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Comparing user acceptance of integrated and retrofit driver assistance systems – A real-traffic study

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The path towards a transport system with fully automated vehicles entails a transitioning period where manual and automated vehicles will coexist in traffic for many years. To realize the many suggested benefits of automated transport, such as lower emissions and improved safety, there is a need for more knowledge concerning the user experience of both manual and automated systems. This study measures and compares driver acceptance of an integrated driver assistance system and a retrofit system based on geofence technology. We focus on two use cases: low-emission zones and school zones. The integrated system was tested by 43 participants driving on a pre-defined test route, using an assisting and visual system with HMI integrated in the dashboard. The retrofit system involved 42 participants and was implemented with an on-board unit with a visual system, using an external screen as HMI. Participants tested the system for eight weeks, including two weeks in black mode. Participants in both trials were experienced drivers and likely to be “early adopters”, and the acceptance of the systems was evaluated through a survey. Although the research design for the two driver assistance systems was not identical, similar questions were given, making it possible to compare driver acceptance and workload. The analysis shows overall high acceptance among the users for both trials. However, the results show that the integrated system had greater levels of satisfaction, usefulness and usability for low emission zones, as well as greater levels of satisfaction and usefulness for school zones. We also conclude that retrofit systems must improve HMI satisfaction to constitute a viable option for transport authorities when integrating novel ITS technologies.

1. Introduction

New vehicle technology, particularly autonomous vehicles (AVs), promises a range of benefits, including better safety, lower emissions, support for improved traffic management, increased driving comfort and higher mobility (Fagnant & Kockelman, 2015; Taeihagh & Lim, 2019). Combined with increasingly more sophisticated Cooperative Intelligent Transport Systems (C-ITS), transport authorities around the world have high expectations about the use and benefit of this emerging technology. While tech companies predicted self-driving cars on the road by 2020, the development has taken longer than expected (NY Times, 2020), and many of the technologies involved are not yet mature. Integrating the automatic systems safely and fairly into society will require considerable time and effort and will begin with a transitioning phase during which

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automated and manual vehicles will coexist in traffic. In Norway, 40 percent of all registered cars are 12 years or older (SSB.no, , 2020). Similarly, the average car in the US is 11,8 years old (USA Today, 2019). This transitioning phase with coexistence of automated and manual systems is therefore likely to stretch over many years and entail multiple challenges, which remains scarcely addressed in the scientific literature.

A prerequisite for a successful coexistence of manual and automatic systems in traffic is developing retrofit system for older cars that can provide the same, or equivalent, functionality as integrated services for Intelligent Transport Systems (ITS). As car manufacturing companies typically focus on developing innovative solutions for ITS services integrated in new vehicles, manufacturing retrofit systems for older vehicles can emerge as a new operative market. Retrofit systems also enables transport authorities to introduce new technologies as tools for increasing safety, efficiency and reducing emissions from the transport sector, despite that not all vehicles are cooperative and connected. Successful development of retrofit systems would enable vehicles at different self-driving levels[1] to have similar functionality, and among the key challenges are communicating traffic rules through digital infrastructure to both manual cars and AVs. Digital traffic rules can be communicated to the AVs or the drivers using geofencing technology. This highlights the importance of designing retrofit system that achieves high levels of acceptance from the users.

We explore two use cases where we investigate user acceptance: Low-Emission Zones (LEZs) and School Zones (SZs). The main aim of LEZs is to improve local air quality in city centers. LEZ has been implemented in several European cities as a measure to reduce air pollution to meet the European Union Air Quality Standards[2]. The European Union regulates emissions of GHGs from most vehicle types through European emission standards and acceptable limit for exhaust emissions of new vehicles sold in the European Union. The "Euro" standards for vehicles are under continuous development, and the current standard is referred to as Euro 6 (European Commission, 2021). This political process at the EU level represents the backdrop for several implementations of LEZ, such as in London[3], Brussels[4] and Berlin[5]. The existing LEZ are primarily implemented using a system based on cameras with Automatic Number Plate Reading (ANPR) technology or stickers in vehicles. For SZs, the main aim is to secure safe speed around schools. SZs is a relatively common solution for protecting vulnerable pedestrians around schools. Here, the most common implementation is traffic signs, although alternative approaches has been explored as well, such as dynamic speed display signs (Rahman, Abdel-Aty, Lee, & Rahman, 2019). When geofence is used for communicating digital traffic rules, this would enable less use of physical infrastructure, which could reduce the cost of implementing such tools for traffic regulation.

Our main aim in this study is to measure the drivers' acceptance levels after using the systems for the two use cases LEZ and SZ, and compare acceptance levels for integrated and retrofit solutions. Collecting experiences from individuals who have physical experience with on-road trials is important for successful implementation (Nordhoff, Louw, Innamaa et al., 2020). Acceptance levels among drivers are important because although driver assistance systems (DASs) are intended to help drivers, poor design and functionality can distract and irritate drivers (Biondi, Strayer, Rossi, Gastaldi, & Mulatti, 2017). DASs, whether retrofit or integrated, must therefore be designed so that they do not compromise safety nor lower the acceptance among users. Low user acceptance can lead to drivers not using or even disabling the system, thereby reducing the predicted benefits (Adell, 2010). The present study reports results from two questionnaire studies, one focusing on retrofitted system (n = 42) and one focusing on integrated system (n = 43). Our study measures acceptance using four different indicators: satisfaction, usefulness, usability, and workload. While many recent studies focus on the acceptance of automated vehicles (e.g., Bernhard, Oberfeld, Hoffmann, Weismüller, & Hecht, 2020; Nordhoff, de Winter, Madigan et al., 2018), we argue that studying such specific use cases is also relevant and valuable, as they are technologically feasible and could therefore be implemented by transport authorities already within a near future.

The remainder of the article is structured as follows. In section 2 we present related literature for both use cases, while in section 3 we present our methodology, including data test setup and data collection, survey design and data analysis methods. In section 4 we present our results, before providing discussions and conclusions in section 5 and 6, respectively.

2. Previous studies on acceptance

Following the CityMobil projects (e.g., Madigan, Louw, Wilbrink, Schieben, & Merat, 2017), several studies focused on the acceptance levels of automated public transport (e.g. Bernhard et al., 2020; Nordhoff et al., 2018). However, these studies are less relevant because they evaluate future public transport services, whereas we study DASs in private vehicles. Other studies have investigated driver acceptance of various levels of automation (e.g., Hartwich, Beggiato, & Krems, 2018; Strauch et al., 2019), or other use cases such as adaptive cruise control (e.g., Reagan, Cicchino, & Kidd, 2020; Beggiato, Pereira, Petzoldt, & Krems, 2015). While there exist a vast variety of studies focusing on the acceptance of DAS, we argue that the specific focus of our study, comparing acceptance levels of integrated and retrofit systems is a valuable addition to the research field. As a background we review the literature on acceptance of "speed management" and "eco-driving".

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[1] Following the Society of Automotive Engineers (SAE) levels, see https://www.sae.org/standards/content/j3016_201806/

[2] Notably EU's air quality directives 2008/50/EC and 2004/107/EC.

[3] Low Emission Zone - Transport for London (tfl.gov.uk)

[4] Low Emission Zone (lez.brussels)

[5] The Low-emission Zone / State of Berlin

There is no consensus on how to define acceptability of DAS and how it should be measured in questionnaires (Vlassenroot, Brookhuis, Marchau, & Witlox, 2010; Adell, 2010). However, Vlassenroot et al. define driver acceptance as "the reaction (beliefs and attitudes) of individuals, based on their behavioural reactions after the introduction of a measure or device" (Vlassenroot et al., 2010: 169).

2.1. Speed management systems

The acceptance of speed management systems has been studied since the 1980 s, and many different systems have been developed and tested. These include both visual, auditory, and haptic support systems. Most predominant in the literature on acceptance are studies on Intelligent Speed Adaptation (ISA). Both ISA and our SZ use cases are varieties of speed management.

ISA systems can be based on many different technologies, all aimed at helping the driver to manage the speed. Studies have found a high potential for ISA to increase traffic safety, where one study suggests that a simple mandatory ISA system would reduce injury accidents by 20% and fatal accidents by 37% (Carsten & Tate, 2005). Adell, Várhelyi, and Hjälmdahl (2008) investigated both auditory and haptic systems in their ISA study. Twenty test drivers drove for a month, and the results show that both systems helped to reduce the mean speed. Both systems were also found to have high levels of acceptance, with a preference for the auditory system. The study also found some country-dependent effects on drivers perceived workload when using the auditory system. Long-term use of the haptic system has been investigated in a study by Adell and Várhely (2008), where 281 test drivers used the system for periods ranging between six months and a year. The test drivers showed high levels of acceptance, but the willingness to pay for it was lower than for other DASs studied elsewhere. Furthermore, while the drivers found the haptic system useful for increasing performance and safety, they also reported that it added emotional pressure on them.

In Vlassenroot, Broekx, De Mol et al. (2007), 34 cars and three buses were equipped with a haptic system. Drivers reported that the system helped them respect speed limits, increased driving comfort, and some of them used the system voluntarily on highways and outside the urban areas studied. Fifteen drivers also chose to keep the ISA-system installed at the end of the test period. However, the study found less acceptance for the 30 km/h speed limit, despite that survey results indicated that most drivers understood its benefits with regard to road safety. Vlassenroot also noted changes in acceptance levels for the haptic system throughout the trial period, especially among professional drivers, which increased their acceptance. Several professional drivers also decided to keep the system in their vehicle after the test-period, indicating high acceptance levels.

In a follow-up study Vlassenroot et al. (2010) focused on redeveloping the concept of acceptance of ISA. The goal of the study was to describe, conceptualize and test relevant indicators that could influence the acceptability and acceptance of ISA. In their predefined categories based on previous research, they made a distinction between general indicators related to the context awareness of the system (e.g., background factors, attitudes to driving behavior and speeding/traffic safety, information about the problem, responsibility awareness) and system-specific indicators directly related to the characteristics of the device (e.g., perceived efficiency, perceived effectiveness, perceived usability, satisfaction).

Adell (2010) and Adell, Várhelyi, and Dalla Fontana (2011) looked at the effects of a driver assistance system for safe speed and safe distance. Twenty test drivers drove a 50 km test route twice. The system had positive effects, such as shorter reaction times and fewer alarm situations, but also negative effects, such as increased number of center line crossings. The overall acceptance levels were high in the survey. No statistically significant difference was found in speed behavior of the driver, nor in driver workload (Adell et al., 2011). No evidence for increased workload was found in Young, Regan, Triggs, Jontof-Hutter, and Newstead (2010) either, which investigated differences between age groups, but they concluded that the ISA system was more effective for experienced drivers.

2.2. Eco-driving systems

There is abounding literature investigating the various aspects of eco-driving. Studies include technical measurement of compliance with the system (Fors, Kircher, & Ahlström, 2015), evaluations of different HMI (Human Machine Interface) solutions (Dahlinger, Tiefenbeck, Ryder et al., 2018 on numerical vs. symbolic feedback; Brouwer, Stuiver, Hof et al., 2015 on personalized feedback; Fors et al., 2015 on continuous vs. intermittent information), fuel-saving potential (Staubach, Schebitz, Köster, & Kuck, 2014), glance behavior (Li, Vaezipour, Rakotonirainy, & Demmel, 2019) and driver acceptance. Lately, eco-driving behavior among electric vehicle users have gained attention (e.g., Wang, Makino, Harmandayan, & Wu, 2020). The following subsections review the literature on acceptance related to the use cases of speed management and eco-driving, respectively. In this section, we summarize the studies that investigate driver acceptance.

Staubach et al. (2014) evaluate an eco-driving support system using a driving simulator with 30 participants. The system communicated with traffic lights through a haptic and visual feedback and gave recommendations to the test drivers concerning fuel-efficient gear shifting and acceleration/deceleration behavior. The acceptance of the system was high, but some test drivers reported that the system distracted them from driving, and others felt restricted by the system.

McIlroy, Stanton, and Godwin (2017) conducted a simulator study with 24 participants, testing a haptic system for encouraging fuel saving. Three time-to-event stimuli were provided, with four, eight respectively twelve seconds. Findings showed that the shortest timing had the worst performance and even reduced performance. The acceptance measures also showed that it was not well received. Conversely, medium/long time-to-event increased performance and were well received. These findings indicate that timing is important to achieve high acceptance levels.

Fors et al. (2015) investigated the difference between an eco-driving system with continuous information and a system that provided intermittent information and executed their experiment in a simulator with professional truck drivers. In general, the test drivers had positive attitudes towards the system, which presented visual, auditory, and haptic feedback, and they tended to comply with the advice given. Most of the test drivers preferred simple and clear information, but there were large differences regarding what type of information they found useful.

Vaezipour, Rakotonirainy, Haworth, and Delhomme (2018) studied different visual systems for eco-driving using a simulator with 40 participants. Findings indicated that all visual systems produced low levels of workload. Drivers also reported high levels of acceptance, regardless of which visual system was presented to the driver. For measuring acceptance, the authors used four different scales: perceived usability, ease of use, usefulness, and system satisfaction.

The findings regarding acceptance of eco-driving indicate an overall high acceptance among users, though negative aspects have been reported as well. For instance, Staubach et al. (2014) discovered feelings of distraction and restriction of the systems giving recommendations to participants concerning fuel-efficient gear shifting and acceleration/deceleration behaviour. Regarding the haptic system, short time-to event was not as well received as longer time-to-event (McIlroy et al., 2017).

3. Methods

In the trials the zones were communicated digitally using a technique called geofencing. By geofencing we refer to a positioning technique where spatial and temporal occurrences are detected using the real-time position of a mobile object (e.g., vehicles, containers, or people) and its position relative to a given geographical reference area, usually a zone represented by a virtual, often dynamic, perimeter. Intercepting the perimeter, or presence within the zone, is registered and processed by the geofencing system itself and by the in-vehicle equipment, or by both (Nait-Sidi-Moh, Bakhouya, Gaber, & Wack, 2013, 127). The digital zones contain traffic rules and information as attributes, communicated to vehicles and drivers on the road as an intelligent transport service.

We have focused our analysis on two use cases, LEZ and SZ, and compare the acceptance level for the retrofit system against the integrated system. One could, however, use the geofence technology on a vast variety of different use cases, including traffic rules which could be communicated digitally to the driver or the vehicle. Fig. 1 illustrates our approach, and highlights that this approach could be utilized for other use cases, referred to in the figure as "use case n". Hence, other use cases such as road works warnings, pedestrian warning, access restrictions, and so on could use the same approach as we do in our study and would allow us to gain more knowledge about how the acceptance levels of retrofit and integrated systems vary.

3.1. Description of use cases

Two use cases are investigated in this study: low-emission zones (LEZs) and school zones (SZs). The principle guiding the first use case, LEZ, is the aim to reduce emissions in city centers and urge drivers of plug-in hybrid vehicles (PEHVs) to prioritize electric mode within these zones. PHEVs have become a highly popular type of vehicle in Norway since PHEVs have reduced import fee on new vehicles, and this has sparked a discussion on whether tolling fees ought to be reduced based on distance driven on electricity. In the retrofit trial the drivers are informed about the upcoming LEZ and the drivers themselves control when to switch between gasoline and electric mode when the vehicle enters a LEZ. In the integrated trial the vehicle switches automatically from gasoline to electricity once the vehicle enters a geofenced LEZ, while the driver is informed about this in the dashboard.

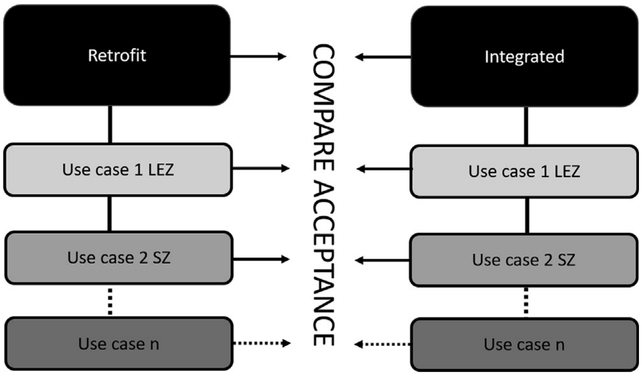


Fig. 1. Comparing acceptance across different use cases for retrofit and integrated systems.

The principle guiding the second use case is encouraging drivers to keep the speed limit within the SZs to increase traffic safety around schools. In the retrofit trial drivers are informed about the upcoming SZ, and themselves determine whether or how they will adjust their speed. In the integrated trial the vehicle automatically starts to lower the speed when entering the SZ, while the driver is informed about this is the dashboard. It is possible for the driver to override the system; hence the system can be characterized as assisting.

The main aim of this study is to explore the acceptance levels among the test drivers. However, an alternative approach is to review the behavior of the test drivers. Particularly interesting is the behavioral adjustment in the retrofit trial where test drivers drove for two weeks with an inactive system, referred to as *black mode period*, followed by a period with implemented feedback to the drivers. See next section or Arnesen, Seter, Tveit, and Bjerke (2021) for a detailed description of the two retrofit trials. In Dahl, Arnesen, and Seter (2020) and Arnesen et al. (2021), the behavioral adjustment to the LEZ were found to be significant. Hence, the test drivers decreased their emissions within the LEZ when compared to the black mode period. For the SZ use case, however, only a small indication towards a slight reduction in speed when entering the geofence zones was detected.

3.2. Description of the retrofit and integrated systems

3.2.1. Retrofit trial

In the retrofit trial, third party hardware was installed in the private cars (all PHEVs) of the test drivers. The hardware consisted of an external on-board unit (OBU) (Samsung Galaxy A10, with Android v9.0 operation system, 6.2 High-Definition screen), installed in the cars using a car air vent clip holder, connected to OBD-II dongle via Bluetooth. The software consisted of an application installed in the smartphone functioning as HMI for the two use cases. The retrofit trial lasted for eight weeks, during which the test drivers drove in black mode for two weeks and in active mode for six weeks. During the black mode period, the system collected information from all trips, but no feedback was provided to the driver through the screen. After two weeks, the display was activated, showing map-based information about LEZs and SZs, see Fig. 2. The

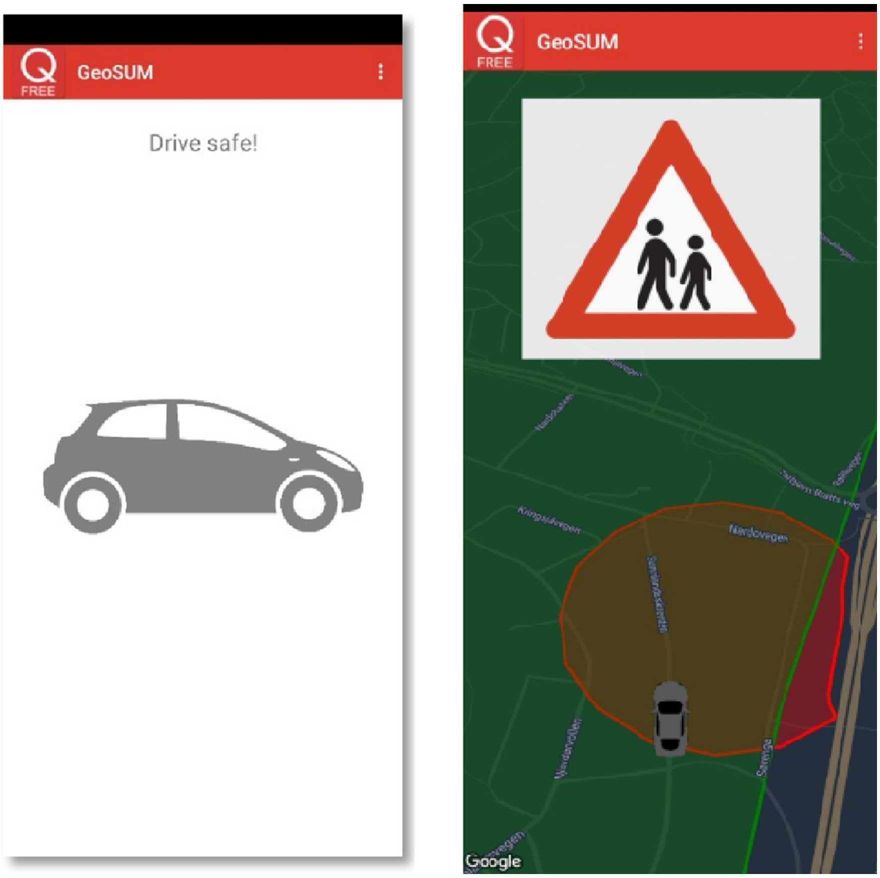


Fig. 2. Photo of the HMI, screen in black mode (left) and screen in active mode (right) showing LEZ in green and SZ in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

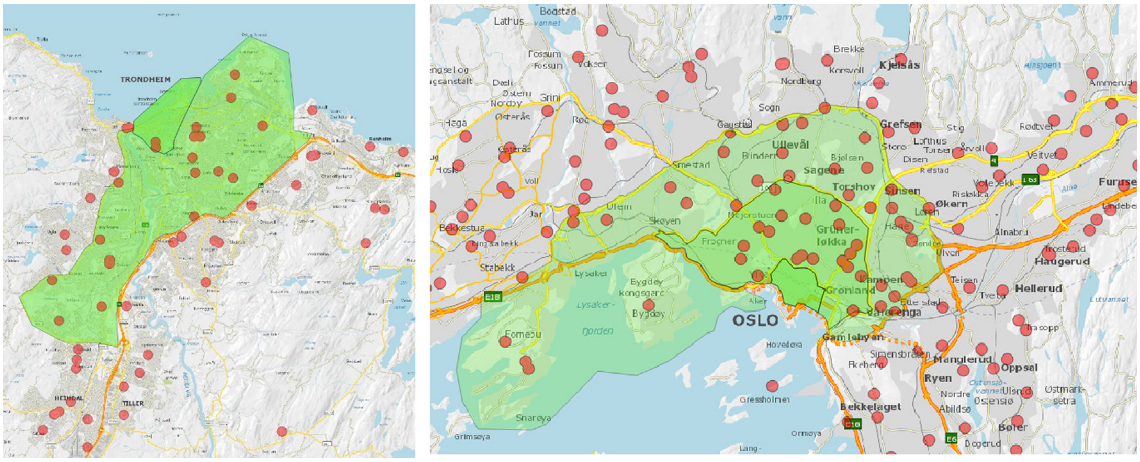


Fig. 3. Map showing school zones (red) and low emission zone (green) for the retrofit system in the city of Trondheim (left) and Oslo (right). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

display also showed information about taxes/reward for driving on fossil fuel and electricity respectively, based on hypothetical tax rules for LEZs. All test drivers had to sign an agreement and a self-declaration before installation.

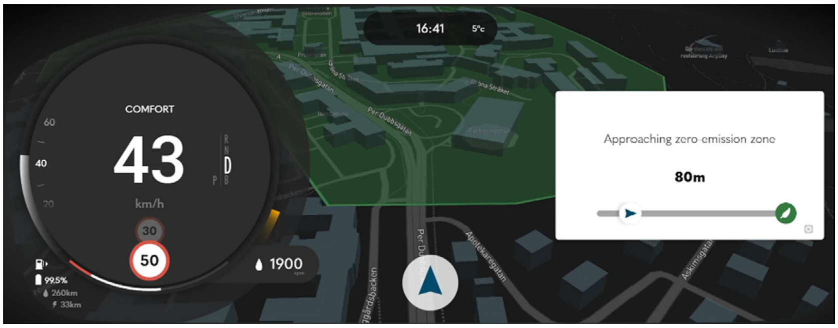
In the retrofit trial, the OBU obtained geofence zones from the cloud of the National Road Database in Norway. All schools in Trondheim and Oslo were identified, and each SZ was defined as a circle with a radius of 150 m around the school. Most roads in school surroundings have a speed limit of 30, 40 or 50 km/h. Roads with higher speed limits that passed through a defined SZ were excluded from the zone by cropping out the road area from the circle. Drivers were notified of an upcoming SZ via a warning sign, se Fig. 2. The LEZs were defined as the city centers of Trondheim and Oslo, as well as two adjacent LEZs in Trondheim and three in Oslo, where road user charges increased as drivers approached the city centers, see Fig. 3 and Dahl et al. (2020) for details. The drivers were informed of the prices driving within the LEZ through the HMI.

3.2.2. Integrated trial

This trial was performed with one single vehicle provided by Volvo Cars, a PHEV Volvo V90 T8 petrol hybrid car. The car had HMI solutions integrated in the dashboard and test software for providing assisting feedback, as well as a measurement computer to log data and a GPS. In the integrated system test, the zones were stored in the vehicle test software and in the Volvo cloud. The zones could have been downloaded to the car from an external database as well (as for the retrofit system), but this was not tested for this case. The HMI in the display of the car informed the driver about the upcoming zones.

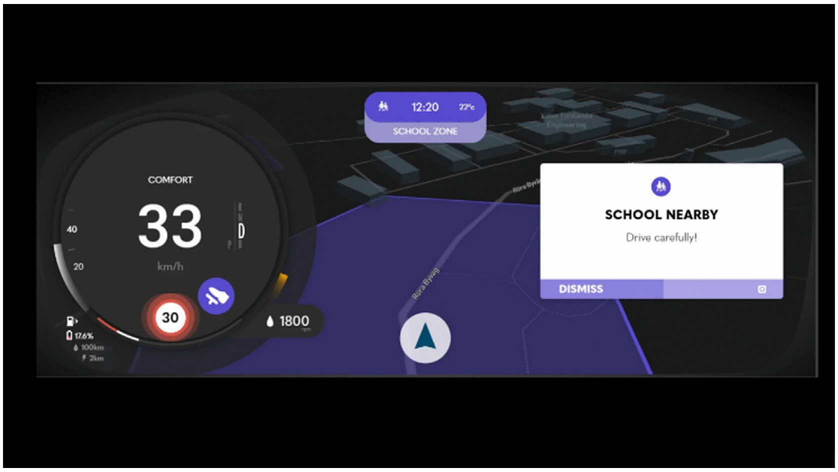
In the LEZ case, the vehicle automatically switched to electric mode when entering the zone (see Fig. 4). LEZs were defined at road sections without curves to ensure that the driver could focus on this functionality.

The SZs were also defined on road sections without curves, and with little traffic so that the experiment would not disturb other vehicles. The actual speed limit on this road section is 50 km/h but a section on this road was set to 30 km/h within the SZ in the experiment. The HMI notified the driver of a SZ prior to entering it, and upon reaching the SZ, the car gradually decelerated to 30 km/h at a maximum of 1 m/s^2, by automatically reducing the speed by using the electric motor for braking and adjusting the mapping of the gas pedal to require more effort from the driver to override the functionality, see Fig. 5 below for the HMI of a SZ. I.e., the vehicle brakes by itself until reaching the speed limit, but the function can be overridden by simply increasing pressure on the gas pedal.


Approaching zero emission zone

80m

Fig. 4. Integrated system HMI, approaching an LEZ (prototype HMI not intended for production).


SCHOOL NEARBY

Drive carefully!

Fig. 5. Integrated system HMI, inside school zone – prototype HMI not intended for production.

Fig. 6 shows the school zone and low emission zone for the integrated system, where drivers were instructed to drive through a pre-defined test track.

Table 1 summarizes the main characteristics of the retrofit and integrated trials and highlights the differences between these in terms of number of participants, trial length and HMI solutions.

3.3. Respondents and recruitment

The test drivers were recruited through several channels: some were recruited through media, where information about the project appeared in several articles, and others were recruited through internal information channels and social media.

The retrofit system test had 42 participants; 64% male and 36% female, aged between 31 and 63 (mean = 47, standard deviation = 9,9). The test drivers used private cars, and some test drivers belonged to the same household. The integrated system test involved 43 participants; 70% male and 30% female, aged between 25 and 65 (mean = 48, standard deviation = 11,4). Participants in both tests had had their driving license for 28 years on average, indicating that the drivers were experienced.

The test drivers in this study are likely to be so-called “early adopters”, which, according to the Diffusion of Innovations Theory (Rogers, 2003), is the first group of individuals to adopt new technologies. The early adopters are in general highly educated, have high income, and have a positive attitude towards new technology. Over 66% of the retrofit test drivers and

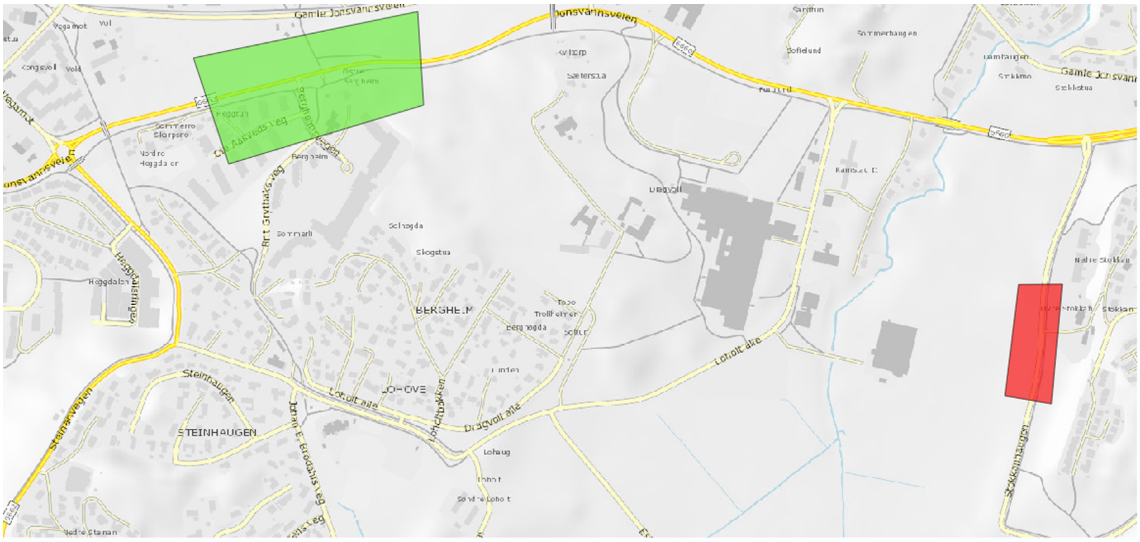


Fig. 6. Map showing school zone (red) and low emission zone (green) for the test of integrated system in the city of Trondheim. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Summarizing the main characteristics of the retrofit and integrated trial.

	Retrofit trial	**Integrated trial**
Number of participants	42	43
Trial length	Six weeks (+2 weeks black mode)	One test round
HMI	Smartphone application	Integrated in test vehicle
Action in LEZ	Driver switches from gasoline to electricity	The vehicle switches automatically from gasoline to electricity
Action in SZ	Driver adjusts speed	The vehicle automatically reduces the speed

over 72% of the integrated test drivers reported to have higher education of four years of more. The questionnaire included questions on attitudes concerning new technology, and the findings from these questions support the notion that the test drivers are likely to be early adopters. Table 2 shows the mean for four questions aiming to measure the test drivers' attitudes concerning technology in general, perceived importance of new technology in cars, perceived importance of technology for preventing human-made climate change, and for minimizing deaths/serious injuries in traffic (on a scale from 1 to 5). The test drivers have a high mean for both the retrofit and integrated test, indicating a positive attitude towards the importance of technology. The question "I think it is important to drive a car with the most recent technology" shows a slightly lower mean for the two systems, especially for the retrofit system. This could reflect the more diverse group of testers for this system.

3.4. Questionnaire

The questionnaire for the retrofit system study was e-mailed to the test drivers after the last day of driving with the system, while the questionnaire for the integrated system study was answered on a tablet in the test vehicle upon completing the test route.

We used an adjusted approach suited for the purpose of our study including questions that measured different indicators of acceptance, and we attempted to measure acceptance using four different indicators: 1) satisfaction, 2) usefulness, 3) usability, and 4) workload. These are based on previous literature (but adapted to the purpose of our use cases), often referred to as perceived ease of use or effort expectancy; perceived usefulness or performance expectancy; and behavioral intention to use the system or effectiveness (e.g., Adell, 2010; McIlroy, Stanton, & Godwin, 2017; Staubach, Schebitz, Köster, & Kuck, 2014; Vaezipour, Rakotonirainy, Haworth, & Delhomme, 2018). All questions focused on how the drivers perceived the functionality after using the systems, which is important for gaining knowledge based on experience. Respondents often have difficulties in assessing technology they are not familiar with (Hardman, Berliner, & Tal, 2019).

Eleven questions (Q1-Q11 for SZ and Q21-31 for LEZ) addressed the participants' **satisfaction** of the retrofit and integrated system, for both LEZs and SZs. The phrasing of the questions was slightly different in the two questionnaires because it had to be tailored to the specific context in which the test was executed (see Appendix). The variables used to measure satisfaction were: "intuitive to use" (Q1, Q21), "not distracting" (Q2, Q22), "precise" (Q3, Q23), "clear and understandable" (Q4, Q24), "easy to follow the information" (Q5, Q25), "interaction not frustrating" (Q6, Q26), "interaction was comfortable" (Q7, Q27), "information was encouraging" (Q8, Q28), "easy to learn how to use" (Q9, Q29), "gave sufficient information" (Q10, Q30), "generally easy to use" (Q11, Q31). Each question was answered using a 5-point Likert Scale, with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. Participants were given two separate questions sets for the integrated system (one for each of the two geofence use-cases) but only one for the retrofit system, concerning the satisfaction of the HMI in general.

We now turn to the second and third indicators of acceptance, **usefulness** and **usability**. The phrasing of the questionnaires also differed slightly regarding usefulness and usability (see Appendix). The usefulness questions focused on how useful the driver thought the technology was for achieving lower emissions (Q12) and how useful the technology was for increasing traffic safety around schools (Q32), answered using a 5-point Likert Scale, from 1 = to no degree, 2 = to a small degree, 3 = neutral, 4 to some degree, 5 = to a large degree. The usability question focused on whether the driver would

Table 2
Retrofit and integrated systems - test driver attitudes.

	Retrofit system			Integrated system		
	Mean	Std. dev.	Obs.	Mean	Std. dev.	Obs.
I am interested in testing new technology.	4.1	1.06823	42	4.4	0.5812098	43
I think it is important to drive a car with the most recent technology	3.4	1.013555	42	3.7	1.1027	43
I believe that technology will be one of the most important tools for preventing man-made climate change.	4.4	0.7778999	41	4.2	0.8518273	43
I believe technology in the transport sector will minimize deaths and serious injuries in traffic	4.6	0.6726359	41	4.5	0.6744465	42

*All question answers vary from 1 (Strongly disagree) to 5 (Strongly agree).

use the technology in their everyday life (Q13, Q33), again based on a 5-point Likert Scale; 1 = unlikely, 2 = somewhat unlikely, 3 = neutral, 4 = somewhat likely, 5 = likely. Usability was not measured for SZs for the retrofit system.

Six questions related to our fourth indicator of acceptance, self-reported **workload** for geofence LEZs (adopted from Adell et al., 2008; Adell et al., 2011; McIlroy et al., 2017; Vaezipour et al., 2018): "mental capacity" (Q14), "physical capacity" (Q15), "feeling time pressure" (Q16), "mobilize energy" (Q17), "stressed" (Q18)," satisfied with reaction" (Q19). The answers were based on a 10-point scale from 1 = a very small degree, to 10 = a very large degree.

3.5. Data analysis

Data collected from the surveys was extracted and processed using STATA 16. As the goal was to assess and compare acceptance of the integrated and retrofit systems, groups were compared using test statistics. Wilcoxon-Mann-Whitney-rank sum test was applied as most of the data violated the assumptions of parametric tests. This tests the null hypothesis: *the distribution of scores for the two groups are equal.* Where distributions were symmetrical and similar in shape, the Welch *t*-test was applied, testing the null hypothesis: *the means are equal.*

Concerning the methods used, we follow previous research, and compare the means of the different variables based on Likert scales ranging from 1 to 5, in a similar manner as Reagan et al. (2020) measuring acceptance of Level 2 driving automation, and Vaezipour et al. (2018) measuring experience of driving simulator realism. Following Vaezipour, Rakotonirainy, Haworth, and Delhomme (2019) and Jamson, Hibberd, and Merat (2015) among others, we applied effect sizes to measure the magnitude of the observed difference of acceptance. Effect sizes were calculated to give an indication of the magnitude of the difference between the groups. It shows the probability that a random value from the first group will be greater than a random value from the other group. For the Wilcoxon-Mann-Whitney test, effect size was calculated using $r = Z/\sqrt{(n_1 + n_2)}$ and evaluated as such: 0.1 = small effect, 0.3 = moderate effect; 0.5 = large effect. For the Welch *t*-test, Hedge's g was calculated, $g = (M_1 - M_2)/SD^{*}_{\text{pooled}}$, where 0.2 = small effect, 0.5 = moderate effect; 0.8 = large effect).

4. Results

4.1. Comparison of effect sizes for acceptance of integrated and retrofit system for low-emission zones

When comparing the means for acceptance of geofence LEZs, the integrated system resulted in considerable higher means across all variables. Looking at the test statistics in Table 3 we see a statistical significance in the difference between the distributions for the integrated and retrofit systems for several of the satisfaction variables: "intuitive to use", "precise", "clear and understandable", "interaction not frustrating", "interaction was comfortable", "easy to learn how to use, "gave sufficient information", "generally easy to use". The largest effect was observed for "usefulness", and for "useability", which also shows statistically significant differences between the integrated and retrofit system.

When comparing the effect sizes for the integrated to the retrofit system, we find that integrated scores higher than the retrofit and so did usefulness and useability. Effects were moderate for the aspects "intuitive to use", "interaction not frustrating", "interaction was comfortable and generally easy to use", and small for "precise, clear and understandable", "easy to learn how to use", and "gave sufficient information". Usefulness and useability also had small effects. No difference was observed regarding "not distracting", "easy to follow the information", and "information/feedback encouraging". But while "easy to follow the information" had high means across the two systems, "not distracting" and "information/feedback encouraging" had lower means than most of the other satisfaction items.

Table 3
Comparison across integrated and retrofit systems, geofence low-emission zones.

	Integrated			**Retrofit**			**Test statistic**		
Items	Mean	Std.dev.	Obs.	Mean	Std.dev.	Obs.		P-value	Effect size
Satisfaction									
Intuitive to use	4.49	0.56	35	4.1	0.63	42	t = 3.05	**0.003***	g = 0.641
Not distracting	3.69	1.13	35	3.38	1.08	42	Z = 1.40	0.161	r = 0.16
Precise	4.43	0.61	35	4.1	0.84	41	Z = 1.82	**0.069*****	r = 0.21
Clear and understandable	4.51	0.56	35	4.13	0.79	41	Z = 2.28	**0.023****	r = 0.26
Easy to follow the information	4.49	0.56	35	4.2	0.85	41	Z = 1.38	0.169	r = 0.16
Interaction not frustrating	4.26	0.61	35	3.65	0.86	42	Z = 3.35	**<0.001***	r = 0.38
Interaction was comfortable	4.2	0.63	35	3.63	0.81	42	Z = 3.22	**0.001***	r = 0.37
Information/feedback encouraging	3.6	0.78	35	3.53	0.93	42	t = 0.38	0.703	g = 0.087
Easy to learn how to use	4.49	0.51	35	4.1	0.90	41	Z = 1.91	**0.057*****	r = 0.22
Gave sufficient information	4.31	0.68	35	3.93	0.97	41	Z = 1.73	**0.084*****	r = 0.20
Generally easy to use	4.49	0.56	35	3.95	0.85	42	Z = 3.2	**0.001***	r = 0.36
Usefulness	4.63	0.65	35	4	1.23	41	Z = 2.54	**0.011****	r = 0.29
Usability	4.74	0.75	34	4.56	0.59	41	Z = 1.95	**0.051****	r = 0.23

Z: Wilcoxon-Mann-Whitney test; t: two sample Welch's *t*-test. * significant at 99% level ** significant at 95% level *** significant at 90% level.

Table 4
Comparison across integrated and retrofit systems, geofence school zones[7].

	Integrated			**Retrofit**			**Test statistic**		
Items	Mean	Std.dev.	Obs.	Mean	Std.dev.	Obs.		P-value	Effect size
Satisfaction									
Intuitive to use	4.48	0.55	34	4.1	0.63	42	t = 2.77	**0.007***	g = 0.63
Not distracting	3.67	0.93	34	3.38	1.08	42	Z = 1.68	**0.093****	r = 0.19
Precise	4.05	0.96	34	4.1	0.84	41	Z = -0.13	0.895	r = 0.02
Clear and understandable	4.29	0.81	34	4.13	0.79	41	Z = 0.99	0.324	r = 0.11
Easy to follow the information	4.38	0.7	34	4.2	0.85	41	Z = 0.26	0.259	r = 0.13
Interaction not frustrating	4.24	0.66	34	3.65	0.86	42	Z = 3.35	**<0.001***	r = 0.38
Interaction was comfortable	4.17	0.76	34	3.63	0.81	42	Z = 3.42	**<0.001***	r = 0.39
Information/feedback encouraging	3.88	0.99	34	3.53	0.93	42	t = 1.6	0.115	g = 0.37
Easy to learn how to use	4.5	0.6	34	4.1	0.90	41	Z = 1.71	**0.088****	r = 0.20
Gave sufficient information	4.38	0.7	34	3.93	0.97	41	Z = 1.91	**0.056****	r = 0.22
Generally easy to use	4.55	0.59	34	3.95	0.85	42	Z = 3.44	**<0.001***	r = 0.39
Usefulness	4.74	0.45	34	3.22	1.26	41	Z = 5.63	**<0.001***	r = 0.65
Usability	4.77	0.5	34	NA	NA	NA	NA	NA	NA

Z: Wilcoxon-Mann-Whitney test; t: two sample Welch's *t*-test. * significant at 99% level ** significant at 90% level

[7] Retrofit satisfaction questions cover both geofence school zones and low emission zones.

In summary, test drivers found the integrated system easier, more comfortable and more intuitive to use. It was also considered more precise, clearer, more informative and more understandable. Furthermore, usefulness and usability both scored significantly higher for the integrated system.

4.2. Comparison of effect sizes for acceptance of integrated and retrofit system for school zones

The integrated system also resulted in a higher acceptance for SZs. The test statistics in Table 4 show a statistical significance in the difference between the distributions for several of the satisfaction variables: "intuitive to use", "not distracting", "interaction not frustrating", "interaction was comfortable", "easy to learn how to use", "gave sufficient information", and "generally easy to use". Usefulness was also found to have a statistically significant difference. Usability data was not collected for the retrofit system, hence, marked with not applicable (NA) in the table.

Satisfaction was higher across all aspects for the integrated system compared to the retrofit system, and so was usefulness. Effects sizes were moderate for "intuitive to use", "interaction not frustrating", "interaction was comfortable", and "generally easy to use", and small for "not distracting", "easy to learn how to use" and "gave sufficient information". Usefulness had a large effect size.

No difference between the two systems was observed regarding "preciseness", "clear and understandable", "easy to follow the information", and "information/feedback encouraging". While the first three items had relatively high means (close to "agree"), "information/feedback encouraging" had a lower mean than most of the other satisfaction items.

In summary, results for SZs were similar to the LEZs. The integrated system was considered easier, more comfortable and informative, as well as more intuitive to use. Geofence SZs were also considered less distracting for the integrated system, although the mean is low compared to other satisfaction questions. The usefulness was high for the integrated system and low for retrofitted system (although the standard deviation is high).

4.3. Workload for low-emission zones for integrated and retrofit system

Workload experienced with geofence LEZs was relatively low for both systems (Table 5), ranging between 1 and 2 for the first five variables (on a scale from 1-low degree to 10-high degree). Furthermore, participants were slightly more satisfied with their own reaction with the integrated system (7.44) than with the retrofit system (6.23). The means are generally higher for the integrated system across all items, but test statistics show that none of the differences were statistically significant and had small effect sizes. Thus, the randomly selected value of group 1 (integrated) is equal to the randomly selected value of group 2 (retrofit).

Z: Wilcoxon-Mann-Whitney test.

Summarizing the results for workload, we find no significant differences in workload between the integrated and the retrofit system, although the average mean is higher for the integrated system. The data collection did not include workload for SZs, and therefore only results from LEZ is shown.

5. Discussion

The main aim of this study was to compare the level of acceptance for retrofit and integrated systems. For both use cases, we find high levels of acceptance. For LEZs, we support findings from previous studies (e.g., Staubach et al., 2014; Vaezipour et al., 2018), finding high level of acceptance. Akin to previous research on ISA (e.g., Adell et al., 2008; Adell, 2010; 2011;

Table 5
Comparison across integrated and retrofit systems of workload, geofence low-emission zones.

	Integrated			Retrofitted			Test statistic		
Items	Mean	Std.dev.	Obs.	Mean	Std.dev.	Obs.		P-value	Effect size
Mental capacity	1.77	1.01	35	2.58	1.89	36	Z = -1.18	0.239	r = 0.14
Physical capacity	1.33	0.58	35	1.84	1.46	37	Z = -1.59	0.113	r = 0.19
Feeling time pressure	1.46	0.82	35	1.94	1.69	35	Z = -0.93	0.355	r = 0.11
Mobilize energy	1.28	0.51	35	1.74	1.37	37	Z = -1.28	0.199	r = 0.15
Stressed of the function/changing fuel source	1.41	0.94	35	1.77	1.52	36	Z = -1.37	0.171	r = 0.16
Satisfied with reaction	7.44	2.86	31	6.23	3.36	33	Z = 0.93	0.352	r = 0.12

Vlassenroot et al., 2007), we also find high acceptance levels among the participants in the use case SZs. High acceptance levels are necessary for successful implementation of DAS and will reduce the risk of frustration and dissatisfaction among drivers, feelings that may lead drivers to refrain from purchasing the DAS, disable it, or use it in an unintended manner (Hartwich et al. 2018). The results of our study indicate higher acceptance for the integrated system compared to the retrofit system overall, both for LEZs and SZs. Several of the variables measuring user acceptance showed significant differences between the integrated and retrofit system. The integrated system for LEZs, conveying more information to the driver, had greater levels of satisfaction, was perceived as more useful and more likely to be used in everyday life. This could reflect the increased level of convenience and comfort of an automated system, which is expected to increase the acceptance among users (Hartwich et al., 2018).

An important finding concerning the acceptance levels of the users is the experience of distraction. The item "not distracting" got lower means than most of the other items, indicating that participants found both systems somewhat distracting. Staubach et al. (2014) also reported that distraction was an issue with haptic and visual feedback. Distraction is a recurrent and critical challenge in studies on DASs since feelings of distraction could constitute a safety issue. Three sources of distraction can be identified: visual (when eyes are not focused on the road), manual (when hands are not on the steering wheel), and cognitive (when attention is diverted from the driving task) (Biondi et al., 2017). For the retrofit and the integrated systems, we argue that manual distraction ought to be lower for the integrated system in the LEZ use case as the vehicle automatically switched to electric mode, without driver intervention. This remains, however, a hypothesis since the workload results showed no significant difference between the two systems.

Turing to the workload, participants reported a low workload for the LEZs, confirming findings of former studies (Adell, 2011; Young et al., 2010). Previous literature showed that increasing the complexity led to increasing workload for eco-driving systems. For instance, when including a feedback system in addition to an advice system, Vaezipour et al. (2018) found higher workload. This suggests that systems with higher complexity ought to increase the workload. Hence, the retrofit system, where the driver is required to switch from gasoline to electric mode manually, is expected to generate higher levels of workload. However, our study showed no significant differences between the two systems. One possible explanation for the lack of significant differences in workload is the relatively longer test period for the retrofit system.

Seen together, the results from the acceptance indicators and workload indicators suggest that the test drivers overall were satisfied with the LEZ systems. The questionnaire also contained a question where the test drivers could write down their feedback concerning their experience with the equipment. The feedback was overall concerned with technical issues with the equipment, particularly for the retrofit equipment, such as cold weather reducing the battery capacity of the smartphone or lack of nigh mode. This gave valuable insight to the retrofit manufacturing company developing the equipment used on our study, highlighting the need for testing the equipment in real-life conditions.

The test drivers in both use cases are likely to be what is referred to as "early adopters" (Rogers, 2003). Studies focusing on early adopters can give more insight into how users in the future will perceive new technology, because these individuals will have a higher level of knowledge which they can use to evaluate the technology more accurately (Hardman et al., 2019). Hence, even though the acceptance levels could be lower for the general population, the results of this study are still interesting as they might point towards the future when such technologies are even more common than they are today. Furthermore, the early adopters have a critical role for the diffusion of innovations, as peer-to-peer communication will arguably lead to faster diffusion of the technology (Rogers, 2003). In this view, the test drivers in our study could be considered "ambassadors" of the technology, increasing the acceptance in the general population.

5.1. Implications of the findings

The high acceptance for both the integrated and retrofit system call attention to the vast possibilities that new technologies such as geofencing provide for policymakers. By using geofencing to communicate digital traffic rules, the transport system could become less dependent on physical infrastructure, which also could reduce the cost. The existing LEZs in Europe represent an illustration of this, where ANPR technology often is used. The physical infrastructure needed for ANPR represent a considerable cost, and using digital infrastructure based on geofencing would reduce the need for physical infrastructure. In addition, digital infrastructure would allow for much more flexibility than today's physical infrastructure does. In the SZ use case, the SZ could for instance be active during daytime, particularly in the morning and afternoon when many pedestrians are found close to schools. Hence, such flexibility could be a powerful tool for policymakers, allowing for pinpointing policies more than previously.

LEZ and SZ are only two of the many available use cases where geofence technology could be used, other examples are for instance road work warnings, que warnings or accident warnings. If vehicles have integrated or retrofit systems to show such information, this could enhance traffic safety and efficiency. Due to high flexibility, warnings on traffic accidents can be generated quickly, and could be used to redirect traffic away from the accident and prioritize emergency vehicles.

Developing retrofit and integrated systems for ITS is, however, a challenging task that requires close collaboration between authorities, car manufacturers, and companies manufacturing retrofit system. Nevertheless, it is a necessary step towards the introduction of novel ITS technologies, as manual and automated vehicles will coexist in traffic for many years. If transport authorities want to start harvesting the benefits of automated transport, it is crucial that ITS services are developed for both integrated and retrofitted systems. Several challenges must be addressed before transport authorities can start introducing new ITS services, be it integrated or retrofit system. Overcoming such challenges will require a considerable amount of testing, failing and redevelopment. Large-scale testing is critical in this regard. DAS are often much more complex when they are moved out of laboratories and into a real-traffic environment, and technologies for different use cases may not be as mature as suggested (DOT, 2021).

We argue, based on the results from the analysis and findings in previous research (e.g., Hartwich et al., 2018; Kidd, Cicchino, Reagan, & Kerfoot, 2017; Pereira, Beggiato, & Petzoldt, 2015), that getting to know a DAS is not a homogenous process. Furthermore, the use patterns and trust in the systems are likely to change as experience with technology increases (Reagan et al., 2020), indicating that the research design in this study with respect to test length is expected to influence the results. Some studies show that the process of getting familiar with a new DAS can be short (Beggiato et al. 2015), while others argue that changes in driver behavior is a lengthy process (Pereira et al., 2015). Hence, more knowledge concerning how users respond to DAS, and vehicles in different SAE levels, both in the short and long term is needed.

One challenge with the implementation of DAS is lack of trust, which is likely to vary across different types of technologies and implementations (Kidd et al., 2017). Varying acceptance levels for different implementations is a major challenge when vehicles at different SAE levels operate in traffic. An interesting example in this regard showing the importance of more knowledge on user acceptance of DAS is the European Commission decision concerning ISA, which from 2022 will be mandatory for new vehicles sold in the EU (ETSC, 2021). Although certain aspects concerning ISA such as the size of symbols in the display is standardized at a general level, the application in itself is developed individually by the different car manufacturing companies. This highlights the need for more knowledge on acceptance levels for different HMIs.

5.2. Limitations of the study

A potential limitation when comparing the retrofit and the integrated system is that the two trials have different design. The integrated system was tested in a test vehicle on a specific route, while the retrofit system was tested using private vehicles for six weeks over a large geographical area. Previous studies have shown that the acceptance of vehicle technology is likely to vary across different implementations of the same technology (Reagan et al., 2020; Kidd et al., 2017). And Adell and Várhelyi (2008) found increased emotional pressure when using a haptic pedal for longer periods of time. This makes direct comparison of retrofit and integrated system challenging, as the implementation of these are unlikely to be identical. Nevertheless, we argue that investigating acceptance levels of different implementations for the same use cases remains valuable for contributing to more knowledge on how manual and automatic systems can coexist in traffic.

Another potential limitation concerns the vehicle used during testing, as test drivers of the retrofit system were driving their own vehicles, entailing that they were familiar with the vehicle used. This is likely to influence the results and could explain why the drivers of the retrofit system rated the workload as low. It is likely that the test vehicle used for the integrated system made drivers more passive and insecure. To mitigate this feeling, participants drove a short circuit on the parking lot prior to undertaking the test route. Having a positive experience with a DAS is a main factor in the decision of using it or not (Hartwich et al., 2018). If test drivers were feeling insecure towards the vehicle, this could influence their evaluation of the DAS.

Another limitation concerns the sample of the study. Both trials involved only around 40 participants each, and these participants are likely to be first adopters. Hence, the findings from this study are unlikely to be representative of the general population. If a representative sample from the population were used, the acceptance levels could be different (see Dahlinger et al., 2018 for similar argument for eco-driving). The acceptance of sub-groups of the population such as young, inexperienced drivers and elderly drivers should also be addressed by future research. For instance, see Young et al. (2010) for example of a study focusing on the acceptance of ISA among young, inexperienced drivers.

6. Conclusion

This study compares the level of acceptance of two driver assistance systems for retrofit and integrated system. We found high levels of acceptance for both systems across different indicators of acceptance. These findings indicate that the transitioning phase during which automated and manual vehicles will coexist in traffic, can be mitigated if similar functionalities with high user acceptance can be developed for older vehicles. This approach could help bridge the gap between vehicles at different SAE levels, and could enable transport authorities to start using novel ITS services aiming at increasing security or traffic efficiency, or reducing emissions. Knowledge on the user's feelings of acceptance of such technologies is an important factor for a potential implementation of such services. Further research on retrofit and integrated system is a precondition for such a development. Studies comparing retrofit and integrated system for other use cases would be an interesting addition to our study.

CRediT authorship contribution statement

Hanne Seter: Funding acquisition, Conceptualization, Methodology, Investigation, Writing - original draft. **Lillian Hansen:** Writing - original draft, Methodology, Formal analysis, Writing - review & editing. **Petter Arnesen:** Funding acquisition, Conceptualization, Methodology, Software, Investigation, Writing - review & editing.

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Appendix

See Tables A1 and A2.

Table A1
Survey question on geofence low emission, integrated and retrofit.

Low emission	**Integrated system**	**Answer categories**	**Retrofit system**	**Answer categories**
Satisfaction	You now get some questions related to the geofence low emission functionality. Here you should only answer how you think the functionality geofence low emissions worked…	1 = strongly disagree2 = disagree3 = neutral4 = agree5 = strongly agree	You will now get some questions related to the user interface. Take as a starting point when the equipment worked. How much do you agree or disagree with the following statements:	1 = strongly disagree2 = disagree3 = neutral4 = agree5 = strongly agree
Q1	The functionality was intuitive to use.		The user interface was intuitive to use	
Q2	The functionality distracted me from driving (turned in analysis)		The user interface distracted me from driving (turned in analysis)	
Q3	The functionality was precise enough for me		The information from the user interface was accurate enough for me.	
Q4	The functionality was clear and understandable.		The feedback from the user interface was clear and understandable.	
Q5	It was easy for me to follow the information to the functionality		It was easy for me to follow the information that the user interface communicated to me.	
Q6	My interaction with the functionality was frustrating (turned in analysis)		My interaction with the user interface was frustrating. (turned in analysis)	
Q7	My interaction with the functionality was comfortable		My interaction with the user interface was comfortable.	
Q8	I think the information from the functionality was encouraging		I find the feedback from the user interface encouraging	
Q9	It was easy for me to learn to use the functionality.		It was easy for me to learn how to use the user interface.	
Q10	The functionality gave me sufficient information.		The user interface gave me sufficient information to perform what was expected of me.	
Q11	The functionality was generally easy to use		The user interface was easy to use in my everyday life.	
UsefulnessQ12	To which degree do you think the functionality geofence low-emission zone would help you drive more environmentally friendly in low emission zones if you had this functionality in your (hybrid) car?	1 = to no degree2 = to a small degree3 = neutral4 = to some degree5 = to a large degree	To which degree would you say that the system has helped you drive more environmentally friendly inside the defined low emission zones	1 = to no degree2 = to a small degree3 = neutral4 = to some degree5 = to a large degree
UsabilityQ13	Imagine that you have all these three functionalities available in your car. Considering your experiences from the test period, to what degree do you consider it likely that you in your everyday would activate the function where the car forces the engine over onto electricity within geofence low emission zone if you could pay a lower fee?	1 = not likely2 = somewhat unlikely3 = neutral4 = quite likely5 = likely	Based on your experiences from the test period, to what degree do you consider it likely that you in your every day would change to electricity within low emission zones if you could pay a lower fee?	1 = not likely2 = somewhat unlikely3 = neutral4 = quite likely5 = likely
Workload	You now get some questions related to how laborious you experienced that the use of the function geofence low emissions was. Here you should only consider geofence low emissions.	1 = a very small degree….10 = a very large degree.	During testing of the geofence low-emission zone, part of the function was linked to switching from fossil fuels to electricity within the low-emission zones in order not to reduce the prize pool. You now get some questions regarding how laborious you experienced this process was to complete during the test period. If you do not have the opportunity to influence this choice on your car model (for example by driving slower or by choosing fuel mode), “do not know” answers all the questions.	1 = a very small degree….10 = a very large degree.

Table A1 (*continued*)

Low emission	Integrated system	Answer categories	Retrofit system	Answer categories
Q14	To what extent did the geofence low-emission function require a lot of mental capacity from you (e.g. thinking, remembering)?		To what extent did the switch from fossil to electricity require a lot of mental capacity from you (e.g. thinking, remembering, look for the right button)?	
Q15	To what extent did the low-emission geofence feature require a lot of physical capacity from you (e.g. stretching, pushing)?		To what extent did the switch from fossil to electricity require a lot of physical capacity from you (e.g. stretching, pressing a button)?	
Q16	To what extent did you feel a time pressure when the geofence low emission feature turned on?		To what extent did you feel a time pressure when you switched from fossil to electricity?	
Q17	To what extent did you feel the need to mobilise a lot of energy (mentally and physically) when the geofence low emission feature turned on?		To what extent did you feel that you had to mobilise a lot of energy (mentally and physically) when you switched from fossil to electricity?	
Q18	To what extent were you stressed by the fact that the function geofence low emissions turned on?		To what extent were you stressed by switching from fossil to electricity?	
Q19	To what extent are you satisfied with how you reacted when the function geofence low emissions turned on?		To what extent are you satisfied with how you made the switch from fossil to electricity during the test period?	

Table A2
Survey question on geofence schoolzone, integrated and retrofit.

Schoolzone	Integrated system	Answer categories	Retrofit system	Answer categories
Perceived ease of use	You now get some questions related to the functionality geofence school zone. Here you should only answer how you think the functionality of the geofencene school zone worked.	1 = strongly disagree2 = disagree3 = neutral4 = agree5 = strongly agree	You will now get some questions related to the user interface. Take as a starting point when the equipment worked. How much do you agree or disagree with the following statements:	1 = strongly disagree2 = disagree3 = neutral4 = agree5 = strongly agree
Q21	The functionality was intuitive to use.		The user interface was intuitive to use	
Q22	The functionality distracted me from driving (turned)		The user interface distracted me from driving (turned in analysis)	
Q23	The functionality was precise enough for me		The information from the user interface was accurate enough for me.	
Q24	The functionality was clear and understandable.		The feedback from the user interface was clear and understandable.	
Q25	It was easy for me to follow the information to the functionality		It was easy for me to follow the information that the user interface communicated to me.	
Q26	My interaction with the functionality was frustrating (turned)		My interaction with the user interface was frustrating. (turned in analysis)	
Q27	My interaction with the functionality was comfortable		My interaction with the user interface was comfortable.	
Q28	I think the information from the functionality was encouraging		I find the feedback from the user interface encouraging	
Q29	It was easy for me to learn to use the functionality.		It was easy for me to learn how to use the user interface.	
Q30	The functionality gave me sufficient information.		The user interface gave me sufficient information to perform what was expected of me.	
Q31	The functionality was generally easy to use		The user interface was easy to use in my everyday life.	
UsefulnessQ32	The functionality of the geofence school zone aims to help drivers maintain the speed limit in particularly vulnerable areas, such as around schools. To what extent do you think the geofence school zone functionality would help you maintain speed limits in particularly vulnerable areas?	1 = to no degree2 = to a small degree3 = neutral4 = to some degree5 = to a large degree	You will now be given some statements related to how useful the geofence school zone is to help drivers maintain the speed limit in these particularly vulnerable areas. To what extent would you say that the system has helped you to keep the speed limits within the defined school zones?	1 = to no degree2 = to a small degree3 = neutral4 = to some degree5 = to a large degree
UsabilityQ33	Imagine that you had these three features available in your car. Based on your experience from the test, to what extent do you consider it likely that you in your everyday life would activate the function geofence school zone where the car helps you slow down at a school?	1 = not likely2 = somewhat unlikely3 = neutral4 = quite likely5 = likely	NA	

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