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The impact of mobility characteristics on public transport and road safety performance in selected European cities

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Abstract

The aim of this paper is to investigate the impact of mobility characteristics on Public Transport (PT) and road safety performance. For this purpose, data for several large European cities on population, road network, traffic, mobility and road fatalities were collected from the European Metropolitan Transport Authorities' reports and the European CARE database. Initially, a database was developed containing data for the period 2014–2018 and then, two linear regression models were developed. The results of the first model indicate that more bus and tram stops, increase in GDP, higher population density and PT public operation have a positive impact on PT demand, while the opposite is the case for increases in car ownership and PT fares. Based on the second model, it is revealed that increases in population density, bus and tram stops, modal share of active travelling modes, GDP and tram speed lead to road fatalities' decrease.

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1. Introduction

Mobility and transport have always been important and critical areas for the well-being of people. Concerning transport systems' efficiency, Public Transport (PT) and Road Safety performance should be examined and measured on a frequent basis. Therefore, it is important to identify the factors that affect PT demand. In order to highlight these factors, it is necessary to use certain performance indicators, which quantify the characteristics of Transportation Systems and describe different areas of their services (Eboli & Mazzulla, 2012).

Relevant studies have highlighted many different factors that affect PT demand, approaching the issue from different perspectives and making it difficult to rank them according to their importance. It is stated that one factor

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that is particularly important in one case may be less critical in another area due to different conditions (Polat, 2012). One of the influencing factors is the population density, the increase of which has a positive effect on the demand of PT, while the opposite is the case for passenger cars (Souche, 2010). Another important factor seems to be the income, which negatively affects the use of buses and positively that of cars (Bresson et al., 2004). In general, economic growth leads to an increase in car ownership (Willumsen, 2002). According to relevant studies, supply also affects demand. Specifically, PT supply and demand are positively correlated (Bonnel & Chausse, 2000). One of the main factors influencing the PT demand is their prices. As expected, higher PT ticket prices lead to lower PT demand (FitzRoy & Smith, 1998; Bonnel & Chausse, 2000; Bresson et al., 2004). Another critical factor is the duration of the journey, which includes all the stages that the passengers go through during their journey. Unsurprisingly, an increase in travel time leads to a decrease in demand (Walle & Steenberghen, 2006). A more general concept often identified in the relevant literature and which may include many different sub-characteristics is the quality of the services provided by the PT. Many of these characteristics are quite difficult to study, as their changes usually lead to changes in other factors, such as prices and travel time (Paulley et al., 2006).

Regarding road safety, most of the studies across the literature examine factors related to driving behaviour (Pires et al., 2020; Ziakopoulos et al., 2021; Bener & Crundall, 2008), weather conditions (Theofilatos & Yannis, 2014) and driving environment (Chen et al., 2018). There are also several studies that examine the influence of various socioeconomic factors on road safety outcomes. On the contrary, there are fewer studies dealing with the impact of mobility characteristics on road safety performance. Public Transport is probable the safest way to travel, when examining the road fatality rates by transport mode and distance traveled by passengers (Beck et al. 2007; Savage 2013). However, Tasic and Porter (2016) concluded that more bus stops lead to more road crashes of all types, possibly due to abrupt changes in the vehicles' speeds and maneuvers. On the contrary, Moeinaddini (2015) concluded that the rate of use of PT is negatively correlated with road crash fatalities.

The objective of this paper is to investigate the impact of various mobility characteristics on performance of Public Transport in terms of PT trips, as well as on performance of road safety in terms of road fatalities.

2. Methodology

In order to achieve the objectives of the present paper, data from the annual reports of the organization of European Metropolitan Transport Authorities (EMTA) were used, which include data on population, road network, traffic and mobility of several large European cities. The 18 European cities that were included in the analyses of the present paper are the following: Amsterdam, London, Oslo, Warsaw, Lyon, Paris, Berlin, Madrid, Rotterdam/Hague, Vienna, Manchester, Stockholm, Budapest, Birmingham, Stuttgart, Helsinki, Bilbao and Frankfurt. Furthermore, data on road fatalities from the European Community database on road crashes (CARE) were also collected. A database was developed containing data from these two data sources for the five-year period 2014-2018 and two different statistical models were developed, using the multiple linear regression for defining the factors that influence the demand of PT (number of trips per 100,000 population) and road fatalities per 100,000 population accordingly.

The basic equation of the multiple linear regression model is the Eq. (1) as presented below:

$$Y_i = \beta_0 + \beta_1 * X_{1i} + \beta_2 * X_{2i} + \dots + \beta_v * X_{vi} + \varepsilon_i \quad (1)$$

The accuracy of the models is assessed through the coefficient of determination R squared (R^2). R^2 shows the percentage of the variability of the dependent variable Y explained by the independent variables X included in the model. R^2 takes values between 0 and 1, with 1 meaning that the independent variables X explain fully the dependent variable Y. Moreover, in order to complement the developed models, elasticity and sensitivity analyses were conducted as well.

Moreover, the elasticity values are calculated for each independent variable of the model. The elasticity value of each independent variable (e_i) is calculated by Eq. (2). The relative elasticity is a normalization of the estimated elasticity values in relation to the lowest elasticity.

$$e_i = (\Delta Y_i / \Delta X_i) * (X_i / Y_i) = \beta_i * (X_i / Y_i) \quad (2)$$

3. Results and Discussion

Before the presentation of the linear regression models' results, it would be fruitful to report some basic descriptive statistics on the two dependent variables. Figure 1 depicts the number of PT trips per population in the 18 examined cities. It can be observed that the highest use of PT per population corresponds to Budapest, while the lowest is recorded in Manchester.

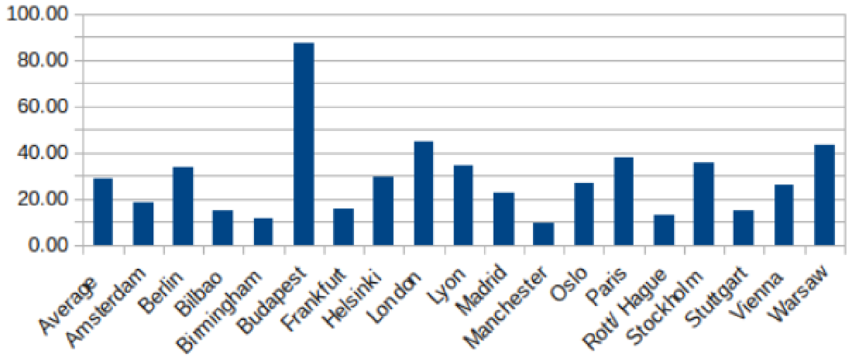

Fig. 1. Average PT trips (in millions) per 100,000 population for the period 2014-2018

Regarding the road safety performance of 12 cities that were also included in the linear regression model for road fatalities per population, based on Figure 2, it is demonstrated that the highest fatalities rates are recorded in Vienna, while the lowest in Birmingham.

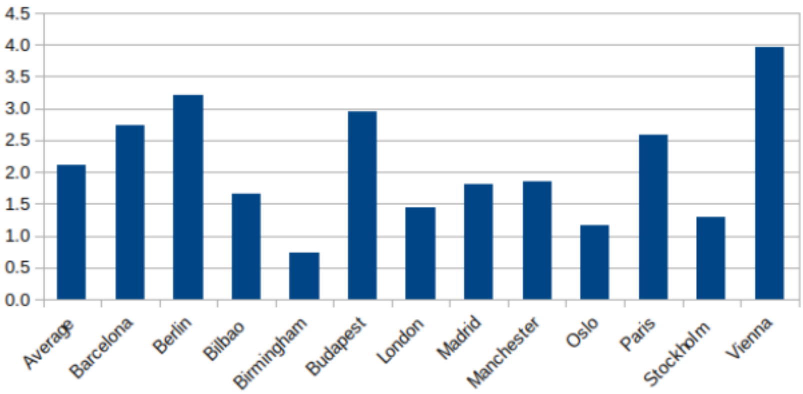

Fig. 2. Average road fatalities per 100,000 population for the period 2014-2018

The final statistical model results appear on Table 1 (for PT trips per population) and Table 2 (for road fatalities per population).

Table 1. Statistical model results for PT trips per 100,000 population (18 cities)

Variables	Estimate	Pr(>|t|)	Absolute Elasticity	Relative Elasticity
(Intercept)	36.37	0.00462	-	-
Bus & Tram Stops/ 100,000 inh.	0.025	0.05221	0.26	1.44
GDP per capita (€)	0.00048	0.03845	0.81	4.46
Metropolitan Area Population density	0.00454	0.00301	0.18	1.00
Car Ownership in PTA area/ 100,000 inh.	-0.00048	0.01374	-0.92	-5.08
Public PT operator (ref. private)	13.12	0.00887	0.26	-
Single trip ticket PTA area (€)	-10.30	0.00132	-0.99	-5.46
Adjusted R^2			**0.279**	

Table 2. Statistical model results for road fatalities per 100,000 population (12 cities)

Variables	Estimate	Pr(>|t|)	Absolute Elasticity	Relative Elasticity
(Intercept)	6.784	<0.001	-	-
Modal Split in PTA area - Soft modes	-3.119	0.03176	-0.52	2.77
GDP per capita (€)	-0.00002	0.00160	-0.46	2.45
Metropolitan Area Population density	-0.00016	0.00672	-0.19	1.00
Bus & Tram Stops/ 100,000 inh.	-0.00148	0.08496	-0.28	1.47
Tram Speed	-0.10370	<0.001	-1.56	8.23
Adjusted R^2			**0.632**	

Based on the results of the two developed statistical models, population density, GDP, bus/tram stops are three factors, which affect both the PT demand and road safety in cities. This could also reflect indirectly the influence of Public Transport on road safety. As mentioned in the introduction section of the paper, one of the most critical factors influencing the demand of PT is ticket prices. Based on the model presented in Table 1, an increase in the price of a single trip ticket is associated negatively with PT demand. PT passengers choose this transport mode instead of passenger cars, mainly due to reduced costs. Therefore, as the ticket prices increase, this advantage of PT decreases and passengers may turn to other solutions such as their passenger cars, which outperform PT in terms of travel time, comfort and reliability. More infrastructure facilities of buses and trams have a positive effect on PT demand. When a higher percentage of the population has easy and quick access to a PT stop, then the probability of preferring it, in comparison with their passenger car increases, since the travel time may not differ significantly. Moreover, public operation of PT has a positive impact on PT demand. Non-transportation factors that affect the demand of the PT are GDP, population density and car ownership per inhabitant. The GDP and population density are positively correlated with PT demand, while the opposite is the case for car ownership.

Concerning road safety outcomes, soft transport modes such as walking and cycling are an important factor that could lead to road fatalities decrease. In most European cities, there is a very well organized infrastructure network, such as wide sidewalks and bicycle lanes, which provide the required safety to the road users. So, as long as the road infrastructure allows it, these transport modes can be considered quite safer than motorized vehicles due to significantly lower speeds. PT infrastructure (i.e. number of bus and tram stops per population) is of particular importance for road safety. These transport modes operate at much lower speeds than passenger cars and provide a satisfactory level of safety to their passengers. At the same time, many and well-organized PT facilities in combination with the improved functional PT characteristics, make them more attractive which could be beneficial for the reduction of road fatalities.

Critical for road safety performance also seems to be some other non-traffic factors such as population density and GDP. An increase in population density means an increase in vehicles and traffic congestion, leading to significantly lower speeds. Therefore, even in the event of a road crash, this may not be so severe. At the same time, a general economic development leads to road fatalities decrease (Nikolaou et al., 2021).

4. Conclusions

This paper enriches the literature on identifying the impact of mobility characteristics on Public Transport and road safety performance. From the various stages of the present study, many interesting results were revealed which were also directly linked to its objectives. Based on the results of the two developed statistical models, it was observed that population density, GDP per capita and the number of bus and tram stops per population are three factors that affect both the demand of PT and the level of road safety in the selected European cities. The application of the first statistical model with the PT trips per population as the dependent variable indicated that more bus and tram stops, increase of GDP, higher population density and public operation of PT have a positive impact on PT demand in contrast to the car ownership and the increase of PT fares with a negative impact on PT demand. Finally, based on the statistical model for road safety performance, it was demonstrated that population density, bus and tram stops, modal share of active travelling modes (walking, cycling), GDP and tram speed have a negative relationship with the dependent variable, showing that as these independent variables increase, road fatalities per population decrease.

Based on the conclusions drawn from the statistical analyses, some recommendations that could increase the PT use and enhance the road safety level of the cities are provided. As it was revealed, price of PT tickets is very important for PT demand. Therefore, it is recommended to keep these prices as low as possible. At the same time, the construction of additional bus and tram facilities is recommended, so that they are easily accessible by everyone. Emphasis should also be given to the infrastructure of soft transport modes. Walking and cycling should be promoted as they could assist to road fatalities reduction. For this reason, it is crucial to develop the appropriate safe infrastructure for these transport modes, which could lead residents to prefer them instead of passenger cars.

References

Beck, L. F., Dellinger, A. M., & O'neil, M. E. (2007). Motor vehicle crash injury rates by mode of travel, United States: using exposure-based methods to quantify differences. American Journal of Epidemiology, 166(2), 212-218.

Bener, A., & Crundall, D. (2008). Role of gender and driver behaviour in road traffic crashes. International Journal of Crashworthiness, 13(3), 331-336.

Bresson, G., Dargay, J., Madre, J. L., & Pirotte, A. (2004). Economic and structural determinants of the demand for public transport: an analysis on a panel of French urban areas using shrinkage estimators. Transportation Research Part A: Policy and Practice, 38(4), 269-285.

Bonnel, P., & Chausse, A. (2000). Urban travel: Competition and pricing. Transport reviews, 20(4), 385-401.

Chen, F., Chen, S., & Ma, X. (2018). Analysis of hourly crash likelihood using unbalanced panel data mixed logit model and real-time driving environmental big data. Journal of safety research, 65, 153-159.

Eboli, L., & Mazzulla, G. (2012). Performance indicators for an objective measure of public transport service quality.

FitzRoy, F., & Smith, I. (1998). Public transport demand in Freiburg: why did patronage double in a decade?. Transport policy, 5(3), 163-173.

Moeinaddini, M., Asadi-Shekari, Z., Sultan, Z., & Shah, M. Z. (2015). Analyzing the relationships between the number of deaths in road accidents and the work travel mode choice at the city level. Safety science, 72, 249-254.

Nikolaou, D., Folla, K., & Yannis, G. (2021). Impact of socioeconomic and transport indicators on road safety during the crisis period in Europe. International journal of injury control and safety promotion, 28(4), 479-485.

Paulley, N., Balcombe, R., Mackett, R., Titheridge, H., Preston, J., Wardman, M., ... & White, P. (2006). The demand for public transport: The effects of fares, quality of service, income and car ownership. Transport policy, 13(4), 295-306.

Pires, C., Torfs, K., Areal, A., Goldenbeld, C., Vanlaar, W., Granié, M. A., ... & Meesmann, U. (2020). Car drivers' road safety performance: A benchmark across 32 countries. IATSS research, 44(3), 166-179.

Polat, C. (2012). The demand determinants for urban public transport services: a review of the literature.

Savage, I. (2013). Comparing the fatality risks in United States transportation across modes and over time. Research in transportation economics, 43(1), 9-22.

Souche, S. (2010). Measuring the structural determinants of urban travel demand. Transport policy, 17(3), 127-134.

Tasic, I., & Porter, R. J. (2016). Modeling spatial relationships between multimodal transportation infrastructure and traffic safety outcomes in urban environments. Safety science, 82, 325-337.

Theofilatos, A., & Yannis, G. (2014). A review of the effect of traffic and weather characteristics on road safety. Accident Analysis & Prevention, 72, 244-256.

Walle, S. V., & Steenberghen, T. (2006). Space and time related determinants of public transport use in trip chains. Transportation Research Part A: Policy and Practice, 40(2), 151-162.

Willumsen, L. G. (2002). Modelling transport. Wiley.

Ziakopoulos, A., Nikolaou, D., & Yannis, G. (2021). Correlations of multiple rider behaviors with self-reported attitudes, perspectives on traffic rule strictness and social desirability. Transportation research part F: traffic psychology and behaviour, 80, 313-327.