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Good practices on transit operation design: bus drivers' perspective

Rubén Cordera[1*] , Margarita Novales[2] , Alfonso Orro[2] , Borja Alonso[1] and Luigi dell'Olio[1]

Abstract

Understanding which aspects can have the greatest influence on the performance, comfort and safety of a public transport system can be of great help in improving its operation and promoting more sustainable mobility. To find out more about these aspects, a survey was carried out among more than 180 drivers of urban bus transport systems in seven medium-sized cities in Spain. The drivers' perspective has been insufficiently taken into account in previous research, despite the fact that these workers have a high and direct knowledge of the operation and problems directly affecting the service. The data collected through this survey have been analysed using descriptive statistics and an Ordered Probit model. The results have allowed us to detect specific aspects to improve the performance and comfort of users and drivers such as the correct location and length of bus stops and enforcing regulation to ensure that buses have priority in traffic and that illegal parking does not interfere with their operations. In addition, bus lanes were seen as important by drivers to improve the comfort and safety of the service. Other factors related to safety were generally highly rated and there was little dispersion in the responses about their importance, although aspects such as proper visibility, avoiding illegal parking, and campaigns to encourage bus users to be aware of their surroundings stood out in the answers. Finally, the payment system was highlighted as very relevant to ensure the performance and comfort of users and drivers during the operation at bus stops. Improving this system was identified as the measure that could have the greatest impact on the performance of the service as a whole.

Keywords Transit policy and design, Bus driver, Safety, Bus stop, Bus lane

1 Introduction

Increasing the satisfaction and safety of users and employees with their public transport system, as well as the ability of public transport to attract new customers from motorised transport, are key policies for achieving more sustainable mobility. Public transport is one of the cornerstones of mobility systems as it enables people to move around with fewer negative externalities than the car [3, 34], while providing greater social equity in access to opportunities [7, 20].

In order to achieve higher quality public transport, it is necessary to diagnose its deficiencies and possibilities for improvement. This diagnosis must be based on reliable information on the perceptions of users, but also of other agents who have first-hand information on the functioning of the system, such as the staff who provide the service. Studies on users' satisfaction and perception of the quality of transport services are a well-established line of research, with several decades of existence [8, 10, 28]. These types of studies, largely based on Customer Satisfaction Surveys (CSS), have made it possible to measure the satisfaction of different types of users with the service, as well as their perception of those aspects that may be of poorer quality, thus helping to design improvement policies to attract new users and strengthen the

*Correspondence:
Rubén Cordera
ruben.cordera@unican.es
[1] SUM+LAB Research Group, Universidad de Cantabria, Av. de Los Castros 44, Santander, Cantabria 39005, Spain
[2] Group of Railways and Transportation Engineering, Universidade da Coruña, Campus de Elviña, A Coruña, Galicia 15071, Spain

loyalty of existing ones [9]. However, the perspective of the employees of public transport services, and especially of bus, tram, or metro drivers, has been insufficiently taken into account in service diagnosis studies. This is despite the fact that the employees are the ones who have the most direct contact with the different characteristics and problems of the service and accumulate a great deal of information and know-how. In order to propose improvements for bus systems, it is relevant to collect this valuable and scarcely exploited system knowledge, which justifies the interest of this research.

This collection has been performed by conducting a survey of drivers of different urban public transport systems in Spain. The research questions are:

- From the perspective of drivers, what are the factors related to stop design and operation which have a higher influence on stop time, user comfort, driver comfort and safety?
- What are the most beneficial effects of bus lanes and are they respected by general-traffic drivers?
- What are the most relevant aspects of the system design in relation to safety?

The data collected through this survey has been analysed using descriptive statistical techniques and quantitative modelling in order to provide inferences and recommendations on which policies could be most positive in enhancing the performance and safety of bus public transport systems. These recommendations could be extrapolated to other bus public transport systems, helping to enhance these services.

The following section reviews previous research that has explored the factors affecting the operation and performance of public transport systems. Section 3 describes the data collection process, as well as the presentation of the study areas considered, the survey design and the implementation of the survey. Sections 4 and 5 analyse the data obtained and present the main results collected. Finally, Sect. 6 offers a series of conclusions.

2 Literature review

There are a large number of factors that can influence the operation of buses in a public transport service and thus affect their performance and the comfort of users and drivers. Included among these all aspects are the ones related to the physical design of stops and their influence on bus entry and leave manoeuvres [18, 42], those related to the operation at stops when the bus is stopped [17], and those related to the existence or not of bus lane [1, 37] and safety (see Table 1 for a synthesis of the literature).

The interaction between vehicles and the physical entry and leave service area has been a relatively understudied topic. However, as Fernandez and Tyler [17] argue, not to take this aspect into account can significantly worsen the performance of public transport systems. These authors, using microsimulation, studied the arrival of buses at bus stops, arguing that good bus stop design can dramatically improve bus operations, especially to avoid queues that can increase both travel times and passenger boarding times. This aspect has also been studied by Wang, Ye, Chen, Xu, and Wang [41] analysing how the failure rate of buses to find a free berth at a stop influences bus operation. The authors proposed a model showing how the failure rate increased with the arrival rate of buses and how the addition of new berths had diminishing returns in both decreasing failure rate and stop capacity. These results are consistent with those presented by Huo, Li, Zhao, and Zhu [24], who found that bus delay at stops increases with the arrival rate of new buses and with other characteristics such as the presence of traffic lights with a high red-to-cycle ratio or having only one berth. A problem also related to bus bunching, which reduces reliability and user satisfaction with public transport services [4, 6]. Another aspect related to the physical dimension of stops is their location. This aspect has been studied by Wang et al. [42], who differentiated between the position of a stop before an intersection, in the middle of a block, or after an intersection. Using a model estimated with real data, they calculated that stops located before an intersection may have longer entry and leave times than those at other locations.

Once the bus has stopped, there are several aspects that can influence service time and customer satisfaction. Among these aspects, the payment system is one of the most relevant. An outdated payment system can greatly slow down operating times, especially if there is a large number of passengers queuing to enter and paying sequentially. Fernandez and Tyler [17] have estimated that this type of queuing, entering the bus and paying one at a time can increase boarding times by 30–40% over more streamlined systems with multiple passengers entering at the same time. Therefore, the authors advocated designing and sizing stops correctly by taking advantage of the availability of micro-simulation tools and real data on passenger demand and bus supply. However, a more modern payment system does not always have to imply shorter payment times, since as Diab and El-Geneidy [11] found, the smart card system introduced in Montreal turned out to be slower than the previous flash pass system, although the time differences can be negligible if crowding is present [19]. Tirachini [38] simulated the time savings that could be gained by replacing a slow payment method, such as cash, with a fast one such

Table 1 Main factors that can influence transit operation

Public Transport Aspect		Main Result	References
Stop Design	Physical design	Relevance of the physical design of stops in the entry and leave manoeuvres of buses and therefore in the performance of the system	Fernandez and Tyler [17], Fitzpatrick et al. [18],Wang et al. [42]
	Location	Stops located before an intersection may have longer entry and leave times than those in the middle of a block or after an intersection	Wang et al. [42]
	Number of berths	The addition of new berths can have diminishing returns in both decreasing failure rate of buses and stop capacity	Wang et al. [41]
Stop Operation	Boarding times	Passengers queuing to board a bus and paying sequentially can increase boarding times by 30–40%	Fernandez and Tyler [17]
	Arrival rate of buses	Bus delay at stops increases with the arrival rate of new buses. Bus bunching decreases reliability and satisfactions of users with the service	Cats [4], Comi et al. [6], Huo et al. [24]
	Presence of traffic lights	Bus delay at stops increases with the presence of traffic lights especially if they have a high red-to-cycle ratio	Huo et al. [24]
	Payment system	An outdated payment system can greatly slow down operating times. However, more modern payment system does not always have to imply shorter payment times	Diab and El-Geneidy [11], Fernandez and Tyler [17], Fletcher and El-Geneidy [19], Tirachini [38]
Bus Lane	Implementation or removal of bus lane	Bus lanes can imply a reduction in journey times of 1 to 2% and increases of reliability odds of 65%. If a lane loses its bus-only status, public transport journey times can increase significantly	Arasan and Vedagiri [1], Mane, Sarkar, Arkatkar, and Bhaskar [30], Surprenant-Legault and El-Geneidy [37]
	Design of bus lane network	A series of disconnected sections of bus lanes can generate very small effects on the quality of service	Truong, Sarvi, and Currie [39]
Safety Issues	Drivers stress	High levels of fatigue and stress among bus drivers are associated with a higher number of accidents. Bus drivers with anxiety trait are also associated with more accidents. Drivers may feel an increased level of stress if they experience delays in journey times, large numbers of passengers wanting to board the bus or if they do not know their route well enough	Bathija et al. [2], Mallia, Lazuras, Violani, and Lucidi [29], Tzouras, Farah, Papadimitriou, van Oort, and Hagenzieker [40]; Zaranka, Pečeliūnas, and Matijošius [44]
	Drivers drowsiness	Drowsiness in bus drivers is strongly related to accidents. Differences of safety culture in diverse countries	Mardi Safitri, Surjandari, and Jachrizal Sumabrata [31], Miller, Filtness, Anund, Maynard, and Pilkington-Cheney [32], Nævestad, Phillips, Laiou, Bjørnskau, and Yannis [33]
	Intersections and corridor design	Great influence of the design of intersections and corridors in accident occurrence	Duduta, Adriazola, Hidalgo, Lindau, and Jaffe [13]
	Users risk of crashes	Users are more at risk of crashes on access roads to bus stops than inside buses	Duduta, Adriazola, Hidalgo, Lindau, and Jaffe [12]
	Urban form and accidents	Denser environments with traditional, pedestrian-oriented designs, have on average fewer accidents	Dumbaugh and Rae [15]

as payment outside the bus. Simulations showed that this change can significantly speed up bus access times, especially when demand is high. In addition, it was also found that the presence of steps can increase vehicle access times.

The influence of exclusive bus lanes has been studied by multiple researchers using both simulation methods and in situ measurements. Arasan and Vedagiri [1] applied a simulation model considering heterogeneity in traffic conditions and showed that buses running in the bus lane could maintain a good level of service and capture demand from other motorised modes such as cars and motorbikes. On a more empirical level, Surprenant-Legault and El-Geneidy [37] evaluated the installation of a bus lane on two parallel streets in Montreal. The results obtained showed a reduction in travel times of 1 to 2% and reliability odds of 65%. The authors concluded, therefore, that the implementation of the bus lane helped to improve travel time and service reliability, both of which are important variables for increasing user satisfaction. Another empirical evaluation was conducted by Mane et al. [30], but in this case based on a real example where a Bus Rapid Transit (BRT) lane lost its exclusivity for public buses due to a court decision. In this case, the authors calculated that the probability of users switching from car use to BRT dropped from 65 to 46% and bus travel times increased significantly. Moreover, these effects are dependent on bus lane design since, as found by Truong et al. [39], the travel time improvements that a lane can generate are proportional to the number of lane sections, so that a series of disconnected sections can generate very small effects on service improvement.

Some research has also studied the safety of different characteristics of public transport systems, with a particular focus on the drivers' point of view. Thus, it has been found that bus drivers may have a high level of stress or fatigue, which may lead to a higher number of accidents [2, 44]. Drivers may feel an increased level of stress if they experience delays in journey times compared to planned journey times, if there are large numbers of passengers wanting to board the bus at bus stops or if they do not know their route well enough [40]. In addition, drivers that present specific personality traits such as hostility and anxiety have a higher crash risk [29]. There is also evidence of drowsiness among bus drivers [32], which is strongly related to accidents, and the importance of different safety cultures in different countries in explaining differences in accident rates [31, 33]. Other physical factors related to stop design also influence safety. Duduta et al. [13] reviewed the literature on safety and accidents in BRT and surface rail public transport systems and found that one of the main factors in accident generation is intersection geometry and

corridor design. In addition, there is consistent evidence that users are more at risk of crashes on access roads to bus stops than inside buses [12], a fact that is also related to urban form, as denser environments with traditional, pedestrian-oriented designs have on average fewer accidents [15].

As we have seen, although previous studies have carried out research about bus drivers' perceptions of safety-related aspects, there is a gap in the literature on bus drivers' perceptions of factors that may be more relevant to the service in relation to the design and operation of bus stops or the effects of the bus lanes. One exception is the work of Plano, Behrens, and Zuidgeest [35] in which the authors carried out a stated preference survey of paratransit drivers with the aim of evaluating their willingness to provide specific services in the city of Cape Town (South Africa). This research aims to fill that gap in order to get a more accurate picture of bus drivers' perceptions in relation to the research questions presented in the previous section. Bus drivers are one of the fundamental agents in the operation of public transport services and, given that they have direct knowledge, their perceptions can be very relevant to detect those aspects that can have a more negative influence on the performance of the service and on the satisfaction of users and the employees themselves.

3 Survey design and sample collected
In this section, the survey objectives and design are presented, as well as a brief description of the cities where it was deployed.

3.1 Survey objective and target cities
Based on the gap detected on the state-of-the-art section, the main objective of the survey is to get a deep knowledge on the perspective of bus drivers from medium-sized cities about certain aspects as the following:

1. The influence of the stops operation and design on stop time, user and driver comfort, and safety.
2. The respect for the existing bus lanes and its influence on operation, safety and user and driver comfort.
3. The aspects that drivers consider as more important from the safety perspective in relation to the interaction with other street users, and to passengers' safety.
4. The influence on the bus system performance of certain changes on its design and operation.

For the deployment of the survey, a series of Spanish medium-sized cities has been selected, whose population is shown in Table 2. The table also contains an estimation of bus lane length for each city, with low values for

Table 2 Cities for survey deployment, population and existence of bus lane

City	Population[a]	Bus lane length (m)	Separator
A Coruña	247,604	-	-
Vigo	296,692	3,036	No separator
Santiago de Compostela	97,848	425	No separator
Ourense	105,643	185	No separator
Santander	173,375	2,675	No separator
Burgos	176,418	5,600	No separator
Terrassa	223,627	6,900	No separator

[a] Source: INE [25]

Table 3 Sample, population and percentage of drivers obtained in each of the cities considered

City	Number of Drivers	Sample	%
A Coruña	226	53	23
Vigo	280	30	11
Santiago de Compostela	96	25	26
Ourense	96	16	17
Santander	256	20	8
Burgos	179	9	5
Terrassa	150	30	20
Total	1283	183	14

Santiago de Compostela and Ourense. There is no bus lane in A Coruña nowadays, although during the period 2008–2011 the city had a bus-lane of 1,745 m, and it is planned to provide a new one in the near future. The survey was conducted between June and October of 2020.

3.2 Focus Group

In order to improve the design of the drivers' survey, and to identify the main concerns and the perspective of urban bus drivers in relation to the research issues, a focus group (FG) was conducted on March 10, 2020.

FGs are an interactive discussion between a number of pre-selected participants, led by a moderator (facilitator) and focusing on a specific set of issues [23]. FGs have been used to assist researchers to develop survey instruments since the 1920s [43]. They allow free discussion among participants avoiding the constraints imposed by questionnaire surveys [27]. This format allows obtaining deeper insights than other techniques [16], which was relevant for this research in order to make the most of the detailed knowledge that bus drivers have about bus operation and safety.

The FG was held at the Compañía de Tranvías de La Coruña's headquarters and was recorded by audio and video. Ten drivers (nine male and one female) participated in the group. Although the number of female drivers in the company was very low (2.2%), an effort was made to add a female participant in the FG to include the female perspective. Participant's age ranged from 36 to 54 years, with an average of 46.8 years and a standard deviation of 5.1 years. Seniority at the company ranged from 11 to 28 years, with an average of 18.1 years and a standard deviation of 6.2 years. Participants were recruited with the assistance of the Compañía de Tranvías de La Coruña.

Before starting the discussion session, the facilitators read an explanatory statement to describe the research to the participants. Copies of this statement were delivered among the drivers, and they were asked to sign a consent form. A discussion guide was prepared beforehand in order to cover the aspects that the researchers were interested in, and for which the drivers' opinions wanted to be obtained.

The FG was structured in four parts: 1) stop design and its effect on the delay associated with them (including dwell time), and on passenger and driver comfort; 2) stop operation and its effect on the same previous aspects; 3) bus lanes, their pros and cons, and their design aspects affecting travel time and passenger and driver comfort; 4) safety concerns and measures to improve safety and avoid crashes. The FG lasted around 1.5 h, with around 40, 20, 15 and 15 min respectively for each part of the interview, although subjects were not strictly separated due to the interrelation among the four themes. As a wrap up of the session, drivers were asked to synthesize their conclusions about the problems and solutions discussed in a sheet of paper.

Audio recordings were transcribed using the NVivo software (NVivo 11), obtaining a verbatim transcript of the discussion. The analysis of the FG information has been the basis of the survey design. This information has allowed us to consider all the aspects that were mentioned during the discussion related to the design and operation of bus stops, safety, and the influence of the bus lane in the service.

3.3 Survey deployment and sample collected

The survey was delivered, in a first pilot phase, to a small number of drivers of A Coruña bus transit operator. Once the survey was tested with this trial, it was deployed among the rest of A Coruña drivers. The surveys of A Coruña and Santiago de Compostela were deployed in paper, while an online version was prepared for the other cities to better address the pandemic conditions. Table 3 shows the final and total number of drivers present in

each of the local bus services, as well as the sample collected in the survey.

In mobility studies, the sample required to obtain reliable results depends on the type of data we are collecting [5]. In our case the required sample for the seven cities as a whole has been calculated using the following expression:

$$n \geqslant \frac{N * z^2 * \sigma^2}{e^2(N-1) + z^2 * \sigma^2} \tag{1}$$

where n is the minimum sample required, e is the maximum acceptable error expressed as a proportion, z is the z-score related to the desired confidence level, N is the total number of drivers and σ^2 is the variance of the variable of interest, in this case of the values of the answers to the survey question where it may be higher. The required sample has been calculated using (1) and assuming a confidence level of 95%, an error of 15% and a variance of 1. Under these assumptions, the required sample would be 151 drivers, so the sample obtained can be considered sufficient to be representative of the population. In the following sections, some city-level results will also be graphically presented for descriptive purposes of the surveyed drivers' opinions. However, in these cases, the sample is not representative of the population for the indicated level of confidence and error.

4 Aspects related to bus stop design and operation

In the first section of the survey, bus drivers of the seven cities sampled rated between 1 (very unimportant) and 5 (very important) diverse aspects of bus stop design and operation. More specifically they were asked about how these aspects would affect four important dimensions of the bus service: a) stop time; b) user comfort; c) driver comfort; and d) safety. The average importance given by the drivers to the different aspects can be seen in Table 4 and the standard deviations of these evaluations are shown in Table 5.

Figure 1 plots the average of the responses, in each city and overall, for the 16 aspects related to stop design. The average evaluations in each city are shown to give an image of the distribution of the answers, although it should be noted that the sample is representative for the whole population but not for each city isolated. The values for each company represent the opinion of the sample of drivers, but we cannot infer accurately the average value of each variable for all drivers of these cities.

If the influence on stop time is taken into account, the aspects considered most important by drivers were the problem of approaching the kerb and deployment of the ramp due to the location of the stop on a curve (code 1.9),

the existence of illegal parking at the stop (1.4), especially relevant in Coruña, Ourense and Vigo, and respect of other drivers for the priority of buses (1.14). Other aspects with a high average were the problem of approaching the kerb and deploying the ramp due to previous curve path of the bus (1.10) and permissiveness with illegal parking (1.6), both problems similar to those already mentioned as the most important and, in the case of the problem of approaching the kerb and deploying the ramp, with a low standard deviation. Therefore, according to drivers, there is a mix of factors relevant to stopping times. Some of these are related to the physical design of the stops and the environment that makes it difficult to approach the kerb and deploy the bus ramp, while others, such as illegal parking or respect of bus priority, are related to citizens' behaviour and enforcement by the authorities.

Examining the results corresponding to the influence of the different aspects on user comfort, the problem of information at the bus stop (1.7) appears as the most important, with higher scores in Coruña, Vigo and Ourense and an important consensus among bus drivers, and again the problems of approaching the kerb and ramp deployment due to the location of the bus stop on a curve (1.9) and of illegal parking at the bus stop (1.4). Therefore, there is some overlap between the factors relevant to stop time and user comfort, although the availability of information appears as a new element to be taken into account in the design of stops.

In the case of comfort for the driver him or herself, aspects such as stop design (1.11), stop length (1.15) and stop length at terminals (1.16) appear to be quite important with a high consensus among drivers. This indicates that for drivers the physical design of stops is very relevant for the correct execution of their work, with special attention to aspects such as the correct length of stops and their position in the traffic lane.

Finally, regarding safety, it can be seen that the scores are generally higher in almost all aspects, with low values of standard deviation in most of them. Of somewhat greater relevancy is the importance given to illegal parking at the stop (1.4) due to the risk of collisions and pedestrian walking on the road, the length of the stopping area (1.15), the position of other obstacles near the stop (1.3) or the approach to the kerb and deployment of the ramp due to the location of the stop on a curve (1.9). These aspects are therefore linked to the design of the stop and the design of the urban furniture, similarly to those mentioned in previous sections, with the exception again of illegal parking.

Considering bus stop operation, drivers were asked to rate each aspect between 1 (very unimportant) and 5 (very important) for stop time, user comfort, driver

Table 4 Evaluations of the average importance in the stop design and operation of aspects related to: a) stop time; b) user comfort; c) driver comfort; and d) safety (1-very unimportant/5-very important)

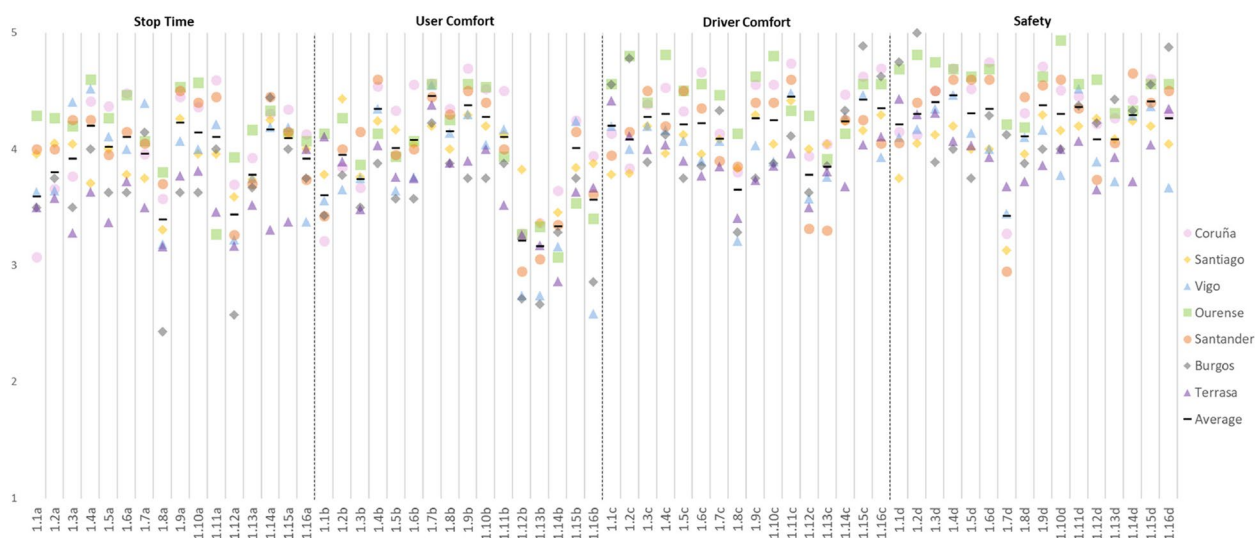| Code	Aspect	Stop Time	User Comfort	Driver Comfort	Safety
	Stop Design				
1.1	Position of stop signpost in relation to kerbside	3.60	3.61	4.20	4.21
1.2	Position of the bus shelter in relation to the kerbside	3.80	3.95	4.09	4.30
1.3	Position of other possible obstacles (such as signs, bollards, containers, trees) in the vicinity of the stop	3.92	3.75	4.28	4.40
1.4	Existence of illegal parking at the stop	4.20	4.34	4.30	4.46
1.5	Existence of illegal parking in the vicinity of the bus stop (before or after)	4.02	4.01	4.21	4.31
1.6	Permissiveness with illegal parking	4.11	4.08	4.22	4.35
1.7	Availability of sufficient information at the stop	3.96	4.46	4.09	3.43
1.8	Excessive slope of the streets in some stops	3.40	4.16	3.65	4.11
1.9	Problem of approaching the kerb and deployment of the ramp due to the location of the stop on a curve	4.23	4.38	4.27	4.38
1.10	Problem of approaching the kerb and deploying the ramp due to previous curve path of the bus	4.14	4.28	4.25	4.30
1.11	Stop design (stop in traffic lane vs. stop out of traffic lane)	4.11	4.11	4.45	4.36
1.12	Proximity of stops to intersections	3.44	3.21	3.78	4.08
1.13	Traffic signals at intersections	3.78	3.17	3.85	4.09
1.14	Respect of other drivers of the priority of buses	4.17	3.34	4.24	4.29
1.15	Length of stopping area at general stops	4.10	4.01	4.43	4.41
1.16	Length of stopping area at terminal stops with regulation time	3.92	3.57	4.35	4.27
	Stop Operation				
2.1	Interference at the stop with school buses	4.23	3.99	4.25	4.28
2.2	Interference at the stop with intercity buses	4.12	3.89	4.10	4.19
2.3	Interference at the stop with other city public transport buses	3.83	3.60	3.82	3.84
2.4	Operation of vehicle kneeling system	4.24	4.60	3.91	4.44
2.5	Operation of the vehicle ramp	4.46	4.63	4.17	4.51
2.6	Operation of door opening/closing system	4.51	4.15	4.40	4.56
2.7	Use of mobile phones, earphones or other distractions of users while paying	4.19	3.43	3.98	4.01
2.8	Lack of cooperation of users in facilitating the access of others by moving to the rear of the vehicle when it is half-full	4.30	4.23	3.99	4.08
2.9	Greater regulation and control of user behaviour, especially for vehicle access and fare payment	4.22	3.96	4.22	3.91
2.10	Weather (especially rain)	3.98	3.93	4.00	4.33
2.11	Operation of the chosen technology for card payment system	4.51	4.52	4.57	3.75
2.12	Payment system chosen by the user in each case (card, cash, ...)	4.40	4.20	4.38	3.54
2.13	Performance of the cash payment system and limit of cash to be refunded	4.30	3.77	4.30	3.47
2.14	Proportion of unsuccessful payment transactions in the case of card payments	4.21	3.99	4.28	3.33
2.15	Technological difficulties with the cash payment system (visibility of the screen, printing of tickets...)	3.89	3.92	4.05	3.20

The colour range is organized considering the data series of this table and the column "Average" showed in Table 7, as follows. Minimum value of the series: green colour; Percentile 50 of the series: yellow colour; Maximum value of the series: red colour. The intermediate colours represent intermediate values

Table 5 Standard deviation of the evaluations of the importance in the stop design and operation of aspects related to: a) stop time; b) user comfort; c) driver comfort; and d) safety

Code	Aspect	Stop Time	User Comfort	Driver Comfort	Safety
	Stop Design				
1.1	Position of stop signpost in relation to kerbside	1.34	1.40	1.25	1.22
1.2	Position of the bus shelter in relation to the kerbside	1.32	1.23	1.32	1.23
1.3	Position of other possible obstacles (such as signs, bollards, containers, trees) in the vicinity of the stop	1.35	1.43	1.28	1.18
1.4	Existence of illegal parking at the stop	1.31	1.27	1.29	1.26
1.5	Existence of illegal parking in the vicinity of the bus stop (before or after)	1.28	1.30	1.25	1.25
1.6	Permissiveness with illegal parking	1.34	1.41	1.36	1.34
1.7	Availability of sufficient information at the stop	1.29	1.01	1.22	1.55
1.8	Excessive slope of the streets in some stops	1.33	1.15	1.26	1.23
1.9	Problem of approaching the kerb and deployment of the ramp due to the location of the stop on a curve	1.23	1.22	1.27	1.30
1.10	Problem of approaching the kerb and deploying the ramp due to previous curve path of the bus	1.20	1.23	1.25	1.31
1.11	Stop design (stop in traffic lane vs. stop out of traffic lane)	1.20	1.25	1.01	1.13
1.12	Proximity of stops to intersections	1.45	1.48	1.32	1.35
1.13	Traffic signals at intersections	1.29	1.46	1.20	1.27
1.14	Respect of other drivers of the priority of buses	1.42	1.56	1.34	1.33
1.15	Length of stopping area at general stops	1.24	1.28	1.12	1.14
1.16	Length of stopping area at terminal stops with regulation time	1.35	1.48	1.05	1.19
	Stop Operation				
2.1	Interference at the stop with school buses	1.14	1.21	1.12	1.17
2.2	Interference at the stop with intercity buses	1.18	1.30	1.19	1.21
2.3	Interference at the stop with other city public transport buses	1.22	1.29	1.22	1.28
2.4	Operation of vehicle kneeling system	1.16	0.95	1.38	1.04
2.5	Operation of the vehicle ramp	1.02	0.88	1.23	0.99
2.6	Operation of door opening/closing system	0.90	1.20	1.02	0.92
2.7	Use of mobile phones, earphones or other distractions of users while paying	1.31	1.60	1.42	1.43
2.8	Lack of cooperation of users in facilitating the access of others by moving to the rear of the vehicle when it is half-full	1.23	1.27	1.32	1.32
2.9	Greater regulation and control of user behaviour, especially for vehicle access and fare payment	1.07	1.24	1.17	1.31
2.10	Weather (especially rain)	1.23	1.27	1.29	1.16
2.11	Operation of the chosen technology for card payment system	0.99	0.99	0.95	1.50
2.12	Payment system chosen by the user in each case (card, cash, ...)	0.97	1.10	1.02	1.50
2.13	Performance of the cash payment system and limit of cash to be refunded	1.18	1.33	1.25	1.56
2.14	Proportion of unsuccessful payment transactions in the case of card payments	1.24	1.28	1.24	1.52
2.15	Technological difficulties with the cash payment system (visibility of the screen, printing of tickets...)	1.33	1.31	1.23	1.56

The colour range is organized considering the data series of this table and the column "Std Dev" showed in Table 7, as follows. Minimum value of the series: green colour; Percentile 50 of the series: yellow colour; Maximum value of the series: red colour. The intermediate colours represent intermediate values
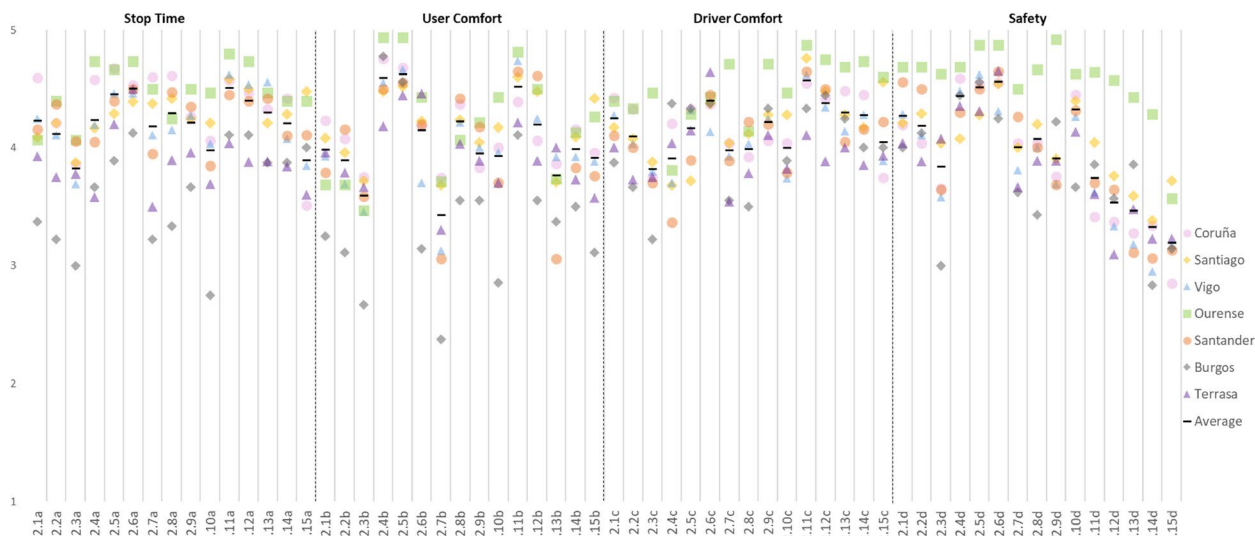
Fig. 1 Evaluation of the average importance in stop design of aspects related to: **a**) stop time; **b**) user comfort; **c**) driver comfort; and **d**) safety in the seven cities considered

comfort and safety. These results can be seen in the second part of Tables 4 and 5 and in Fig. 2.

For stop time, the performance of the technology chosen for the card payment system (2.11), the payment system chosen by the user in each case (2.12) and the performance of the cash payment system (2.13) were considered to be particularly important. These factors had a high average in all cities, especially in Ourense, and presented a low standard deviation given that failures in the payment system can greatly slow down the entry of users into the vehicles. This is coherent with the Transit

Capacity and Quality of Service Manual [36] which states that defective fare media or cash related issues can influence dwell time significantly. The importance given to aspects such as the functioning of the door opening and closing system (2.6) and the operation of the vehicle ramp (2.5) were at the same level in all cities. The operation of the ramp and the kneeling of the vehicle (2.4) are also cited as very relevant for the comfort of users and for their safety (in the latter case, the door closing system is also important) with a high degree of agreement among drivers. Card payment is again repeated as very

Fig. 2 Evaluations of the average importance in the operation of stops of aspects related to: **a**) stop time; **b**) user comfort; **c**) driver comfort; and **d**) safety in the seven cities

important also for the comfort of the driver him or herself, together with the payment system chosen by each user, as well as the functioning of the door opening and closing system. Thus, factors related to the payment system as well as factors related to the operation of the doors, ramp and kneeling systems, are considered most relevant by drivers.

5 Respect and influence of the bus lane, safety and modification of different aspects

This section of the survey examines the degree of respect for the existing bus lanes in cities and the influence of these in different aspects of the service. In addition, the survey also asked about the relevance of other aspects on safety and which kind of measures could be taken into account to improve the bus service.

Considering together the six cities where the question on the degree of respect for the bus lane was asked (Table 6), at least 50% of the drivers considered this to be

null or low. The lack of respect is especially relevant in Vigo where this figure rises to 87%, Ourense (64%) and Santiago (61%). On the other hand, in Santander and Burgos, compliance seems to be perceived as higher. This question and the one about the overall influence of the bus lane in the service were not asked in the survey of A Coruña given that this city does not currently present a reserved bus lane. However, almost all the drivers have or have had experience driving on the bus lane and only seven of the respondents did not answer the questions about evaluating its influence in different aspects of the service.

Among the aspects considered most likely to be influenced by the bus lane (first part of Table 7 and Fig. 3) are increased driver comfort (4.7), increased user comfort during acceleration/braking (4.9), and reduced stress in keeping schedules (4.6). Overall, in the six cities where drivers responded to this question, the influence of the bus lane on the service was considered high with a

Table 6 Bus drivers' perceived respect of bus lanes by private vehicle drivers

Respect bus Lane (%)	Santiago	Vigo	Ourense	Santander	Burgos	Terrassa	General
Null	48	40	14	0	11	13	23
Low	13	47	50	15	0	30	29
Medium	26	7	22	35	45	40	28
High	9	0	0	45	44	13	15
Full respect	4	6	14	5	0	4	5
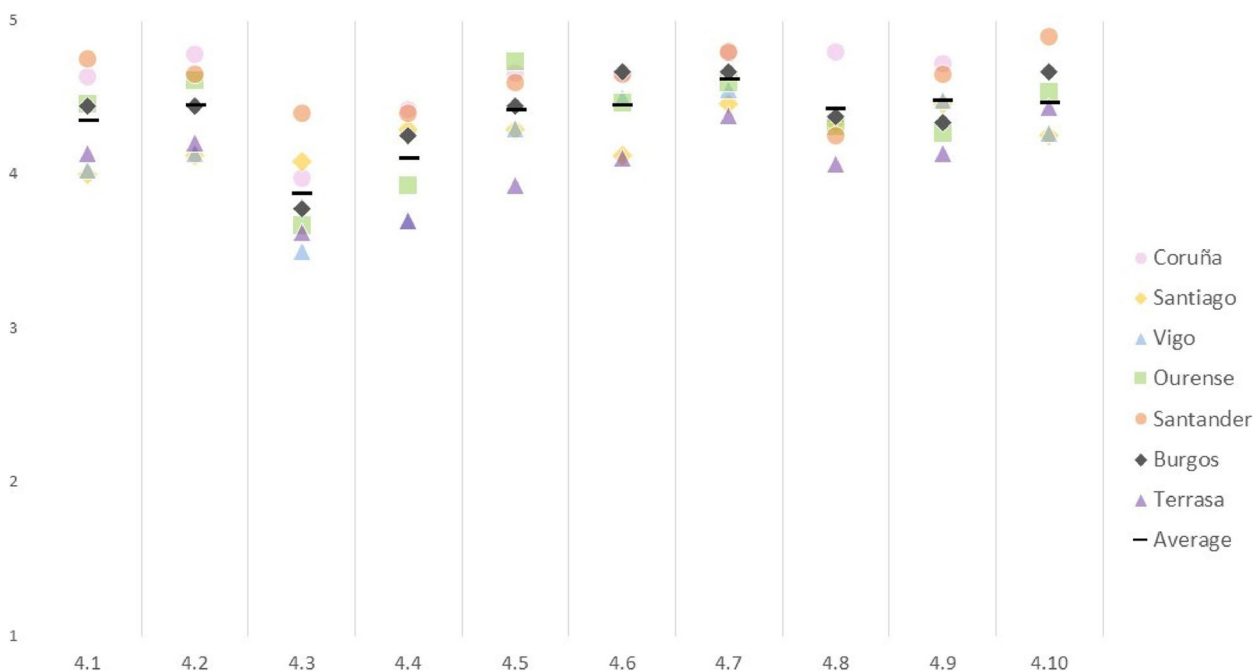
Fig. 3 Evaluations of the average importance of the influence of the bus lane in different aspects

Table 7 Evaluations and standard deviations of the evaluations in reference to: a) different aspects according to their influence on the bus lane; b) different aspects according to their influence on safety; c) possible modifications to improve the bus service

Code	Aspect	Average	Std Dev
	Influence of the bus lane		
4.1	Speed of operation	4.35	1.06
4.2	Reliability of timetables	4.45	0.97
4.3	Traffic safety with respect to pedestrians (on the adjacent pavement)	3.87	1.15
4.4	Traffic safety with respect to other vehicles	4.10	1.14
4.5	Operation of stops	4.42	0.91
4.6	Reduced stress in keeping schedules	4.45	1.04
4.7	Increased driver comfort	4.61	0.84
4.8	Increased user comfort (boarding and alighting)	4.42	0.95
4.9	Increased user comfort (acceleration and braking)	4.48	0.89
4.10	Overall influence of the bus lane on the service*	4.46	1.02
	Safety		
5.1	Position of pedestrian crossings in relation to bus stops	4.49	0.95
5.2	Painting of road markings (slipperiness when it rains)	4.53	0.95
5.3	Pavement condition	4.51	1.00
5.4	Visibility at crossings	4.63	0.90
5.5	Limited visibility due to inadequate arrangement of street furniture (boards, planters, posts, bins, etc.)	4.56	0.87
5.6	Bus turning points at the end of the line without sufficient space, forcing manoeuvres without sufficient visibility	4.62	0.87
5.7	Circulation on streets that are inappropriate because they are excessively narrow or have excessive traffic	4.61	0.88
5.8	Necessity to turn from unsuitable lanes (left turn from right lane, entering a roundabout from the right to turn left)	4.56	0.89
5.9	Interference from general traffic vehicles turning right with the bus on streets with bus lanes	4.50	0.92
5.10	Interference from bicycles in the bus lane where it is allowed	4.45	1.01
5.11	Difficulties created by excessively winding lines	4.35	0.84
5.12	Visibility restrictions due to double parking at pedestrian crossings	4.59	0.90
5.13	Concentration of passengers and pedestrians due to the stop being on a narrow sidewalk	4.32	1.00
5.14	Inattention of pedestrians who are distracted by mobile phones and/or headphones and do not respect the rules	4.64	0.88
5.15	Undue crossing by pedestrians to avoid missing the bus at the stop, or after alighting from the bus	4.65	0.86
5.16	Conflict between the need to ensure safety and the pressure or need to keep to the timetable	4.40	1.01
5.17	Location of cameras inside the bus directed towards the passenger area to enhance security	4.45	0.96
	Modification of different aspects		
6.1	Influence on the respect of the reserved bus lanes of the use of a physical separator	4.02	1.18
6.2	Influence of the use of a physical separator on the movement of buses	3.91	1.22
6.3	Influence on system performance of the arrangement of the bus lane in the centre of the road, rather than on the side, on two-way streets	3.11	1.50
6.4	Influence of sharing the bus lane with bicycles on the system performance	2.62	1.60
6.5	Influence on the time at stop of the implementation of a pay-at-stop system or with validation at the bus without driver involvement, being able to board through all the doors of the vehicle	4.21	1.27
6.6	Influence on fraud of the implementation of a payment system as in the previous question, considering that fraud control is carried out by inspectors and with a large fine if there is no ticket	4.17	1.23
6.7	Influence on the speed of operation of the distance between stops	3.94	1.10

The colour range is organized considering separately two data series (average and standard deviation) of this table and of tables 4 (average) and 5 (standard deviation) as follows. Minimum value of the series: green colour; Percentile 50 of the series: yellow colour; Maximum value of the series: red colour. The intermediate colours represent intermediate values

* This aspect was not asked in the survey of A Coruña

mean value of around 4.5. However, while in some cities, such as Terrassa, the ratings tended to be below average, in others, such as Santander or A Coruña, they were above average. Nevertheless, the standard deviation of responses in this specific part of the survey are particularly low.

In order to obtain a ranking of the aspects that can be most influenced by the bus lane from the drivers' perspective, an Ordered Probit model [22] has been estimated with the overall evaluation question as dependent variable (code 4.10) and the rest of the aspects introduced as independent variables. This type of model was selected because of its ability to correlate a categorical dependent variable with continuous or categorical independent variables, as it is the case in the data of our survey.

This model was implemented for the bus lanes part of the questionnaire because it is necessary to obtain objective reasons to support the implementation of this kind of infrastructures, which are usually controversial due to the reduction of space for general traffic that they imply. The fact that bus drivers consider bus lanes as a useful instrument to improve bus services and safety may be a justification for providing them but it is useful to control for several aspect at the same time in order to properly rank all items.

Considering the influence of different aspects in which the bus lane may be more relevant (Table 8), the most important were speed of operation (4.1), increased driver comfort (4.7) and traffic safety with respect to pedestrians (4.3), all of them with relevant and significant or nearly significant parameters according to the t-test. Other aspects such as Operation of stops (4.5) were close to be significant and the rest did not present significant parameters. These results are compatible with the evaluations obtained through the average direct assessment stated by the drivers especially referring to increased driver comfort, although in this case the speed of operation was considered more important than the reliability, that was not significant and presented a low parameter.

The questions and evaluations regarding which aspects were considered most important in terms of safety can be consulted in the second part of Table 7 and in Fig. 4. In general, almost all aspects had high scores, above four, and the lowest dispersion of all the survey parts in the evaluations given among cities and drivers. The most important aspect was pedestrians crossing the road inappropriately to avoid missing the bus at the stop (5.15), followed by the related issue of inattention of pedestrians who are distracted (5.14). Drivers therefore perceive that it is important for pedestrians to pay more attention to their surroundings in order to avoid safety problems. This issue is also linked to the lack of visibility at crossings (5.4) and, in terms of the physical design of stops, the lack of space for turning at the end of the line (5.6). It should be noted that drivers in Vigo as well as in Santiago and Santander gave high scores to the importance of possible interference with bicycles in the bus lane (5.10).

Finally, in order to assess which actions could have a more positive impact on the public transport system, drivers were asked to rate different actions with scores ranging from 1: very negative to 5: very positive (third part of Table 7 and Fig. 5).

The aspects that were cited as most positive in all cities were those related to the influence of the implementation of a pay-at-stop system with boarding through all vehicle doors (6.5) or with validation on the bus without driver involvement and with fraud control (6.6), in the latter case with few differences between the evaluation given in different cities and among drivers. The next most highly rated aspects were the respect of

Table 8 Ordered Probit model of bus lane aspects

Code	Aspect	Parameter	t-test
-	Constant	-1.71	-3.33
4.1	Speed of operation	1.07	4.03
4.7	Increased driver comfort	1.01	3.51
4.3	Traffic safety with respect to pedestrians	0.43	1.60
4.5	Operation of stops	0.29	1.10
4.8	Increased user comfort (boarding and alighting)	0.01	0.05
4.2	Reliability of timetables	0.00	0.01
4.4	Traffic safety with respect to other vehicles	-	-
4.6	Reduced stress in keeping schedules	-	-
4.9	Increased user comfort (acceleration and braking)	-	-
Log-Likelihood		-53.38	
McFadden's R^2		0.47	
AIC		126.8	
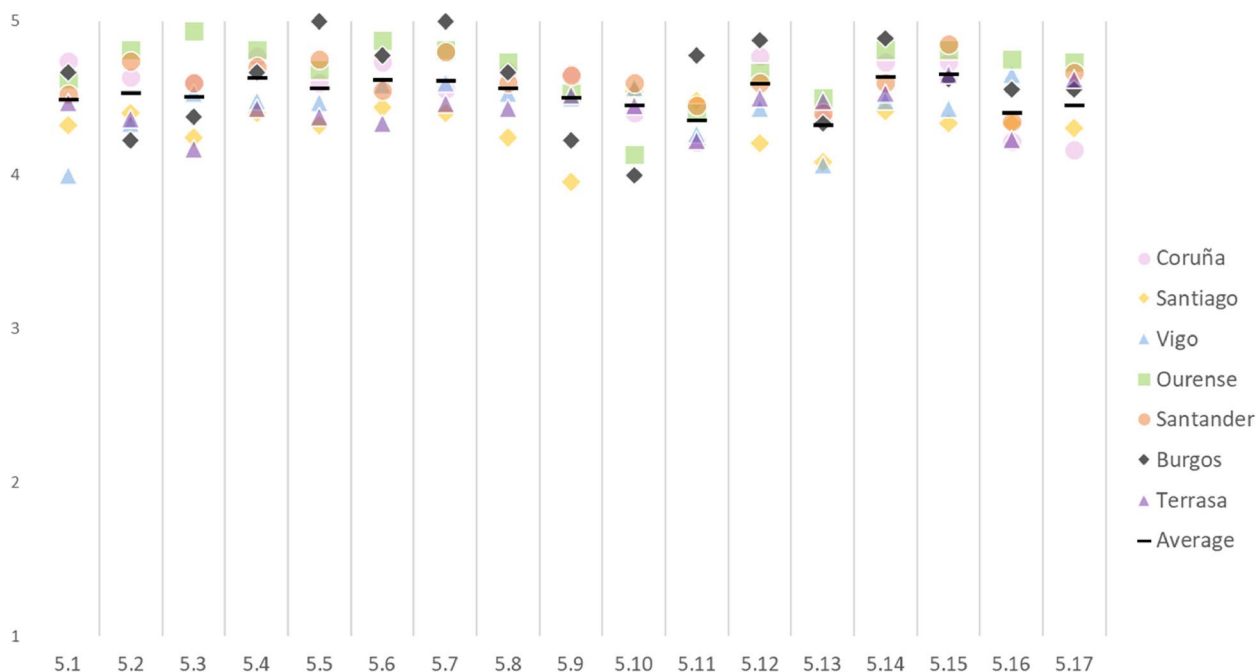
Fig. 4 Average evaluation of the importance of different aspects on safety
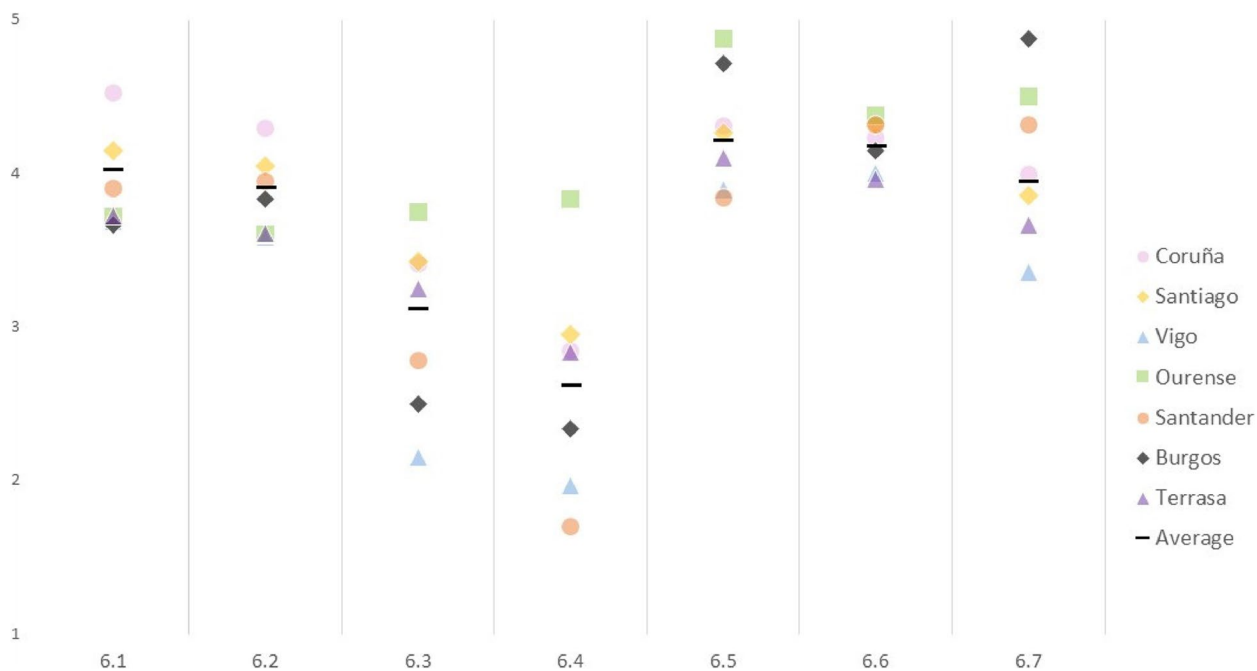
Fig. 5 Average evaluation of the potential impact of various changes

reserved bus lane through the use of a physical separator (6.1), especially in Coruña, and the influence on the speed of operation of the distance between stops (6.7), especially in Burgos. It is notable, therefore, that the payment system is considered by many drivers to be very important in the operation of bus stops and, furthermore, that a faster validation system without driver involvement, but with fraud control or with

passengers boarding at all gates, could improve the service significantly.

6 Discussion and conclusions

Although numerous researchers have studied the influence of the design and operation of bus stops, and the provision of bus lanes, on the system performance, comfort and safety, there is a gap in the literature in considering the bus drivers' perspective about the relevance of the different factors examined. This research aims to fill this gap, given that their perceptions can be extremely relevant as they are the ones who run the buses through these infrastructures in a daily basis, and who have a continuous interaction with users. In order to do so, a survey was deployed among bus drivers in seven Spanish medium-sized cities. After analysing the survey results, several insights can be highlighted.

From a policy point of view, considering the drivers' perspective, efforts should be made in relation to stop design in the following aspects: providing the stop with an adequate length (both for regular and terminal stops); avoiding the interference of several obstacles (such as shelter, signs, bollards or trees) with the bus manoeuvre; locating the stop on the traffic lane (online instead of offline) whenever possible; and properly locating stops in order to make it easier for the bus to manoeuvre to enter the stop and deploy the ramp. In addition, enforcement of parking regulations and bus priority when leaving the stop would reduce stop time. Finally, sufficient information should be provided at the stop to improve its performance. The factors that can have an influence on the time it takes a bus to enter and leave the service area such as the adequate length of the bus stop, obstacles in the stop, the location of the stop, having the bus the priority to leave the service area and the presence of cars illegally parked on the stop, have been less studied before [42], probably due to the higher difficulty in collecting data. However, these factors can have an influence on the dwell time even higher than the time spent boarding and alighting, if the number of passengers is small [14]. In addition, the location of the stop on the traffic lane has been shown to reduce dwell time in works such as Glick and Figliozzi [21] using stop-level and GPS data.

In order to obtain a proper performance in relation to stop operation, technological aspects are critical in two different fields: card payment technology and its reliability, as well as vehicle mechanical functioning of opening/closing doors, ramp and kneeling. The importance of the paying method on entry times has been highlighted by previous research [38] and the implementation of a card payment technology can therefore speeding up the entry of users. However, this would only happen if it replaces slower payment systems such as the use of cash and show

a reliable behavior, something that it is not always true according to the comments of the drivers obtained in the FG. The vehicle mechanical functioning of doors, ramp and keeling is critical in the dwell time of buses especially in order to avoid dwell times abnormally high [14].

Additionally, the provision of bus lanes could boost the perceived quality of the system. Drivers consider that bus lanes have a critical influence, not only for their own job, specifically in increased driver comfort and reduced stress in keeping schedules, but also for bus performance in relation to increased user comfort, reliability of timetables, operation of stops, speed of operation and traffic safety with respect to other vehicles. In relation to bus lanes, the use of a physical separator is seen as important to guaranteeing the respect of the reserved bus lane, a respect that was null or low according to 52% of the bus drivers. These results were partially supported by the ordered probit model estimated which showed that speed of operation, increased driver comfort and traffic safety with respect to pedestrians were the aspects with a higher influence on the overall evaluation of the influence of the bus the lane on the service. Previous studies have also shown that bus lanes can influence speed of operation [30], although the influence in the reliability of the system is probably more important [37]. In addition, the positive influence in the comfort of bus drivers and passengers has been less mentioned in previous works although it can be significant in improving citizens perception of the quality of the system.

In relation to safety, from a policy perspective, information campaigns for pedestrians to emphasize the importance of paying attention in order to avoid accidents may be useful. From the design perspective, it is important to consider visibility (for example at crossing or turning points) something in line with the idea that pedestrian-oriented designs can help to increase safety [15]. And again, to enforce parking regulation to avoid double parking at pedestrian crossings that hinders visibility, and illegal parking at the stop that forces passengers to cross the roadway. Vehicle mechanical functioning is also perceived as highly relevant for safety. Finally, it is critical to consider the bus routes and its implications to safety, such as: the circulation on streets that are inappropriate because they are excessively narrow or have excessive traffic; the necessity to turn from unsuitable lanes (left turn from right lane, entering a roundabout from the right to turn left); the interference with the bus from general traffic vehicles turning right on streets with bus lanes; the interference with bicycles in the bus lane where it is allowed; or the difficulties created by excessively winding lines. It is noteworthy that all the aspects of the specific safety block of the survey got a high score (over four) with low

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dispersion, which means that all safety factors considered are important for drivers. This may be an indication of their specific concern about safety.

As a way of improving the bus system performance, the implementation of a pay-at-stop system with validation at the bus, without driver involvement and with the possibility to board through all doors, seems to be the most promising one from the drivers' perspective. Nevertheless, systems to avoid fraud should be implemented in that case. This strategy is also supported by some previous research such as the works of Jara-Díaz and Tirachini [26] who recommended passenger boarding using all the available bus doors and Fletcher and El-Geneidy [19] for the case of offboard fare collection.

As can be concluded from this research, the drivers' perspective confirms the main aspects considered as important in the literature, related to the design, operation and safety of bus systems. This paper gives a more specific and detailed analysis of the different factors that can be considered for improving performance and safety of bus systems, as well as the importance that drivers give to them. Further research may take into account some limitations of this study. Firstly, the survey could be extended to other study areas, and more specifically to large cities where the challenges may be somewhat different from those of medium-sized cities. In addition, the opinions of drivers, based on their work experience, could be supplemented by other studies based on experiments to provide additional evidence on the positive effects of some of the policies proposed.

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