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Exploring factors influencing bus travel time in mixed traffic

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Abstract

In this study, we analyse the factors that influence bus travel time in mixed traffic to enhance transit planning and operations. We consider factors related to general traffic (travel times, traffic flow rate and occupancy), internal operations (stream and previous patronage, i.e. the number of boardings in the considered stretch and before entering it), and weather conditions. A large amount of data was obtained from different sources: Bluetooth sensors, inductive loop detectors and transit management system. After the data cleaning and processing, a model was developed for a case study in A Coruña. The results show that the stream patronage is the variable with most impact on bus travel time. However, the influence of all general traffic variables on bus travel time is almost the same as stream patronage. Therefore, these results confirm that the implementation of an exclusive bus lane is essential to decrease bus travel time and enhance transit. This model could be used to quantify the time savings that the bus exclusive bus lane would entail.

1. Introduction

Improving public transport is a fundamental tool to encourage users who normally travel by private vehicle to use transit, and thus, contribute to achieving a more sustainable mobility. To accomplish this aim, it is essential that public transport become more attractive to potential passengers. The public transport travel time is one of the most important factors that users take into account when deciding which means of transport to choose. For this reason, it is relevant to study and quantify the factors influencing bus travel time.

It is also relevant for operation and transit network planning to determine the factors that influence bus travel time in mixed traffic, and to have tools to forecast it. The availability of a large amount of information automatically obtained and stored by sensors and management systems, allows to develop new approaches and models.

The Transit Capacity and Quality of Service Manual (Transportation Research Board, 2013) and the Highway Capacity Manual (2010) studied several factors that may affect transit travel time. Factors influencing bus speeds were also analysed in Levinson (1983) in mixed traffic. The penalty of traffic congestion on bus speeds was also the aim of research in McKnight et al. (2004), who also considered the general traffic travel time and boardings among other variables.

The type of operating environment also affects transit travel time. Tu et al. (2013) obtained a reduction of the passenger travel time by 1.2 s on a 500 m long stretch if a bus priority bus lane was implemented.

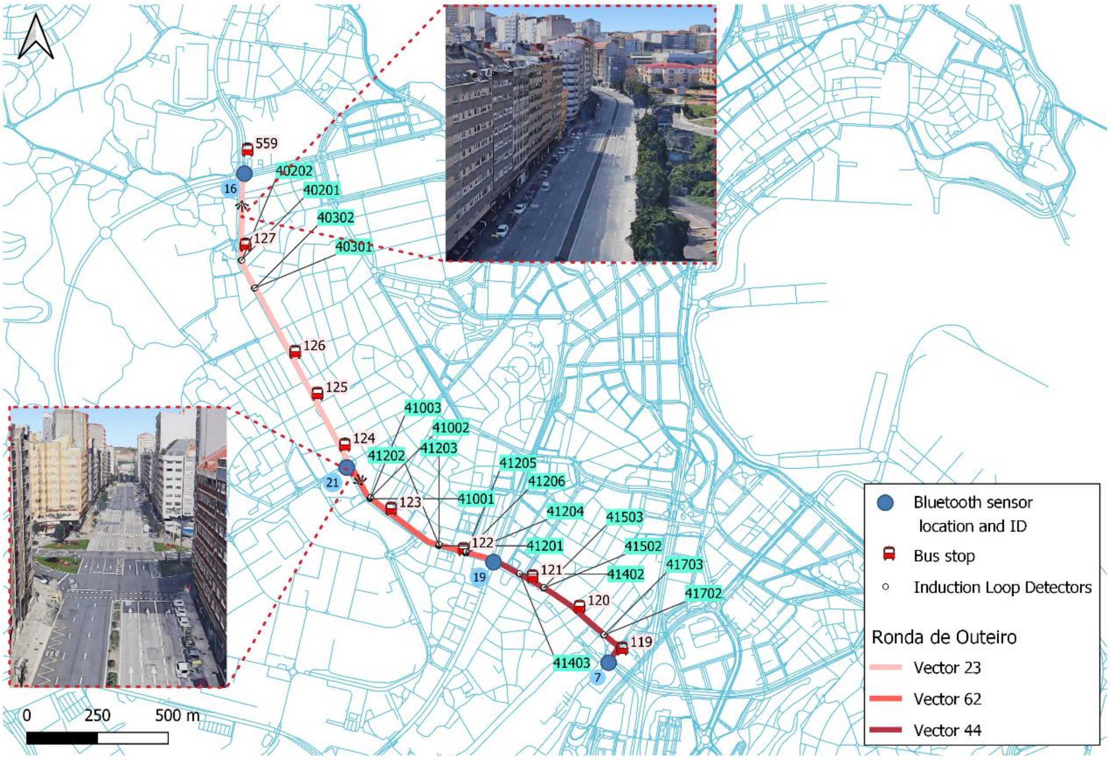
2. Case study

2.1. Context

The analysis of the factors that influence bus travel time is undertaken in the city of A Coruña, Spain. This city is the second one of the region regarding the number of inhabitants, 245,711 in 2019, but the first one in population density with a difference of more than double that of the second city.

In this study, we will analyse the data obtained in a corridor of the city named Ronda de Outeiro with 2,448 m length. Its location is shown in Figure 1. This corridor has been selected due to the simultaneous availability of general traffic records (inductive loop detectors and Bluetooth sensors) and urban bus data. The bus lane circulates along the corridor without deviations and makes use of all the stops represented in figure 1.

Figure 1: Location of bus stops, inductive loop detectors, Bluetooth sensors and vectors of the studied corridor



Ronda de Outeiro is one of the most significant arterials in the A Coruña urban area. 68.67% of the corridor length has two-mixed traffic lanes, and the rest is a three-lane section. There are 20 signalised intersections, 10 non-signalised intersections and five crosswalks with traffic lights located between intersections. A total of 38.63% of this corridor has adjacent parking lane. In the corridor there are four Bluetooth sensors managed by the city council, and 10 bus stops (seven lane stops and three bay stops) served by several lines operated by Compañía de Tranvías de La Coruña (CTC), that is the local provider of bus services. The stream located between two Bluetooth sensors is named a vector. In this paper, bus line 14 is studied for Ronda de Outeiro. The location of these sensors and bus stops is shown in Figure 1.

2.2. Definition of variables

In this study, the traffic data obtained in Ronda de Outeiro during the year 2019 is analysed. The 2020 data are available, but in A Coruña, as in most cities in the world, the measures imposed to contain the spread of COVID-19 have caused an unprecedented drop in the bus demand (Orro et al., 2020). Although this decrease has not been homogeneous throughout the city (Montero-Lamas et al., 2022), these data do not correspond to normal traffic situations, so they have been discarded for this analysis.

The bus travel time could be affected by many different factors. In this study we aim to quantify the influence of the weather, general traffic and bus operation internal factors (previous and stream patronage) on bus travel time in mixed traffic. All the variables analysed are displayed in Table 1.

Table 1: Definition of variables used in the model

Variable	Abbreviation	Definition
(a) Dependent variable used in multiple linear regression (MLR)		
BusTraffcTime (s)	BTT	Travel time of the bus in the stream.
(b) Independent variables used in MLR		
GeneralTraffcTime (s)	GTT	Travel time of the general traffic.
AccumulatedRainfall (l/m2)	AR	Accumulated rainfall.
PreviousPatronage	PP	Number of boardings from the first bus stop of the line to the beginning of the corridor
StreamPatronage	SP	Number of boardings from bus stop 119 to 127 (Figure 1).
TrafficFlowRate (veh/h)	TFR	Traffic flow rate.
IndLoopOccProp (%)	ILOP	Roadway occupancy: Percentage of time that the loop has a vehicle standing over it.

The company that provides bus services in A Coruña records each bus arrival time during all journey. From these data, it is possible to obtain the bus travel time by calculating the difference between the first and last stops' arrival times (119 and 559, respectively).

The number of users waiting at the bus stop to board and the number of passengers who have already boarded influence bus dwell time, and therefore the total bus travel time. On the one hand, the more people are waiting to board, the longer the bus will be at the stop. The stream patronage variable considers the number of boardings within the corridor, that is, between stops 119 and 127. On the other hand, even if there were no passengers waiting to board in the corridor, the bus may stop to alight the passengers who have boarded before stop 119. For this reason, we also consider the previous patronage as the boardings between the first stop of the line and the stop prior to 119 (14 stops).

The absence of an exclusive bus lane forces public transport and private vehicles to share the same mixed platform despite the consequences and penalties that this entails. To inquire how the presence of general traffic has affected the travel time of the bus, the general traffic travel times between each Bluetooth sensor are calculated (Figure 1), that is, the general traffic travel times per vector. However, this calculation has been refined to consider only the vehicles that circulate along this vector at the same period as each bus trip, that is, those that have really been able to influence its speed. To accomplish this processing, the bus route is divided into three sections that correspond to the three general traffic vectors, with stops 122 and 124 setting this division.

As the Bluetooth sensors record the average travel times of general traffic every 3 minutes, the entry and exit of each bus trip in each vector is considered to obtain the general traffic travel time of the 3-minutes periods involved. Finally, the average travel time per vector is calculated by taking the average of these periods. The total general traffic travel time for the corridor will be the sum of the average travel times of each vector.

In addition to travel time, traffic flow rate and occupancy are two other factors related to general traffic that influence bus speeds. The data for calculating these variables is obtained from inductive loop detectors (IDLs) located throughout the city (Figure 1), one per lane. These IDLs record information per minute and its processing follows the same criterion as general traffic travel time, using only the records of the vehicles that temporarily coincide with each bus travelling through that vector. Turn-exclusive lanes data are discarded as they do not affect bus trips considered.

To obtain the traffic flow rate, the data of each cross section where the ILDs are located are added, and then the average of all sections in the corridor is calculated. To obtain the roadway occupancy, the average of the values per cross section is calculated, and finally the average value of the ILDs sections along the corridor is obtained.

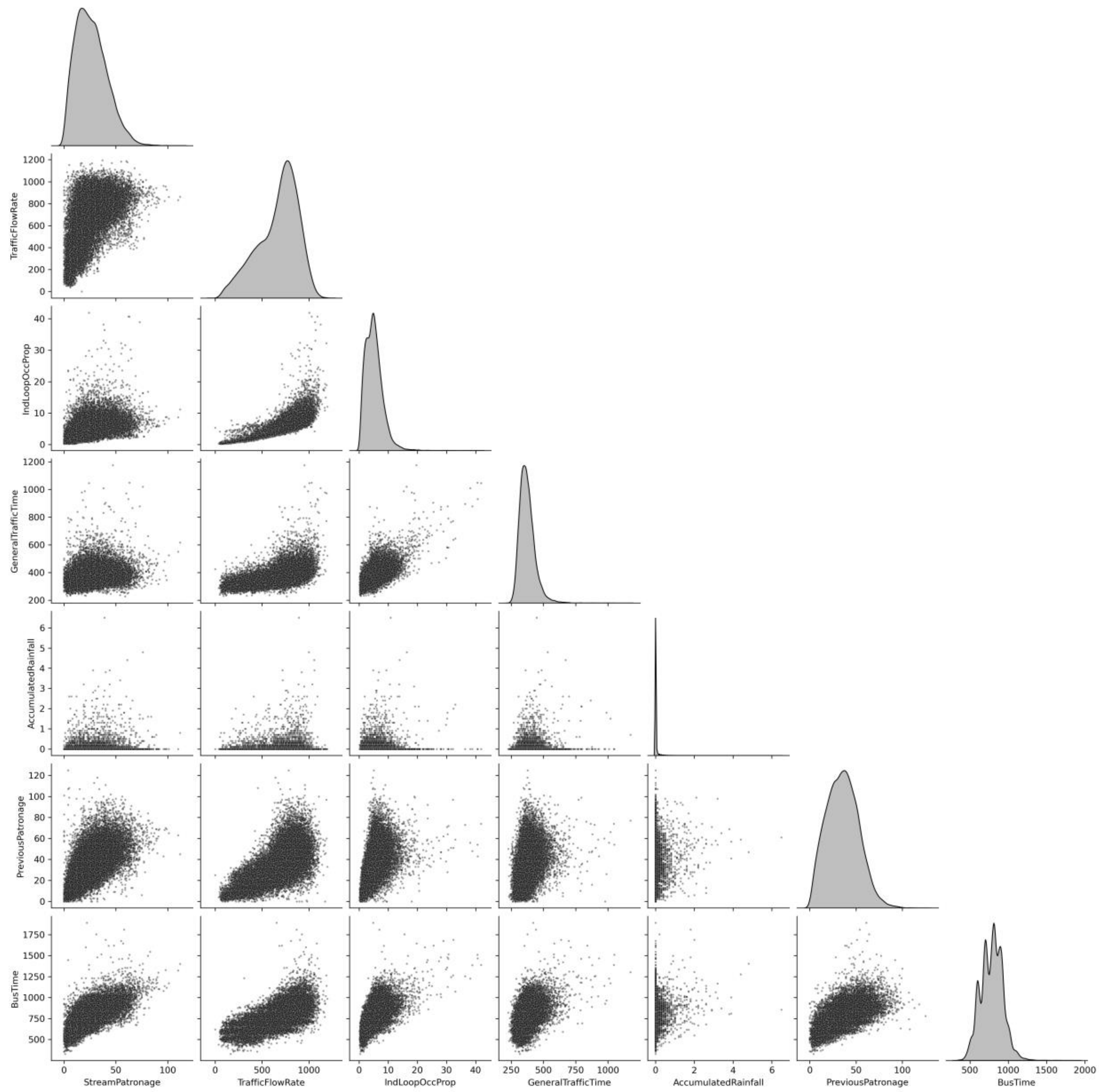
In addition to the variables related to general traffic and bus patronage, the rainy conditions may also influence bus travel time. The accumulated rainfall is recorded each ten minutes by the Torre de Hércules meteorological station, located 3 kilometres away from the corridor.

A data cleaning has been undertaken for each variable and more than 20 million data were processed. In Table 2, the descriptive statistics of the variables is shown, including the mean, minimum, maximum and quartile values for each of the variables listed in Table 1The scatter plot matrix, which shows the relationships between the analysed variables, is presented in Figure 2. This figure intends to reflect the tendency and saturation zones of these relationships, not the data individually (there are more than 21 thousand points).

Table 2: Descriptive analysis of the variables used in the model

	SP	TFR	ILOP	GTT	AR	PP	BTT
count	21,591	21,591	21,591	21,591	21,591	21,591	21,591
mean	26.404	668.512	5.158	373.521	0.028	35.608	784.919
std	14.883	215.058	3.060	62.251	0.179	17.061	143.279
min	0.000	0.000	0.207	227.557	0.000	0.000	329.000
25%	15.000	528.194	2.949	331.988	0.000	23.000	688.000
50%	25.000	713.000	4.833	364.773	0.000	35.000	793.000
75%	36.000	825.738	6.714	403.137	0.000	47.000	885.000
max	112.000	1,194.444	41.847	1,174.473	6.500	125.000	1,892.000

Figure 2: Scatter plot matrix of variables used in the model



3. Methodology and results

The purpose of the methodology is to quantify the impact of several factors related to general traffic, rainy conditions and bus patronage on bus travel time. For this aim, a Multiple Linear Regression model is developed to predict bus travel time from the variables already described. The results are listed in Table 3 and all the variables are significant at the 99% level of confidence. The R-squared value of the model is 64.4%. R-squared is a goodness-of-fit measure on a 0 – 100% scale that indicates the percentage of the variance in the dependent variable (bus traffic time) that the independent variables explain together.

Table 3 shows the unstandardized coefficient, the standard error and the standardised coefficient (SC) of each of the analysed variables, which is calculated by multiplying the unstandardized coefficient by the ratio of the standard deviations of the independent variable and dependent variable. Regarding the SC the stream patronage weighs more than twice as much as each other variable. In contrast, the accumulated rainfall is the variable with less influence on bus travel time.

Table 3: Multiple Regression Model results

	Coef	Std err	SC	N	R^2
				21,591	0.644
const	438.4776	4.253			
StreamPatronage	4.2373	0.052	0.440		
TrafficFlowRate	0.1159	0.005	0.174		
IndLoopOccProp	7.9641	0.352	0.170		
GeneralTrafficTime	0.2312	0.013	0.100		
AccumulatedRainfall	14.1117	3.301	0.018		
PreviousPatronage	0.8217	0.051	0.098		

4. Conclusions

In this paper we explore the factors influencing bus travel time. A methodology is proposed to determine the influence of general traffic, bus patronage and rainy conditions on bus travel time. This methodology was applied in a case study in the city of A Coruña where a main corridor was analysed and interesting conclusions have been drawn from the results. Regarding the standardised coefficients (Table 3), the stream patronage is the variable that individually influences the most the bus travel time. However, the joint impact of all general traffic variables (occupancy, traffic flow rate and general traffic travel time) are pretty close to the influence of the stream patronage (0.444 and 0.440 respectively).

Stream patronage time is unavoidable and the more boardings the better, although any measure to reduce it will have positive consequences on the final bus travel time. However, the variables related to general traffic can be improved by implementing an exclusive bus lane, so this measure is highly recommended. This conclusion reveals the importance of having an exclusive bus lane to improve bus travel time. The time savings of this implementation will be estimated in future works following this line of research.

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