

Spatial and temporal variation of user satisfaction in public transport systems

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ABSTRACT

Surveys are a commonly applied method to establish user satisfaction levels with a public transport system. Regardless of the type of survey carried out and the methodology used, the studies usually present a time specific image of the service, showing the results in aggregate form or differentiating by lines and socio-economic characteristics of the users. However, satisfaction is not usually analysed as a variable with temporal or spatial variation. This research presents a case study applied to the city of Santander (Cantabria, Spain) in which an analysis is made about the evolution of satisfaction with the service over a day on various lines that integrate the city's public transport system. At the same time, it analyses how this perception changes at different points in the city. The results show that overall user satisfaction with the service decreases at peak times of the day, experiences more variations in lines with lower frequencies and can depend on the direction and location of the trip. In addition, some attributes were more relevant than others, also showing significant differences in their importance at different time slots and bus lines. These results can help to improve transport services, showing the spatial-temporal differences that exist in the evaluations carried out by users.

1. Introduction

Improving service quality and user satisfaction may help to increase the number of public transport users and customer loyalty. In addition, encouraging the use of public transport is one of the pillars of the promotion of sustainable mobility, given its ability to transport people more efficiently than private motorised transport, reducing congestion (Nguyen-Phuoc et al., 2020), the emission of pollutants (Beaudoin et al., 2015; Borck, 2019; Gendron-Carrier et al., 2018) and providing greater social equity (Cuthill et al., 2019; Foth et al., 2013; Manaugh and El-Geneidy, 2012).

Among the tools that have been applied to promote an improvement in user satisfaction with public transport services are Customer Satisfaction Surveys (CSS) (de Oña and de Oña, 2015). This type of survey attempts to measure the degree of user satisfaction with the service, given that higher satisfaction can be identified as the most important determinant of a favourable behavioural intention to use public transport (Lai and Chen, 2011). In addition to general satisfaction, CSS also

measure the perception of the quality of particular attributes of the service, with the aim of detecting those that could be improved to have the greatest impact in terms of satisfaction and therefore use of public transport. These attributes can be very diverse and therefore are usually classified into different groups, such as those proposed by the UNE-EN 13186 (2003) standard, namely: public transport supply (service offered, accessibility), performance of the service (information, trip time, customer service, comfort, safety) and environmental impact. Other authors have pointed out the existence of basic attributes (occupancy, service coverage, reliability) in which, if the perception of quality is low, demand for the service may be seriously compromised, while others are non-basic and contribute to satisfaction, but are not decisive for the users choice of service (characteristics of stops, cleanliness of vehicles, friendliness of employees) (Eboli and Mazzulla, 2008).

However, user satisfaction is not a static phenomenon, but can vary both spatially and temporally. In spatial terms between different service delivery zones within the same urban area (Cordera et al., 2019), between different cities or even between different segments of transport

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lines. In terms of time, satisfaction can be variable between different parts of the day (peak/off-peak time) or between different time intervals. Knowing this variability in user satisfaction can be important to diagnose when and where the service has problems. This study proposes to further this line of research by analysing and modelling user satisfaction obtained through a CSS carried out in Santander (Cantabria, Spain) considering the spatio-temporal variations of the responses. The CSS took into account both users' satisfaction with the service at a general level and their perception of the quality of the service in 24 specific aspects.

There has been limited attention to this spatial and temporal diversity in the technical literature on the measurement of service quality and customer satisfaction in public transport. An example is the work of Allen et al. (2020), who combined survey data on user satisfaction in the Santiago de Chile Metro with data on the operation of the service such as occupancy levels, frequencies, commercial speed and the occurrence of critical accidents. In addition, the authors disaggregated the analysis across system lines, periods of the day, days of the week, stations, and years, making this work the most notable example of considering spatial and temporal variability in satisfaction. However, this study did not take into account the variability of satisfaction and quality perception at a level of the different segments along the same line, which may provide more details on the factors influencing customer choices.

Cats et al. (2015), Börjesson and Rubensson (2019), de Oña et al. (2016) and Kawabata et al. (2020) have all used time series data that allowed them to analyse the evolution of customer satisfaction over time. Cats et al. (2015) examined how customer satisfaction changed in Sweden between 2001 and 2013, showing a decline in customer satisfaction generated by poorer customer interface and increased travel time. Börjesson and Rubensson (2019) also used customer satisfaction data in Sweden, in this case between 2008 and 2016, finding a significant relationship between satisfaction and the level of crowding and service reliability. De Oña et al. (2016) conducted research on the evolution of satisfaction and the perception of service quality using index numbers and data obtained from a CSS carried out between 2007 and 2013. This made it possible to detect a rise in satisfaction with the service in the first years of the series (2008–2010) together with a fall in the following years (2010–2012) and a slight recovery at the end of the period (2013). However, this study did not take into account spatial differences in service satisfaction or the explanatory factors that explained these changes. Kawabata et al. (2020) used data from the Benchmarking in European Service of Public Transport for the years 2001–2015 to support the hypothesis that improved service quality positively influences both user satisfaction and frequency of service use. Although the authors demonstrated the existence of this relationship, they also detected the existence of a time lag from when the improvement in quality occurs until it translates into higher frequency of use by users. Other research has also taken into account the effect of the 2008 financial crisis on user satisfaction, such as those conducted by de Oña et al. (2018) and Efthymiou and Antoniou (2017) for the Spanish and Greek cases, respectively.

Among the studies that have focused more on spatial differences, de Oña (2020) used data from five European cities: Madrid, Rome, Berlin, Lisbon and London, to examine the role of involvement in public transport, demonstrating its mediating role between user satisfaction and the behavioural intention to use it. This line of research was extended by the same author in de Oña (2021), considering whether satisfaction was a partial or complete mediating factor between service quality and behavioural intention, using data collected in the same five cities. This spatial comparison established that the structural equation model (SEM) that considered satisfaction as a full mediating factor had a better fit in all cities with the exception of London. Moreover, in all five cities factors such as frequency, punctuality, speed and intermodality were the most relevant. Other research by Eboli et al. (2018) analysed the spatial variation of transit service quality evaluated at railway stations. In this research, supported by a CSS collected by a railway

operator providing regional and suburban services in the North of Italy, the authors estimated a geographically weighted regression in order to investigate the spatial variations of each specific service quality attribute across the study area. They concluded that the areas with the lowest perceived railway service quality are the most distant from Milan, given their less dense railway network and fewer railway stations. However, these studies did not consider spatial differences in satisfaction on an intraurban scale. In contrast, the research of Ji and Gao (2010) considered this dimension and showed that urban areas with poorer accessibility to bus stops and to opportunities generally presented lower satisfaction with public transport.

As can be seen from the review of previous studies, most of the research that has taken into account the diversity of user satisfaction has done so more in temporal than spatial terms and more at the scale of different study areas (cities) than within the same transport system. In contrast, this research will focus on the spatial and temporal diversity of user satisfaction at the intra-urban scale, an approach that has been less explored and may support the identification of factors that can explain this diversity.

The following section reviews the data available from the CSS that formed the basis for this study. Section 3 describes the methodology used, both for estimating the contribution the different factors make to overall satisfaction and for differentiating the ratings at spatial and temporal levels. Section 4 presents the results obtained, paying special attention to the temporal and spatial variations in satisfaction. Finally, a number of conclusions and policy recommendations are drawn from these results.

2. Data available

2.1. Study area and data collection

We selected Santander as our case study area. Santander is the capital of the region of Cantabria and the main urban centre of an emerging metropolitan area. It is a medium-sized city with a population of 173,375 (INE, 2020) and a mainly service based economy. According to a 2013 mobility survey updated with traffic transit and pedestrian counts in 2018, regarding urban mobility (including commuting) the largest proportion of the citizens use private motorised transport (48%), followed by walking with 42%. Public transport by bus accounts for 8% and is more often used for study and health related trips (Aloi et al., 2020).

The data collection was based on a CSS asked between October and November 2017 in the city of Santander. The questionnaires were completed through face-to-face interviews on 4 urban lines operated by the local public transport company: line 1, line 2, line 3 and line 13 (Fig. 1). These lines were selected because they already have data available about user satisfaction and the perception of service quality as they boast a quality certification regulated by European Standard UNE-EN 13816.

The CSS was divided into 2 main sections. In the first part of the survey, the public transport users were asked a total of 7 questions related to their socio-economic and trip characteristics. The questions addressed: age, gender, employment status, level of monthly income, level of bus use, purpose of the trip (origin and destination) and whether they had an alternative mode of transport available to make the same journey they were making by bus. The second part of the survey focused on obtaining information on user satisfaction and their perception of service quality. In total, the users stated their perception of the quality of 24 attributes related to the system, as well as their overall satisfaction with the service as a whole. All the passengers were instructed about the importance of focusing on the current trip and not on past experiences with the system.

In order to define their perception of the quality of the different attributes, the respondents were asked to perform two activities. To facilitate the completion of these activities, the attributes were grouped

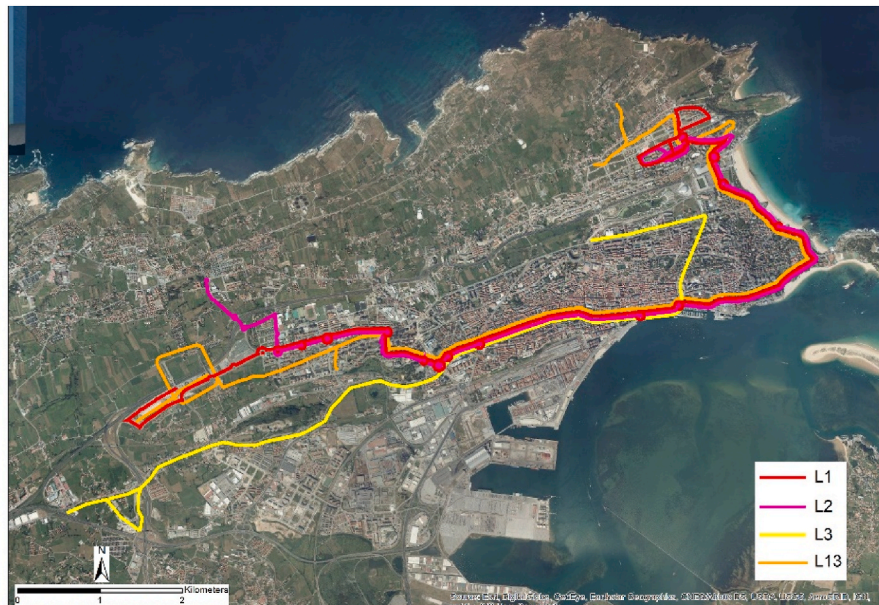


Fig. 1. Bus lines studied in the city of Santander.

into randomly selected clusters of 4 attributes. Each respondent only evaluated 3 groups of attributes, thus evaluating only 12 of the 24 attributes defined for the whole survey. This design was chosen to ensure that the surveys could be completed within an acceptable time frame and without tiring the respondents. The first exercise to be carried out, within the group of attributes, was based on a conventional quality level assessment based on a 5-point scale (from Very Bad to Very Good). Once the attributes had been assessed, the respondents were asked to choose from the four attributes they were shown the one they considered to be the most important and the one they considered the least important, thus performing a Best-Worst Case 1 exercise. To conclude the survey, respondents assessed overall satisfaction using the same 5-point scale defined above.

2.2. Sample collected

A total of 808 valid surveys were obtained in a time slot between 8 a. m. and 8 p.m. The number of surveys carried out in the different lines and time slots are shown in Table 1.

Table 2 shows the socio-economic characteristics of the sample for each of the transport lines analysed and for the total number of surveys. With regards to gender, it can be seen that women are over-represented in all cases. The age of the respondents is more evenly distributed, although there are more observations from people under 25 years of age

and fewer observations from people over 75 years of age. Another aspect to note in terms of age is the variation between lines 1, 2 and 3 compared to line 13. The first three show a higher number of younger users, while line 13 shows a much higher number of users over 65 years old. In terms of employment status, the majority of respondents are employed, followed by students and retired people. On line 13, in terms of age difference, the number of retired people is higher than on the other lines. Almost half of the respondents could have made the same trip by car. The potential use of bicycles is very low, as is the use of motorbikes. The main trip purpose is home-related, followed by work. The trip purpose by line is broadly similar, however, on line 3 there are fewer trips related to leisure, while on line 13 there is a higher number of trips for shopping. More than half of the users surveyed can be considered recurrent users, with the majority of respondents making between 5 and 15 trips per week. As for the income level of the sample, the distribution is similar on all lines, however, about 40% of the respondents preferred not to answer this question as it is a sensitive issue.

Table 3 shows the perceived quality level of the attributes ranked from highest to lowest value. The highest rated attribute is the use of alternative fuel vehicles (hybrid vehicles at the time of the survey). In second place are the access and egress times to and from stops, which demonstrates a good density of stops along the network. On the other hand, lower scores were obtained for service attributes such as frequencies and fares. Finally, environmental variables such as air conditioning systems and noise also received low scores. Some of the attributes showed a higher level of consensus in the evaluations such as cleanliness or bus comfort, whereas the perceived quality of others was more diverse, especially regarding the information given to the user (attributes Information on the mobile phone, Ease of understanding the line map, and Information at stops).

3. Methodology

3.1. Calculation of overall satisfaction

The availability of several observations at different times of the day requires an aggregation method in order to be able to compare the results of different public transport lines and time slots on different sections of the lines.

The process that has been followed starts with the division of the public transport lines into sections that coincide with the passenger

Table 1
Sample size and distribution.

Time of day	Completed Surveys				Total
	Line 1	Line 2	Line 3	Line 13	
≤ 9:00	24	28	30	16	98
9:01–10:00	35	36	31	34	136
10:01–11:00	21	28	8	11	68
11:01–12:00	15	12	9	4	40
12:01–13:00	18	9	13	20	60
13:01–14:00	28	10	50	16	104
14:01–15:00	10	8	12	4	34
15:01–16:00	14	28	5	8	55
16:01–17:00	10	33	15	18	76
17:01–18:00	14	17	19	19	69
18:01–19:00	21	13	3	17	54
19:01+	4	4	3	3	14
Total	214	226	198	170	808

Table 2

Socio-economic variables considered in the survey.

Attribute	Level	Line 1	Line 2	Line 3	Line 13	Total
Gender	Man	36%	31%	33%	31%	33%
	Woman	64%	69%	67%	69%	67%
Age	<25 years old	25%	23%	35%	16%	25%
	25–34 years old	15%	14%	16%	9%	14%
	35–44 years old	15%	17%	15%	11%	15%
	45–54 years old	12%	17%	13%	26%	17%
	55–64 years old	19%	14%	11%	18%	15%
	65–75 years old	10%	12%	7%	23%	11%
	>75 years old	4%	2%	3%	6%	4%
Employment status	Household chores	4%	6%	4%	4%	5%
	Employed	43%	45%	47%	54%	47%
	Unemployed	9%	9%	5%	8%	8%
	Student	27%	23%	34%	11%	24%
Other mode of transport available	Retired	17%	17%	11%	23%	17%
	Car (driving)	35%	34%	36%	38%	35%
	Car (passenger)	12%	11%	11%	12%	12%
	Bicycle	9%	6%	4%	4%	6%
	Bike	2%	5%	3%	1%	3%
	Other	41%	44%	46%	46%	44%
Trip purpose(O/D)	Home	36/31%	57/15%	54/38%	34%/34%	46/29%
	Work	24/23%	18/27%	17/21%	29/29%	22/25%
	Studies	12/12%	5/12%	15/18%	4/7%	9/13%
	Health	4/6%	3/8%	4/3%	5/3%	4/5%
	Shopping	6/6%	4/8%	3/7%	8/8%	5/7%
	Leisure	12/14%	9/21%	3/5%	14/11%	10/13%
	Other	4/9%	4/10%	5/7%	6/9%	5/9%
Number of bus journeys made per week	<5	29%	27%	24%	29%	26%
	5–15	52%	49%	62%	52%	54%
	15–30	17%	21%	15%	17%	18%
	>30	2%	2%	0%	2%	1%
Level of income	<900€	9%	7%	7%	5%	7%
	900€ - 1500€	20%	19%	19%	23%	20%
	1500€ - 2500€	13%	12%	23%	20%	17%
	>2500€	17%	13%	9%	18%	14%
	No answer	41%	48%	42%	35%	42%

boarding and alighting stops on each of the lines. Dividing the line into sections, the data from the passenger surveys is processed in such a way that the overall journey satisfaction (OS) is assigned to the sections that run between the passenger boarding and alighting points. Thus, to establish the journey evaluation, the data for each of the journeys between the stops are aggregated (Fig. 2). To do this, the individual scores of each user are collected and assigned to each of the sections of line that the passenger uses on their journey between the up and down stop. The average score of the passengers who have used each section is calculated to obtain the score for that section. In order to visualise the data correctly, each user's score has been extrapolated to a scale between 1 and 10, compared to the initial scale which valued journeys between 0 and 4.

Finally, to obtain the scores calculated on the lines in different time segments, the procedure followed consists of grouping the observations by time slots and applying a division like the one made for the aggregate of all lines, dividing the scores by the number of slots on the lines according to the number of passengers boarding and alighting the bus.

3.2. Best-Worst modelling

The survey conducted was based on Best-Worst (BW) case 1 exercise (Louviere et al., 2015). The BW-based models have been conducted considering a Multinomial Logit (MNL) specification, where the unobservable part of the utility is assumed to be distributed according to a generalised extreme value type 1 distribution (Gumbel distribution) independent and identically distributed among alternatives.

A total of K attributes have been defined in the survey. In each exercise a subset Y of 4 different attributes was shown. The probability of choosing an alternative b as best and an alternative $w \neq b$ as worst is defined as $P_{BW}(bw | Y)$. The survey did not allow choosing the same

option as both best and worst. An example can be seen in Fig. 3 where the person surveyed must define the most and least important attribute in three sets, each one containing four attributes.

Table 3

Perceived quality levels of attributes and overall satisfaction.

Order	Attribute	Acronym	Mean	Std. Dev.
1	Use of hybrid buses	HY	8.10	1.91
2	Access time to the bus stop	AT	7.34	2.24
3	Egress time from stop to final destination	DT	7.29	2.22
4	Vehicle cleanliness	CL	7.04	1.75
5	Ease of transfer	TR	6.96	2.24
6	Information at stops	IS	6.90	2.43
7	On-board information	IB	6.83	2.24
8	Bus comfort	CM	6.77	1.86
9	Reliability	SR	6.75	2.16
10	Driver friendliness	DK	6.57	2.12
11	Quality of stops	ST	6.56	2.03
12	Information on the mobile phone application	IM	6.53	3.19
13	Coverage of the lines	LC	6.50	2.07
14	Information on the website	IW	6.46	2.39
15	Space for people with reduced mobility	RM	6.27	2.22
16	Waiting time	WT	6.26	2.27
17	Level of occupancy	OC	6.25	2.17
18	Ease of understanding the line map	MD	6.21	2.46
19	Trip time	TT	6.18	2.14
20	Service offered (frequencies and timetables)	SE	6.10	2.42
21	Driving style	DS	5.98	2.15
22	Price	PR	5.83	2.35
23	Heating/air conditioning	CA	5.77	2.49
24	Noise	NO	5.71	2.06
	Overall satisfaction	OS	6.73	2.01

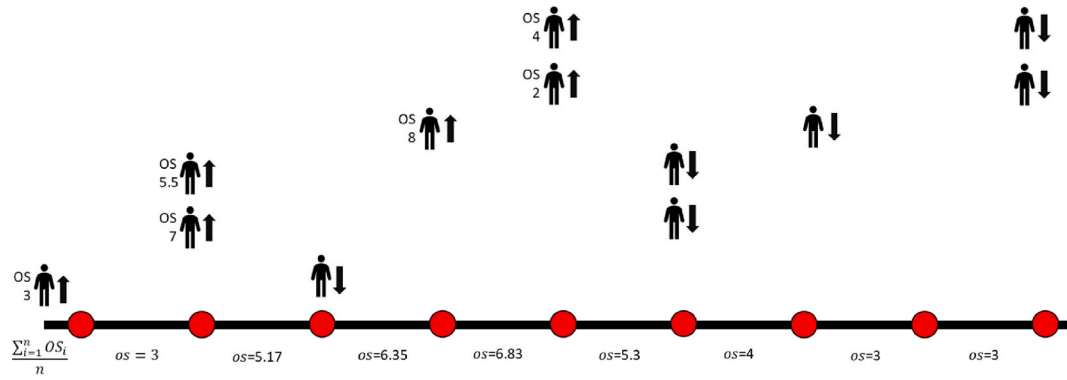


Fig. 2. Estimation of overall satisfaction by line segment.

Most Important Attribute to You	Set 1 of 3	Least Important Attribute to You
<input type="radio"/>	Waiting Time	<input type="radio"/>
<input checked="" type="radio"/>	Service offered	<input type="radio"/>
<input type="radio"/>	Line coverage	<input type="radio"/>
<input type="radio"/>	Information on board	<input checked="" type="radio"/>

Fig. 3. Example of Best-Worst choice scenario about the importance of the attributes (Set 1 of 3).

The probability of choice calculated using a Logit specification is defined as a Maxdiff model (Marley and Louviere, 2005). The expression of the model is:

$$P_{BW}(bw|Y) = \frac{\exp[v(b) - v(w)]}{\sum_{l,k \in Y, l \neq k} \exp[v(l) - v(k)]} \quad (1)$$

where $v(\cdot)$ is the observable utility calculated as a function of the attributes $v(k) = \delta_k y_k$ where y_k is an indicator vector between 0 and 1 that takes the value 1 when an attribute k is shown in the question and 0 otherwise. Thus, the parameter δ_k represents the relative importance of an attribute against the base attribute, which is assigned $\delta_0 = 0$. To include temporal variability in the model some sample heterogeneity needs to be considered. The model parameter is defined as $\delta_i = \delta + \Lambda t_i$, where δ remains a constant parameter dependent on attribute k , while Λ represents the variation over the parameter value for each time slot t_i to which each individual i belongs.

4. Results

4.1. Spatial variation of satisfaction

Fig. 4 shows the spatial analysis of the 4 lines surveyed, differentiating the sections between stops. The average satisfaction for each section has been calculated in accordance with the method presented in section 3.1. In general, it can be observed that the variation in satisfaction along a line is not very important. Likewise, satisfaction is very similar along the four lines of the network, where overall satisfaction is found to be the average.

An analysis of line 1 shows a greater variation at the ends of the line which are located in zones of the city with a lower density of lines. The north-east area shows contrasting levels of satisfaction, with some users valuing positively their satisfaction with the line, while other users are less satisfied with the service. The western end also shows lower

satisfaction with the line.

Line 2 shows a higher level of satisfaction than the other lines, although satisfaction is somewhat lower in a section of the central and western area of the line. Satisfaction in this area reflects a directional nature, with users being more satisfied when using the service in an easterly direction.

Line 3 shows medium satisfaction on almost the entire line, with the exception of several sections with low satisfaction and one section in the east with higher satisfaction. The latter part corresponds to a section of the line that is only used at specific times of the day and serves to connect the city centre with the university area. Satisfaction on this section is also seen to be directional, being higher in the direction of the university. The reason for this may be due to the fact that the public transport alternative for accessing the university area from the city centre requires a longer journey and therefore this line is the best available alternative.

Finally, line 13 shows a higher level of satisfaction in the north-eastern part of the line, especially when using the service in a north-easterly direction. The rest of the line shows a medium level of satisfaction, with the exception of the western end, where user satisfaction is lower. This last zone also corresponds to an area of the city with a very low density of public transport.

4.2. Temporal variation in overall satisfaction

With the data obtained from the questionnaires, an analysis was made of how satisfaction varies over the course of a day. To do this, the responses obtained were grouped into 1-h bands, for a period between 8 a.m. and 8 p.m. Fig. 5 shows the variation in the average overall satisfaction throughout the day. The times of lowest satisfaction correspond to the peak periods of use of the transport system, with the lowest score being obtained in the midday peak hour. In the off-peak hours of the day, overall satisfaction is higher than average, with the highest level of satisfaction in the afternoon off-peak hour.

A similar analysis has been carried out segregating the results by line (Fig. 6). The results show that the variation in overall satisfaction throughout the day is different depending on the line. Lines with higher frequency and higher ridership (lines 1 and 2) show a smaller hourly variation in satisfaction. However, lines with lower frequency show a much higher variation in satisfaction. Line 13 shows a different satisfaction profile to the others, with the lowest level of satisfaction observed in the theoretical off-peak hour in the morning. This phenomenon may be due to the fact that the main users of this line are elderly people who tend to have different mobility schedules to other users.

To check whether the variability of satisfaction is significant throughout the day, an ANOVA test was carried out for overall

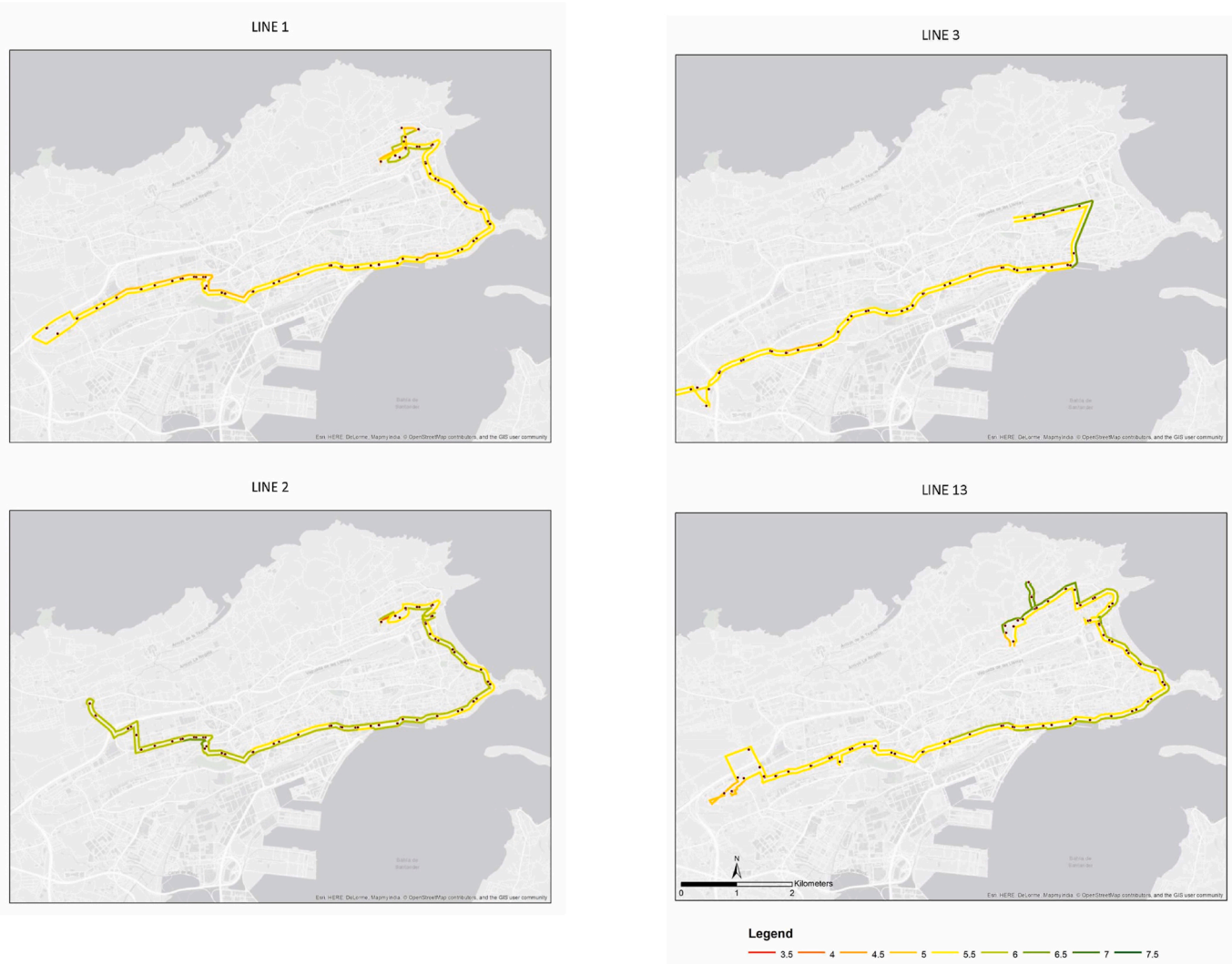


Fig. 4. Spatial variation in overall satisfaction on lines 1, 2, 3 and 13.



Fig. 5. Temporal variation of overall satisfaction.

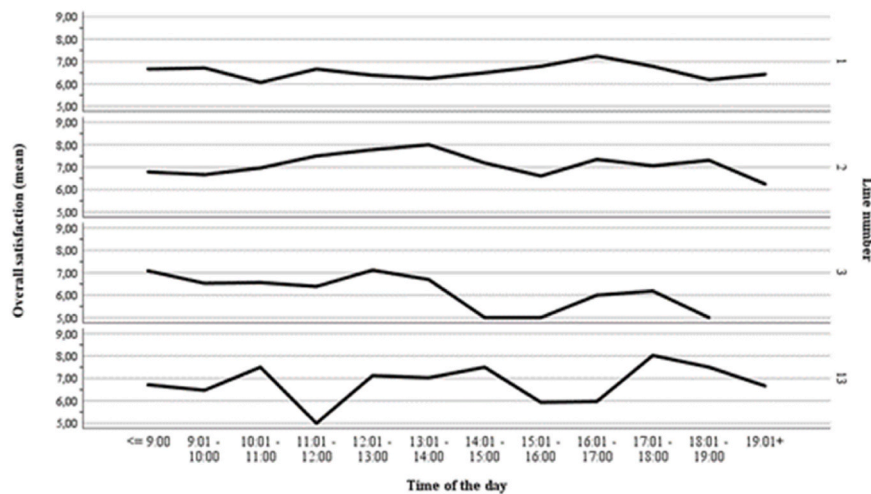


Fig. 6. Temporal variation in overall satisfaction by line.

Table 4

ANOVA test considering time and line differences.

ANOVA test	Por Hour		Per Time Slot		Per Line	
	F Value	Sig.	F Value	Sig.	F Value	Sig.
OS	0.653	0.784	0.535	0.750	4.045	0.007
AT	0.986	0.459	1.389	0.227	1.762	0.154
WT	1.376	0.181	0.857	0.510	0.746	0.525
TT	1.553	0.111	1.988	0.080	1.517	0.210
DT	1.514	0.124	0.692	0.630	1.499	0.214
PR	2.940	0.001	2.783	0.017	0.975	0.404
TR	0.840	0.600	1.192	0.313	0.540	0.655
SE	1.046	0.405	1.455	0.204	10.128	0.000
SR	0.650	0.785	0.649	0.662	2.448	0.063
LC	2.679	0.003	3.464	0.004	1.718	0.163
IS	1.119	0.344	1.413	0.219	1.806	0.146
IW	1.606	0.101	1.134	0.344	0.783	0.505
IB	1.123	0.342	1.200	0.309	2.903	0.035
OC	2.655	0.003	4.154	0.001	9.317	0.000
CA	1.381	0.179	2.710	0.020	5.952	0.001
RM	0.977	0.467	1.257	0.282	0.381	0.767
CM	1.541	0.115	2.188	0.055	2.039	0.108
CL	1.042	0.408	1.285	0.269	0.724	0.538
DS	0.996	0.450	0.993	0.422	1.959	0.120
DK	1.550	0.111	2.295	0.045	1.302	0.273
HY	1.126	0.340	0.494	0.781	0.662	0.576
NO	1.948	0.033	1.551	0.173	3.292	0.021
IM	1.265	0.245	1.900	0.094	6.411	0.000
ST	0.869	0.571	0.772	0.570	1.516	0.210
MD	1.021	0.427	1.947	0.086	1.478	0.220

satisfaction and all the quality attributes assessed. Likewise, the ANOVA test considered 3 types of conditioning factors: firstly, the variation was analysed by time of day, secondly, by period of the day (morning peak hour, morning off-peak hour, midday peak hour, evening peak hour and evening off-peak hour) and, finally, the same test was performed considering the different lines analysed. The results of the three tests are shown in Table 4. Those variables whose variations were found to be significant are highlighted in bold.

The results of the ANOVA test show that the variability of most attributes does not depend on the time of day or the line. However, some attributes are perceived to be different. The hourly variation is generally smaller than when considering time slots. Price (PR), line coverage (LC), occupancy (OC) and noise (NO) are attributes that have been evaluated differently depending on the time of day. In the case of time slots, the attributes with the greatest variation across different periods of the day are price, line coverage, occupancy, heating/air conditioning (CA), bus comfort (CM) and driver kindness (DK). To a lesser extent, travel time

Table 5

MNL model based on Best-Worst considering temporal variation.

Variable	Acronym	Parameter	Z value
Access time to the stop	AT	1.517	12.13
Waiting time	WT	2.042	15.96
Trip Time	TT	2.296	17.50
Egress Time	DT	1.678	13.29
Fare	PR	1.912	15.24
Ease of transfer	TR	1.193	9.48
Ease of transfer*Morning peak time	H1TR	−0.595	−2.97
Ease of transfer* Afternoon peak time	H3TR	0.580	3.01
Service offered (frequencies and timetables)	SE	2.313	17.99
Service reliability	SR	2.401	18.84
Line coverage	LC	2.317	17.84
Line coverage * Morning peak hour	H1LC	0.321	1.86
Information at stops	IS	1.420	11.20
Information at stops * Morning peak hour	H1IS	0.547	2.49
Information at stops *Midday peak hour	H2IS	−0.553	−2.98
Information at stops * Afternoon peak	H3IS	0.578	2.92
Information on the website * Morning peak hour	H1IW	−0.536	−3.17
Information on board	IB	0.299	2.38
Occupancy level	OC	1.503	12.02
Occupancy level * Morning peak hour	H1OC	−0.303	−1.95
Heating/air conditioning	CA	0.467	3.74
Space for people with reduced mobility	RM	1.669	13.07
Bus comfort	CM	1.158	9.26
Bus comfort * Afternoon peak hour	H3CM	−0.325	−2.21
Vehicle cleanliness	CL	0.942	7.67
Driving style	DS	1.514	11.95
Driver friendliness	DK	0.557	4.33
Driver friendliness * Midday peak hour	H2DK	−0.465	−2.79
Driver friendliness * Morning off-peak	H4DK	0.555	4.06
Use of hybrid vehicles	HY	1.121	8.84
Noise	NO	0.506	4.09
Information on mobile application	IM	1.011	7.99
Quality of stops	ST	0.630	4.96
Ease of understanding the line map	MD	1.266	9.81
Ease of understanding the line map * Morning off-peak time	H4MD	−0.501	−4.05
Log-likelihood		−5325.90	
Pseudo R ²		0.12	

(TT), mobile information (IM) and ease of map design (MD) also vary across different periods of the day. In contrast to the time variation, overall service satisfaction does vary depending on the line analysed. Closely related to the above, both the perception of frequency (SE) and service reliability (SR) also change depending on the line. Other line-

related aspects that vary by line are information on the bus (IB), occupancy level, heating/air conditioning system, noise, and information on mobile devices.

4.2.1. Modelling results

Table 5 shows the estimated MNL model considering the time variation of the importance of the attributes collected in the CSS. To include the time variable, the following time slots have been used: morning peak hour (7:00–9:00), morning off-peak hour (9:00–13:00), midday peak hour (13:00–15:00), afternoon off-peak hour (15:00–17:00 and 19:00 onwards) and afternoon/evening peak hour (17:00–19:00). These time slots have been considered in order to have enough observations to estimate the model. The parameter values show the level of importance of each attribute, i.e., the higher the value, the greater the importance of that aspect. Variables that consider interaction provide variation due to the time slot with which they interact. Therefore, if an interaction shows a negative parameter, that attribute has a lower importance in that time slot, whereas, if it shows a positive value, the importance increases. In the final model, only those interactions that have been found to be statistically significant have been considered. The model showed a log-likelihood of -5325.9 and a McFadden's R^2 of 0.12 , having a significantly better goodness of fit than the null or only constants models according to a likelihood ratio test.

The estimated models make it possible to establish the level of importance of each attribute for each time slot analysed. Table 6 shows the normalised values of importance and the average perceived quality for each attribute in each time slot. The most important attribute in each time slot has been assigned a value of 10, while the least important attribute has been assigned a value of 0, and the remaining values have been weighted linearly between these two values according to the results of the model.

The most important variables for users were those most closely related to the operational characteristics of the lines, namely the coverage of the lines, the reliability of the service and the service offered (timetables and frequencies). These three variables have proved to be important, making it clear that the variation in the importance of the attributes throughout the day is not very noticeable.

The least important attributes for users were those related to additional or secondary services, such as information on the website,

information on the bus, the heating system and noise. In the case of these less important attributes, the variability throughout the day is greater than in the case of the most important attributes, and although their importance increases, they do not reach high levels of relevancy.

The attributes whose importance changes significantly are ease of transfer (TR), which is much more important in the afternoon peak hour compared to the rest of the day, and information at stops (IS) and driver friendliness, which are more important in the all-day peak versus off-peak hours.

4.3. Spatial and temporal variation of satisfaction

Finally, it is possible to combine the temporal with the spatial analysis to study the evolution of customer satisfaction throughout the day at the different points of the network. Fig. 7 shows the results for overall satisfaction for line 1 over the 6 periods analysed. The same process could be carried out for all lines and all attributes; however, such information has not been added in the article in order to avoid redundancies.

Analysing the images as a whole, it can be observed that satisfaction changes both spatially and temporally simultaneously, i.e., at different times of the day satisfaction is different at different points in the network.

Looking at the morning peak hour (7:00–9:00), it can be seen that satisfaction is clearly directional in nature. Users who take the bus from the north (mainly residential) to the west (residential and work) show a more negative satisfaction with the service, while in the opposite direction satisfaction is higher. In the morning off-peak hour (9:00–13:00) the effect is the opposite, satisfaction is worse in the eastbound direction, while it increases in the westbound direction, and the ends of the line show a clear lower satisfaction. In the midday peak hour, the trend is similar to the morning peak, with lower overall satisfaction especially in the northeast end. The lowest level of satisfaction was observed at 15:00, at the end of the midday peak hour and the beginning of the afternoon off-peak hour. In the early afternoon (15:00–17:00) the trend changes again, in this case the directionality is more homogeneous, while the distinction is between the central area of the line and the peripheral areas, where lower satisfaction is observed. In the afternoon/evening peak hour (17:00–19:00) the trend is similar, with the worst

Table 6
Importance (Imp) and perceived quality (Qual) of the attributes by time slots.

Var	Morning peak Time		Morning off-peak time		Midday peak time		Afternoon peak time		Afternoon off-peak time	
	Imp.	Qual.	Imp.	Qual.	Imp.	Qual.	Imp.	Qual.	Imp.	Qual.
AT	6.47	7.39	6.32	7.67	6.32	7.21	6.32	7.00	5.80	7.08
WT	8.12	6.08	8.51	6.18	8.51	6.20	8.51	6.50	8.29	6.47
TT	8.92	5.92	9.56	6.04	9.56	6.60	9.56	6.27	9.50	6.35
DT	6.97	7.44	6.99	7.38	6.99	6.92	6.99	7.30	6.56	7.42
PR	7.71	5.82	7.96	5.74	7.96	6.06	7.96	5.64	7.68	6.25
TR	3.57	7.62	4.97	7.02	4.97	6.94	7.38	6.67	4.32	6.71
SE	8.98	5.55	9.64	5.99	9.64	5.98	9.64	6.41	9.58	6.45
SR	9.25	6.37	10	6.94	10	6.59	10	6.81	10	6.64
LC	10	5.69	9.65	6.78	9.65	6.25	9.65	6.27	8.07	6.94
IS	7.89	6.49	3.61	6.94	5.92	6.50	8.32	7.50	2.62	6.94
IW	0	5.36	0	6.46	0	6.74	0	6.67	1.13	6.77
IB	2.63	7.13	1.24	6.85	1.24	7.15	1.24	6.33	0	6.75
OC	5.47	6.12	6.26	6.48	6.26	5.83	6.26	5.81	7.17	6.82
CA	3.16	6.07	1.94	5.55	1.94	6.07	1.94	5.21	0.80	6.48
RM	6.95	6.55	6.95	6.36	6.95	6.37	6.95	6.18	6.52	5.64
CM	5.34	7.20	4.82	6.73	4.82	6.33	3.47	6.60	5.63	7.09
CL	4.66	7.40	3.92	7.09	3.92	6.95	3.92	6.63	3.06	7.06
DS	6.46	5.45	6.31	6.22	6.31	5.90	6.31	5.82	5.78	6.01
DK	3.44	6.19	0.38	6.82	4.63	6.89	2.32	6.11	0.80	6.46
HY	5.22	8.08	4.67	8.01	4.67	7.98	4.67	8.21	3.91	8.28
NO	3.28	5.56	2.11	5.42	2.11	5.99	2.11	6.16	0.99	5.65
IM	4.87	6.90	4.21	6.14	4.21	6.19	4.21	7.80	3.39	6.41
ST	3.67	6.20	2.62	6.52	2.62	6.89	2.62	6.42	1.58	6.72
MD	5.68	6.41	5.27	6.38	3.19	6.46	5.27	6.11	6.98	5.78

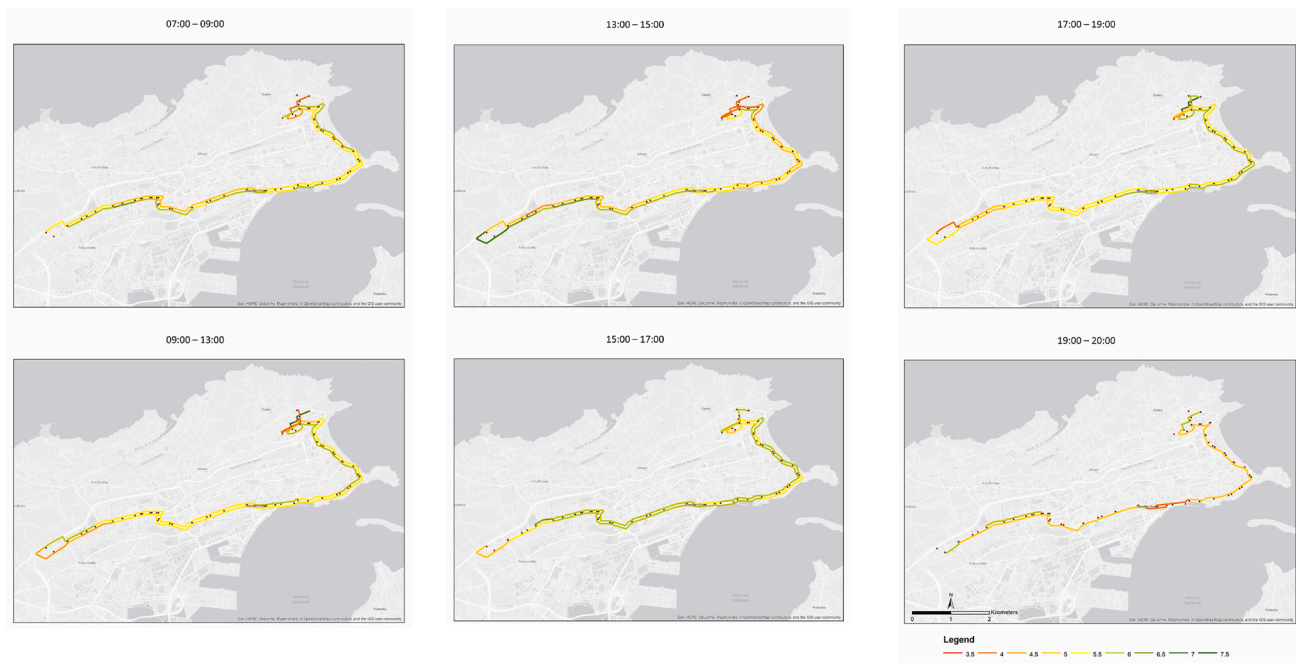


Fig. 7. Spatial and temporal variation of overall satisfaction on line 1.

user opinions at the ends of the line. From 19:00 onwards, satisfaction is low across the board.

Therefore, observing the daily variations in user satisfaction, it can be said that they tend to be lower at the ends of the lines and show differences according to the directionality of journeys and time slots, which can be related to the trip purposes, e.g., compulsory purposes (work, studies) during peak hours.

5. Discussion and conclusions

This article presented a methodology that complements the current state of the art. The variation in satisfaction between different lines of the same service has been analysed in various studies. However, the spatial and temporal variation in satisfaction between lines at an intraurban scale has not previously been taken into account, and this study has shown that such variation exists and may be significant.

Spatial analysis of the lines has shown that there is a clear distinction between various points in the network in terms of perceived quality and satisfaction. In general, peripheral areas with a lower density of public transport lines tend to rate the service worse than areas that are not end of line and where more lines are available. This variation can be higher or lower depending on each area and line, making it necessary to study each case specifically. This result agrees with previous studies that also found similar differences in the satisfaction among central and peripheral areas, the latter usually having a lower provision of services (Eboli et al., 2018; Ji and Gao, 2010).

On the other hand, the temporal analysis of satisfaction has shown that the perception of users changes throughout the day. Considering the average user, it can be said that the lowest levels of satisfaction are found during the peak hours of the day. In the specific case of this article, the worst level of satisfaction has been observed in the midday peak hour, whereas in previous studies, such as Allen et al. (2020), the period with the worst evaluation was the p.m. peak period between 18 and 20 h due to crowding in metro stations. Analysing the time variation by line, it has been observed that the variation is less important on lines with higher frequency and demand (better performance), compared to less frequently used and lower frequency lines (worse performance). Another important aspect is that the type of user affects the hourly location of the point of least satisfaction, such is the case of line 13. On

this line, the number of elderly users is high, so that the hours of greatest use are displaced from the rest of the lines, this being a factor that affects the variation in satisfaction, since on this line the worst level was observed in the morning off-peak hour.

The estimated BW models have made it possible to study the variation in the importance of the different attributes throughout the day. As in previous studies (Börjesson and Rubensson, 2019; de Oña, 2021; Eboli and Mazzulla, 2008), it has been found that the most important attributes are those related to the coverage, reliability and service offered (basic attributes) whereas other services such as web or on-board information are the least important (non-basic attributes). In this respect, although there is a variation in the levels of importance between the different attributes, the variability throughout the day is not significant in most cases. Some exceptions are ease of transfer, which becomes more important to users in the evening rush hour, information at stops, which is more important in the daytime rush hour, and driver friendliness, which is also more important in the rush hour.

Finally, the complete analysis of spatial and temporal variation has shown that customer satisfaction changes with time of day and location, with directionality of flow being an aspect to consider. Therefore, these results support the idea that it is important to provide a service as good as possible especially in the direction of the main movements at peak hours, in order to improve the satisfaction of the users.

In summary, the study presented in this paper has shown that customer satisfaction changes depending on the area of the city and the time of day where it is analysed. This result can be used by operators to improve services in a more targeted way, acting in those places and at those times where satisfaction is lower.

Author contributions

Eneko Echaniz: Conceptualization, Methodology, Formal Analysis, Investigation, Writing-Original draft. **Rubén Cordera:** Data Curation, Investigation, Writing - Review & Editing, Visualization. **Andrés Rodríguez:** Investigation, Data Curation, Software, Visualization. **Sol edad Nogués:** Supervision, Writing - Review & Editing, Funding acquisition, Project administration. **Pierluigi Coppola:** Validation, Writing - Review & Editing. **Luigi dell'Olio:** Conceptualization, Resources, Writing - Review & Editing, Validation, Funding acquisition.

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References

- Allen, J., Muñoz, J.C., de Dios Ortúzar, J., 2020. On the effect of operational service attributes on transit satisfaction. *Transportation* 47, 2307–2336. <https://doi.org/10.1007/s11116-019-10016-8>.
- Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echaniz, E., Gonzalez, F., Ladisa, C., Lezama-Romanelli, R., Lopez-Parra, A., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodriguez, A., Sanudo, R., 2020. Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the city of santander (Spain). *Sustain. -Basel* 12 (9). <https://doi.org/10.3390/su12093870>.
- Beaudoin, J., Farzin, Y.H., Lin Lawell, C.Y.C., 2015. Public transit investment and sustainable transportation: a review of studies of transit's impact on traffic congestion and air quality. *Res. Transport. Econ.* 52, 15–22. <https://doi.org/10.1016/j.retrec.2015.10.004>.
- Borck, R., 2019. Public transport and urban pollution. *Reg. Sci. Urban Econ.* 77, 356–366. <https://doi.org/10.1016/j.regsciurbeco.2019.06.005>.
- Börjesson, M., Rubensson, I., 2019. Satisfaction with crowding and other attributes in public transport. *Transport Pol.* 79, 213–222. <https://doi.org/10.1016/j.tranpol.2019.05.010>.
- Cats, O., Abenoza, R.F., Liu, C., Susilo, Y.O., 2015. Evolution of satisfaction with public transport and its determinants in Sweden: identifying priority areas. *Transport. Res. Rec.* 2538 (1), 86–95. <https://doi.org/10.3141/2538-10>.
- Cordera, R., Nogués, S., González-González, E., dell'Olio, L., 2019. Intra-urban spatial disparities in user satisfaction with public transport services. *Sustain. -Basel* 11 (20), 5829. <https://doi.org/10.3390/su11205829>.
- Cuthill, N., Cao, M., Liu, Y., Gao, X., Zhang, Y., 2019. The association between urban public transport infrastructure and social equity and spatial accessibility within the urban environment: an investigation of tramlink in London. *Sustain. -Basel* 11 (5), 1229. <https://doi.org/10.3390/su11051229>.
- de Oña, J., 2020. The role of involvement with public transport in the relationship between service quality, satisfaction and behavioral intentions. *Transport. Res. A-Pol.* 142, 296–318. <https://doi.org/10.1016/j.tra.2020.11.006>.
- de Oña, J., 2021. Understanding the mediator role of satisfaction in public transport: a cross-country analysis. *Transport Pol.* 100, 129–149. <https://doi.org/10.1016/j.tranpol.2020.09.011>.
- de Oña, J., de Oña, R., 2015. Quality of service in public transport based on customer satisfaction surveys: a review and assessment of methodological approaches. *Transport. Sci.* 49 (3), 605–622. <https://doi.org/10.1287/trsc.2014.0544>.
- de Oña, J., de Oña, R., Eboli, L., Mazzulla, G., 2016. Index numbers for monitoring transit service quality. *Transport. Res. A-Pol.* 84, 18–30. <https://doi.org/10.1016/j.tra.2015.05.018>.
- de Oña, R., de Abreu e Silva, J., Muñoz-Monge, C., de Oña, J., 2018. Users' satisfaction evolution of a metropolitan transit system in a context of economic downturn. *Int. J. Sustain. Transp.* 12 (1), 66–74. <https://doi.org/10.1080/15568318.2017.1328546>.
- Eboli, L., Forciniti, C., Mazzulla, G., 2018. Spatial variation of the perceived transit service quality at rail stations. *Transport. Res. A-Pol.* 114, 67–83. <https://doi.org/10.1016/j.tra.2018.01.032>.
- Eboli, L., Mazzulla, G., 2008. A stated preference experiment for measuring service quality in public transport. *Transport. Plann. Technol.* 31 (5), 509–523. <https://doi.org/10.1080/03081060802364471>.
- Efthymiou, D., Antoniou, C., 2017. Understanding the effects of economic crisis on public transport users' satisfaction and demand. *Transport Pol.* 53, 89–97. <https://doi.org/10.1016/j.tranpol.2016.09.007>.
- Foth, N., Manaugh, K., El-Geneidy, A.M., 2013. Towards equitable transit: examining transit accessibility and social need in Toronto, Canada, 1996–2006. *J. Transport Geogr.* 29, 1–10. <https://doi.org/10.1016/j.jtrangeo.2012.12.008>.
- Gendron-Carrier, N., Gonzalez-Navarro, M., Polloni, S., Turner, M.A., 2018. *Subways and Urban Air Pollution*. National Bureau of Economic Research, Cambridge, MA.
- Ji, J., Gao, X., 2010. Analysis of people's satisfaction with public transportation in Beijing. *Habitat Int.* 34 (4), 464–470. <https://doi.org/10.1016/j.habitatint.2009.12.003>.
- Kawabata, Y., Ryo, T., Friman, M., Olsson, L.E., Lättman, K., Fujii, S., 2020. Time-series analysis of the causal effects among perceived quality, satisfaction, loyalty, and frequency of public transportation use. *Front. Built Environ.* 6 (137) <https://doi.org/10.3389/fbuil.2020.00137>.
- Lai, W.-T., Chen, C.-F., 2011. Behavioral intentions of public transit passengers—the roles of service quality, perceived value, satisfaction and involvement. *Transport Pol.* 18 (2), 318–325. <https://doi.org/10.1016/j.tranpol.2010.09.003>.
- Louviere, J.J., Flynn, T.N., Marley, A.A., 2015. *Best-worst Scaling: Theory, Methods and Applications*. Cambridge University Press, Cambridge.
- Manaugh, K., El-Geneidy, A., 2012. Chapter 12. Who benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in public transport provision. In: Geurs, K.T., Krizek, K.J., Reggiani, A. (Eds.), *Accessibility Analysis and Transport Planning*. Edward Elgar Publishing.
- Marley, A.A.J., Louviere, J.J., 2005. Some probabilistic models of best, worst, and best–worst choices. *J. Math. Psychol.* 49 (6), 464–480. <https://doi.org/10.1016/j.jmp.2005.05.003>.
- Nguyen-Phuoc, D.Q., Young, W., Currie, G., De Gruyter, C., 2020. Traffic congestion relief associated with public transport: state-of-the-art. *Publ. Transport* 12 (2), 455–481. <https://doi.org/10.1007/s12469-020-00231-3>.
- UNE-EN 13186, 2003. *UNE-EN 13186. Transportation. Logistics and services. Public passenger transport*. In: AENOR (Ed.), *Service Quality Definition, Targeting and Measurement*.