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# ADAS at work: assessing professional bus drivers' experience and acceptance of a narrow navigation system

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## Abstract

Due to the argued benefits of passenger comfort, cost savings, and road safety, the bus sector is showing increasing interest in advanced driver-assistance systems (ADAS). Despite this growth of interest in ADAS and the fact that work tasks are sometimes complicated (especially docking at bus-stops which may occur several hundred times per shift), there has been little research into ADAS in buses. Therefore, the aim of this study was to develop further knowledge of how professional bus drivers experience and accept an ADAS which can help them dock at bus-stops. The study was conducted on a public route in an industrial area with five different bus-stops. Ten professional bus drivers got to use a narrow navigation system (NNS) that could dock automatically at bus-stops. The participants' experience and acceptance were investigated using objective as well as subjective data (during and after the test-drive) and data were collected using interviews, questionnaires, and video recordings. The participants indicated high levels of trust in and acceptance of the NNS and felt that it had multiple benefits in terms of cognitive and physical ergonomics, safety, and comfort. However, the relatively slow docking process (which was deemed comfortable) was also expected to negatively affect, e.g., timetabling, possibly resulting in high stress levels. Therefore, when investigating users' acceptance of ADAS in a work context, it is important to consider acceptance in terms of the operation, use, and work system levels and how those levels interact and affect each other.

**Keywords** Automated vehicle · User acceptance · Advanced driver-assistance systems · User experience · Bus drivers · User study

## 1 Introduction

Adaptive cruise control, blind-spot detection, emergency braking, and lane-keeping assist are examples of advanced driver-assistance systems (ADAS). These are developed to improve such things as driver and passenger comfort, fuel efficiency, and road safety, either by providing the driver with information or by taking automatic actions. Most often, the focus in research has been on ADAS in private cars. However, ADAS in heavy vehicles has garnered increasing attention in recent years (Blades et al. 2020; Richardson et al. 2018). Moreover, commercial fleets have increasingly implemented ADAS (such as lane departure warning and

forward collision warnings) with the aim of improving safety (Mele 2018).

The benefits noticed in other heavy vehicles are likely to transfer to the bus sector. Bus-driving in urban areas involves a range of work tasks, including inspecting vehicles prior to departure, adhering to traffic laws and transit regulations, following pre-established routes (often to tight schedules), picking up and dropping off passengers at designated stops, and assisting passengers in different ways. Even though interest in ADAS is growing and the work tasks are complicated, there has been little research into ADAS in buses. However, Blades et al. (2020) suggest that systems, such as forward collision warning (FCW) and intelligent speed assistance (ISA) systems, have been successful in, for example, reducing the number of imminent pedestrian/vehicle collision events and improving speed limit compliance. One specific situation identified as particularly demanding for bus drivers is docking at bus-stops (e.g., Dukic Willstrand et al. 2017) which can occur several hundred times per work shift. This has been found to be: (1) physically demanding

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due to the manoeuvring required, (2) challenging to conduct consistently, and (3) mentally demanding and safety-critical due to such factors as vulnerable road users (VRUs) moving around outside the vehicle. Docking has therefore been suggested as a situation in which implementing ADAS might be beneficial (Nowakowski et al. 2015).

However, whilst the systems offer several potential benefits, the introduction of automation does not always replace human work but instead changes the character of the work to be performed, creating new roles where humans and automation cooperate to accomplish the goal (Bainbridge 1983; Dekker 2004). This new relationship of shared control may introduce new conflicts between the user and the automated system (Vanderhaegen 2021). These conflicts may occur due to, for example, overreliance, reduced situation awareness, and inadequate mental model of automation functioning (Hancock et al. 2020; Saffarian et al. 2012). Moreover, ADAS also impacts not only the driving experience, in terms of, for example, how drivers feel whilst driving (Eckoldt et al. 2012); they also challenge the traditional role of professional drivers as vehicle operators and may pose an issue for them. Thus, driver acceptance is essential in implementing these systems into the overall transportation system.

Therefore, the explorative study presented in this paper aimed to develop further knowledge of how professional bus drivers experience and accept ADAS; more specifically, a narrow navigation system that can assist bus drivers when docking at bus-stops. The following questions were addressed:

- How do professional bus drivers perceive and understand an automated system that assists in docking the bus?
- What benefits and/or challenges/issues do professional bus drivers anticipate if an automated system was implemented which assisted in docking the bus at bus-stops?

## 2 A tentative framework for studying experience and acceptance

From a socio-technical perspective, addressing questions regarding professional drivers' acceptance and experience of ADAS is a matter of addressing the relationship between users (as actors) and technical systems in a work and organisational context.

Overall, although there are a few exceptions (e.g., Brookhuis and de Waard 2006; Xu et al. 2021), investigations into professional drivers' usage of ADAS are scarce. Earlier research has focused on private car drivers and their acceptance of ADAS (e.g., Rahman et al. 2017) or their experience of using ADAS (Adell 2009; Hartwich et al. 2018; Jun et al. 2019; Novakazi et al. 2020).

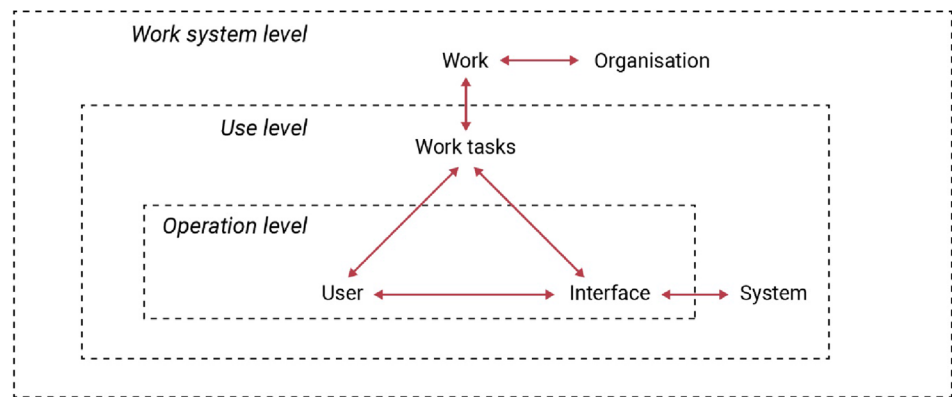
Furthermore, most earlier studies have relied predominantly on three theoretical models: (1) theory of planned behaviour (TPB) (e.g., Ajzen and Fishbein 2005), (2) the technology acceptance model (TAM) (Davis 1989), and/or (3) the theory of acceptance and use of technology (UTAUT) (e.g., Venkatesh 2000; Venkatesh et al. 2003). TPB explains a person's behaviour in terms of individual factors, including the person's attitude towards the behaviour and subjective norms resulting from social and environmental surroundings. TAM has replaced attitude measures with two components that determine user acceptance and usage of new technology: (1) perceived usefulness, i.e., the extent to which users believe the new system will help them do their job better, and (2) perceived ease-of-use, i.e., evaluating the effort of using the application. UTAUT, combining TPB and TAM, proposes four constructs as determinants of user acceptance and usage behaviour: performance expectancy, effort expectancy, social influence, and facilitating conditions (supporting organisational and technical infrastructure) with gender, age, voluntariness, and experience as moderating factors.

Based on these models (and the focus on private car drivers), drivers' acceptance of ADAS has been explained in terms of *individual factors* (cf. TBP), or *judgements* of system design and performance (cf. TAM) or a combination of both (cf. UTAUT). However, although Rahman et al. (2017) suggest that all three models may explain drivers' intention to use ADAS, the influence of work and organisation have not been sufficiently considered.

Understanding the relationship between users and technical systems also means understanding that relationship at different levels. For example, Brookhuis and de Waard (2006) suggested that the impacts of ADAS should be considered on the lower level of the individual driver as well as the higher level of traffic flow. For considering the context of work and organisation when introducing ICT systems, Eason (1991) proposed an analysis on three levels: individual, organisational, and social system levels. Based on activity theory (Leontiev 1981), Karlsson (1996; 2001) has argued for: (1) an operation level, concerned with fits/misfits between the user and the properties of the technical system, (2) an action level, involving the relationship between user, goal fulfilment, and functionality of the technical system, and (3) an activity level describing users' motives for their usage and the way the system interacts with other technical systems in the specific use context. Based on Eason's three levels, Brookhuis and de Waard (2006) notion, and the hierarchical model proposed by Karlsson (1996), we are proposing that investigations into drivers' acceptance and experience must be addressed on three levels (see Fig. 1). These are the operation, use, and work system levels.

The **operation level** concerns users' interaction with the system's user interface for input and receiving feedback. In the

**Fig. 1** Tentative framework describing three levels to address in relation to acceptance of ADAS at work



case of an ADAS, this might include drivers interacting with input devices to activate/deactivate the system, adjust system settings, etc., and receive feedback on these actions through different in-vehicle displays plus the vehicle's behaviour in terms of, e.g., acceleration and deceleration (cf. Ekman et al. 2019). From an acceptance and user experience perspective, perception of ease-of-use is assumed to be a critical factor.

A more aggregated level is the **use level**. Use implies that someone is using something for a particular purpose (or task). For ADAS, this means drivers using the system to manage the driving of the bus. How the driver perceives his/her role may be important, depending on whether the driver understands the system as assisting or replacing them. To use the system to accomplish the driving task, it is assumed that the driver must understand and acknowledge its purpose, where it can be used and how it may support the driving task. Thus, understanding when to use the system is considered here as an aspect of perceived ease-of-use. The other factor is perceived usefulness, or the degree to which drivers perceive the system as useful in driving the bus in the specific situations where the system can and should be activated.

The highest aggregate level is the **work system level**. This refers to how the system supports users in their work and to what degree it complies with organisational goals. In the case of ADAS, this means how the system supports the drivers in their role as bus drivers and as actors in the bus transport system. It also means contributing to organisational goals such as adhering to stipulated timetables for different bus routes, plus driving that is more efficient and consumes less energy. Perceived usefulness on a work system level means the degree to which drivers perceive that the system supports or hinders them in fulfilling these goals.

### 3 Method

To answer the research questions, an explorative study was conducted in which ten professional bus drivers got to use a narrow navigation system (NNS) that could automatically

dock at bus-stops. The study was conducted on a public route with five different bus-stops in an industrial area.

#### 3.1 Setup

The NNS could carry out the lateral and longitudinal dynamic driving tasks which must be completed just before and during docking at bus-stops. During which, the NNS performed the acceleration and deceleration as well as the steering, without any need for the participant involvement in the dynamic driving task, except being ready to intervene if the NNS failed. The system consisted of five lidar sensors, which were used to create a three-dimensional map of the area. Each docking was conducted identically, according to a pre-programmed route with coordinates and velocity plotted every 25–50 cm. The system navigated by comparing data from the sensors with the previously created map and predefined route. The speed upon activation of the system was approximately 20 km/h.

A test leader inside the bus prepared the NNS for activation some distance prior to the bus-stop, by initiating the system. Once the test leader had initiated the process, the participant could activate the NNS by keeping a handover button (on the far right of the dashboard) depressed for half a second (see Fig. 2). Two activation indicators (blue LEDs), one next to the handover button and one above the windshield (see Fig. 2), indicated that the system was activated. Once activated, the driver was still responsible for the driving task and was told to monitor the system and always be ready to intervene if the NNS failed. The driver could deactivate the system at any time by pushing the brake pedal. The driver could also override the system by turning the steering wheel. However, this would not cause the system to deactivate.

In addition to the NNS, the bus was equipped with a geofencing system that adjusted the maximum speed of the bus to 20 km/h within five zones connected to the respective bus-stops. This allowed the transitions to be as smooth as possible. A pop-up window in the driver cluster showed the



Fig. 2 Cockpit layout

speed limit for the zone and a speedometer indicated when the bus was inside a geofencing zone.

### 3.2 Participants

Ten participants took part in the study; nine male and one female. All participants were professional bus drivers with between 1 and 41 years' driving experience ( $M = 14.1$ ,  $SD = 14.4$ ). Their ages ranged from 32 to 71 ( $M = 52.3$ ,  $SD = 11.9$ ). They all had the same or similar bus driver training and had all experience from driving in Gothenburg city, currently on bus routes that included the area in which the test was conducted. All participants were recruited to the study via their employer and their participation was compensated by the employer as regular working hours.

Most of the participants really enjoyed their occupation. They felt that the job offered a lot of freedom and variation, and involved plenty of contact with passengers whilst allowing them to operate a heavy vehicle with the necessary concentration. Many participants also mentioned a strong sense of responsibility for passenger safety, especially for families, children, and people with disabilities riding on the bus. Furthermore, the participants had a very positive general attitude towards technology and believed that new technology makes life easier. In the context of buses, they believed that technical advances could make driving safer and more

convenient. However, some concerns were also raised about such technological advances. Some believed that, even if an advancement was positive, it could sometimes be difficult to understand how to use such new technical products.

### 3.3 Test route

To achieve as natural a setting as possible, the study was conducted on public roads with regular traffic located in an industrial area of Gothenburg. The area was chosen as it was used by other road users, including both cars and heavy vehicles, and thus offered similar conditions to where participants usually drive. Creating this “normal” setting was considered important to be able to investigate participants' experience and acceptance. Yet, at the same time, the area could not have too heavy traffic, since the NNS was in a prototype stage of development. The participants drove a 2.7 km route which included five bus-stops of differing kinds, ranging from regular bus-stops to roadside parking spaces. There were also two backup bus-stops in case one of the original ones was occupied by other buses and/or cars. Figure 3 shows the test route, plus the type of bus-stops and geofencing zones.

### 3.4 Procedure

The study was divided into four parts: a pre-test interview, instructions, a test-drive, and a post-test interview.

In the first part, the **pre-test interview**, the participants first received general information about the test procedure from the test leader. Their informed consent was obtained [under the General Data Protection Regulation (GDPR)] in an interview room next to the test course. Next, a semi-structured individual interview was conducted. This provided an understanding of each participant's previous experience and their preferences regarding their occupation and technology.

After the pre-interview, the participants were guided to the test vehicle for the test-driving session. There, they received verbal **instructions** about safety aspects and system functionality. They were first instructed about the technical features of the system (e.g., sensors and lidar) and then informed that: (1) they were responsible at all times and had to supervise the automated system and intervene if an error occurred or that they believed that the situation was not safe enough to use the automated system; (2) the test leader would instruct them (e.g., where and how to activate the system and approximately where to position the bus in the lane) during an initial lap, but they would always be nearby and able to ask for help; (3) the test leader would inform them when it was possible to activate the system using the activation button on the dashboard; (4) two blue lights, located on the dashboard and over the windshield, indicated that the automated system was active; (5) they could always override



**Fig. 3** Test route (yellow) with stretches where the NNS could be used (orange), bus-stops (red circles), and geofencing zones (green) (Color figure online)

the system by steering and/or deactivate the system by pushing the brake pedal; and (6) there were geofencing zones that would limit the speed of the vehicle and that these were indicated by a symbol on the display.

The participants were also allowed to familiarise themselves with the system in an enclosed area before the actual test-drive. During the practice session (approximately 10 min), they got to activate the system, override the steering, and deactivate the system by pushing the brake pedal. After the practice session, a check list was used to ensure that the participants had understood the instructions; had got to test the different activation and deactivation procedures; and that they felt confident enough to initiate the test-drive procedure.

During the **test-drive**, each participant drove the test route a total of six times. First, there was one manual lap to become familiar with the route and the different bus-stops and then two laps using the NNS. During the first of the two initial laps with the NNS, the test leader helped the participants by instructing them where to position the bus and what speed to maintain when activating the system. After the first three laps, the participants were allowed a short break and

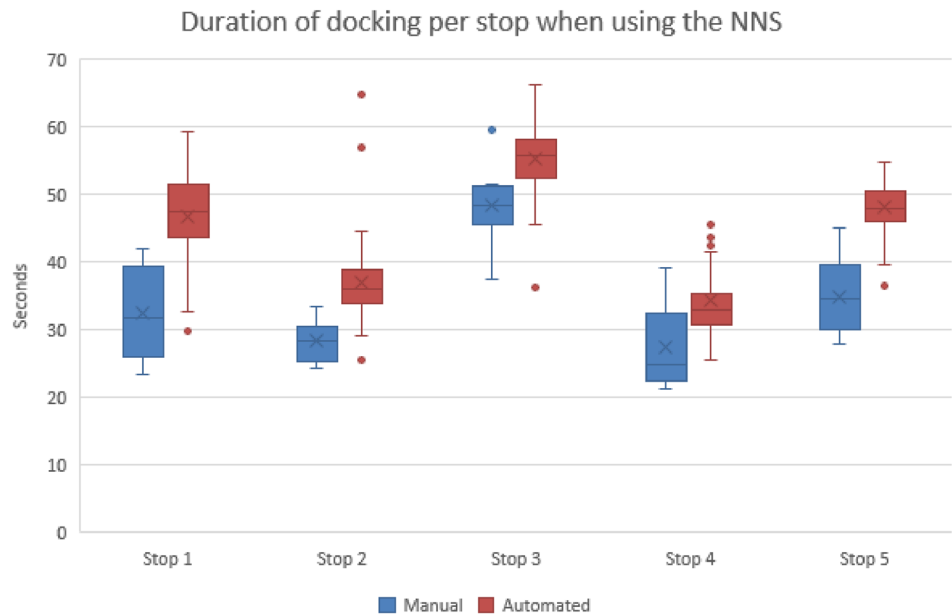
were asked about their initial experience and understanding of the system. Finally, to give them longer exposure to the system and become more familiar with it, the participants drove three more consecutive laps during which they used the system. Figure 4 shows the duration of the docking sequences for each bus-stop, both when driving manually and when using the system. The test-drive took a total of approximately 2 h for each participant.

In the final part of the study, the **post-test interview**, the participants went back to the interview room. They completed a questionnaire regarding trust and acceptance and were then interviewed about their experience of the automated system and its anticipated effects on their everyday work.

### 3.5 Data collection

Objective and subjective data was collected during and after the test-drive. The data collection aimed at gathering data regarding aspects deemed as important for acceptance—trust, perceived benefits, perceived effort, ease-of-use, and compliance. Subjective data were collected through

**Fig. 4** Duration of dockings when driving manually and using the NNS for each stop



interviews and questionnaires, focusing on participants' acceptance of the system as experienced in the test but also investigating anticipated benefits and and/or challenges/issues and thereby their expected acceptance of the system in their everyday work context. Objective data were collected through video recordings, to document the driver's interaction with the user interface of the NNS and identify any behavioural changes related to trust, such as hands on the steering wheel (or not).

**Interviews** were conducted before, during, and after the test-drive. All were semi-structured in nature, with a combination of open and closed questions. The pre-test interview was aimed at understanding the participants' previous experiences and preferences and thereby better understanding the other data collected. More specifically, this related to whether and how the participants' experience of the NNS was affected by earlier experiences. The pre-test interview focused on the participants' experience and attitude towards their occupation, work environment, technology in general and (the idea of) NNS in particular, as well as their expectations about the system they would be testing in the study. The short interview between the two test-drive blocks focused on the participants' initial experience and understanding of the system. This was aimed at capturing information that might be overlooked in the post-test interview. Finally, after the test-drive, a longer post-test interview was held to gain a deeper understanding of the participants' acceptance of the system. This interview focused on their: (1) general experience, (2) trust in the system, (3) understanding of the system, and (4) anticipated effects of using such a system in their everyday work.

**Questionnaire** data on the drivers' acceptance of the system were collected via a modified SKAS-scale

(questionnaire items appear in Fig. 6). The tool has been developed in an earlier project with ADAS, yet not statistically validated, and the modification done for this study includes elimination of items not useful for the specific system under investigation, i.e., the NNS. The tool includes four aspects for which specific items have been formulated: trust and control (three items), perceived benefit (seven items), perceived effort (eight items), and compliance (two items), and is based on a solid theoretical foundation including the diffusion of innovations theory (Rogers 1995), TAM (Davis 1989) and UTAUT (Venkatesh et al. 2003).

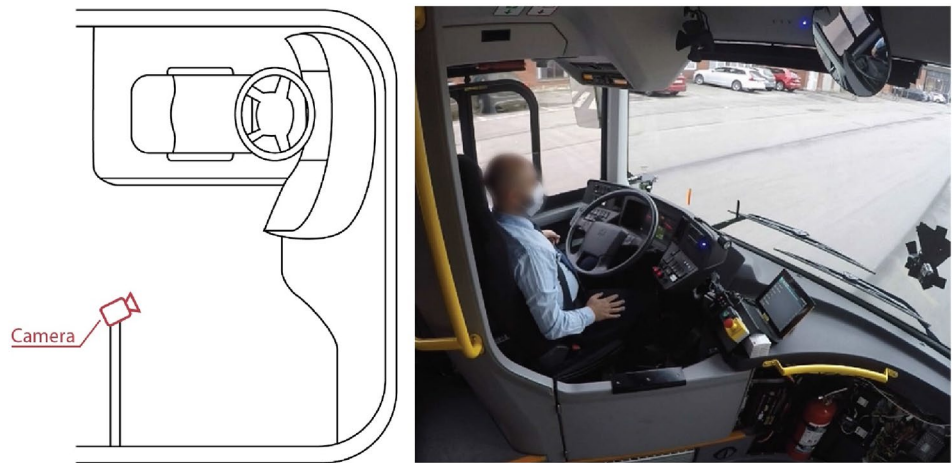
Additional information on trust in the NNS was collected via a second questionnaire (Ekman et al. 2021) after the test ride to complement the interview and video data. The tool focuses on both the user's trust in the system itself and the system's ability to carry out the intended task (docking at a bus-stop in this case).

**Video data** were collected during the test ride, to investigate behavioural indications of trust. A camera (facing the participants from behind as illustrated in Fig. 5) was used to collect objective data, and capture changes in hand position; the position of hands on or off steering wheel being a behaviour commonly used to measure trust (e.g., Yu et al. 2021).

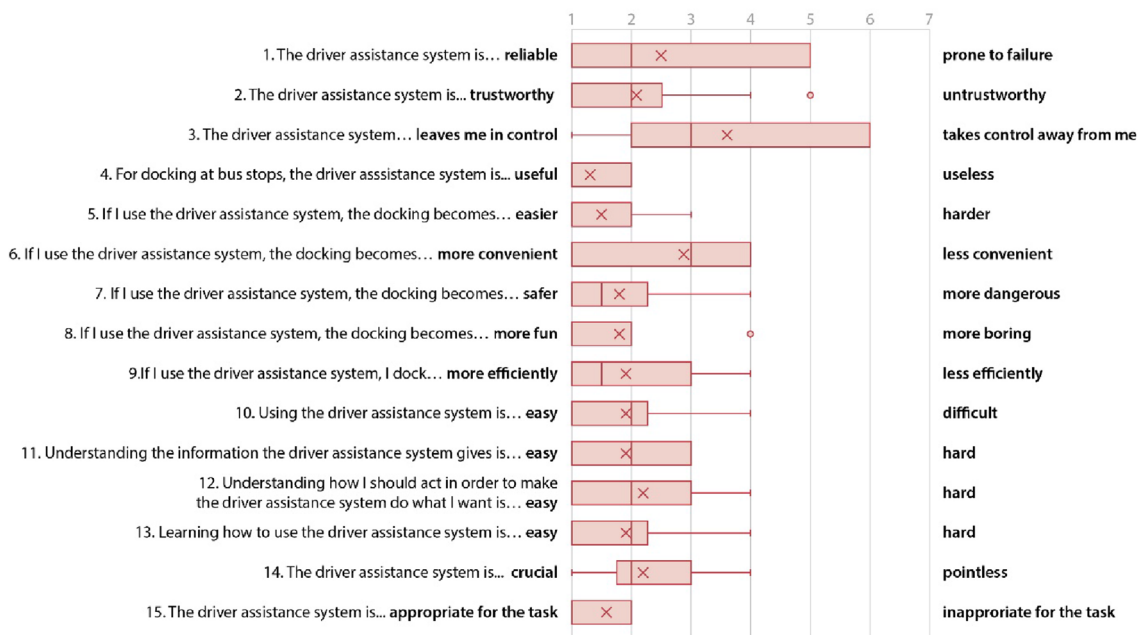
### 3.6 Analysis

Conclusions from the study were drawn based on triangulation, i.e., a combination of multiple methods and measures used to cross-check findings and compensate for the weaknesses of one method with the strengths of another. The triangulation comprised a thematic analysis of the interview data, a compilation of the questionnaire data, and an analysis of the video data.

**Fig. 5** Camera positioning and view



**Acceptance**



**Fig. 6** SKAS-questionnaire results

The thematic analysis was intended to reach a deeper understanding of the participants’ experience and acceptance of using the automated system, whilst identifying any underlying factors. A thematic analysis is an analytical approach aimed at identifying themes and patterns in qualitative data (Mills et al. 2010) (in this case the interview transcripts). The analysis was initially inductive in nature, meaning that there were no predetermined themes; any themes were created during the analysis. A second round of analysis was then conducted, with the themes organised into the three levels of the analysis framework (described in Sect. 2, *A tentative framework for studying experience and acceptance*).

This was to identify any patterns within and between the levels.

Questionnaire data were compiled, primarily to complement the interview data analysis and identify the participants’ level of trust in and acceptance of the NNS. A comparison of the questionnaire data and interview data was also conducted. This focused primarily on finding similarities and dissimilarities in the data (triangulating the findings) and identifying specific factors appearing to influence the participants’ acceptance and trust to a lesser or greater extent.



To facilitate the analysis of behavioural changes, the video data were manually annotated by two researchers (the first and second authors). This covered the drivers' hand positioning, as this is believed to be an indication of trust. It was also intended to include the drivers' intervention behaviour, such as braking when the system was active, in the analysis, but this only occurred once and were therefore excluded from the analysis. The video data from all laps, both when participants drove manually (one lap) and then used the automated system (five laps), were annotated. A total of 292 dockings were annotated (eight were excluded due either to camera malfunctions or technical issues with the system), with a total time of 208 min. When using the automated system, the data were annotated for the period from activation of the system until its deactivation. When driving manually, the data were annotated from when participants were informed of where they would subsequently be able to activate the NNS and until the vehicle came to a full stop at the bus-stop. The annotation scheme for the hand position had five states: (1) both hands on steering wheel, (2) right hand only on steering wheel, (3) left hand only on steering wheel, (4) no hands on steering wheel, and (5) hands hovering (close to steering wheel without touching it and with palm(s) facing it).

To analyse how the automated system affected participant behaviour, the annotated data on hand position were investigated by comparing the mean percentage of each state and participant over the five laps with the automated system.

## 4 Findings

The findings are organised into four sections, first covering general acceptance and experience and then according to the three levels of operation, use and work system. This section uses abbreviations such as P1 for Participant 1 and so on for P2–P10.

### 4.1 General acceptance and experience

The participants' acceptance of the NNS was generally high and their overall experience positive. They described testing the NNS as "comfortable", "fun" and "exciting". This generally high level of acceptance is reflected in the results of the acceptance questionnaire (see Fig. 6), with most questionnaire items rated very positively (note: a lower number corresponds to a more positive score), especially the items relating to usefulness, whether the system was fun to use and whether the system was appropriate for the task.

However, there were three items where the participants' responses differed, more specifically: (1) "the system is reliable", (2) "the system leaves me in control", and (3) "the docking becomes more convenient". Reasons for the more

negative ratings of system reliability and convenience of docking might be that participants experienced elements of the bus's driving behaviour as "jerky", especially during the transition from manually operating the bus to handing over the control to the NNS and when coming to a full stop during the bus-stop docking sequence (this is further described in Sect. 4.2 Operation Level). The fact that the responses regarding control had the most diverse ratings may be explained by the participants' different perceptions and understanding of the system. Some participants saw the NNS as an assistive tool; others saw it as a system that took over the docking completely (this is further described in Sect. 4.3 Use Level).

## 4.2 Operation level

### 4.2.1 Understanding the operation of the NNS

In general, the participants found it rather easy to understand how to operate the NNS. The information given before the test-drive was, according to the participants, sufficient to understand how to operate the system. Although the participants understood how to activate the system, some found it difficult to choose the right speed and lane placement for the handover sequence; in other words, when to activate the system. There were many things to consider before initiating the handover sequence and they thus believed that continuous information on exact speed and lateral positioning was necessary during handovers. Moreover, many participants believed the system was both overly sensitive and harsh during the handover sequence and this was found to be unsettling. For example, "When you activate this [NNS], and we're not exactly correctly placed [in the lane] there was a significant jerk in the bus ..." (P6). This, in turn, was perceived as having to negotiate with the NNS as to how the handover sequence should be done. This negotiation felt unnecessary, awkward, and difficult to adapt to. One participant even described the handover sequence as very rigid and not adapted to the user at all, which then reminded them of a rollercoaster—"It [the NNS] seems to be programmed in one way, the way they [developers] have driven it, it becomes very much like a rollercoaster". Thus, the participants felt that the system should be better adapted to the driver.

Furthermore, most participants understood whether the system was active or not, either through the blue light in the dashboard or the driving behaviour of the bus which they believed was a clear indicator of the system being activated. However, although most understood that the blue light showed whether the NNS was active, a few participants also believed that a red light on the dashboard indicated that it was active (the red light actually related to another function on the bus). Those who had noticed and identified the blue light as indicating the NNS being activated also felt that they gave a lot of attention to that

light. This caused one participant some concern—“Then I was focused only on that blue light. That’s not good because if you focus on that too much [the blue light indicating when NNS is active] you lose focus on the road” (P9).

#### 4.2.2 Trust in the bus’s ability to carry out its manoeuvring task

Participants described how they had a high level of trust in the ability of the bus to carry out its manoeuvring task. This was also evident from the questionnaire, in which all items regarding trust had high ratings, with median scores for each item between 5.5 and 6.5 (a higher score is more positive) on a scale from 1 to 7 (see Fig. 7).

Data from the video analysis of the participants’ hand positions also indicated high levels of trust. The findings showed that the participants largely did not touch the steering wheel or hover their hands over it (see Fig. 8) when the system was activated during docking.

A comparison between the percentage of “no hands on steering wheel” and the questionnaire data on user trust in the system indicates a correlation (Spearman’s  $\rho=0.59$ ) between participants not having their hands on the steering wheel and their subjective rating of trust in the system (see Fig. 9). Hence, the more the participants trusted the system, the more willing they were to let go of the wheel.

The findings (see Fig. 8) also show that for most of the time (even at the outset of the test-drive), many participants had no hands on the steering wheel (Median<sub>lap1</sub> = 90%, Mean<sub>lap1</sub> = 77%). The findings also show that the percentage of “no hands on steering wheel” increased over time (Median<sub>lap5</sub> = 97%, Mean<sub>lap5</sub> = 89%). This indicates that the participants’ trust increased as they gained more experience of the system. This was further borne out by the participants in the interviews, with a majority stating that their trust in the NNS formed whilst using it as they increased their understanding of the system’s capabilities and limitations. Trust was primarily affected by the

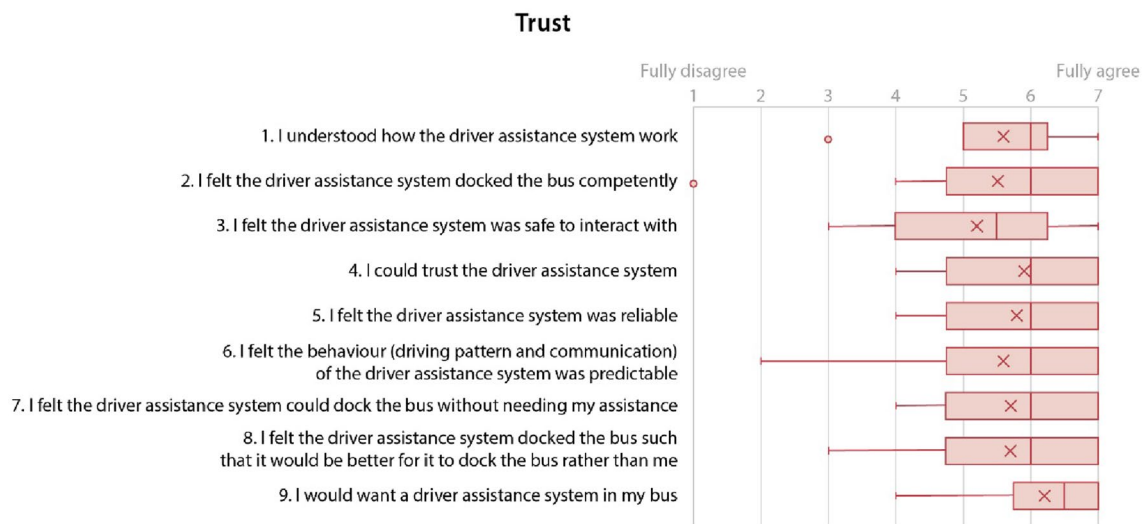
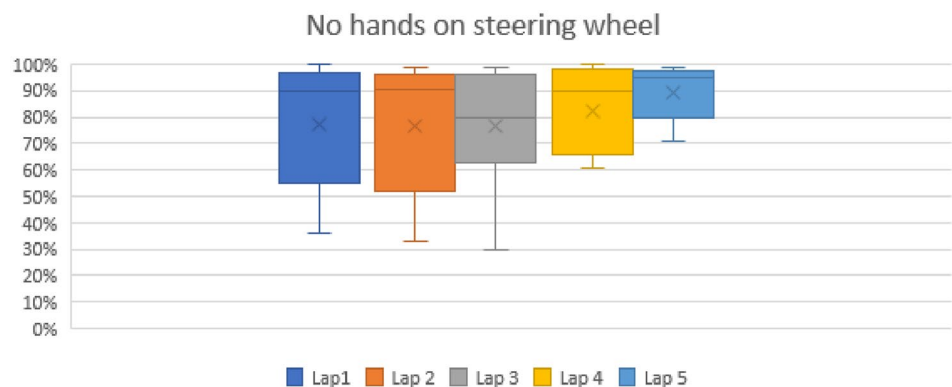
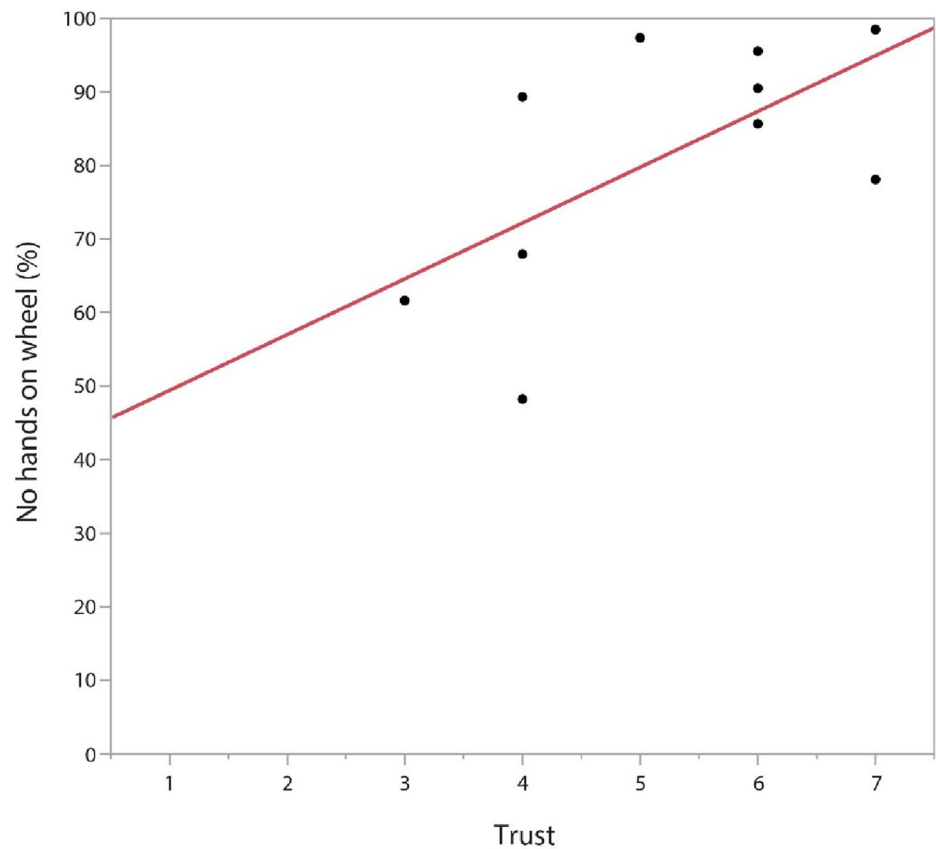


Fig. 7 Trust-questionnaire results

Fig. 8 Percentage of time using the NNS with no hands on the steering wheel during the five laps



**Fig. 9** Correlation between percentage of time participants had their hands on the steering wheel and their subjective rating of trust in the system. The higher the participants rated their trust, the more they had no hands on the steering wheel when using the NNS



performance of the NNS, with participants experiencing the system's driving behaviour as predictable and dependable. For example, one participant described how the bus drove "calmly and nicely and went on acting in this way. You could say it had consistent behaviour." (P3).

However, although the participants generally had a high level of trust in the system's ability to carry out the manoeuvring task, some thought it performed unpredictably and unreliably during certain sequences. A common reference was to the aforementioned handover sequence. In this situation, a majority of the participants did not fully trust the system, as they found the handover unsettling. This was also reflected in the trust questionnaire, in which the item with the lowest ratings was whether the NNS was safe to interact with (see Fig. 7). Another sequence that some participants mentioned was when there were other road users present—"He [a semi-trailer driver] cut the corner and the bus closed in on the semi. That was then I had to do something and, since I was close to the brake pedal, the ride ended there. I was uncertain about whether it [the NNS] really works." (P6). The participants argued that the NNS's driving behaviour did not convey whether it had identified the semi or not and they were therefore unable to predict whether the system would avoid the vehicle or not. Thus, the participants took control of the bus.

### 4.3 Use level

#### 4.3.1 Perceived usefulness of NNS

The docking phase was experienced as rather calm, smooth, consistent, and precise. Many participants believed that using an NNS could assist in making the job as a bus driver easier and simpler—"It makes things easier for bus drivers, much easier and simpler. Especially since the worst part is getting in and out of bus-stops" (P5). Participants felt that docking the bus consistently, close to the kerb and without errors, was difficult, especially over a long period and multiple bus-stops. They therefore believed that the NNS would perform better than an actual human bus driver. They felt moreover that the greatest benefits would be in complex traffic environments, like city centres or when assisting bus drivers in handling different types of obstacles and difficult passages; a car wrongfully parked in a bus-stop, or a poorly designed bus-stop. One of the participants even suggested that an NNS might be a favourable way of learning how to dock efficiently and safely at bus-stops and that it might thus help new drivers.

Participants also believed there would be benefits and issues relating to **cognitive ergonomics**. Some of them believed that the NNS could increase a driver's awareness

of their surroundings, since it is easier to focus on the traffic environment when the NNS is controlling the docking sequence. Conversely, others felt that driver awareness might be diminished due to them not being as vigilant as when driving the bus manually. Some also believed that implementing an NNS could decrease tiredness, because less attention is needed compared to manual docking. This could lower the risk of incidents. Thus, according to the participants, there could be a lower cognitive load on the driver if there are NNSs available, especially in adverse weather conditions which demand greater focus from the driver.

Participants believed furthermore that there may be positive benefits from a **physical ergonomics** perspective, such as a decreased workload due to fewer driving tasks being done by the driver. Bus drivers may have to dock at hundreds of bus-stops every day and less manoeuvring when docking might lead to less turning of the steering wheel and, thus, potentially to less neck, shoulder, and arms pain.

Many participants felt that the decrease in speed when approaching a bus-stop could lead to improved **safety**. One aspect of this was a lower risk of accidents, such as passengers falling over when onboard a bus. The lowered docking speed might also decrease the risk of incidents with pedestrians, cyclists, and other vehicles, combined with the fact that the NNS was considered better at identifying possible incidents and having better reaction times than human bus drivers. This, in turn, could allow children and passengers with disabilities and those using pushchairs, walkers, or sticks to embark/disembark the bus more easily. However, for some participants, the handover sequence and coming to a full stop at bus-stops increased their perception of risk as they believed that the NNS's jerky behaviour could lead to standing bus passengers falling over.

#### 4.3.2 Understanding “what the NNS is” and its relationship to the user

Even though the training was quite extensive—including verbal information on system functionality and the role of the driver, a practice session and a checklist to verify that they had understood—there were two different main views of “what the NNS is”. Some participants understood it to be a system that conducts the task of driving without any human involvement whatsoever, whilst others viewed it as a tool, merely supporting the bus driver in docking. Indications of the same phenomena can also be seen in the SKAS-questionnaire (see Fig. 6) where the item regarding control had the most mixed answers, indicating that participants had different views on the amount of control they had when using the NNS.

Those who interpreted the NNS as a system that drives without human involvement did so, because the NNS was able to dock the bus by itself. Thus, they believed the NNS

to be capable of multiple tasks (such as driving and identifying and calculating any upcoming risks) and that the driver therefore only needs to hand over control. The bus driver's role during docking would be more or less just opening and closing the doors for the passengers. Several participants believed that since the bus handled so many tasks, it also communicates information to other road users, such as using the turn indicator to show that the bus is about to turn into the bus-stop (i.e., docking). In fact, the system did not do this. This resulted in several participants forgetting to signal that they were about to dock at the bus-stop which created frustration among some.

The other group of participants believed that the NNS only takes over parts of the driving task. This allowed the bus drivers to get support from the NNS in operating the bus and that they could therefore better monitor the traffic environment for any upcoming risks. This group of participants felt that the driver's role was to always be in control of safe operation. However, some felt that it was sometimes difficult to understand who was in charge, especially in the hypothetical situation of a bus-stop with obstacles—“I'm thinking, if someone runs out in front of the bus, will the bus-stop by itself or do I need to brake?” (P4). These participants viewed the NNS as an assistive tool that could be used by bus drivers to increase safety, comfort, and precision rather than (as interpreted by the other group) a system that takes control and can dock without any driver attention at all. Thus, participants had different views of “what the NNS is” and this affected how they perceived the driver's role when using the system.

Furthermore, the participants understood (to a greater or lesser extent) where to use the system and how it would work in different contexts. They felt that the information given by the test leaders about where the system could be used worked as a reference point (in other words, when it was time to activate the system). The information the test leaders gave, plus a decrease in speed to 20 km/h (when entering geofencing zones), indicated to the participants that the NNS was ready to be activated. However, most of them still waited for an explicit clearing signal from the test leader that the NNS was ready. Thus, the participants felt that it was important to get information on when and where one should use the NNS; both from instructions before use and from the system itself.

#### 4.3.3 Trust in the system's ability to carry out the docking task

Participants stated that their level of trust was affected by the bus's ability, not only to carry out the manoeuvring task but also the docking task within the traffic environment. Many said that they trusted the NNS and that they could rely on the system to dock the bus, as mentioned by one of

the participants when asked if he trusted the system—“Yes, from what I’ve experienced so far. I tested it [docking the bus with the NNS] six times and it worked. It was good in every way” (P5). The participants felt that they just needed to monitor the docking sequence.

Participants’ trust in the NNS was also highly affected by the traffic environment in which they experienced the NNS—“Here [in an industrial area] it isn’t a problem, but in rush-hour traffic, how will it react then?” (P8). The environment in which the tests were run involved light traffic. In other words, the number of cars, trucks, pedestrians, and cyclists was quite low. The participants felt that they could trust the system to conduct the docking sequence in this environment but that if the traffic had been denser, with higher levels of complexity and risk, they would not have trusted it to the same extent and had therefore not relied on it as much.

#### 4.4 Work system level

Participants frequently mentioned the pressure they felt when having to drive slower than other traffic, thus forcing other road users, such as cars and trucks, to slow down. They also mentioned the pressure from bus passengers who often want to arrive at their destination as quickly as possible. This external pressure caused stress, especially during rush-hour. Thus, although the participants believed the NNS would bring multiple benefits when docking the bus, they were concerned about its effect in decreasing speeds even further. The reasons for these concerns were mainly that the pre-docking phase was found to be inefficient, as participants felt the NNS had to be activated too far in advance of the actual docking phase (when driving into the bus-stop) and were concerned about driving too slowly before reaching the bus-stop—“It always comes back to the bus being so slow; in part, before you’ve even reached the bus-stops, when you drive into the stops and just before stopping” (P6).

As with the pre-docking phase, many participants thought that the NNS drove too slowly, primarily in the final sequence, just before coming to a full stop. Thus, a majority of the participants thought the NNS might increase their stress levels. They felt that it was important for bus drivers to be able to choose when and where they want to use the system. In other words, a bus driver should be able to decide whether to activate the system or not, so as to dock quicker when necessary. Without this, they felt that there would be a risk of stress which could lead to compensating behaviours on their part, such as driving faster between bus-stops to make up for lost time. However, there were also concerns that the option to turn off the system might lead to no-one using it at all—“Many [bus drivers] turn off the currently available aids and don’t use them. The radio is turned off, the ticket machine is turned off...” (P6). Thus, even though

it is favourable to be able to choose whether and when to use the system, this may also lead to the system not being used at all, thus missing out on any positive benefits from it, and furthermore, even if the NNS was seen to provide multiple benefits when docking (use level), the participants were concerned about how the system would affect their work overall (work system level).

## 5 Discussion

The aim of the study was to develop further knowledge about how professional bus drivers experience, trust, and accept an ADAS that can assist them when docking at bus-stops. This was accomplished in a trial where data were collected both on drivers’ behaviour, perception, and understanding of such a system and on the benefits and/or challenges/issues they anticipate if such a system were to be implemented.

The participants were generally positive to the NNS and expected benefits in terms of increased comfort and safety. These are benefits mentioned in relation to ADAS in general, as well as key factors in earlier studies of professional truck drivers’ (and their employers’) acceptance of highly automated driving (Richardson et al. 2017). Some participants also anticipated benefits in terms of reduced mental workload in connection with docking. This was evidenced in a study by Collet et al. (2003) but only after driver habituation to the system. The fact that some participants commented on their focus on the user interface in connection with the docking procedure, rather than observing the situation around the vehicle, is further indication that the introduction of NNS is not necessarily a simple plug-and-play process but rather one that requires learning. However, physical ergonomic benefits were also mentioned as possible outcomes of NNS introduction. As far as the authors are aware, this aspect has not previously been addressed in relation to ADAS. Nevertheless, several studies report on bus drivers’ work-related symptoms in terms of pain in neck, upper arms, lower back, and so on (e.g., Mård 2006; Taklikar 2016) part of which can be attributed to the muscular activity involved in manoeuvring a bus. However, positive effects have been found to the introduction of a dynamic steering system, which for example automatically returns the steering wheel to the dead-ahead position when the driver lightens his or her grip on the wheel (Ahlström et al. 2019; Bligård and Johansson 2019). Hence, if no manual manoeuvring of the bus is required when docking at bus-stops, this could contribute to a reduction in musculoskeletal stress and improved ergonomic work conditions.

The participants thought that the NNS handled the docking well, each docking procedure being very precise and generally regarded as smooth. Consequently, they expressed

and indicated a high level of trust in the bus's ability to carry out the manoeuvring task and dock at bus-stops. In other studies too, professional drivers have expressed a high level of trust after experiencing automated systems in heavy vehicles (mainly trucks) (e.g., Castritius et al. 2020). However, even though users may express trust in an automated system in general, studies have also shown that there are circumstances where they express less trust. For example, in the present study, the participants said that they trusted the NNS less in certain situations due to the bus's driving behaviour, a finding which matches earlier studies which have shown the relevance of considering driving behaviour in users' formation of trust in automated driving systems (e.g., Abe et al. 2018; Ekman et al. 2021). There is evidence also of other situational factors influencing users' trust. Yang et al. (2018) found that although the truck drivers in their study were positive about using a cooperative adaptive cruise control in general, they nonetheless preferred driving manually in heavy traffic or when merging onto a major road. In the present study, the participants mentioned possible differences in system performance between the traffic conditions in which the trials took place and heavy traffic, rush hours, and so on. Hence, the findings of this and earlier studies emphasise the importance of evaluating ADAS in different and as realistic traffic conditions as possible in order for these influencing factors to emerge, so that we can understand which factors influence users' trust in automated systems.

Based on the assumption that the relationship between drivers and automated systems must be analysed on different levels, the analysis identified acceptance aspects on three levels: operation, use, and work system levels. Regarding the use and work system levels, the participants related system usefulness to carrying out the task of docking (use level) but also to being able to perform the work of bus driving overall (work system level). Furthermore, the participants' understanding of the NNS concerned how to operate it (operation level) but also what it was and where to use it (use level). Likewise, users' trust in the NNS was also identified on the operation and use levels, where trust seems to have been influenced by the NNS's driving behaviour and its ability to carry out the task of docking.

The importance of analysing the results whilst taking the different levels into consideration is evident in that even though there were both positive and negative comments relating to all three levels, comments that could be related to the work system level were mostly negative (such as concerns about efficiency), whilst comments referring to the operation level were predominantly positive. This indicates a degree of independence between the levels. In other words, whilst high degrees of user trust and acceptance are indicated on one level, on another level, trust and acceptance may be low. Comments referring to different levels may therefore contradict each other, as seen in the study in

which a slow docking process was regarded as positive on the use level, because it could make docking more comfortable, but negative on the work system level, since it was expected to affect the timetable as well as the efficiency of the public transport system overall. This might result in high levels of stress and compensatory driving behaviour, with drivers driving faster between stops or turning off the system. Hence, an ADAS such as NNS must not be designed with a specific (sub-) task only in mind. The system design must also match the users' goals related to the work context within which it will be used. In this particular case, this means being efficient when docking at bus-stops. Otherwise, routines and timetables need to be adapted to the NNS. There is thus a need to consider organisational issues when investigating professional users' acceptance of automated systems, something that was also noted by Castritius et al. (2020) who, following focus groups with truck drivers, saw that an organisational influence was missing and added it into their investigation of professional drivers' acceptance of automation in trucks. Possible conflicts and nuances regarding factors that influence users' trust and acceptance (as well as rejection) may be missed unless all three levels are considered when investigating how users' trust and acceptance are impacted by different automated systems. However, it is suggested here that the differences between the levels are not sufficiently taken into account in commonly used acceptance scales based on theories or models, such as TPB (e.g., Ajzen and Fishbein 2005), TAM (Davis 1989), and UTAUT (e.g., Venkatesh 2000; Venkatesh et al. 2003).

Considering the participants' comments, a degree of independence between levels is assumed. However, interdependency between levels was also identified; in other words, aspects on one level were observed to affect aspects on another level. In the study, the participants understood "what the NNS is" (use level) in two different ways. This affected the way the participants perceived their own role in collaborating with the automated system and whether or not they need to be an active part. This in turn likely affected how the participants perceived the way the system would be operated (operation level). For example, depending on their view of the system, drivers may be more or less inclined to keep their foot over the brake pedal ready to intervene if needed or to signal to other road users using the turn indicator.

Finally, the environment that the study was conducted in had rather few road users, but chosen due to the limitation of having a prototype system, which may have affected the participants' level of acceptance in the NNS. With more traffic on the roads and especially pedestrians on the sidewalk and at bus-stops, the participants may be more reluctant to use the system, at least in the beginning, which was also speculated by a few of the participants. Therefore, future work should investigate how drivers experience and accept

an updated NNS during denser traffic conditions, similar to the conditions of driving in the city centre. Additionally, the study also had an explorative character with a rather small number of participants, too few to generalise the findings. However, the triangulation of methods provided indications that when investigating user trust and acceptance of ADAS in a work context, it is important to consider these aspects at different levels. Therefore, future work should further investigate user trust and acceptance of ADAS using more participants to be able to identify clearer patterns and make more rigorous conclusions.

## 6 Conclusion

To conclude, an NNS that can automatically dock a bus at bus-stops seems to be a promising ADAS from different perspectives, as it was perceived positively by the participants and considered to have multiple benefits for bus drivers, passengers, and the transport organisation. However, for successful implementation and acceptance by drivers in a public transport system context, it is crucial to consider the trade-off between efficiency and other benefits of the NNS taking into consideration the objectives of the work and work organisation. Furthermore, when investigating user trust and acceptance of ADAS in a work context, it is important to consider these aspects at different levels; the operation, use, and work system levels, as well as how these levels affect each other, so as to grasp the nuances regarding factors that influence users' trust and acceptance of automated systems. The study contributes to research on ADAS in heavy vehicles by providing empirical data on users' acceptance of an ADAS that automatically can dock a bus at bus-stops. It also contributes by proposing a three-level perspective that enables more precise analysis of user experience and acceptance, allowing researchers and developers to identify on which level acceptance issues may arise, whether there are conflicts between the levels, and to create appropriate design adjustments.

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