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Research Article

Evaluating effectiveness and acceptance of advanced driving assistance systems using field operational test

Kasi Nayana Badweeti[1], Vinayak Devendra Malaghan[1,2], Digvijay Sampatrao Pawar[1,✉], Said Easa[3]

[1]Department of Civil Engineering, Indian Institute of Technology Hyderabad, Kandi, Medak, 502285, India
[2]Department of Civil Engineering, Pandit Deendayal Energy University, Gandhinagar, Gujarat, 382355, India
[3]Department of Civil Engineering, Toronto Metropolitan University, Toronto, ON, M5B 2K3, Canada

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ABSTRACT: A large number of reported road collisions are caused by driver inattention, and inappropriate driving behaviour. This study investigated the effectiveness and acceptance of Advanced Driving Assistance Systems (ADAS) for driver age groups, gender, occupation (professional/non-professional), and road type (expressway, urban roads, and semi-urban road) based on the Field Operational Test (FOT). The ADAS is provided with assistance features, such as Lane Departure Warning (LDW), Forward Collision Warning (FCW), and Traffic Speed Recognition Warning (TSRW). In total, the FOT involved 30 participants who drove the test vehicle twice (once in the stealth phase and once in the active phase). The FOT included three sections: expressway (20.60 km), urban road (7.2 km), and semi-urban road (13.35 km). A questionnaire was used to determine user acceptance of the ADAS technology. In addition, parametric and non-parametric statistical tests were carried out to determine ADAS's significant effects. The FOT results showed statistically significant differences in the LDW's acceptance and effectiveness for gender, age group, occupation, and road type before and after exposure to ADAS. Male participants showed significant lateral behavior improvement compared to female participants. Old-aged drivers scored the highest acceptance score for the technology compared to middle and young-aged drivers. The subjective ratings ranked the assistance features in descending order as TSRW, LDW, and FCW. This study's findings can support policy development and induce trust in the public for the technology adoption to improve road traffic safety.

KEYWORDS: driving assistance system, forward collision, lane departure warning, traffic speed recognition, road safety

1 Introduction

With the rising vehicle population on the road and the expansion of the road network, societies face potential challenges by witnessing human fatalities due to recurrent and severe road collisions. According to the World Health Organization (WHO), approximately 1.3 million people die each year as a result of road traffic crashes (WHO, 2018). Road collisions are multi-causal and are often due to the interaction of three primary factors: road environment, vehicles, and human factors (Malaghan et al., 2020; Malaghan and Pawar, 2022). Human's limited information processing capabilities depend on three fallible mental functions: attention, perception, and memory. Human error leads to collisions, evidently when the driver fails to avoid a situation demand that surpasses the abovementioned limitations (Green and Senders, 2004). Thus, driver inattention/distractions are the primary road safety concerns as they comprise potential risk factors in road traffic collisions. Rear-end, sideswipe, and angle collisions are significantly attributed to driver's inattention, failure to keep a safer distance from the lead car, and inappropriate driving behaviour (Knipling et al., 1993; Mosedale and Clarkson, 2004).

In India, approximately 28,000 (fatal) and 90,000 (non-fatal) rear-end collisions were reported in 2019. Besides, the road collisions due to sideswiping were around 16,000 fatalities and 59,000 non-fatalities for 2019 (MORTH, 2019). Therefore, Advanced Driving Assistance Systems (ADAS) with different safety features have been developed and commercialized to enhance driver behaviour, perceptual ability, and vigilance. For example, the assistance systems primarily include lane departure warning (LDW) (Blaschke et al., 2009) and forward collision warning (FCW) (Ben-Yaacov et al., 2002; Shinar and Schechtman, 2002). The ADAS assists in correcting driving behavior. The potential risky circumstances can be safely prevented if the alerts (auditory, haptic, and visual) from the assistance systems are correct and prompt (Li et al., 2015; Son et al., 2015). The LDW alerts the drivers for unintentional lane departure to drive within the lane. The forward collision warning alerts the driver to prevent an impending collision with an object ahead. Time headway, lane position, and the vehicle's stability indicate driving performance, so road traffic safety is influenced by driving performance (Li et al., 2015; Zhang et al., 2016).

Most previous studies examined the ADAS efficacy on lane position and time headway (THW) (Feng et al., 2016; Zhang et al., 2016b). Some of these studies inferred that the drivers could maintain longer and safer headway with longitudinal support (Ben-Yaacov et al., 2002; Shinar and Schechtman, 2002) and drive within the lane with lateral support (Blaschke et al., 2009; Son et al., 2015). In contrast, the ADAS effect on the headway (Sayer et al., 2011; Son et al., 2015) and keeping lane (Adell et al., 2011; Lyu

✉ Corresponding author.
E-mail: dspawar@ce.iith.ac.in

et al., 2019) was reported to be insignificant. In addition, regarding driver characteristics (e.g., age, gender, and driving experience), the findings about ADAS effect on driving performance were not consistent (Atombo et al., 2016; Feng et al., 2016; Pan et al., 2021; Zhang et al., 2016). For instance, some studies showed that the assistance system could help improve the driving performance of male drivers and vice versa (Rezaei et al., 2021). In contrast, fewer studies reported that the ADAS effect was insignificant across age and gender (Adell et al., 2011; Shinar and Schechtman, 2002).

Furthermore, the acceptance of ADAS technology was influenced by personal feelings, driver characteristics, and road environment (Birell et al., 2014; Li et al., 2015). Regarding age, older drivers had a higher acceptance rate for the FCW than younger drivers (Najm et al., 2006; Oxley and Mitchell, 1995). Considering gender differences, males were affected by the perceived usefulness in deciding whether or not to accept new technology, but females were influenced by perceived ease of use (Venkatesh and Morris, 2000). In addition, the road environment may influence drivers' expectations regarding ADAS performance in various traffic situations, which can affect ADAS acceptance. For example, driver acceptance was lower on urban roads than on freeways and expressways (Li et al., 2015; Lim et al., 2021). On the other hand, subjective acceptance scores across age, gender, and aggression can contribute to driver performance differences (LeBlanc et al., 2013; Sayer et al., 2011). For total acceptance by the drivers, LDW showed a higher user acceptance level than FCW (Yang et al., 2018). In contrast, FCW had a higher acceptance level than LDW (Li et al., 2015).

The ADAS concept is relatively new in India, and it is ambiguous whether these systems can significantly affect driver behavior in actual traffic scenarios. Specifically, the acceptance and ADAS effectiveness on various roadways and with varying driver characteristics need to be justified using a Field Operational Test (FOT). When assessing ADAS, previous research conducted FOT on homogeneous traffic. However, whether ADAS acceptance and effectiveness for age group, gender, and driver occupation (professional/non-professional) is the same for Indian drivers (heterogeneous condition) requires further investigation. With this motivation, the present study evaluates the ADAS effect on driving performance (in terms of the number of warnings for LDW, TSRW, and FCW) and driver characteristics in various road environments based on a field operational test.

2 Literature review

2.1 ADAS effect on driving performance

Most previous studies investigated the influence of LDW assistance on lateral behavior and FCW assistance on longitudinal behavior. In the car-following situations, Taieb-Maimon and Shinar (2001) evaluated the actual headway by instructing the drivers to maintain a "minimum safe distance" and "comfortable, normal distance when overpassing" the following vehicle. Their results showed that a substantial percentage of drivers maintained THW, regarded as unsafe, concerning their reaction time. Ben-Yaccov et al. (2002) instructed the drivers to keep a THW of 1 s to check their maintained headways. The drivers were likely to overstate their THW and drive with shorter and unsafe headways; however, the In-Vehicle Collision Avoidance System (IVCAMS) alerted the drivers to keep safer and longer time headways.

Apart from the longitudinal support, the lateral assistance from the LDW system decreased unintentional lane departures and assisted the drivers in driving within the lane (Alkim et al., 2007). For example, in the field experiment study using in-vehicle information systems (IVIS), Blaschke et al. (2009) observed no lane departures when the drivers were provided with lateral support. However, they were engaged in secondary tasks. On the other hand, Saito et al. (2016) developed an assistance system that judged the driver's state (e.g., asleep or drowsiness) and alerted the drivers to evade lane departure collisions.

2.2 ADAS effect on driver characteristics

Several studies examined the effect of driving performance on ADAS and its impact on age and gender based on FOT. For example, Shinar and Schechtman (2002) assessed the ADAS effectiveness for the driver's longitudinal behavior. Their results showed a 25% reduction in shorter headway (< 0.8 s) and 14% improvement in longer headways greater than 1.2 s. From the perspective of gender, the assistance system improved the car-following behavior of male, female, young, and old drivers irrespective of the day/night driving conditions. In a real-world driving experiment, Son et al. (2015) found no significant effect of ADAS on FCW. However, when driver assistance systems were used, the total number of lane departures decreased. Male drivers maintained greater THW and improved lane deviation compared to female drivers. The younger drivers (25–35) kept THW lesser than 1.5 s and lower lane deviation than late-middle-aged drivers (55–65). From the view of acceptance towards the ADAS, the late-middle-aged and male drivers indicated more likely acceptance than younger and female drivers. In a field operational test, Lyu et al. (2019) examined the ADAS influence on driving performance and driver characteristics of Chinese drivers. When participants were exposed to ADAS, the proportion of the time headway journey that lasted longer than 1.2 s increased; however, no significant improvement in the mean lane position was observed. The effect of ADAS on the gender for THW and lane deviation was found insignificant (Lyu et al., 2019). Table 1 summarizes the literature review showing different types of assistant features and the parameters used in measuring driving performance.

2.3 ADAS effect on driving performance and driver characteristics

Some studies investigated the ADAS effect exclusively on driver characteristics. For example, Li et al. (2015) evaluated the impact of ADAS features, such as Side Blind Zone Alert (SBZA), LDW, and FCW, on driving performance and technology acceptance based on age, gender, and aggression. From the gender point of view, males received more FCW, but lesser LDW than females. Female drivers indicated higher acceptance of the ADAS features than male drivers. From the age perspective, younger drivers (21–35) received more SBZA than older drivers (51–65). Based on the subjective ratings, SBZA showed the highest acceptance, followed by FCW and LDW. From the naturalistic driving data, Montgomery et al. (2014) used the FCW feature of ADAS to investigate the braking behavior difference among different age and gender groups in car-following scenarios. The results showed that females braked earlier than males (i.e., Time to Collision (TTC) of females was higher than males). From the age point of view, female and older drivers applied brakes before younger drivers; however, the difference in braking among the drivers of the different age groups (18–20, 21–30, 31–50, and 50+) was insignificant. Similarly, Kusano et al. (2015), based on the NDS data, found that young drivers (18–30) had lower TTC compared

Table 1 Characteristics of previous studies on the effectiveness and acceptance of ADAS

Reference	Country	Method	Participant	ADAS	Parameter
Driving simulator study					
Saito et al. (2016)	Japan	Driving simulator	15 M, 5 F	Speed	Lane-keeping performance, driver arousal state
Maltz and Shinar (2004)	Israel	Driving simulator	49 M, 87 F	FCW	THW, response time
Scott and Gray (2008)	USA	Driving simulator	16 drivers	FCW	THW, TTC, response time
Chen et al. (2011)	Australia	Driving simulator	8 M, 8 F	ICWS	Reaction time, speed, deceleration, the proportion of collisions
Yan et al. (2016)	China	Driving simulator	21 M, 20 F	Speed warning system	Operating speed, entrance speed, speeding ratio, maximum deceleration, average deceleration
Field operational test study					
Shinar and Schechtman (2002)	Israel	FOT	29 M, 14 F	FCW	THW
Ben-Yaacov et al. (2002)	Israel	FOT	15 M, 15 F	FCW	THW
Blaschke et al. (2009)	Germany	FOT	18 M, 12 F	LDW	Lateral deviation, questionnaire
Adell et al. (2011)	Italy	FOT, Questionnaire	10 M, 9 F	FCW	THW, No. of alarms, alarm length, speed, workload, reaction time
Birrell et al. (2014)	UK	FOT	30 M, 10 F	FCW, LDW, ACC, and braking advice	*V*, THW, yaw rates, acceleration and braking forces
Li et al. (2015)	China	FOT, Questionnaire	22 M, 11 F	FCW, LDW, SBZA	Acceptance, ATKP
Wang et al. (2012)	China	FOT	26 M, 7 F	ACC, FCW/FCA	THW, TTC, speed, acceleration, brake pressure, relative distance/speed, acceleration pedal/throttle pressure
Son et al. (2015)	Republic of Korea	FOT, Questionnaire	26 M, 26 F	FCW, LDW	Acceptance, FCWC, THW, LDWC, SDLP, PJ1.5
Sullivan et al. (2008)	USA	FOT	21 M, 21 F	LDW (drift), CSW	Reaction time
LeBlanc et al. (2013)	USA	FOT	18 M, 18 F; 18 M, 18F; 18 M, 18 F	FCW	TTC, THW
Montogomery et al. (2014)	USA	FOT	52 M, 32 F	FCW	TTC
Kusano et al. (2015)	USA	FOT	6 M, 6 F; 5 M, 15 F; 3 M, 14 F; 7 M, 8 F	FCW	TTC, speed

Note: *V*-speed; THW-time headway; FOT-field operational test; ATPK-alert per 100 km; ACC-Adaptive Cruise Control; LDW-lane departure warning; FCW/FCA-forward collision warning/avoidance; SDLP-standard deviation of lane position; FCWC-forward collision warning count; LDWC-lane departure warning count; SDLP-standard deviation of lane position; PJ1.5-Drivers traveling less than 1.5 s; CSW-curve speed warning; ICWS-intersection conflict warning system; TTC-time to collision.

to the drivers of the older-age drivers (30–51+). The middle age drivers (31–50) and mature-age drivers (51+) had significantly higher TTC than novice drivers (8–20). From the view of gender, female drivers had higher TTC than male drivers.

2.4 ADAS previous studies on user acceptance

Several FOTs have been conducted to understand the relationship between ADAS effectiveness and the system's acceptance in actual traffic for designing in-vehicle warning systems and precisely estimating their safety assistance. Son et al. (2015) showed that drivers of different genders and ages have considerably different rates of acceptance of ADAS. Male participants accepted the FCW more consistently than female participants. Compared to LDW, FCW has higher acceptance by the drivers. Stevens (2012) conducted a study to understand older drivers' attitudes toward user requirements for in-car information systems. The author found that older drivers rated the system higher and were likely to use it than younger drivers. According to Viborg (1999), older drivers were more favorable to ADAS services than younger drivers. Li et al. (2015) investigated ADAS acceptance on Chinese roadways. They found that the FCW had a higher rate of driver acceptance than LDW. Similarly, Lyu et al. (2019) stated that drivers significantly accepted the FCW feature more than the LDW feature and this acceptance was much higher on freeways and expressways than on urban roads.

Based on an assessing of drivers' age, duration time, and road type effects on ADAS acceptance, Xu et al. (2021) concluded that ADAS acceptance varies significantly among different driver ages on commercial vehicles. According to the results, FCW (69.2%) is substantially more accepted than LDW (38.8%). In addition, LDW systems are more acceptable to older drivers at higher vehicle speeds. In contrast, the FCW system acceptance decreases as vehicle speed increases.

3 Research gaps and objectives

Several studies have assessed ADAS effect on driving performance and driver characteristics. However, previous studies showed variations in the reported results, where the effect was found to be significant in some studies and insignificant in others. Moreover, the available studies are fewer, and no research studies on the influence of ADAS on driver performance/characteristics have been conducted in India. Therefore, exploring the effectiveness and driver acceptance of ADAS for Indian conditions is necessary. Thus, the primary objectives of this research are as follows:

- To evaluate the effects of age group, occupation, gender, and road type (expressways and urban roads) on the ADAS effectiveness in actual traffic conditions using FOT.
- To evaluate ADAS acceptance using a questionnaire based on gender, age group, and occupation characteristics.

4 Methodology

4.1 Test vehicle

The instrumented passenger car (Fig. 1a) was equipped with an ADAS (MDAS-9), a Global Positioning System (GPS), and Lasers were used to FOT. The ADAS was fixed to the windshield, a GPS device comprising an antenna was fixed to the car's sunroof, a GPS box near the dashboard, and four cameras were used. The first camera was fixed to the windshield (Fig. 1b) to record the road environment. The second camera was fixed to the windscreen facing the driver (Fig. 1c). The third camera was fixed to the front-left door to trace the wheel path (Fig. 1d). Finally, the fourth camera was fixed to the windscreen facing the ADAS (Fig. 1e), to analyze the data from the features of the ADAS. The ADAS displays the data such as operating speed (e.g., 70 km/h), traffic speed limit recognition (e.g., 100 km/h), lane detection (green dotted lines), and TTC (e.g., 2.5 s) as shown in Fig. 1e. In addition, the lasers were fixed to the car's sunroof to record the distance headway (Fig. 1a). The experiment cost primarily includes the instrumented vehicle, including devices such as ADAS, Video VBOX Pro, and laser sensors, and was about $17,608.32 (USD).

4.2 Vehicle data

Video vbox pro, an advanced data collection tool was used to record the continuous vehicle kinematics data at 10 Hz and the video data of the surrounding road environment. Vehicle kinematic data were collected during the experiment, including speed, distance travelled, headway, longitudinal and acceleration, lateral accelerations, position, and time every 0.1 s. However, vehicle kinematics were not considered for the analysis.

4.3 Test route

The experiment test route was selected considering traffic variations on various road types. For the experiments, a combined route in Hyderabad, India was selected (a semi-urban road, an expressway, and an urban road). The test route length was 41.15 km and included three sections (semi-urban road, expressway, and urban road) (Fig. 2). The rural highway comprised two lanes in each direction, posted speed limits ranging from 60 to 80 km/h, and a length of 13.35 km (yellow color). The express highway consisted of 4 lanes in each direction, with 100 km/h posted speed limit. The rural highway's total length was 20.60 km (blue color). The urban road included 2 or 3 lanes in each direction, with posted speed limits ranging from 40 to 60 km/h and a length of 7.2 km (black color). During the FOT, the participants completed 60 trips, 30 in the stealth phase and 30 in the active phase. To prevent bias in the instructions, a research student who traveled in the test vehicle during the experiment provided verbal route guidance to the participants. All the

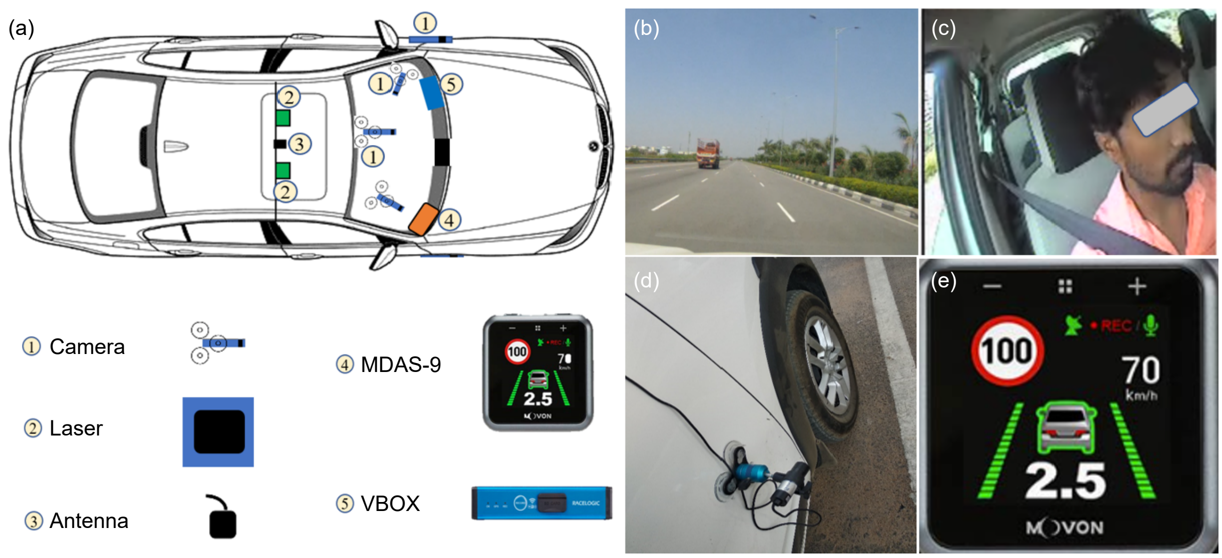

Fig. 1 Instrumented vehicle: (a) test vehicle with instruments, (b) Camera 1 (road data), (c) Camera 2 (driver data), (d) Camera 3 (LDW data), and (e) Camera 4 (ADAS data).

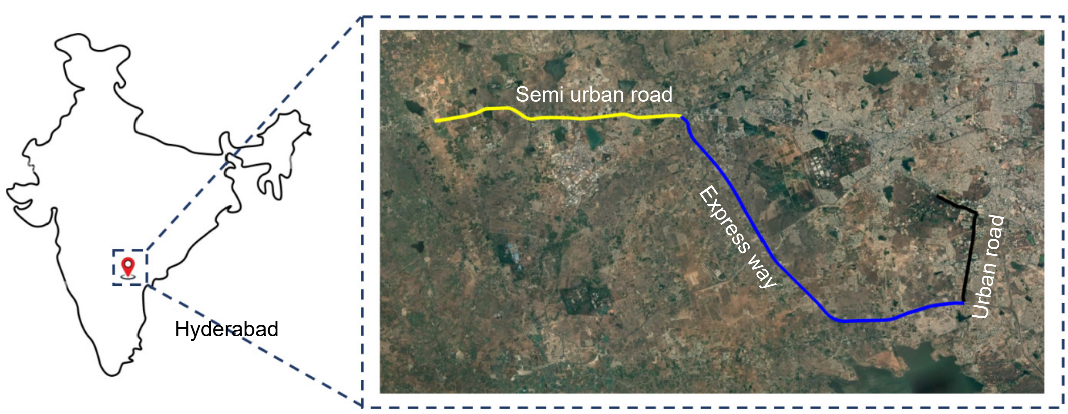

Fig. 2 Selected test routes for the field operational test.

participants drove the same test vehicle.

4.4 Participants

In this experiment, 30 participants were recruited based on their convenience sampling to determine ADAS effectiveness and acceptance for various age groups, gender, occupations, and road types. The groups were young (21–35), middle (36–50), and old (51–65). The participants who were not previously exposed to ADAS with a minimum of 2 years of driving experience were selected for this experiment to avoid bias in the driver behaviour and acceptance of the technology. The participants' descriptive statistics of demographic details are presented in Table 2. Each participant received a gift voucher worth Rupees (Rs.) 500 for participating in the experiment. The data were collected during daytime and dry weather.

4.5 Test procedure

The experiment was carried out in three stages (Fig. 3). In the pre-experiment, the participants drove the test vehicle on the trial route to become familiar with the test vehicle. In this stage, each participant drove on a trial test route (2 km) at the Indian Institute of Technology (IIT) Hyderabad campus in India to get accustomed to the test vehicle. Finally, each participant signed a consent form before the main experiment for participating in this FOT.

The primary experiment involved three phases (Fig. 3). In the stealth phase, each participant drove the test vehicle in one direction on the selected road sections (semi-urban, expressway, and urban road). Then, in the training phase, the participants were introduced to the features of the ADAS and were instructed to drive on the trial route in real-world traffic with the support of the ADAS systems to get accustomed to the specific warnings from different assistance features of the ADAS. Finally, in the active phase, ADAS was enabled, and the main experiment was conducted on the same test route in the opposite direction (Fig. 3). In the post-experiment, each participant completed a questionnaire related to driver demography and technology acceptance (~25 min) (Fig. 3).

In this experiment, three levels of FCW events were considered to evaluate the effectiveness of FCW in longitudinal driver behavior: Level 1 ($TTC \geq 0.9$), Level 2 ($0.6 < TTC < 0.9$), and Level 3 ($TTC \leq 0.6$). The average forward collision warning (FCW) counts up to level 3 considered to analyze the FCW system. The LDW system was evaluated by counting the number of lane departures when the test vehicle departed the lane unintentionally without turning on the indicator. The minimum activation speed for the assistance features (FCW, LDW, and TSRW) was 30 km/h. The LDW and FCW were given in both visual and auditory modalities, while the TSRW was in visual modality alone.

4.6 Questionnaire

The post-experimental questionnaire constitutes two sets of questions related to participant demography and technology acceptance. Five questions were asked related to the driver demography, and 63 questions were to measure the perceptive scale for technology acceptance. Of the 63 questions, 21 were asked for LDW to determine user acceptance (Table 3). The same questionnaire was used for FCW and TSRW. In addition, the questionnaire includes four-attitudinal questions related to 'safe', 'pleasant', 'desirable', and 'comfort' (Son et al., 2015; Yang and Kim, 2018). All of the questionnaires concerned the participants' feelings about ADAS and their experiences during the main experiment of the active phase. A 7-point Likert scale (1–7) was used in this experiment to develop the user acceptance model, where 1 (strongly disagree), 4 (neither agree nor disagree), and 7 (strongly agree).

4.7 User acceptance model for ADAS

The questionnaires related to ADAS were used to determine the acceptance score of users for driver assistance features. Son et al. (2015) developed an ADAS driver acceptance model in which 'safe' and 'desirable' were considered in perceived usefulness, and 'pleasant' and 'comfort' were considered in the perceived ease of use.

Between these four subjective feelings about technology acceptance, 'safe' and 'desirable' indicate positive feedback, while 'annoying' and 'unpleasant' represent negative responses. The Technology Acceptance Model (TAM) was used in this study to examine the ADAS acceptance behaviours (i.e., user attitude toward) to determine user acceptance (Davis, et al., 1989; Son et al., 2015), as Eq. (1):

$$A = U + EOU \tag{1}$$

where A is the user acceptance, U is the perceived usefulness, and EOU is the perceived ease of use. The perceived usefulness is an average score calculated using a rating scale of 'safe' and 'desirable' based on the participant questionnaire responses, as Eq. (2):

$$U = (S_{\text{safe}} + S_{\text{deirable}})/2 \tag{2}$$

where S_{safe} is the subjective safety rating score and S_{deirable} is the subjective desirable rating score from the questionnaire.

The EOU is an average score determined from participant questionnaire responses using a rating scale of "pleasant" and

Table 2 Descriptive statistics of the driver demography

Independent variable	Participant number	Age (year)		Driving experience (year)	
		M[a]	SD[a]	M[a]	SD[a]
All	30	37.8	9.8	13.7	9.6
Young	12	28.7	4.4	6.9	4.4
Middle	12	39.0	1.8	14.4	7.9
Old	6	53.6	2.3	26.1	9.0
Male	20	39.2	11.5	17.1	9.8
Female	10	35.1	4.1	7.1	4.2
Professional	10	36.4	12.7	15.4	12.1
Non-professional	20	38.6	8.2	12.9	8.3

Note: [a] M-mean and SD-standard deviation.

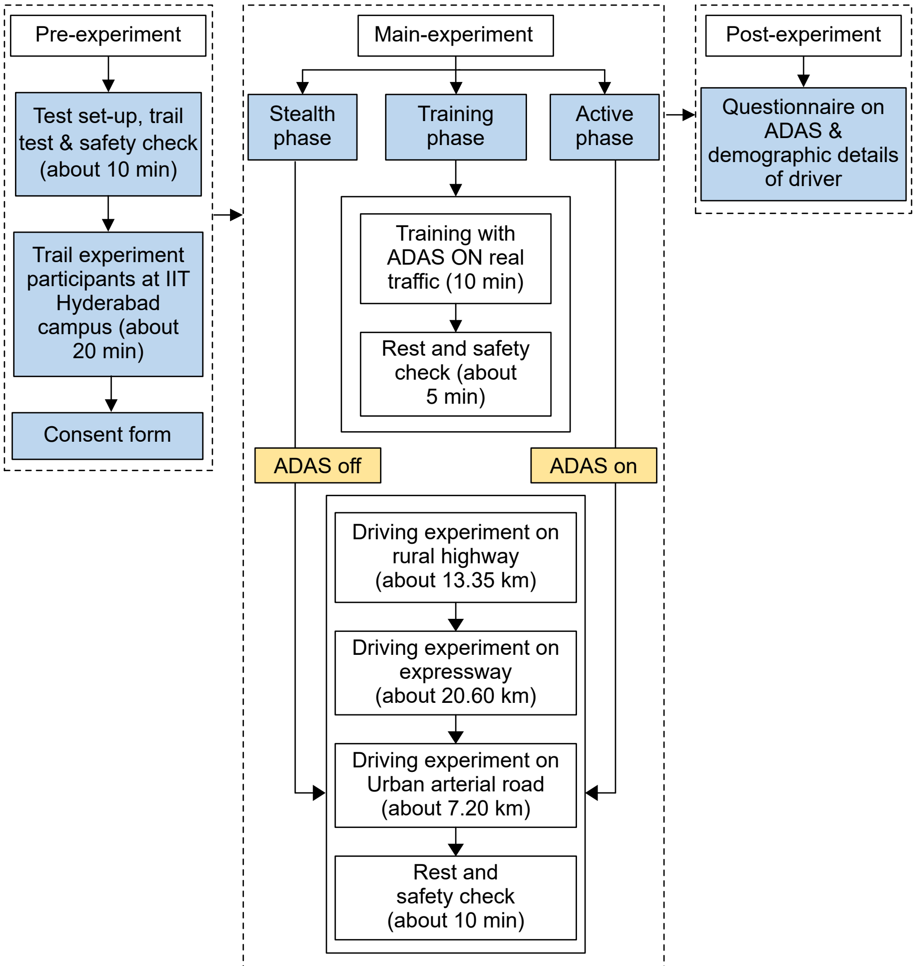

Fig. 3 ADAS experimental procedure.

"comfort", as Eq. (3):

$$EOU = (S_{\text{pleasant}} + S_{\text{comfort}})/2 \tag{3}$$

where S_{pleasant} is the subjective pleasant rating score and S_{comfort} is the subjective comfort rating score.

Finally, ADAS user acceptance is expressed as the average of U and EOU, as Eq. (4):

$$A\,(\%) = \frac{\frac{U + EOU}{2}}{C_{\text{rating scale}}} \times 100 \tag{4}$$

where A is the ADAS user acceptance (%) and $C_{\text{rating scale}}$ is the scale of the subjective rating (i.e., 7 points).

4.8 Data extraction and analysis

The number of FCW and LDW were manually extracted in the laboratory based on the age group (young, middle, and old), gender (male and female), occupation (professional and non-professional), and road type (semi-urban road, expressway, and urban road) by looking at the video. The data were analyzed in three steps. First, descriptive statistics of the count data were computed. Second, the normality test was conducted to determine whether the data showed normal distribution, and then parametric and non-parametric tests were used to determine the effectiveness of ADAS features. Finally, a Cronbach's alpha test was used to ensure participant responses' consistency, and then the acceptance of the technology acceptance was calculated using the user acceptance model.

5 Results

To evaluate ADAS effectiveness in the stealth and active phases, the field data were analyzed using two dependent variables (FCW and LDW) and four independent variables (age, gender, occupation, and road type). These dependent variables are typically used to measure driving performance. The SPSS version 22 program was used to analyze the data and conduct various statistical tests.

5.1 Effect of LDW

The ADAS effectiveness for age, gender, occupation, and road type in terms of the number of lane departure warnings during the stealth and active phase was analyzed (Fig. 4). As noted, for different age groups, the number of LDW decreased during the active phase compared to the stealth phase (Fig. 4a). Similarly, the number of LDW decreased for the gender type (Fig. 4b), occupation (professional/non-professional) (Fig. 4c), and road type (Fig. 4d). The count data for LDW showed non-normal distribution for age, gender, occupation, and road type (Table 4). Hence, to investigate whether a significant difference exists in the number of LDW for independent variables during the stealth and active phase, the Wilcoxon signed-rank non-parametric test was used. The means of each group of independent variables in the active phase were compared using the Kruskal–Wallis H test. Table 5 presents the descriptive statistics and results of the Wilcoxon signed-rank test.

The difference in the number of lane departure warnings

Table 3 User acceptance questionnaire for ADAS

Perceived usefulness								
1. Driving with a lane departure warning, would you feel safer than driving without it?								
Very unsafe	1	2	3	4	5	6	7	Very safe
2. Would you desire to drive with the lane departure warning?								
Very undesirable	1	2	3	4	5	6	7	Very desirable
3. I would feel safe to use the vehicle equipped lane departure warning?								
Not at all likely	1	2	3	4	5	6	7	Very likely
4. How frequently will you utilize the lane departure warning for short distance travelling?								
Not at all likely	1	2	3	4	5	6	7	Very likely
5. How often will you be using the lane departure warning for long distance travelling?								
Not at all likely	1	2	3	4	5	6	7	Very likely
6. I think I can depend on lane departure warning for safe travelling?								
Not at all likely	1	2	3	4	5	6	7	Very likely
7. ADAS can correctly give the lane departure warning?								
Not at all likely	1	2	3	4	5	6	7	Very likely
8. Lane departure warning would be useful for my traveling?								
Not at all likely	1	2	3	4	5	6	7	Very likely
9. Using lane departure warning in the vehicle for traveling would be desirable to me?								
Not at all likely	1	2	3	4	5	6	7	Very likely
10. Using lane departure warning in the vehicles for travelling would be assisting?								
Not at all likely	1	2	3	4	5	6	7	Very likely
11. The vehicles equipped with the lane departure warning will make the drive safer?								
Not at all likely	1	2	3	4	5	6	7	Very likely
12. Lane departure warning will effectively interact with the vehicle?								
Not at all likely	1	2	3	4	5	6	7	Very likely
13. Would lane departure warning be able to respond to hazardous driving situations faster than a human driver?								
Not at all likely	1	2	3	4	5	6	7	Very likely
14. Will the lane departure warning reduce my risk of getting involved in an accident or crash?								
Not at all likely	1	2	3	4	5	6	7	Very likely
15. Would lane departure warning be effective in reducing road crashes or accidents resulting from human error?								
Not at all likely	1	2	3	4	5	6	7	Very likely
Perceived ease of use								
16. Do you feel using the lane departure warning as unpleasant?								
Very unpleasant	1	2	3	4	5	6	7	Very pleasant
17. Would you feel that using the lane departure warning while driving is more annoying than not using it?								
Very annoying	1	2	3	4	5	6	7	Very comfortable
18. I could feel comfortable use lane departure warning for commuting if my friend, child, husband, relatives, parents, and other loved ones.								
Not at all likely	1	2	3	4	5	6	7	Very likely
19. Using the lane departure warning in the vehicle, I would suggest my friends and relatives be comfortable while driving?.								
Very Uncomfortable	1	2	3	4	5	6	7	Very comfortable
20. I would find it pleasant to use the vehicles equipped with the lane departure warning?								
Not at all likely	1	2	3	4	5	6	7	Very likely
21. Using lane departure warning in the vehicle for traveling would be pleasant?								
Not at all likely	1	2	3	4	5	6	7	Very likely

between the stealth and active phases was statistically significant for the young-age group ($Z = -2.307, p = 0.021$), middle-age group ($Z = -2.430, p = 0.015$), and old-age group ($Z = -2.032, p = 0.042$). The mean lane departure warning was higher in the middle-age group ($M = 2.91, SD = 3.55$) than in the young-age group ($M = 2.18, SD = 4.21$) and old age group ($M = 2.50, SD = 1.37$) (Table 5). For male drivers, the difference in the number of LDW was statistically significant ($Z = -3.632, p < 0.001$) between the stealth phase and active phase. In contrast, female drivers showed no statistically significant difference ($Z = -1.429, p = 0.153$) between the phases. The mean number of LDW for female drivers ($M = 5.10, SD = 4.65$) was higher than for male drivers ($M = 1.21, SD = 1.39$).

For occupation, the difference in the number of LDW for professionals ($Z = -2.680,\ p = 0.007$) and non-professionals ($Z = -2.899,\ p = 0.004$) drivers was statistically significant. Thus, the mean lane departure warning for non-professional drivers ($M = 3.52, SD = 3.84$) was higher than for professional drivers ($M = 0.70, SD = 1.05$). Further, it can be observed that the difference in the number of LDW was statistically significant for the expressway ($Z = -2.565,\ p = 0.010$) and urban road ($Z = -2.007, p = 0.045$). In contrast, for the semi-urban road ($Z = -1.628, p = 0.103$), the difference between the stealth and active phases was not statistically significant. The mean number of

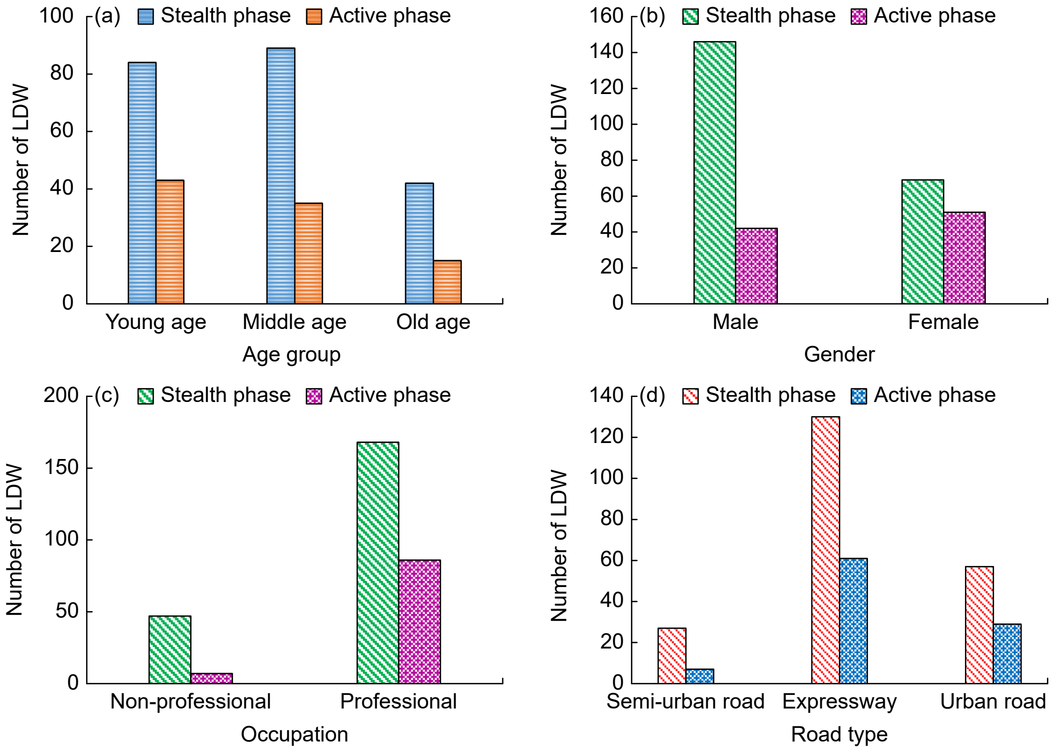

Fig. 4 Number of Lane Departure Warning (LDW) count (times): (a) age group, (b) gender, (c) occupation, and (d) road type.

Table 4 Normality test results for LDW

Dependent variable: LDW		
Independent variable	Shapiro-Wallis's test, p-value	
	Stealth phase	Active phase
Young age	0.030	0.010
Middle age	0.010	0.010
Old age	0.020	0.001
Male	0.001	0.001
Female	0.001	0.001
Professional	0.002	0.002
Non-professional	0.008	0.002
Semi-urban road	0.001	0.001
Expressway	0.001	0.001
Urban road	0.001	0.004

LDW was greater for the expressway ($M = 2.25, SD = 3.28$) than for the urban road ($M = 1.45, SD = 1.39$) and semi-urban road ($M = 0.70, SD = 1.33$).

The independent variables of LDW (i.e., age group ($p < 0.001$), gender ($p < 0.001$), occupation ($p < 0.001$)), and road type ($p < 0.001$) were non-normal based on the Shapiro–Wilk normality test. Hence, the Kruskal–Wallis test was performed for independent variables in the active phase. Using the Kruskal–Wallis H test, the difference in the mean of LDW was statistically significant for gender ($H(1) = 7.037, p = 0.008$) and occupation ($H(1) = 5.837, p = 0.016$), but was not statistically significant for age group and road type ($H(2) = 1.581, p = 0.454$ and $H(1) = 3.975, p = 0.137$)(Table 5).

5.2 Effect of FCW

In the active phase, the number of FCW is slightly higher across all age groups (Fig. 5a), genders (Fig. 5b), occupations (Fig. 5c), and road types (Fig. 5d), than that in the stealth phase. The count data for FCW of the independent variables, such as age group, gender, and occupation, are normally distributed (Table 6). The paired t-test was used to investigate the FCW effectiveness between the stealth and active phases. The one-way ANOVA test was used to compare the means within each group of independent variables in the active phase.

Table 5 shows the descriptive statistics and statistical analysis results. It was found that the difference in the number of FCW for the semi-urban road was statistically significant ($t(29) = -2.354, p = 0.026$). The mean FCW was larger for the semi-urban road ($M = 2.51, SD = 1.77$) compared to the urban road ($M = 1.62, SD = 1.54$) and the expressway ($M = 0.10, SD = 0.30$). The count data for FCW of the expressway and urban road showed non-normal distribution during the stealth and active phases (Table 6). Hence, the Wilcoxon signed-rank test was performed. Further, it can be observed that the difference in the number of FCW was not statistically significant for the expressway ($Z = -0.921, p = 0.357$) and urban road t ($Z = -0.834, p =$

Table 5 Statistical results for LDW and FCW

Independent variable	Stealth phase		Active phase		*p*-value	
	M[a]	SD[a]	M[a]	SD[a]	Wilcoxon signed-rank test	Kruskal–Wallis H test
Dependent variable: Number of Lane Departure Warnings						
Young age	4.36	4.61	2.18	4.21	**0.021**[b]	
Middle age	7.41	5.90	2.91	3.55	**0.015**[b]	0.454
Old age	7.00	2.75	2.50	1.37	**0.042**[b]	
Male	5.78	5.19	1.21	1.39	**< 0.001**[b]	**0.008**[b]
Female	6.90	4.70	5.10	4.65	0.153	
Professional	4.70	3.43	0.70	1.05	**0.007**[b]	**0.016**[b]
Non-professional	6.94	5.54	3.52	3.84	**0.004**[b]	
Semi-urban road	2.70	3.09	0.70	1.33	0.103	
Expressway	4.81	4.16	2.25	3.28	**0.010**[b]	0.137
Urban road	2.85	2.13	1.45	1.39	**0.045**[b]	
Dependent variable: Number of Forward Collision Warnings						
Young age	3.40	1.24	3.72	2.12	0.639	
Middle age	3.58	2.59	3.77	2.89	0.829	0.950
Old age	2.94	1.68	4.11	1.99	0.159	
Male	3.65	1.86	3.64	1.96	0.988	0.586
Female	2.86	2.06	4.16	3.10	0.050	
Professional	3.35	1.10	3.61	2.26	0.735	0.736
Non-professional	3.40	2.28	3.93	2.84	0.369	
Semi-urban road	1.87	1.08	2.51	1.77	**0.026**[a]	
Expressway	0.18	0.49	0.10	0.30	—[c]	—[c]
Urban road	1.35	1.19	1.62	1.54	—[c]	

Note: [a] M-Mean and SD-Standard deviation. [b] $p < 0.05$. [c] non-normal data.

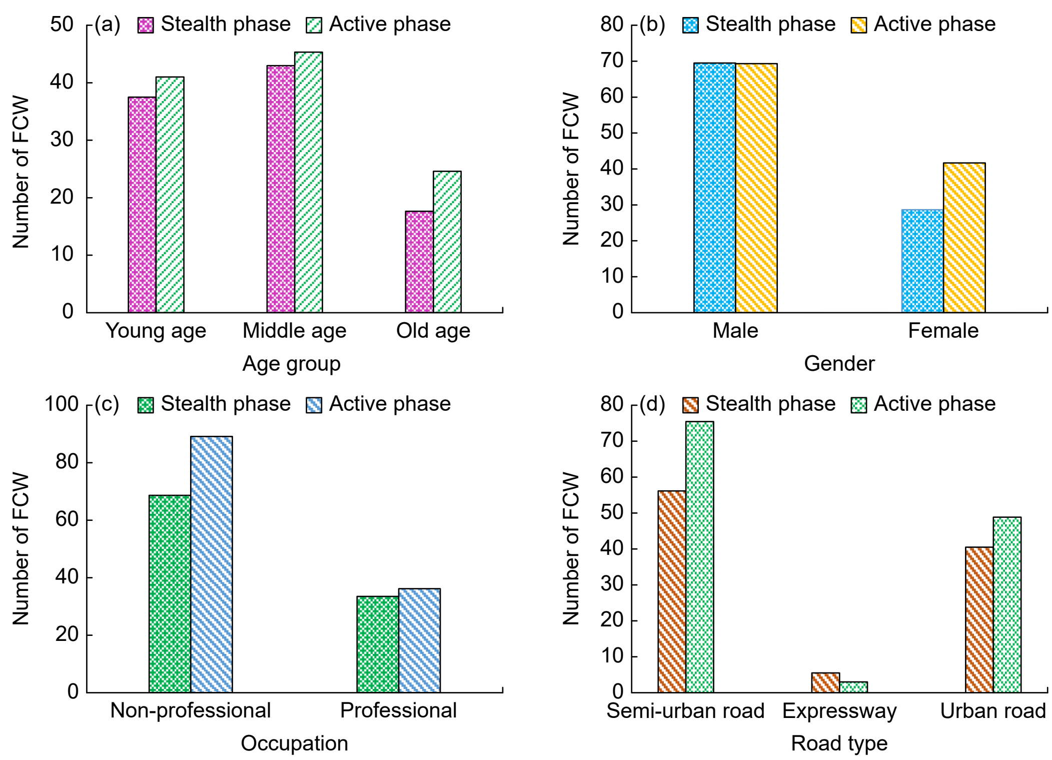

Fig. 5 Number of Forward Collision Warning (FCW) count (times): (a) age group, (b) gender, (c) occupation, and (d) road type.

0.404).

The difference in the number of FCW between the active and stealth phases for other independent variables was not statistically significant: male and female ($t(18) = 0.015, p = 0.988$ and $t(9) = -2.257, p = 0.050$), occupation ($t(9) = -0.350, p = 0.735$, and $t(18) = -0.921, p = 0.369$), young-age group, and middle-age group ($t(10) = -0.484, p = 0.639$ and $t(11) = -0.221, p = 0.829$), and the old-age group ($t(5) = -1.656$, $p = 0.159$). The independent variables of FCW (i.e., age group ($p > 0.114$), gender ($p > 0.114$), and occupation ($p > 0.114$) were

Table 6 Normality test results for FCW

Dependent variable: FCW		
Independent variable	Shapiro–Wallis's test, *p*-value	
	Stealth phase	Active phase
Young age	0.342	0.909
Middle age	0.456	0.499
Old age	0.313	0.845
Male	0.789	0.504
Female	0.514	0.887
Professional	0.164	0.624
Non-professional	0.725	0.251
Semi-urban road	0.127	0.188
Expressway	0.01[a]	0.01[a]
Urban road	0.02[a]	0.03[a]

Note: [a] $p < 0.05$.

normal based on the Shapiro–Wilk normality test. Hence, one-way ANOVA was performed for independent variables in the active phase (Table 5). However, road type ($p > 0.114$) was non-normal, and therefore, the Kruskal–Wallis test was used. The difference between the FCW on road types was statistically significant using the Kruskal–Wallis H test ($H(2) = 47.33$, $p = 0.001$). The one-way ANOVA test showed the difference in the means of FCW was not statistically significant for age ($F(2,26) = 0.051, p = 0.950$), gender ($F(1,27) = 0.304, p = 0.586$), and occupation ($F(1,27) = 0.116, p = 0.736$).

5.3 Effects of age group, gender, and driver professionalism on the acceptance of ADAS

For questionnaires, the reliability coefficients of Cronbach's alpha values for the FCW, LDW, and TSRW were 0.928, 0.905, and 0.648, respectively. As a result, the reliability of subjective scores from participants for FCW, LDW, and TSRW for user acceptance is adequate (Son et al., 2015; Van Der Laan et al., 1997). The mean scores of the user acceptance model for FCW, LDW, and TSRW were calculated using Eq. (4) (Table 7). The independent variables of TSRW (i.e., age group ($p > 0.935$) gender ($p > 0.919$), and occupation ($p > 0.809$)) were usually distributed based on the results of the normality test (Shapiro–Wilk test). Later, the parametric tests (one-way ANOVA and independent sample t-test) were performed to check the statistically significant difference among age groups, gender, and occupation in the user acceptance of TSRW. The user acceptance and statistical significance results for the FCW, and LDW among age groups, gender, and occupation are presented in Table 7. The statistical results showed the difference in the mean acceptance scores for various age groups was statistically significant ($p < 0.018$). The mean acceptance score of the old age group ($M = 93.33, SD = 3.53$) was significantly greater compared to the middle age group ($M = 88.11, SD = 7.27$) and young age group ($M = 84.29, SD = 4.91$). However, the mean acceptance scores for TSRW among gender ($p > 0.621$) and occupation ($p > 0.941$) were insignificant.

The independent variables of FCW (i.e., age group ($p < 0.001$), gender ($p < 0.01$), and occupation ($p < 0.001$)) were non-normal based on the Shapiro–Wilk normality test. Hence, the non-parametric tests (Kruskal–Wallis test for age group and Manny–Whitney U test for gender and occupation) were performed. The difference in the mean acceptance scores for FCW across all age groups was not statistically significant ($p > 0.249$), gender ($p > 0.271$), and occupation ($p > 0.604$). However, the mean acceptance score of the old age group ($M = 89.71$, $SD = 2.99$) was higher than that of the middle age group ($M = 86.68, SD = 16.62$) and young age group ($M = 83.47, SD = 10.17$). Male participants ($M = 88.97, SD = 6.86$) showed higher mean acceptance scores than female participants ($M = 80.65$, $SD = 18.16$), and professional drivers ($M = 86.98, SD = 8.09$) showed slightly higher mean acceptance score than non-professional drivers ($M = 85.71, SD = 14.02$).

The independent variables of LDW were normal based on the Shapiro–Wilk test (i.e., age group ($p > 0.834$) and gender ($p > 0.576$)), and the parametric tests were conducted (one-way ANOVA test for age group and independent sample t-test for gender). In contrast, the occupation data were non-normal based on the Manny–Whitney U test ($p < 0.044$). In the case of LDW, the difference in the mean acceptance scores between males and

Table 7 User acceptance results for FCW, LDW, and TSRW

Independent variable	FCW		*p*-value	LDW		*p*-value	TSRW		*p*-value
	M[a]	SD[a]		M	SD		M	SD	
Young age	83.47	10.17		83.01	9.45		84.29	4.91	
Middle age	86.68	16.62	0.249	85.76	12.85	0.159	88.11	7.27	**0.018**[b]
Old age	89.71	2.99		93.34	3.45		93.33	3.53	
Male	88.97	6.86	0.271	89.43	7.93	**0.026**[b]	88.19	7.09	0.621
Female	80.65	18.16		80.31	12.97		86.89	5.66	
Professional	86.98	8.09	0.604	88.06	8.98	0.621	87.60	8.32	0.941
Non-professional	85.71	14.02		85.48	11.48		87.80	5.86	

Note: [a] M-Mean and SD-Standard deviation. [b] $p < 0.05$.

females was statistically significant ($p < 0.026$). Male participants showed significantly greater mean acceptance scores ($M = 89.43, SD = 7.93$) than female participants ($M = 80.31, SD = 12.97$). However, the mean acceptance scores for LDW among age groups ($p > 0.159$) and occupations ($p > 0.621$) were insignificant.

6 Discussion

This study explored ADAS's influence on driving performance and driver characteristics. Previous studies showed that the LDW feature of ADAS provided lateral support and was beneficial in reducing the lateral offset/lane deviation and number of lane departures (Sayer et al., 2011; Son et al., 2015). From the perspective of age and gender, male drivers showed more improvement in their lateral behavior than female drivers (Son et al., 2015). The difference in the LDW across different age groups was not statistically significant (Son et al., 2015). The number of LDW was higher on highways than that on urban and rural roads (Lyu et al., 2019; Son et al., 2015). The findings of this study are consistent with the abovementioned studies in terms of the ADAS effects on driving performance, age, gender, and road environment.

This study showed no significant difference in FCW when provided with/without longitudinal support. The effect was consistent across different age groups, genders, occupations, and road types. Also, the number of FCW was higher in the active phase than that in the stealth phase, but the difference was marginal across the independent variables. The results are similar to Son et al. (2015) and Yang et al. (2018). The FCW seemed to have no measurable impact on driving behavior, and the reason could be high-speed traffic situations leading to more FCWs with no significant difference in the stealth phase and active phase (Li et al., 2015).

This study's results revealed that gender significantly influenced LDW acceptance. Male drivers showed higher acceptance scores than female drivers. In contrast, among different age groups and occupations, no significant difference was observed in the system's acceptance. However, the older age group drivers were found to be more likely to accept the LDW, followed by middle and young driver groups. This study's findings agree with the results reported by Stevens (2012); older-age drivers rated the system higher than middle- and young-age drivers. Similarly, Son et al. (2015) stated that the middle-age drivers resulted in higher acceptance scores than younger drivers. In addition, compared to young-age drivers, older drivers showed a more favorable attitude toward the usefulness of advanced driver assistance systems (Viborg, 1999).

The findings showed that the number of LDW differs significantly between the stealth and active phases. This implies that drivers accepted ADAS and perceived it as positively influencing their driving performance. In addition, the FCW effect was found to be less significant than that of LDW. Therefore, the potential reason for this inconsistency is that different driving behaviours influence ADAS effectiveness and acceptance of forward collision and lane departure warnings.

According to Gaspar et al. (2016), undistracted drivers typically reacted by steering and braking, whereas distracted drivers predominantly reacted one of two ways: steering then braking or braking exclusively. Examining steering responses indicates two types of drivers: those who respond early and those who respond late. Late responses were associated with a higher degree of uncertainty in lane departures, and the findings were consistent across both groups. Furthermore, they found that drivers performed different manoeuvres to prevent the inevitable hazard depending on the perception time of the warning. The perception time for forward collision and lane departure warnings in this study were different and were based on the device's triggering algorithms. This indicates that the algorithm's level of sensitivity impacts ADAS effectiveness.

Previous studies did not explore the effects of non-professional/professional drivers on the acceptance of ADAS features, namely, LDW and FCW. The results of this study showed that the difference in the acceptance of FCW and LDW between professional and non-professional drivers was not significant. However, for FCW and LDW systems, professional drivers have a higher acceptance score than non-professional drivers.

7 Concluding remarks

This study has presented an operational field test to evaluate ADAS effectiveness by comparing the number of LDW and FCW in the stealth and active phases. Also, the effect of age, gender, and occupation on ADAS effectiveness was evaluated. A questionnaire was conducted to examine the subjective scores of drivers of different age groups, genders, and occupations for acceptance of the system. The data for the counts of LDW and FCW were checked for normality, and parametric/non-parametric tests were performed to determine the statistical significance for ADAS features between stealth and active phases. Based on this study, the following comments are offered:

1) The number of lane departures decreased when the drivers were provided with lateral support. Male and non-professional drivers showed significant improvement in lane departure compared to female and professional drivers when provided with lateral support. Furthermore, the drivers of the older-aged group showed a lesser number of lane departures than the young- and middle-aged groups in both stealth and active phases, inferring that the older drivers drive safely and cautiously.

2) The number of FCW was insignificant across ages, genders, occupations, and road environments. This infers that FCW was ineffective in influencing the longitudinal driving behavior as each driver maintained a comfortable headway based on their driving style, irrespective of the warnings provided.

3) Overall, the drivers of different ages, genders, and occupations showed positive attitudes toward ADAS technology acceptance. Drivers ranked and showed higher acceptance scores for TSRW, followed by LDW and FCW. For all three assistance features, the drivers of the older age group showed more likely acceptance.

This study has a few limitations. Specifically, professional female drivers and the cultural background of the drivers' population were not considered. Future research may address the gender ratio (including professional and non-professional drivers) and the cultural background of the driver population in heterogeneous traffic conditions. In addition, some interactions of driver-road characteristics on ADAS performance were not considered in this study and could be explored in the future. Finally, in this study, drivers were exposed to ADAS for a short time, and the future research may expose the drivers to longer time to evaluate the reliability of the presented results.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adell, E., Várhelyi, A., Fontana, M. D., 2011. The effects of a driver assistance system for safe speed and safe distance–A real-life field study. Transp Res C Emerg Technol, 19, 145−155.

Alkim, T. P., Bootsma, G., Hoogendoorn, S. P., 2007. Field operational test "the assisted driver". In: IEEE Intelligent Vehicles Symposium. June 13-15, 2007, Istanbul, Turkey. IEEE, 1198−1203.

Atombo, C., Wu, C., Zhong, M., Zhang, H., 2016. Investigating the motivational factors influencing drivers intentions to unsafe driving behaviours: Speeding and overtaking violations. Transp Res F Traffic Psychol Behav, 43, 104−121.

Ben-Yaacov, A., Maltz, M., Shinar, D., 2002. Effects of an in-vehicle collision avoidance warning system on short- and long-term driving performance. Hum Factors, 44, 335−342.

Birrell, S. A., Fowkes, M., Jennings, P. A., 2014. Effect of using an in-vehicle smart driving aid on real-world driver performance. IEEE Trans Intell Transp Syst, 15, 1801−1810.

Blaschke, C., Breyer, F., Färber, B., Freyer, J., Limbacher, R., 2009. Driver distraction based lane-keeping assistance. Transp Res F Traffic Psychol Behav, 12, 288−299.

Chen, H., Cao, L., Logan, D. B., 2011. Investigation into the effect of an intersection crash warning system on driving performance in a simulator. Traffic Inj Prev, 12, 529−537.

Davis, F. D., Bagozzi, R. P., Warshaw, P. R., 1989. User acceptance of computer technology: A comparison of two theoretical models. Manag Sci, 35, 982−1003.

Feng, Z., Lei, Y., Liu, H., Kumfer, W. J., Zhang, W., Wang, K., *et al.*, 2016. Driving anger in China: A case study on professional drivers. Transp Res F Traffic Psychol Behav, 42, 255−266.

Gaspar, J., Brown, T., Schwarz, C., Chrysler, S., Gunaratne, P., 2016. Driver behavior in forward collision and lane departure scenarios. In: SAE Technical Paper Series. 400 Commonwealth Drive, No. 2016-01-1455.

Green, M., Senders, J., 2004. Human error in road accidents. Visual Expert. https://www.visualexpert.com/Resources/roadaccidents.html

Knipling, R. R., Wang, J. S., Yin, H. M., 1993. Rear-end Crashes: Problem Size Assessment and Statistical Description. Technical Report, No. HS-807 994.

Kusano, K. D., Chen, R., Montgomery, J., Gabler, H. C., 2015. Population distributions of time to collision at brake application during car following from naturalistic driving data. J Saf Res, 54, 95.e29−104.

LeBlanc, D. J., Bao, S., Sayer, J. R., Bogard, S., 2013. Longitudinal driving behavior with integrated crash-warning system. Transport Res Rec, 2365, 17−21.

Li, G., Cheng, B., 2015. Field operational test of advanced driver assistance systems in typical Chinese Road conditions: The influence of driver gender, age and aggression. Int J Automot Technol, 16, 739−750.

Lim, K. L., Whitehead, J., Jia, D., Zheng, Z., 2021. State of data platforms for connected vehicles and infrastructures. Commun Transport Res, 1, 100013.

Lyu, N., Deng, C., Xie, L., Wu, C., Duan, Z., 2019. A field operational test in China: Exploring the effect of an advanced driver assistance system on driving performance and braking behavior. Transp Res F Traffic Psychol Behav, 65, 730−747.

Malaghan, V., Pawar, D. S., 2022. A short-term naturalistic driving study onD predicting comfort thresholds for horizontal curves on two-lane rural highways. J Transp Eng A Syst, 148, 04022045.

Malaghan, V., Pawar, D. S., Dia, H., 2020. Modeling operating speed using continuous speed profiles on two-lane rural highways in India. J Transp Eng A Syst, 146, 04020124.

Maltz, M., Shinar, D., 2004. Imperfect in-vehicle collision avoidance warning systems can aid drivers. Hum Factors, 46, 357−366.

Montgomery, J., Kusano, K. D., Gabler, H. C., 2014. Age and gender differences in time to collision at braking from the 100-car naturalistic driving study. Traffic Inj Prev, 15, S15−S20.

Ministry of Road Transport and Highways (MORTH), 2019. Road accidents in India 2019. New Delhi, India: MORTH.

Mosedale, J., Purdy, A., Clarkson, E., 2004. Contributory factors to road accidents. https://trid.trb.org/view/864416

Najm, W., Stearns, M., Howarth, H., Koopmann, J., Hitz, J. S., 2006. Evaluation of an automotive rear-end collision avoidance system (No. FHWA-JPO-06-055). Department of Transportation, National Highway Traffic Safety Administration, Washington, DC, USA.

Oxley, P. R., Mitchell, C. G. B., 1995. Final report on elderly and disabled drivers' information telematics (Project EDDIT). Commission of the European Communities DG XIII, R & D Programme Telematics Systems in the Area of Transport (DRIVE II), Brussels, Belgium.

Pan, C., Xu, J., Fu, J., 2021. Effect of gender and personality characteristics on the speed tendency based on advanced driving assistance system (ADAS) evaluation. J Intell Connect Veh, 4, 28−37.

Rezaei, M., Yazdani, M., Jafari, M., Saadati, M., 2021. Gender differences in the use of ADAS technologies: A systematic review. Transp Res F Traffic Psychol Behav, 78, 1−15.

Saito, Y., Itoh, M., Inagaki, T., 2016. Driver assistance system with a dual control scheme: Effectiveness of identifying driver drowsiness and preventing lane departure accidents. IEEE Trans Hum Mach Syst, 46, 660−671.

Sayer, J. R., Bogard, S. E., Buonarosa, M. L., LeBlanc, D. J., Funkhouser, D. S., Bao, S., *et al.*, 2011. Integrated vehicle-based safety systems light-vehicle field operational test, key findings report. The University of Michigan Transportation Research Institute, Ann Arbor, Michigan, USA.

Scott, J. J., Gray, R., 2008. A comparison of tactile, visual, and auditory warnings for rear-end collision prevention in simulated driving. Hum Factors, 50, 264−275.

Shinar, D., Schechtman, E., 2002. Headway feedback improves intervehicular distance: A field study. Hum Factors, 44, 474−481.

Son, J., Park, M., Park, B. B., 2015. The effect of age, gender and roadway environment on the acceptance and effectiveness of Advanced Driver Assistance Systems. Transp Res F Traffic Psychol Behav, 31, 12−24.

Stevens, S., 2012. The relationship between driver acceptance and system effectiveness in car-based collision warning systems: Evidence of an overreliance effect in older drivers? SAE Int J Passeng Cars-Electron Electr Syst, 5, 114−124.

Sullivan, J. M., Tsimhoni, O., Bogard, S., 2008. Warning reliability and driver performance in naturalistic driving. Hum Factors, 50, 845−852.

Taieb-Maimon, M., Shinar, D., 2001. Minimum and comfortable driving headways: Reality versus perception. Hum Factors, 43, 159−172.

Van Der Laan, J. D., Heino, A., De Waard, D., 1997. A simple procedure for the assessment of acceptance of advanced transport telematics. Transp Res C Emerg Technol, 5, 1−10.

Venkatesh, V., Morris, M. G., 2000. Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. MIS Q, 24, 115–139.

Viborg, N., 1999. Older and younger drivers attitudes toward in-car ITS. Bulletin, 181, 3000.

Wang, J., Zhang, L., Zhang, D., Li, K., 2013. An adaptive longitudinal driving assistance system based on driver characteristics. IEEE Trans Intell Transp Syst, 14, 1–12.

World Health Organization (WHO), 2018. Global status report on road safety. Geneva: World Health Organization.

Xu, Y., Ye, Z., Wang, C., 2021. Modeling commercial vehicle drivers' acceptance of advanced driving assistance system (ADAS). J Intell Connect Veh, 4, 125–135.

Yan, X., Wang, J., Wu, J., 2016. Effect of In-vehicle audio warning system on driver's speed control performance in transition zones from rural areas to urban areas. Int J Environ Res Public Health, 13, 634.

Yang, X., Kim, J. H., 2018. Acceptance and Effectiveness of Collision Avoidance System in Public Transportation. In: International Conference of Design, User Experience, and Usability, 424–434.

Zhang, H., Wu, C., Yan, X., Qiu, T. Z., 2016. The effect of fatigue driving on car following behavior. Transp Res F Traffic Psychol Behav, 43, 80–89.

Kasi Nayana Badweeti is pursuing a doctoral program in Transportation Systems Engineering in the Department of Civil Engineering at the Indian Institute of Technology (IIT), Hyderabad (IITH). Prior to beginning his doctoral studies, he received his M.S. degree in Transportation Engineering from the National Institute of Technology (NIT), Uttarakhand in 2021 and his B.S. degree in Civil Engineering from JNTU Kakinada University in 2017. He worked as a Junior Research Assistant Fellow (JRAF) on Advanced Driving Assistance Systems (ADAS) at the NM-ICPS Technology Innovation Hub on Autonomous Navigation and Data Acquisition Systems (TiHAN)-Indian Institute of Technology Hyderabad for a period of eight months. His research interests are Pedestrian Safety and ADAS.

Vinayak Devendra Malaghan is an Assistant Professor in Transportation Engineering in the Department of Civil Engineering, Pandit Deendayal Energy University (PDEU), Gandhinagar. Prior to joining PDEU in 2022, Vinayak was a Postdoctoral fellow in IITH from 2021. He joined Transportation Systems Engineering at the Indian Institute of Technology Hyderabad in 2017 as a Ph.D. student. He later converted to a joint doctoral program between the Indian Institute of Technology Hyderabad and Swinburne University of Technology. Prior to his doctoral studies, he obtained his M.S. degree in Transportation Engineering from Birla Institute of Technology and Science, Pilani, Pilani campus, and his B.S. degree in Civil Engineering from Visveshvaraya Technological University. His research predominantly focuses on Naturalistic Driving Studies (NDS), Highway Geometric Design, Modelling Driver Behaviour, Advanced Driving Assistance Systems, and Emerging Technologies with emphasis on Road Safety. He was awarded with Research Excellence Award for having three journal publications from IITH in 2021. His research articles have appeared in *Journal of Transportation Engineering, Part A: Systems*, *Journal of Advanced Transportation*, and *Transportation Letters*.

Digvijay Sampatrao Pawar is an Associate Professor in Transportation Systems Engineering in the Department of Civil Engineering, IITH. Prior to joining IITH in 2016, Digvijay was a senior research associate in IIT Bombay from 2015. He received his M.Tech and Ph.D. degrees in Transportation Systems Engineering from IIT Bombay, India, in 2015. His research predominantly focuses on traffic operations and safety, human factors and highway geometric design with emphasis on Intelligent Transportation Systems (ITS), Advanced Driving Assistance Systems and Naturalistic Driving Studies (NDS). His contributions in developing Intelligent Transportation Systems (ITS) for improving driver and pedestrian safety at uncontrolled intersections are noteworthy. He has played a key role in designing and implementing several ITS technologies and establishing testbed at IITH for studies on autonomous vehicle systems. His research articles have appeared in *Transportation Research Part C*, *Accident Analysis & Prevention*, *Transportation Research Part F*, *Transportation Research Record*, *Journal of Transportation Engineering, Part A: Systems*, *Journal of Safety Research*, *Safety Science*, *Journal of Advanced Transportation*, *IATSS Research*, *Transportation Letters*, etc.

Said Easa is currently the Director of Quality Assurance, FEAS, and Professor in Transportation Engineering in the Department of Civil Engineering, Toronto Metropolitan University Toronto, Ontario, Canada. He received his M. Eng. degree in Transportation Engineering from McMaster University, Canada, in 1976 and then he received his Ph.D. degree in Transportation Engineering from University of California at Berkeley, USA, in 1981. He completed his B.Sc. degree in Civil Engineering from Cairo University in 1972. His research primarily focuses on Road Safety and Geometric design, Human Factors and Ergonomics in Transportation, Traffic Operations and Management, Intelligent Transportation Systems, Geomatics Engineering Highway Drainage, and Highway Materials and Education. He has Society Member-ship for PEMAC Asset Management Association of Canada Canadian Society for Civil Engineering (CSCE) and American Society of Civil Engineers (ASCE). He was awarded IAAM Medal for 2018 from the International Association for Advanced Materials for "notable and outstanding research in the Advanced Materials Science & Technology". He has also got Best Paper Award from *Journal of Transportation Engineering: Part A: Systems*, American Society of Civil Engineers, for paper entitled, "Innovative roadside design curve of lateral clearance: roadway simple horizontal curves", by You, Q. and Easa, S., 2018. He has anAward of Academic Merit from Transportation Association of Canada "in recognition of his long-term contribution to the advancement of the academic field and to the development of tomorrow's transportation leaders", in 2010. He received Frank M. master's Transportation Engineering Award, from American Society of Civil Engineers in recognition of "outstanding contributions to ASCE and the transportation profession throughout his career at national and local levels both professionally and as an academician", in 2001. He played a key role in the development of road safety research lab at Toronto Metropolitan University Toronto, Ontario, Canada. His research articles appeared in *Transportation Research Part C*, *Accident Analysis & Prevention*; *Transportation Research Part F*, *Transportation Research Record*, *Journal of Transportation Engineering, Part A: Systems*, *Journal of Safety Research*, *Safety Science*, *Journal of Advanced Transportation*, *IATSS Research*, *Transportation research part A*, *Journal of Surveying Engineering*, *Transportation Research Part B*, *Construction and Building Materials*, *Journal of Intelligent and Connected Vehicles*, *Computer-Aided Civil and Infrastructure Engineering*, *Transportation Letters*, etc. He is currently working on an in-vehicle collision warning system that takes into account the specific design of the vehicle and the driver's unique characteristics.