptance. This suggested that drivers are easier to accept DMS than on-board HMI for the fog warning system, which can be understood as drivers prefer to get message head up rather than looking at the display on the screen in the cab.
- The fog density has no significant effect on drivers' acceptance of the CV-VSL system. However, in practice, drivers' acceptance of the CV-VSL system is expected to be higher in heavy fog than no fog area because of the higher risk in heavy fog. Therefore, better eye-catching signs need to be further designed for the DMS and on-board HMI under low visibility conditions.
- Drivers above 30 years old have significantly higher acceptance of on-board HMI, DMS in light fog, as well as DMS in heavy fog than younger drivers. Experienced drivers' acceptance of the on-board HMI in light fog is lower than that for fresh drivers. Aggressive drivers' acceptance of the on-board HMI is higher than that for conservative drivers. This indicated that the age, driving year, and driving personality influence drivers' acceptance of the technology differently.

The findings of this study also provide some important practical implication for marketers. For the location of the on-board display, automobile manufacturers should assign the on-board display at the up-head position to increase the access to warning information. For the warning message, better eye-catching signs need to be further designed under low visibility conditions. For different drivers, more personalized designs should be considered. For example, aggressive drivers are more acceptable to the new technology, therefore, they can be provided with more multi-source information; while conservative drivers are less acceptable to the new technology, therefore, the existing information should be further optimized for them. Thus, the marketers can design their marketing strategies for the on-board HMI.

The acceptance in this study was calculated by only three questions, which is relatively less than the proposed questions by previous studies (Davis, 1989). In the future study, questions about drivers' perceived usefulness, PEOU, attitude towards use, and behavior intention to use are all needed to be

Table IV Analysis results of the effect of driver's gender, age, driving experience, and driving personality on CV-VSL acceptance

Pr > F	DMS	HMI	DMS light fog	DMS heavy fog	HMI light fog	HMI heavy fog
Gender	0.380	0.297	0.982	0.238	0.103	0.689
Age	0.291	0.078*	0.027**	0.057*	0.11	1
Driving year	0.808	0.342	0.186	0.169	0.045**	0.691
Driving personality	0.620	0.048**	0.920	0.968	0.485	0.221
Gender*Age	–	–				
Gender*Driving year	0.786	0.310	0.079	0.175	0.335	0.976
Gender*Driving personality	–	–	–	–	–	–
Age*Driving year	–	–	–	–	–	–
Age*Driving personality	–	–	–	–	–	–
Driving year*Driving personality	0.271	0.108	0.922	0.967	0.751	0.610

Notes: **Significant at 95% level; *significant at 90% level designed in the questionnaire to develop the TAM. In addition, the relationship between drivers' acceptance and the effectiveness of CV-VSL system, and the relationship between drivers' acceptance and driving workload (calculated from physiological indexes) could also be analyzed in the future.

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