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A longitudinal Study on Bus Drivers' and Passengers' Experience and Acceptance of an Automated Docking Support System

MIKAEL JOHANSSON
FREDRICK EKMAN

DEPARTMENT OF INDUSTRIAL & MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
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Mikael Johansson
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Avdelning Design & Human Factors
Institutionen för industri och materialvetenskap
Chalmers tekniska högskola
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The study presented in this report is part of the UITP eBRT2030 project, founded by Horizon Europe research and innovation programme under grant agreement No 101095882 and was conducted in collaboration with Volvo Buses, Svealandstrafiken, and VL.

Omslag: Buss utrustad med Narrow Navigation (NN) Systemet för automatiserad dockning vid hållplatser på plats i Västerås, Linje 1, foto Mikael Johansson

Executive Summary

Introduction

An evaluation of an advanced driver assistance system in buses called the Narrow Navigation (NN) System, developed by Volvo Buses, was carried out and co-financed within the EU project eBRT-2030 (European Bus Rapid Transit 2030) in collaboration with Volvo Buses, VL and Svealandstrafiken AB. This naturalistic, longitudinal study investigated real-world use and acceptance of the NN system, which automates aspects of the docking process, a task often described as stressful and cognitively demanding. The study examined how drivers' experience and acceptance evolve over time and evaluates passenger comfort during automated dockings using the NN system.

Method

A Volvo 7900 electric bus equipped with the NN system operated along a 13 km public bus route in Västerås, Sweden. Five professional drivers participated in a 3.5-month trial following a three-day training. Data were collected via interviews, questionnaires, and driving logs. Passenger comfort was assessed through questionnaires comparing automated and manual dockings.

Findings

Drivers' experiences with the NN system evolved over time, shaped by technical performance and context. Initial experience varied, but all drivers reported increased trust and acceptance over timeas they learned how to interact with the system. This increase in trust and acceptance was temporarily disrupted in the middle of the test period due to experiences often technical issues (e.g., positioning errors, interface lag) that caused frustration but were not seen as safety-critical. After, drivers adapted their behavior to the NN system; user trust stabilized but did not fully return to initial peak levels.

The NN system was highly valued during docking for its precision and consistency, reducing driver stress and improving passenger comfort significantly compared to manually operated buses. However, departures were problematic due to slow, indecisive acceleration, making it less suitable for merging into traffic.

Control transitions improved with experience, though drivers desired smoother handovers and more adaptive system behavior. LED indicators were preferred over audio due to ambient noise.

Conclusion

The NN system shows strong potential for improving docking consistency, driver ergonomics, and passenger comfort. However, its performance during departures and control transitions highlights the need for further refinement.

Future Research Directions

Future research should therefore:

(i) Investigate the potential benefits of automated docking systems using a larger sample size and examine in greater detail how driving behavior influences user experience and acceptance at both national and international levels.

(ii) Explore how an NN system with enhanced functionality—such as advanced object detection, auto-braking, and adaptive driving behavior—would be perceived in real public transport operations.

(iii) Assess the potential economic benefits of an NN system, including reduced tire and wheel axle wear and tear, and/or fewer sick leaves due to upper body aches and pains.

Acknowledgements

The study presented in this report is part of the UITP eBRT2030 project, founded by Horizon Europe research and innovation programme under grant agreement No 101095882 and was conducted in collaboration with Volvo Buses, Svealandstrafiken, and VL. We would like to begin by extending our sincere thanks to Volvo Buses for the opportunity to contribute to the study, and especially to Joakim Jonsson, Gustaf Bergström, and Isac Olofsson for their excellent collaboration.

We would also like to express our special thanks to the bus drivers at Svealandstrafiken, who so generously shared their experiences and reflections with this project. Your contribution has been invaluable, and without your commitment this project would not have been possible.

Göteborg, september 2025
Mikael Johansson & Fredrick Ekman

1. Introduction

In recent years, automated driving systems such as advanced driver assistance systems (ADAS) have gained increasing attention, particularly in the context of passenger vehicles. These systems are designed to either support the driver or fully take over specific driving tasks, with the potential to enhance road safety, improve traffic efficiency, and increase comfort.

Despite this growing interest, research on automation in heavy-duty vehicles—such as buses and trucks—remains relatively limited (Richardson, Flohr, & Michel, 2018). Even fewer studies have explored the use of such systems in real-world settings or empirically examined the impact on bus drivers (Akridge et al., 2024).

One scenario of particular relevance is bus docking—the process of entering and exiting bus stops. This task is often repeated hundreds of times throughout a driver's shift and is frequently cited as stressful and cognitively demanding (Dukic Willstrand et al., 2017). ADAS could help reducing this workload and improving the overall working conditions for bus drivers (Nowakowski, Shladover, & Tan, 2015).

A previous study investigating a similar ADAS for automated bus docking identified potential benefits for bus drivers. While drivers acknowledged the system's potential to improve working conditions—such as reducing mental load and physical strain—they also expressed concerns about whether they would trust it to perform docking in complex traffic environments (e.g., crowded city centers), as well as about its broader implications for their role and work (Johansson et al., 2022).

Building on these findings, the present study therefore investigates how professional bus drivers experience and accept an ADAS that automates aspects of the docking process under bus operations in real-world conditions over time. In addition, it investigates how passengers perceive ride comfort during these automated dockings.

To address these objectives, the study is guided by the following research questions:

1. How do bus drivers experience and accept an ADAS that assumes control over parts of the docking process?
    a. How does bus drivers' experience and acceptance of ADAS change over time?
2. Do bus drivers perceive benefits of their overall working conditions from using ADAS?
3. How do passengers experience ride comfort during automated dockings at bus stops?

2. Method

To investigate bus drivers' and passengers' perceptions of an ADAS that assists with the dynamic driving task during dockings, a Volvo 7900 electric bus (12 meters in length) was equipped with an automated docking system—referred to as the Narrow Navigation (NN) system. The NN system could take over longitudinal and lateral control during docking maneuvers, while the driver remained responsible for manual driving between stops.

2.1. Test route

The study was conducted on public roads along an existing bus route (bus route 1) in the city of Västerås, Sweden (see Figure 1). This route was selected due to its diversity in stop characteristics and its coverage of suburban, industrial, and city-center areas. The 13 km route included 60 bus stops, of which 57 were possible for docking using the NN system. A one-way trip along this route took approximately 50 minutes.

Figure 1 - Bus route 1.

2.2. Setup - Narrow Navigation System

The NN system could perform lateral and longitudinal dynamic driving tasks during the approach to and departure from bus stops. It utilized two lidar sensors to create a three-dimensional map of the area. Each docking maneuver followed a pre-programmed path defined by coordinates and velocity points spaced every 10–32 cm. During operation, the system matched real-time sensor data with the pre-defined map to navigate accurately.

2.2.1. Driver Interface

Settings

Upon startup, bus drivers logged into the system via a touchscreen interface (see Figure 2, item 1), which enabled the storage of personal settings for future use. Through the interface, bus drivers could select the bus route (only route 1 was available during the study), activate or deactivate specific stops where they wished to use the system, and adjust the volume of audio notifications. Additionally, they could adjust the brightness of both the display and a status-indicating LED (see Figure 2, item 2).

The LED provided real-time feedback on system status:

- Green indicated availability.
- Blue indicated activation.
- Orange indicated disabled bus stop.
- Red indicated a system error.

Figure 2 - Driver interface.

Docking Procedure

When approaching a bus stop, if the bus was laterally within +- 0.5 m of the pre-defined digital path, the LED light turned green, a sound signal was played, and the touchscreen indicated - changing background color to green and presenting a text - that activation was possible. Bus drivers could then activate the NN system by holding down an activation button, located to the far right of the dashboard, for half a second (see Figure 2, item 3). Upon activation, the LED light turned blue, a second sound played, and the screen's background turned blue and displayed a confirmation message that the system was activated (see Figure 3 for the graphical user interface sequences on the touchscreen).

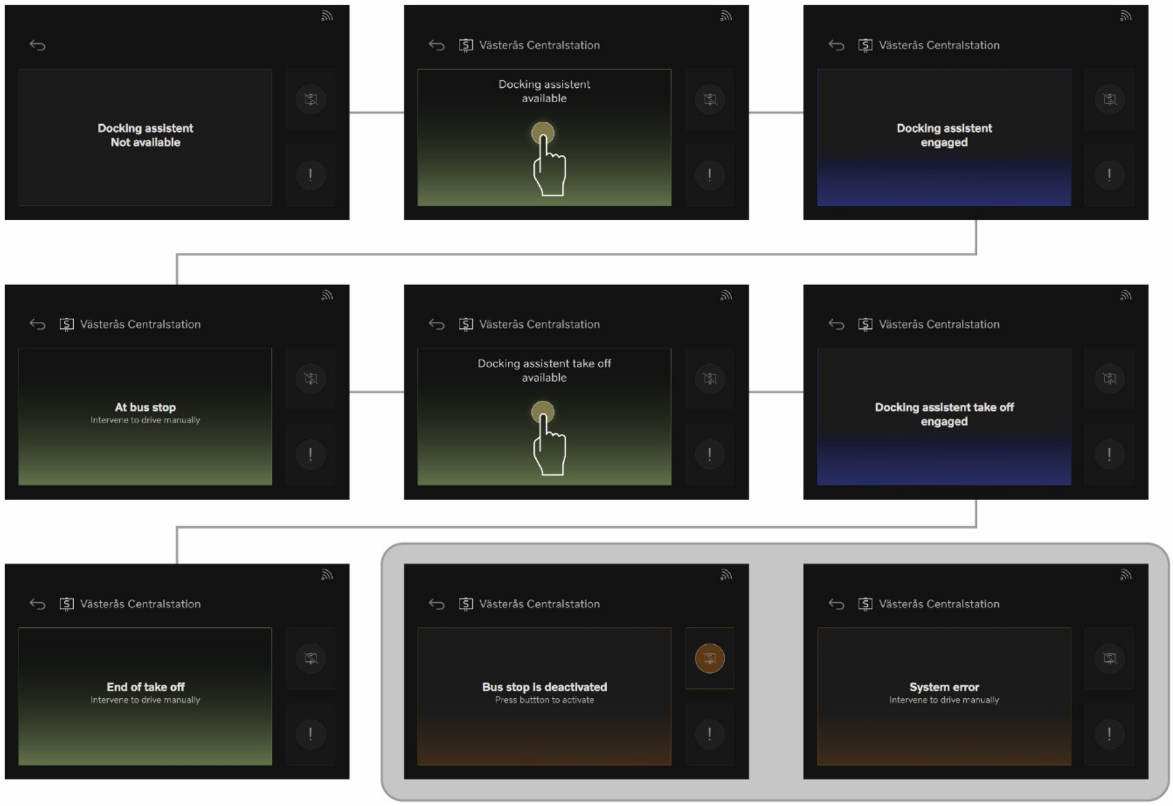

Figure 3 - Flow of graphical user interface sequences on the touchscreen during the docking procedure with the NNS, including normal operation and error screens (gray background).

While active, the NN system handled lateral and longitudinal control of the dynamic driving task but did not respond to obstacles that appeared; the driver still retained full responsibility and could override the system at any time by braking or steering. The system automatically disengaged if the steering angle or distance deviated significantly from the pre-defined path. At the end of the pre-defined path, once the bus was stationary, the system indicated that the maneuver was complete. The same procedure was available for departing from as when approaching the bus stop.

If the driver did not take control of the dynamic driving task at the end of the pre-defined path for department, the bus would stop automatically.

2.3. Procedure

The study procedure consisted of two parts, first a comprehensive three-day training session and then a 3.5-month long trial period in operation.

2.3.1. Training session

On Day 1, bus drivers received an overview of the project, its purpose, the study procedure, such as the test route, and provided informed consent (in line with GDPR). They then received a detailed introduction to the NN system, including information that participants can hand over steering and speed control to the vehicle, allowing the bus to drive automatically. That the system can only be activated where a digital path has been created, for example when approaching and departing from a bus stop; between bus stops, the bus is driven manually by the participant, and each digital track is customized for each unique bus stop so the bus drives the same way every time with consistent speed and precision. When the bus is performing the dynamic driving task, the driver monitors the driving and is ready to take over when necessary, for example if a person steps in front of the bus.

A live demonstration followed on a segment of the test route, where bus drivers got to observe the activation and de-activation procedure. They also received instructions regarding system description and safety, including a description of the hardware (Lidar, GPS and computers), user interfaces (light indicator, display and handover button), and activation and deactivation procedures.

The day concluded with practical training at the depot, including tasks such as activating and canceling automated driving, performing lane changes into bus stops, and experiencing simulated anomalies with sharp steering movements.

On Days 2 and 3 of the study, participants completed supervised driving sessions along the bus route to familiarize themselves with the NN system and the test route. Each driver received approximately four hours of practical driving experience. After completing the training sessions, drivers were provided with personal logins for the NN system.

2.3.2. Trial period

Following training, bus drivers used the NN system-equipped bus one day per week over a 3.5-month test period (mid-January to late April). This extended exposure was intended to allow bus drivers to develop usage patterns and enable the study to capture not only their initial acceptance of the system as well as identifying changes over time.

2.4. Data collection

The data collection focused on both primary users—i.e., the bus drivers—and secondary users—i.e., the passengers. It aimed to capture bus drivers' acceptance and experience of using the NN system, as well as passengers' perception of ride comfort during automated dockings. An overview can be seen in Figure 4.

2.4.1. Bus drivers

Both subjective and objective data were collected during and after the test period. Subjective data were gathered through semi-structured interviews and questionnaires, while objective data were obtained via driving logs.

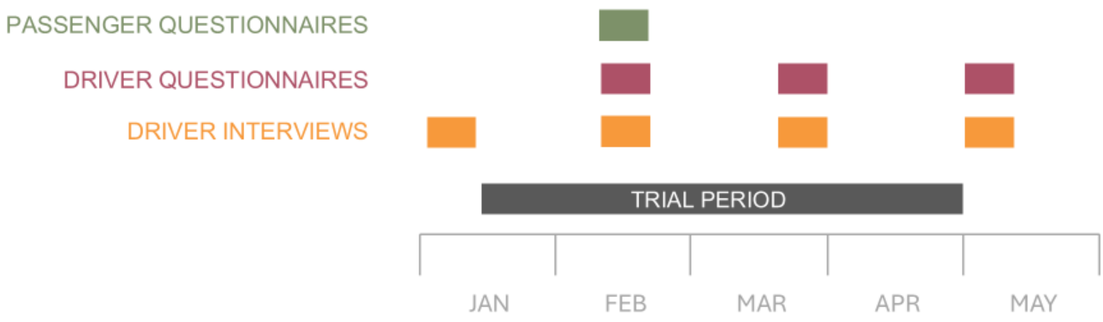

Figure 4 - Overview of data collection methods.

Interviews were conducted before, during, and after the test period to capture both initial and long-term experiences and acceptance. All interviews followed a semi-structured format, combining open- and closed-ended questions. The pre-test interviews aimed to understand participants' previous experiences and expectations, serving as a baseline for interpreting subsequent responses-i.e., if and how the participants' experience of the NN system was affected by earlier experiences. The following interviews were conducted after three weeks and again after two months to explore general experiences and acceptance of the NN system, including how useful they perceived it was to solve a relevant task and how willing they were to have it in the buses and use it. A final interview, conducted after the test period, focused on participants' long-term acceptance and overall experience. In this interview, participants were asked to sketch a curve illustrating how their experience evolved over time and to reflect on their use of the system with the aid of individualized driving data visualizations, which depicted the frequency and duration of automated docking events at different bus stops.

Questionnaires were administered in conjunction with the interviews—after three weeks, after two months, and at the conclusion of the test period. A modified version of the SKAS was used to assess user acceptance (See Johansson et al., 2022 for more details). This data complemented the interviews and allowed for the identification of trends or changes in acceptance over time.

Driving data were collected continuously throughout the test period. This included activation logs for each bus stop, capturing when and for how long the NN system was used, as well as whether activation occurred when approaching, departing, or both. Additional data included the driver ID, timestamp, and deviation from the predefined path (distance and speed). Filters were applied to exclude irrelevant events, such as when bus drivers passed stops without docking (e.g., no passengers waiting or signaling to exit). Furthermore, logs captured any adjustments made to user interface settings and manual activations or deactivations of specific bus stops.

2.4.2. Passengers

Passengers' perceptions of comfort during dockings performed by the NN system were assessed via a short questionnaire. The questionnaire consisted of eight items measuring aspects such as:

- General ride comfort.
- Smoothness of acceleration and deceleration.
- Perceived safety.
- The appropriateness and effectiveness of the docking maneuver.

Responses were collected from passengers on both the automated bus and comparable manually driven electric Volvo buses operating on the same route to be able to compare the comfort experience of the NN system with current docking behaviors.

To maintain consistency across conditions, responses from passengers riding on similar time schedules and route conditions were prioritized. Test leaders approached passengers immediately after they had experienced at least one docking maneuver and invited them to complete the questionnaire. Participation was voluntary and anonymous.

2.5. Data analysis

Conclusions of the study were drawn based on triangulation[1] consisting of a thematic analysis of the interview data, a compilation of the questionnaire data, and an analysis of the driving data.

The thematic analysis of the interview data was conducted to gain a deeper understanding of the participants' experience and acceptance of the NN system, as well as to identify any underlying factors. Thematic analysis is a qualitative method aimed at identifying patterns and themes in data—in this case, the interview transcripts (Braun and Clarke 2006). The analysis followed an inductive approach, meaning that no predefined themes were used; instead, themes emerged through the process of analysis. Both authors read the transcripts together and extracted statements deemed relevant. These were then grouped into themes based on similarity. This was done iteratively, with some themes being merged and others split, in order to refine the analysis and identify recurring patterns.

[1] A combination of multiple methods and measures used to cross-check findings in order to compensate weakness of one method with strengths of another

Questionnaire data from the bus drivers were compiled to primarily complement the interview analysis. The aim was to detect potential changes in bus drivers' acceptance of the NN system over time. A comparison of the questionnaire and interview data was also carried out, focusing on identifying similarities and differences between the two sources. This triangulation aimed at identifying specific factors influencing participants' varying levels of acceptance of the NN system, such as the driving behaviour or reliability of the system.

In addition, questionnaire data from passengers were used to compare passengers' ride comfort experiences between dockings performed by the automated bus and those by manually driven buses. Differences in ratings were analyzed using Mann–Whitney U tests (Wilcoxon rank-sum tests), a non-parametric test used for ordinal or non-normally distributed data. Analyses were performed in R (version 2025.09.0+387; R Core Team, 2024) using the *rstatix* package (Kassambara, 2021). Statistical significance was assessed at the $\alpha = 0.05$ level [2] using two-tailed tests.

To analyze how bus drivers used the NN system, descriptive statistics were applied to activation data. This provided an overview of the total number of activations per driver, the proportion of activations performed in relation to possible activations, and how usage patterns changed over time.

2.6. Participants

2.6.1. Bus drivers

Five bus drivers[3] took part in the study: three male and two female. All were professional bus drivers with between 4 and 29 years of experience (Mean = 12.6, Standard Deviation = 10), and their ages ranged from 30 to 64 years (M = 44, SD = 12.8). Participants were recruited through their employer, and their participation was compensated as part of their regular working hours.

2.6.2. Passengers

A total of 200 passengers completed the questionnaire: 61 had traveled on the automated bus, while 139 had traveled on manually driven buses. A greater number of responses were intentionally gathered from manually driven buses to reflect the variation in driving styles among bus drivers.

Of the respondents, 74 were male and 126 female. Among them, 54 males and 85 females rode manually driven buses, while 20 males and 41 females rode the automated bus. Passenger ages ranged from 18 to 95 years (M = 42.6, SD = 17.5), with similar age

[2] Results were considered significant if there was less than a 5% chance they happened randomly.
[3] The sample size was selected to ensure that each driver had consistent and prolonged exposure to the NN system throughout the study period.

distributions among users of manually driven buses (M = 43.7, SD = 17.4) and the automated bus (M = 40.1, SD = 17.5).

3. Findings

3.1. Bus Drivers' Work and Work environment

Interviews conducted before the test period revealed that bus drivers generally found their job enjoyable. They appreciated interacting with passengers, delivering good service, and contributing to society by enabling mobility. This positive outlook was reinforced by a rather good work-life balance, with little need to bring work home. Most bus drivers found the job stimulating and seldom boring.

However, they also described several challenges. Unfavourable working hours—including weekends, evenings, and early mornings—made balancing work and family life difficult. Long shifts, often reaching the legal maximum, were also a concern, as they could lead to reduced alertness toward the end of a workday. During peak hours, the schedule could be too tight to allow proper breaks, while at other times, excessive buffer time created inefficiencies.

While interactions with passengers were mostly positive, they were also considered to have downsides—such as encounters with intoxicated or aggressive individuals. Other road users were also mentioned as a challenge, particularly when cutting in front of the bus without understanding the risks involved.

The driving experience was also influenced by the quality of the bus. Some buses had heavy steering, which bus drivers said caused fatigue and pain in the shoulders, back, arms, and wrists.

Finally, bus drivers expressed mixed feelings about new technology. While they generally welcomed technology that supports their daily tasks, there was some skepticism toward ADAS in buses due to the potential risks if the system were to fail. Bus drivers were curious about automation but cautious, and uncertain whether these systems would assist in their work—or eventually replace them.

3.2. Overall Experience & Trust Over Time Using NN System

In total, the bus drivers activated the NN system 8,569 times, using it for 28.7 hours and covering a distance of 310 km. Their overall experience of the NN system was positive, with several expressing that the system worked better than initially expected. All bus drivers stated that they would like to have a system like the NN system in the buses they drive. This positive sentiment was reflected in their acceptance ratings in the questionnaire: most post-trial scores (as seen as black circles in Figure 5) were four or lower on a scale from one to seven, where one was most positive.

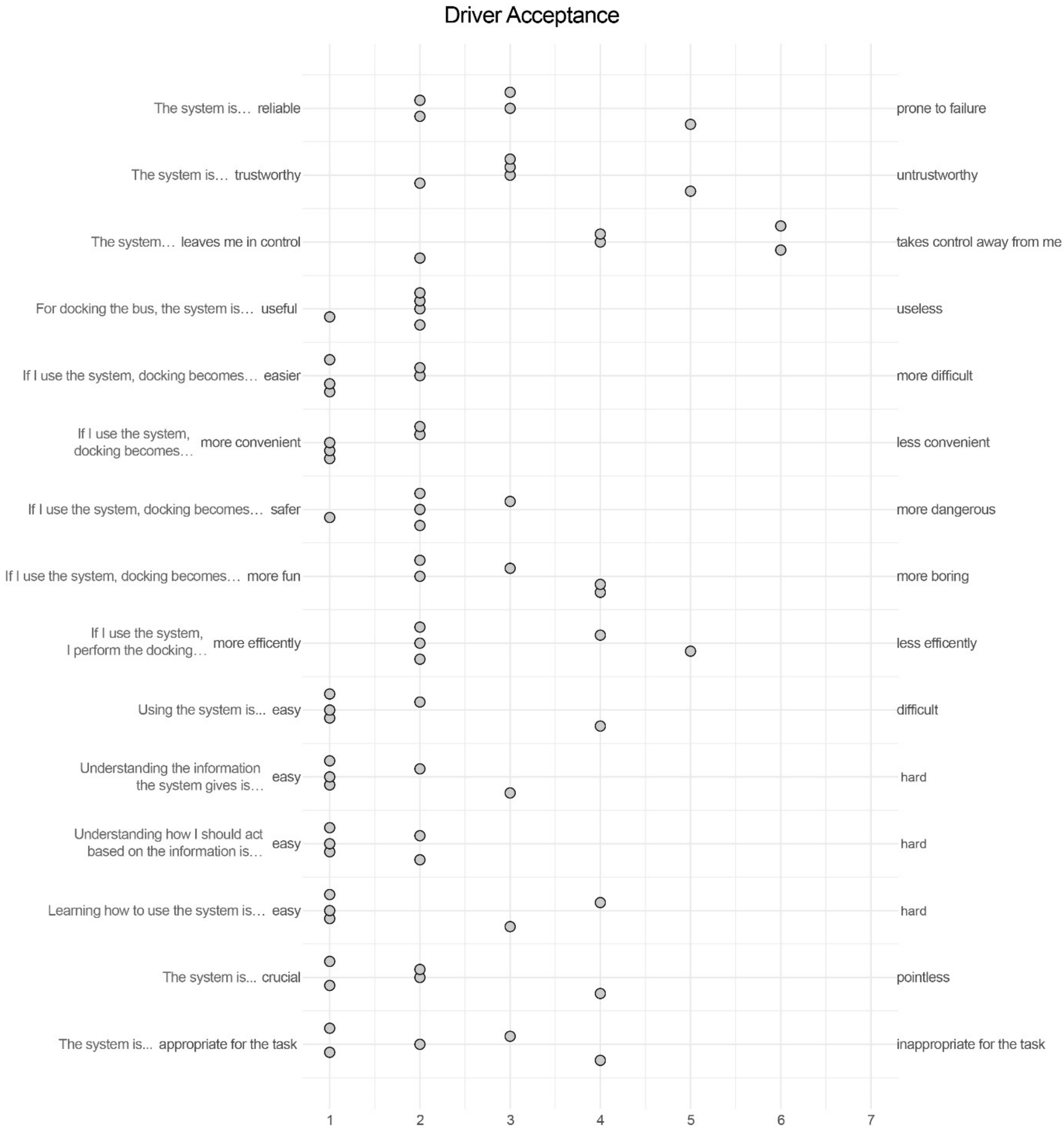

Figure 5 - Drivers' acceptance ratings from the post-trial session, based on a semantic differential questionnaire (SKAS). Each item was rated on a 7-point scale, with positive anchors on the left and negative anchors on the right.

However, some bus drivers emphasized the difficulty of rating the NN system as a whole because their experience varied significantly between *approaching* and *departing* bus stops. The system would probably have received more favorable ratings when used for approaching stops and less favorable ones for departures (discussed further in Section *3.3. NN System Usefulness When Docking*). This discrepancy was also evident in usage data: bus drivers used the NN system when approaching bus stops on average 82% of the time, but only 58% of the time when departing (see Table 1).

Table 1 - Number of NN system activations by driver during bus docking, separated into approaching and departing phases. ´Possible activations´ refers to the total number of docking opportunities available to each driver. The activation rate is the proportion of opportunities where the system was engaged.

	APPROACHING			DEPARTING			TOTAL		
User	Activations	Possible Activations	Activation Percentage	Activations	Possible Activations	Activation Percentage	Activations	Possible Activations	Activation Percentage
P1	1218	1548	79%	109	1511	7%	1327	3059	43%
P2	1111	1317	84%	952	1339	71%	2063	2656	78%
P3	884	1092	81%	821	1059	78%	1705	2151	79%
P4	638	853	75%	530	884	60%	1168	1737	67%
P5	930	1038	90%	733	988	74%	1663	2026	82%
	4781	**5848**	**82%**	**3145**	**5781**	**58%**	**7926**	**11629**	**70%**

An overview of NN system activations can also be seen in Figure 6.

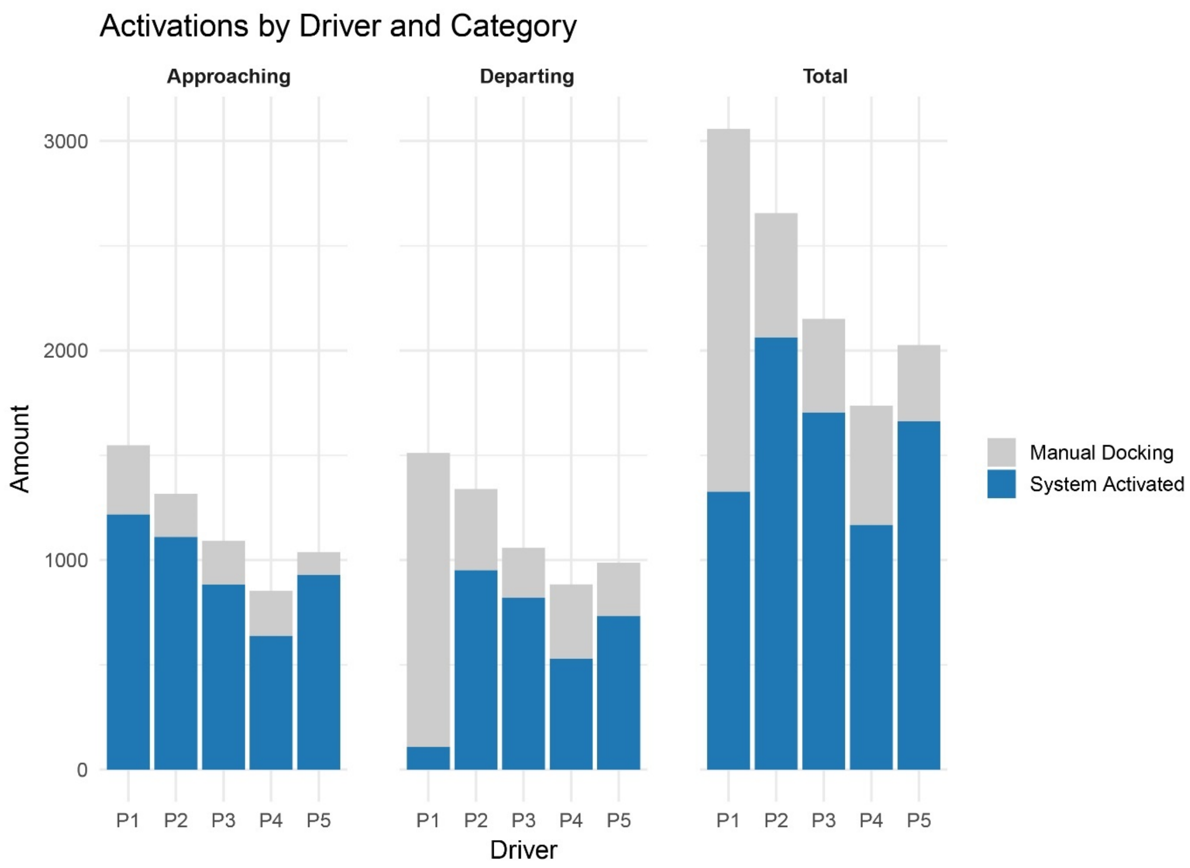

Figure 6 - Stacked bar chart showing the number of NN system activations per driver across three categories: Approaching, Departing, and Total. For each driver (P1–P5), the total possible activations are represented by the full height of each bar. The lower (blue) portion of each bar represents NN system activations, while the upper (grey) portion indicates the number of non-activated events (manual dockings).

3.2.1. Bus Driver experience over time

Based on interview narratives and user experience curves drawn by the bus drivers, their experience over time was divided into three phases: **familiarization, disruption,** and **recovery** (illustrated as three areas overlaying the bus drivers' own user experience curves in figure 7).

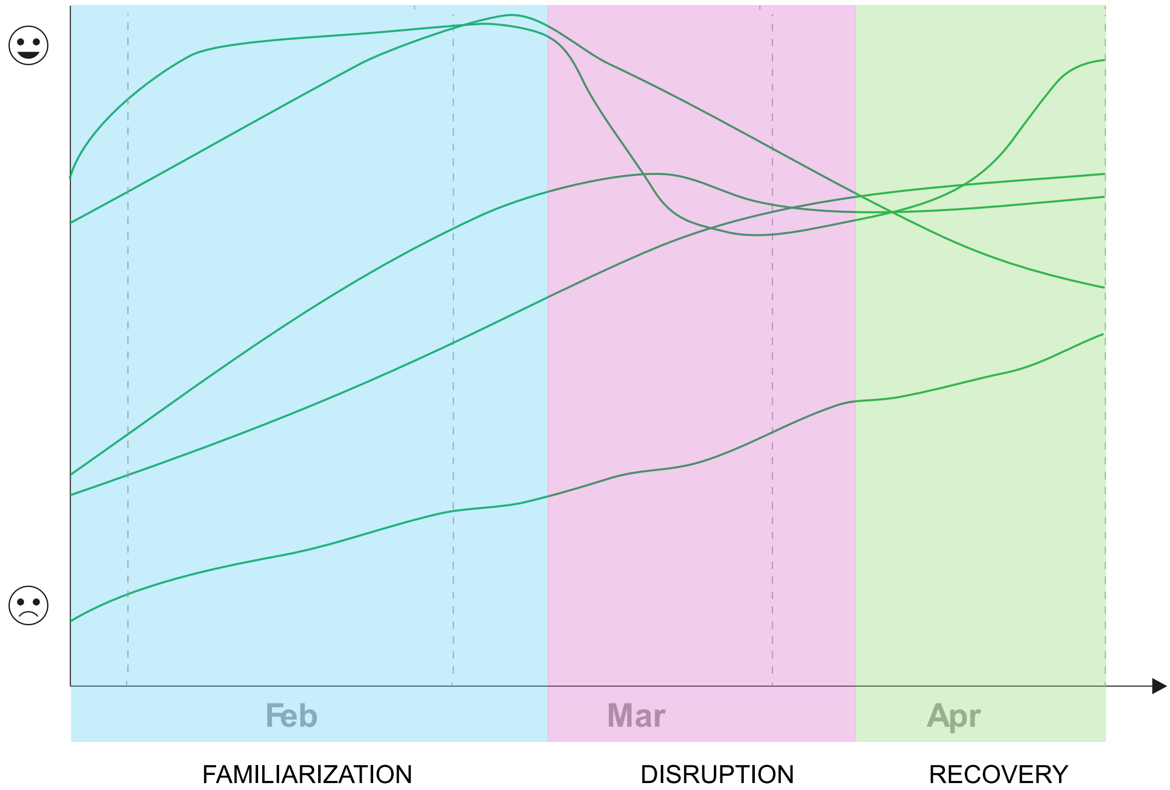

Figure 7 - Bus drivers' experience with the NN system over time, as illustrated through their own user experience curves. The drivers' experiences are divided into three phases—familiarization (blue), disruption (purple), and recovery (green)—shown as coloured areas overlaying the individual curves.

Familiarization Phase

This phase was characterized by increasing trust and familiarity with the system. Initial experiences varied: some bus drivers were immediately positive, while others were a bit more skeptical in the beginning. For some bus drivers, letting go of control was a concern initially and resulted in increased stress levels when activating the NN system, as described by one driver:

"The first few times I drove [using the NN system]*, I found it quite hard to let go of control... I'm so used to steering myself, I'm used to having that control completely. I might also have a bit of a need for control, so it was difficult to let go completely at first. — but you get used to it, you accept how the system works, and you also learn how it feels in the bus."* (P2)

Regardless of their starting point, all bus drivers stated that the experience became more positive, and trust grew over time, until mid to late March, which marked the end of this phase. At this time the bus drivers' experience was very positive (which is also visible in the user experience curves) and they had established a rather high level of trust in the system, even if it was emphasized by several participants that they did not fully trust the system. Although they didn't trust the system *fully*, this was considered positive — they emphasized their responsibility as bus drivers to stay vigilant:

"I don't fully trust It [NN system]*, I don't. And I don't think you should either. Because I still need to be mentally aware of what's around me. Is it crowded? Is someone in the way? The system can't detect that, so I have to stay alert."* (P2)

Increased trust was largely attributed to the system's consistent behavior and the bus drivers learning how to interact with it — especially how to position the bus and regulate speed to ensure a smooth handover. Bus drivers described that it took at least three days of driving to get familiar with the system, after which they felt calmer and more comfortable using the NN system and the interaction procedures became more automatic to perform.

Disruption Phase

In the disruption phase, bus drivers' experiences became more negative — as seen in the downward trend of their user experience curves (Figure 7). The system was seen as less reliable[4], with recurring issues like not finding the correct position, lagging interfaces, or bus stops being deactivated without reason. The negative effect on their experience was mentioned by all bus drivers, but the magnitude differed between bus drivers, where some described it as a small dip in their positive experience while others experienced it as a more negative experience. One driver emphasized that since it was a seemingly easy problem affected the experience more:

"I thought, it [NN system] *shouldn't be that easy for it to fail. Like, it just loses position even though it's a regular GPS. For example, your car GPS shouldn't just lose position — that's worthless."* (P3)

Trust declined as a result, although most bus drivers didn't feel unsafe since they did not experience the problems as safety-critical - such as deviating from the pre-recorded path or unintended excessive speeding - but still became more vigilant, one driver describing that:

"It hasn't done anything dangerous in traffic — it's mostly been like, 'Oh, we stopped two meters too far ahead,' and then I report that. But I've never felt afraid that it would steer into traffic or onto the sidewalk or anything like that." (P1)

Recovery Phase

Toward the end of the test period, bus drivers had learned and adapted to how the NN system functioned, adjusting their behavior to better cooperate with the system. They also perceived the system as more reliable again, which contributed to more stable—and in some cases, more positive—experiences. Although trust recovered, it did not reach the very high levels observed at the end of the familiarization phase. Bus drivers reported trusting the NN

[4] This may be partly attributed to a temporary GPS malfunction and lag between subsystems, which caused delays in the information provided by the interfaces.

system to a high degree but remained slightly more vigilant and continued to prefer retaining control in crowded locations.

Acceptance Ratings Over Time

Acceptance questionnaire ratings over time largely reflected the phases described above. From Interview 1 (Week 3) to Interview 2 (after two months), most ratings remained stable or became more positive (indicated by red arrows pointing left in Figure 8). In contrast, from Interview 2 to Interview 3 (after the test period had ended), a slightly greater number of ratings became more negative than positive (indicated by more blue arrows pointing right than left in Figure 8), suggesting a dip in acceptance toward the end of the study. Consistent with the bus drivers' experience curves and interview responses, overall acceptance increased over time, with items rated more positively in the final session compared to the first.

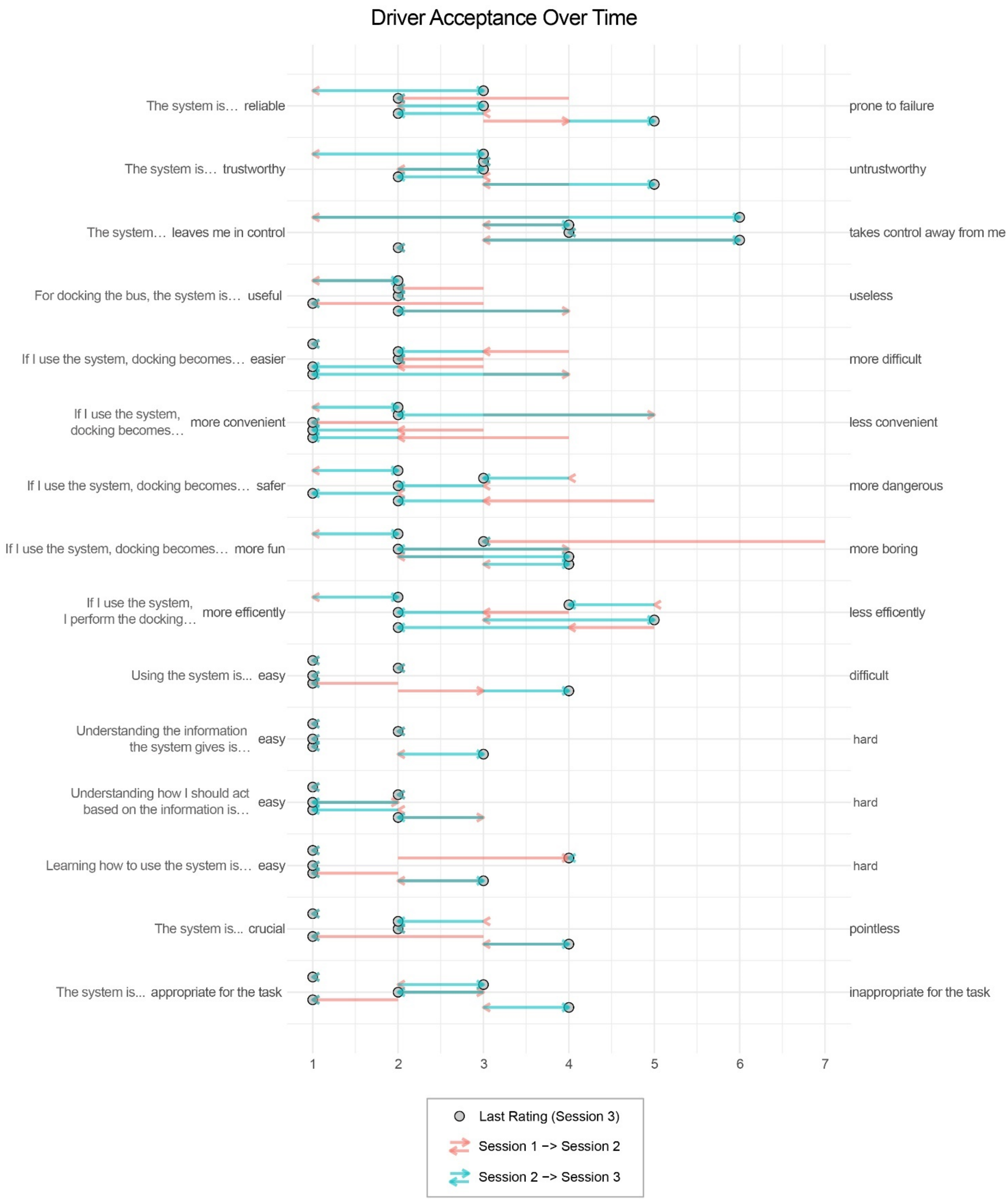

Figure 8 - Driver acceptance ratings of the NNS over time, based on a semantic differential questionnaire (SKAS). Each item was rated on a 7-point scale, with positive anchors on the left and negative anchors on the right. Circles represent the final ratings (Session 3), while arrows show changes between sessions: red arrows indicate shifts from Session 1 to Session 2, and blue arrows indicate shifts from Session 2 to Session 3.

3.3. NN System Usefulness When Docking

Despite bus drivers' generally positive view and high acceptance of the NN system, all bus drivers emphasized a distinct contrast between its usefulness when *approaching* versus *departing* from bus stops.

3.3.1. Approaching Bus Stops

The NN system was seen as highly useful when approaching stops. It was considered to make docking safer, more comfortable, and more consistent — a task that, according to the bus drivers, could otherwise suffer due to fatigue or momentary distractions:

"It [NN system] *does the same thing every time and approaches each stop calmly. Sometimes someone presses the button late, or I forget to stop, and then the braking is a bit harder... Or maybe I'm just tired and misjudge something — in the end, I'm only human."* (P5)

The quality of the dockings by the NN system when approaching was considered to be as good or better than dockings performed manually by the bus drivers themselves. One of the most positive bus drivers stating:

"Approaches are much better with the system. I'd even say that when it's working, it docks better than any driver — including myself." (P1)

This perception was primarily attributed to the smoothness of the driving behavior and the consistent precision during docking. One driver even reported receiving compliments from passengers—unaware that it was the system driving:

"Most of the customers were very happy. Some even thanked me, 'You drive so well,' and they didn't know it was the system. I didn't always have the energy to explain, so I just said, 'Thank you.'" (P5)

Bus drivers stated that they used the NN system almost every docking when approaching, and usage data confirmed frequent use during approaches —between 75–90% (M = 82%) of all dockings was conducted using the NN system (see Figure 9).

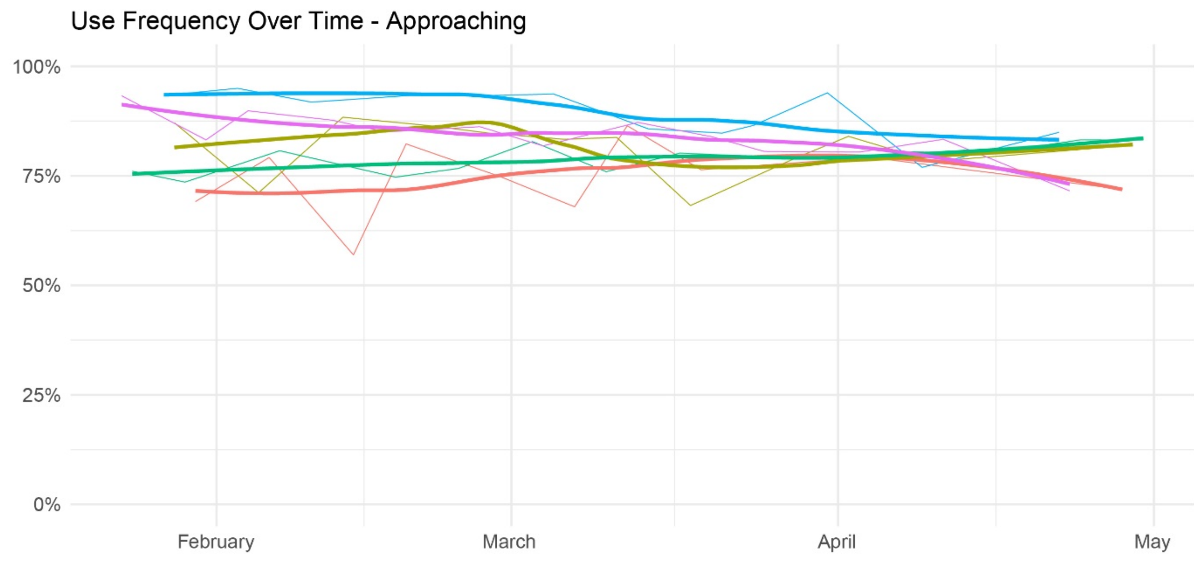

Figure 9 - Activation frequency of the NNS during bus stop approaches over the trial period. Thin lines show each driver's daily usage rate, expressed as the percentage of activations out of possible activations. Thick lines represent smoothed trends for each driver, calculated using a LOESS function.

The main reason for not using the NN system when approaching was usually due to situational factors: e.g., a bus stop already occupied by other buses or crowded with pedestrians, which mostly occurred in the city center. When another bus was occupying the bus stop, bus drivers explained that they often docked manually since the NN system was not able to detect objects and automatically break. Situations with crowded bus stops, was deemed as especially dangerous and most bus drivers preferred to remain in control over driving functions — both for safety and flexibility in adapting speed and distance:

"First of all, I drive differently when there are a lot of people. I don't stay as close to the curb as the system does — people hit their heads on the mirrors. And I probably drive slower. I believe I should have control when there are lots of passengers." (P4)

However, to make the system even more useful — particularly when approaching, but also when departing from stops — all bus drivers emphasized the need for it to detect objects ahead and adapt its speed or brake automatically. A few also suggested a less critical, but still valuable, improvement: enabling the system to adjust its driving style based on the external and internal environment. For example, driving more slowly and keeping a greater distance when many pedestrians are present, or adapting its path when there are snowbanks

3.3.2. Departing from Bus Stops

In contrast to the positive experience of using the system when approaching bus stops, the system was consistently seen as less useful when departing. Use rates varied greatly between bus drivers with one driver rarely using the NN system at all:

“It’s not safe. I have very few departures because I think it's a pain to use. Unlike approaching — where it feels nice to hand over — departing just causes stress. I don’t know how it will behave. Will it start after one second or three? Will it steer weirdly and creep out while cars pile up behind? I’d rather check my mirror, see it’s clear, hit the gas, blink, and just pull out. I don’t need to think, ‘Should I take over now?’ or ‘Will it jerk?’ There’s nothing positive about it.” (P1)

Driving data reflected this variability (see Figure 10), with total activation rates ranging from 7% to 78% (M = 58%).

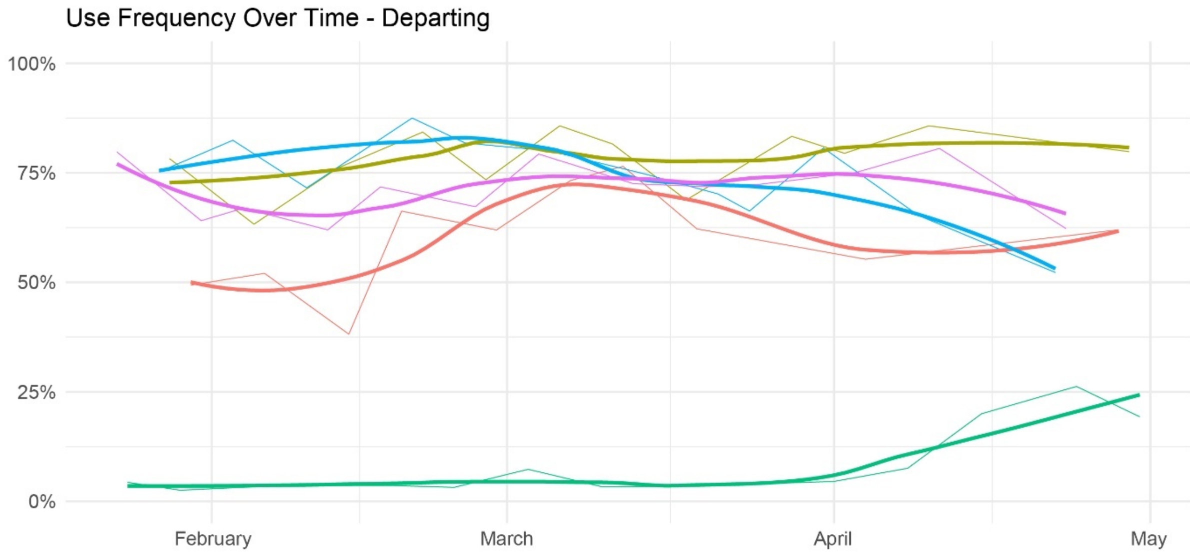

Figure 10 - Activation frequency of the NNS during bus stop departures over the trial period. Thin lines show each driver’s daily usage rate, expressed as the percentage of activations out of possible activations. Thick lines represent smoothed trends for each driver, calculated using a LOESS function.

Most participants, regardless of use rate, described that they did not use the NN system when there was heavy traffic since the system was perceived as too slow and hesitant, which created stress:

“During departures, especially in rush hour, I drive myself — to save time. Otherwise, you’re late. Sure, when I have time, I use it — so I don’t have to turn the wheel. But when I’m in a hurry, I drive myself. The system starts slowly, turns slowly. If I drive, it’s twice as fast and just as smooth.” (P3)

The main issue was a combination of the nature of departures and the driving behavior of the system. Participants described that when departing from a bus stop, especially when there is heavy traffic, you must be assertive and quickly accelerate and enter the next lane, to not stop the traffic or create dangerous situations. The driving behavior of the NN system was instead perceived to start accelerating too late from the point of activation and accelerating too slowly, making it hard to merge into traffic swiftly and safely:

“From the moment I look left and see it’s clear, I activate the system — but it’s like there’s a delay, like it’s thinking, ‘Now I’ll start.’ And in that time, cars catch up behind. So it becomes a stress factor — I have to be sure no one’s behind me.” (P2)

Some bus drivers noted that turns were initiated too late, resulting in sharp angles and awkward movements that confused other road users. While all agreed that the driving behavior could be improved to enhance both the experience and the system’s usefulness, there was also uncertainty about whether such improvements would be sufficient to make the system viable in complex scenarios—such as during departure.

3.4. Bus Driver-NN System Control transitions

One part of using the NN system that bus drivers often described as more challenging was the control transitions—specifically, activating the NN system and handing over parts of the dynamic driving task, or disengaging it and taking over control again.

The activation phase was the more frequently mentioned of the two. Initially, bus drivers experienced activations as unpleasant due to abrupt changes in speed and lateral positioning, which led to a jerky transition. However, the quality of transitions improved significantly during the first month. After the familiarization phase, transitions were generally described as smooth, as bus drivers had learned how to position the bus and at what speed to activate the system effectively. A few bus drivers noted that if they activated the NN system too close to a bus stop after receiving the notification, the driving behavior could still become jerky. Most bus drivers eventually reported that system activation had become almost automatic and that they had learned approximately where activation was possible at each stop. One driver even mentioned that they sometimes instinctively reached for the activation button when driving a non-equipped bus:

"I have to admit, after driving this bus and then switching to a regular one, I instinctively reach for the button at the point where a handover usually happens" (P2).

The timing of activation after receiving the availability signal changed over time and varied between bus drivers. Initially, most bus drivers activated the NN system as soon as they received the signal. Later, however, different strategies emerged. Many began waiting longer before activation, explaining that they felt less stressed and aimed for a smoother transition by adapting their positioning. One driver explained:

"Sometimes if you press at low speed and from far away, it takes a long time to roll forward [and reaching the bus stop]*, but you eventually find the right spot to activate* [the NN system]*"* (P3).

Another factor influencing activation timing was the type of bus stop and surrounding infrastructure—for example, whether there were speed bumps or tight curves. This led to some activations occurring closer to the stop and others further away.

The need to adjust one's driving to match the predefined digital path was perceived by some as a disadvantage. While bus drivers didn't expect the system to adapt completely to their positioning or speed, they believed it should be more flexible and handle the transition more smoothly:

"What I wish for the most is for it to be more dynamic... If I'm slightly off, the system forces me into the path abruptly. It shouldn't have to feel like that... What really bothers me is that even when there's still quite a bit of distance left to the bus stop, instead of making a gentle correction if I'm slightly misaligned, it's like it gets pulled toward the line like a magnet — making an unnecessarily aggressive correction that I don't think is needed. I believe it could have adjusted more smoothly over the remaining distance to the stop" (P1).

In addition, some bus drivers also found the transition when disengaging the NN system slightly challenging—though not to the same extent as activation. Early in the test period, it was difficult to gauge how much to accelerate when taking back control to ensure a smooth transition. One driver noted that this difficulty was exacerbated by uncertainty about when the digital path would end, suggesting a need for clearer feedback:

"I also find it hard to know when the path ends... a kind of meter would be helpful so I know when it's time to take over. Sometimes I wait too long, and it creates a stressful moment when the system suddenly disengages" (P1).

3.4.1. Interface

To understand when the NN system could be activated, most bus drivers relied primarily on the LED light, as they found the audio signal difficult to distinguish due to the general noise level on the bus and the many other competing sounds. Two of the bus drivers had even muted the audio entirely—one at the beginning of the test period and the other midway through. One of them explained:

"It was actually quite nice not having the sound on. It works—I see the light and all that, and sometimes I don't even need to look at the light; I just get a feeling that now it's possible to activate. And when there are so many other sounds chiming, this chime becomes just a bit too much." (P1)

Even though the LED was the primary source of feedback for system availability, bus drivers who had kept the audio signal activated still appreciated having redundancy. One driver emphasized that different conditions affected which feedback source they relied on more:

"If it's the middle of the day, sometimes I miss that the light is on, so I prefer to use the sound. Then in the evening, sometimes it beeps and after a few seconds I forget about it and then check if the light is on. Especially during the day, I usually increase the brightness so I can see it clearly, and in the evenings I lower it a lot." (P5)

The LED's color scheme was perceived positively, as it allowed bus drivers to quickly and clearly interpret the system's status—whether activation was available, the system was active, or an error had occurred. The initial brightness and positioning of the LED were considered sufficient in most conditions. However, visibility decreased in direct sunlight, making it harder to distinguish between colors. In contrast, during darker conditions, bus drivers often dimmed the light to avoid distraction.

The screen display was mainly used in specific situations—particularly when something didn't work as expected or when logging in at the start of a shift. One driver reflected:

"The few times the system hasn't worked or the light doesn't come on, then I think, 'Oh, what's going on here?'—and that's when I start checking the display where it shows the stop and so on. So I've mainly used the sound and the sugar cube [Square LED light] *and then looked at the screen to see what it* [NN system] *says." (*P2)

Thus, when approaching a stop, bus drivers generally knew from experience when activation would be possible and used the LED light to confirm the exact moment and verify successful activation. The display was consulted primarily when something seemed off—such as when the LED signaled an error or other cues were unclear or absent.

Suggestions for improving the interface centered around the activation button. Many bus drivers suggested relocating the button to the steering wheel so they wouldn't need to take their hand off the wheel or shift their attention away from the road during a critical moment. A few also recommended that the button itself light up in sync with the LED indicator, using the same color scheme to better communicate both its position and system status. Other suggestions included displaying statistics about system usage and providing additional information, such as handover speed and path position relative to the bus.

3.5. Effects of using the NN System

Bus drivers saw several positive effects from using the NN system – for themselves, passengers and the organization.

3.5.1. Passenger comfort

The most frequently emphasized benefit of the NN system mentioned by bus drivers was the increased comfort for passengers. The system's consistent and smooth driving style—especially its ability to stop close to the curb—contributed to a noticeably more pleasant experience for those on board.

This improvement was also evident in the passenger questionnaire, which compared buses using the NN system with manually driven electric buses operating on the same route (see Figure 11). Across all eight comfort-related items, passengers rated the NN system more positively. Mann–Whitney U tests revealed statistically significant differences for all items except appropriateness. Ratings for the manual condition were also more varied (indicated by wider boxes and longer whiskers in Figure 11), likely reflecting the diverse driving styles of different drivers. Dockings performed with the NN system were rated similarly to the most comfortable manual dockings.

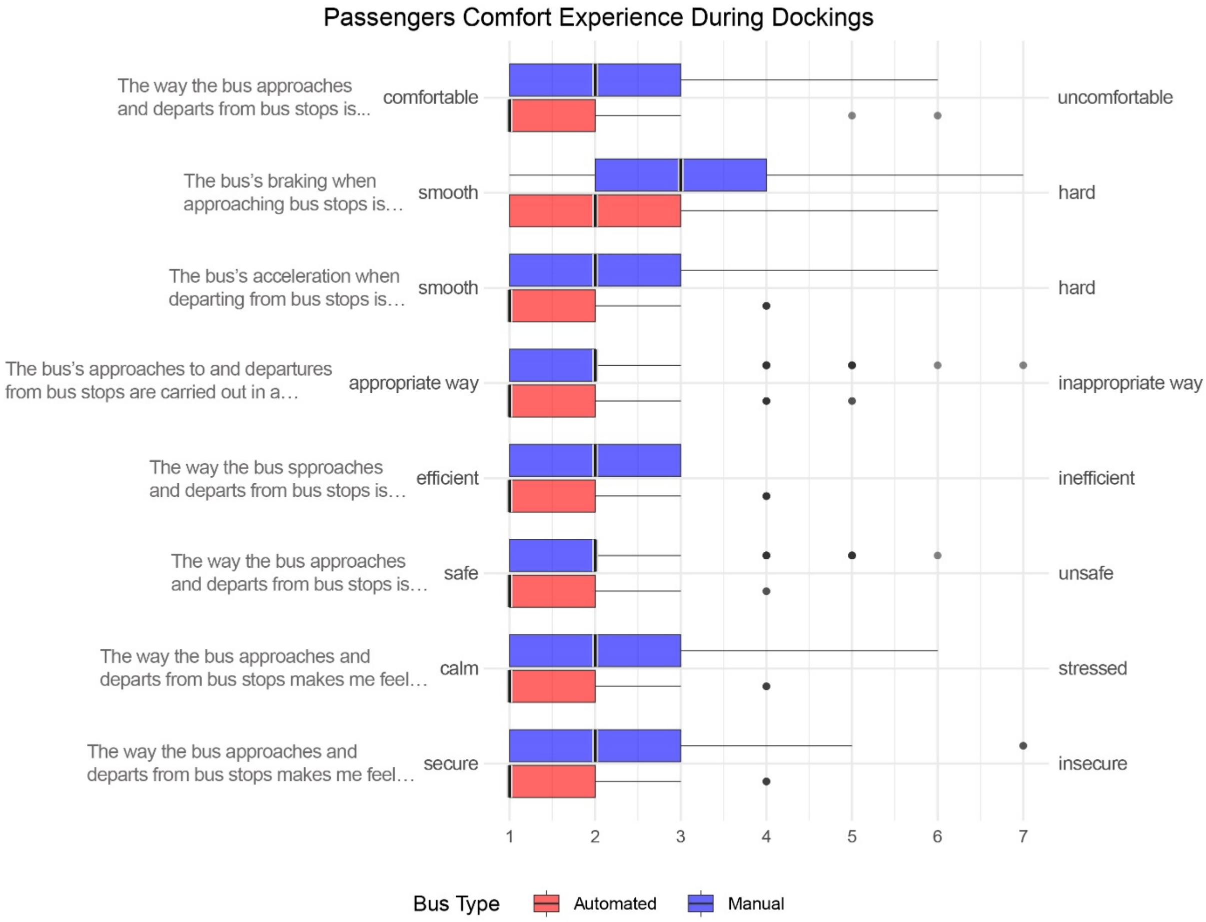

Figure 11 - Passenger ratings of ride comfort for buses driven with the NNS compared to manually driven electric buses on the same route. Ratings were collected on an seven-point semantic differential scale, with lower values indicating more positive evaluations. Each boxplot shows the distribution of ratings across passengers: the thick horizontal line indicates the median, the box represents the interquartile range (middle 50% of responses), and the whiskers extend to the most extreme values within 1.5 times the interquartile range.

3.5.2. Bus drivers' physical and psychological ergonomics

All bus drivers, to varying degrees, believed that prolonged use of the NN system would have positive effects on their physical well-being—particularly by reducing strain on the shoulders and arms. One driver noted that they already felt a difference between days driving the NN system-equipped bus and those driving manually operated ones, despite only using the system about once a week:

"It [NN system] *saves my shoulders… Do you know how many times you have to steer back and forth with both hands?"* (P3)

Many bus drivers also believed that using the NN system reduced stress levels. Because the system took over one part of the dynamic driving task—managing speed and positioning when docking—bus drivers could focus more on other parts of the driving task. A few specifically mentioned that manual docking could be stressful, especially when the bus brakes were overly sensitive or hard to control:

"I'd be less stressed. I've noticed that when I'm driving a regular bus—especially certain ones with really unresponsive brakes—it's hard to get a smooth stop. It's either too soft or too hard, and I miss the curb. I'm not satisfied with my own dockings, and I don't think the passengers are either. The system just handles it. I feel very calm when I drive with it. Sometimes when you're driving manually, you stress yourself out, and it becomes jerky—accelerating, braking. But with this, you have to slow it all down and get into a flow. You realize, I'm on time anyway, it's going fine. I feel calmer when I use the system." (P1)

However, one driver expressed uncertainty about whether the NN system would reduce stress, particularly during peak hours. In those conditions, the slower behavior of the system when departing from stops was described as potentially frustrating.

"I don't get stressed, but during rush hour, it could make you unnecessarily late. Other buses catch up if I use it [NN system] *for every docking and departure. With dense traffic and lots of people getting on and off, it might become a hindrance."* (P3)

Another positive psychological effect mentioned was the increased variability and engagement in the task of driving. Alternating between fully manual driving and system monitoring was believed to make the job more dynamic and helped some bus drivers stay alert. One driver described this as:

"You start being more awake and focused on the road. Sometimes when I don't have the system, I'm just driving, thinking about other things. But when I have it, I'm waiting for the signal—I know I'll get it here, and the bus will drive itself to the stop. You become more active, it becomes a collaboration between the driver and the bus." (P5)

3.5.3. Bus drivers' Manual Driving Behavior

Another effect noted by several bus drivers was how the NN system influenced their own driving behavior. Many described driving more calmly and smoothly—not only during docking but also between bus stops—in order to better prepare for activation and ensure a seamless transition:

"If I want it [NN system] *to work every time, I have to drive the way the bus wants. Otherwise, it wouldn't work. I have to drive in a way that fits the digital path before I even enter it, if I want to get the notification as early as possible. I can't start adjusting after I've*

already started entering the digital path—that's too late. I notice that if I don't get the notification, it's because I'm driving too fast" (P1).

Some bus drivers also mentioned that using the NN system had made them more aware of their own manual docking behavior, which they began trying to improve. Others did not perceive any notable change in how they drove.

3.5.4. Organizational aspects

From an organizational perspective, bus drivers believed that implementing the NN system—or a similar system—across the fleet would be beneficial in two key ways. First, it would likely reduce wear and tear on the buses, especially damage from hitting curbs during docking, leading to cost savings for the operator. Second, several bus drivers suggested that the technology could enhance the company's public image—portraying it as forward-thinking and attentive to employee well-being.

4. Conclusion

This study investigated professional bus drivers' experiences and acceptance of an NN system for automated docking, focusing on how the system was experienced, used, and accepted in everyday operations. The findings suggest that automated docking is considered a relevant use case for automation—particularly during approach— that addresses an existing challenge—achieving consistent, smooth, and safe approaches to bus stops every time. Bus drivers generally reported positive experiences and high acceptance of the NN system when approaching bus stops, highlighting the system's smooth and consistent driving behavior as a key strength. However, its performance during departure was perceived as less satisfactory, which lowered overall acceptance and perceived usefulness of the system.

The process of handing over control to and from the NN system emerged as a particularly critical and demanding aspect of the interaction. This moment required high levels of driver adaptation and was described as the most challenging part to learn. The bus drivers developed individualized strategies for managing handovers—relying on a mix of visual, auditory, and infrastructural cues, such as lamp posts, bus shelters, and other familiar landmarks, to determine when to hand over control - they also expressed a desire for a more cooperative system that better supports the transition.

The driving style of the NN system was central to the bus drivers' overall appraisal. Smoothness, predictability, and appropriate speed adjustments were seen as essential for both comfort and safety. Conversely, abrupt corrections—especially during minor misalignments—were noted as areas needing improvement. Even small variations in speed and slight delays in system actions shaped how the driving style was perceived. These nuances illustrate that driving style is not just a technical detail but an important element to consider, which influences trust in and willingness to use the system.

Despite the challenges, bus drivers anticipated several benefits from wider implementation of such a system, including reduced cognitive load, less physical strain, and a more consistent and comfortable experience for passengers. To further enhance usefulness, improved system reliability is essential, along with the addition of key functions such as object detection and automatic braking. These were seen as critical steps in improving the NN system from a helpful assistive tool to a fully integrated and dependable part of bus operations.

A system like the NN system shows strong potential—particularly when approaching bus stops—but to improve acceptance and usefulness and fully realize its benefits, it must offer reliable performance, smooth and cooperative control transitions, advanced object detection capabilities, and a well-calibrated driving style that aligns with driver expectations. Future research should therefore (i) investigate the potential benefits of automated docking systems using a larger sample size, and examine in greater detail how driving behavior influences user experience and acceptance at both national and international levels; (ii) explore how an NN system with enhanced functionality—such as advanced object detection, auto-braking, and adaptive driving behavior—would be perceived in real public transport operations; and (iii) assess the potential economic benefits of a NN system, including reduced tire and wheel axle wear and tear, and/or fewer sick leaves due to upper body aches and pains.

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