Multilevel Comparative Analysis of Road Safety in European Capital Cities

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Abstract

The objective of this research is the comparative road safety analysis in selected European capital cities, aiming to a better understanding of road accident characteristics and causes in European megacities. Despite the continuous urbanization and the shift of population to large urban areas, this research question has received little attention in the existing literature. A database was developed for this analysis containing data regarding the number and the characteristics of road fatalities, the population and other demographic, socioeconomic and transport indicators of nine selected European capital cities for the period 2007 - 2011. Multilevel Poisson statistical models were developed, allowing for a more accurate representation of the hierarchical structure of road safety data, and they led to the identification of several factors affecting the road safety level in the selected European capital cities, revealing some additional aspects of road safety performance in these cities. Factors found with a statistically significant effect concerned city characteristics (road network length, population density, public transport use) and accident characteristics (road user and vehicle type). The comparison between the European capital cities showed that the larger the city's road network is, the higher the level of road safety is in this city.

Background & Objective

- The ever-increasing urbanization of nations around the world results in implications for road safety, due to the more complex traffic problems prevailing in cities.
- In 2010, 38% of all traffic accident fatalities in the EU-19 occurred in urban roads.
- Little research investigating thoroughly road safety characteristics has been conducted in cities level and most related studies focus on vulnerable road users.

Objective

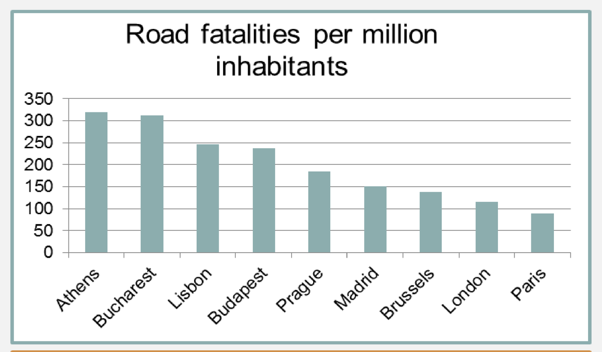
the comparative analysis of road safety in selected European capital cities, aiming to a better understanding of road accident characteristics and causes in European megacities

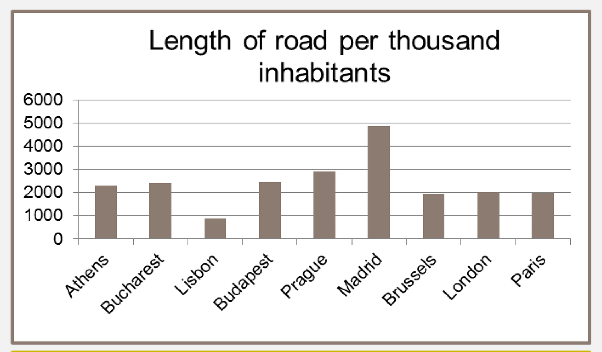
- The selected European capital cities are three representative cities from each basic European geographic region (southern, northern and eastern Europe).
- Due to the hierarchical nature of geographically structured road safety data, multilevel models were developed in order to handle appropriately the resulting dependences among the observations and provide a more comprehensive analysis of road safety in the examined European capital cities.

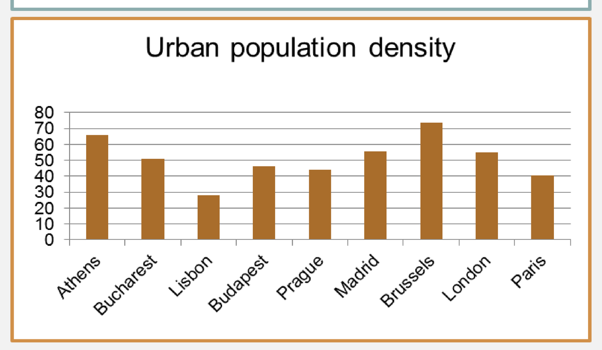
Methods and Data

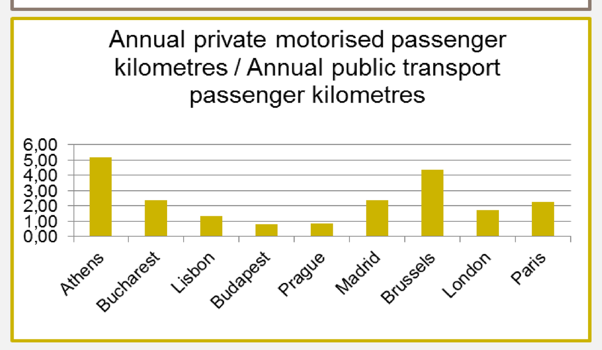
Data Collection

- The data collected for the objectives of this research concern the number and the characteristics of road fatalities, the population and other indicators of the selected European capital cities for a five-year period from 2007 to 2011.
- The road accidents data derived mainly from CARE, the European Database on Road Accidents.
- The variables referring to other characteristics or indicators of the capital cities were derived from the database "Mobility in Cities", by the International Association of Public Transport (UITP).
- The dependent variable of the analysis is the number of persons killed (at 30 days from the accident) for each capital city.
- The independent variables that are examined concern the accident (accident date, weather and lighting conditions), the traffic unit (traffic unit type) and the person involved in the road accident (age, gender, road user type).
- The variables examined concerning the capital cities are the population, the urban population density, the length of road per thousand inhabitants and the rate of annual private motorised passenger kilometres per annual public transport passenger kilometre.







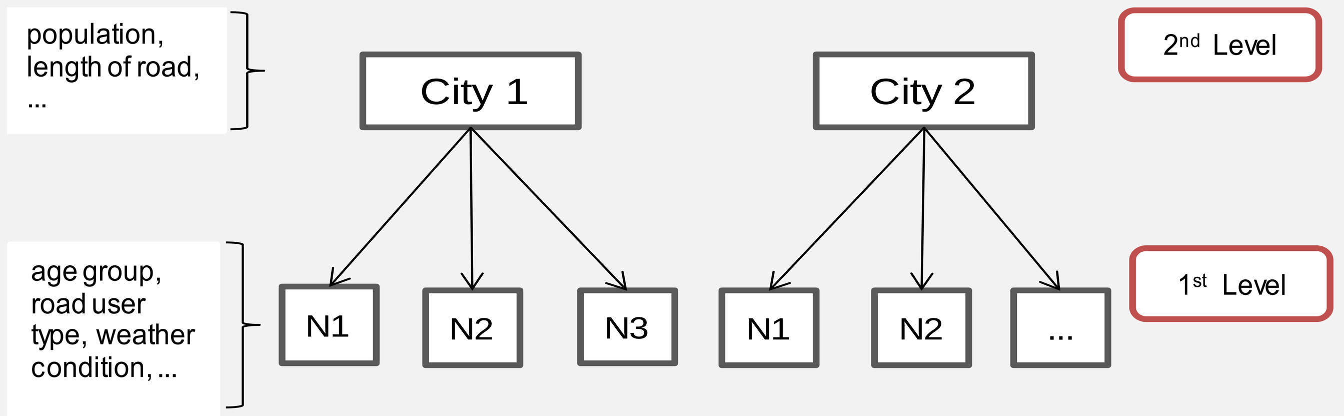


- It can be seen that the cities rankings change significantly for each characteristic or indicator.
- It appears therefore that the road safety level of European cities can not be explained by a single characteristic of the cities; cities have variable characteristics and hence, it is important to take this variation into consideration in the analysis.

Methods and Data (cont.)

Analysis Method

- Most of the data of interest for road safety research happen to be **hierarchically organized**, i.e., to belong to structures with several hierarchically ordered levels.
- One of the main problems associated with such hierarchical data organisation is the **dependence** that generates among the observations.
- Statistical models have been developed that allow accounting for hierarchical data structures, and taking into account the dependency they introduce among the data. These models are labelled **multilevel models**.
- The present research is based on a geographical data hierarchy. More precisely, the **first level** of the hierarchy is the **accident level**, which contains data about each road accident case with all its defining characteristics.
- All these data are nested into the capital cities that the accidents occurred, and which constitute the **second level** of the hierarchy, that is to say the **city level**.



- A Poisson distributed response vector (O_{ij}) of observed cases is assumed, in which (i) refers to the accident level and (j) refers to the city level, and therefore it is necessary to include an offset of expected numbers of cases E_{ij} in the model.

$$O_{ij} \sim Poisson(\pi_{ij} E_{ij})$$
$$\log(\pi_{ij}) = \beta_{0j} + \beta_{1j} x_j$$
$$\beta_{0j} = \beta_0 + u_{0j}$$
$$\beta_{1j} = \beta_1 + u_{1j}$$

- In order to handle the overdispersion, one option is to consider an additional parameter (α), resulting to an Extra-Poisson or quasi-Poisson distribution.

$$var(O_{ij}\pi_{ij}) = \alpha\sigma_1^2 \pi_{ij} E_{ij}$$

- The review of multilevel analyses in road safety research shows that statistical and conceptual consequences may occur when ignoring a hierarchical structure in the data. In the majority of cases, multilevel model formulations:
  i. allow improving the fit of the model to the data
  ii. allow identifying and explaining random variation at specific levels of the hierarchy considered
  iii. can yield different (more correct) conclusions than single-level model formulations with respect to the significance of the parameter estimates.

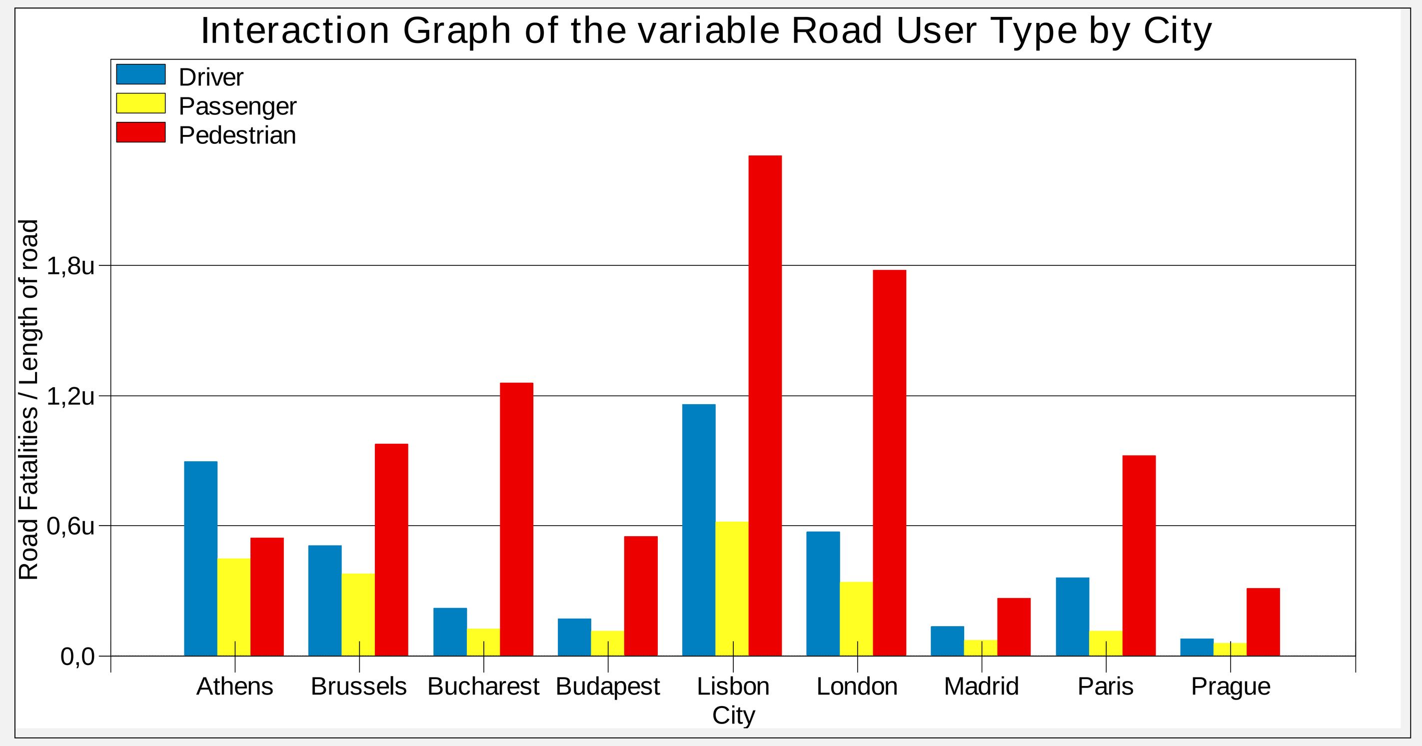
Model development

Poisson multilevel model - Road accidents and capital cities data			
Dependent variable	Fatally Injured (at 30 days)		
Offset	Natural logarithm of Length of Road per 1.000 inhabitants		
Independent variables	**Coefficient β_i**	**S.E.**	**t-test = β_i/ S.E.**
Fixed Part			
cons	-6,322	0,591	-10,697
Month_1	0,937	0,073	12,836
Day of Week_1	0,540	0,058	9,310
Person Age Group_1	-0,854	0,132	-6,470
Person Age Group_3	0,224	0,068	3,294
Person Age Group_4	0,228	0,075	3,040
Person Gender_2	-0,416	0,062	-6,710
Road User Type_1	-0,399	0,081	-4,926
Road User Type_2	-1,009	0,113	-8,929
Traffic Unit Type_1	-0,254	0,074	-3,432
Traffic Unit Type_3	-1,151	0,148	-7,777
Traffic Unit Type_4	-0,322	0,094	-3,426
Weather_1	1,095	0,086	12,733
Urban population density(persons/ha)	-0,043	0,015	-2,867
Annual private motorised passenger kilometres / Annual public transport passenger kilometres	0,242	0,136	1,779
Random Part			
2nd Level: City			
$\sigma^2 u_0$ (Variation coefficient)	0,123	0,063	1,952
1st Level: Case ID			
Extra-Poisson coefficient	3,795	0,133	28,534

- It is noted that the random city variation is statistically significant, suggesting that there is indeed random variation due to unobserved common characteristics of the cities.
- The number of road fatalities is higher during winter months than summer months (July, August). This may be related to the fact that city mobility is reduced during summer due to the holiday season.
- The number of road fatalities is higher in working days than in the weekend. This may be related to the increased mobility during weekdays due to work obligations in all these cities, compared to the lower travel demand during weekends.
- The number of road fatalities is higher in men than women. This may be due to the more aggressive driving behaviour of male drivers compared to female drivers, as it is confirmed by international literature. Moreover, the number of male drivers is generally larger than the number of female drivers.
- The number of road fatalities in the categories of driver and passenger is lower than in the pedestrian category. Indeed, pedestrians are among the most vulnerable road users in cities, and each pedestrian involvement in road accidents has increased mortality likelihood due to their difference in mass and speed and their inadequate protection compared to motorists.
- The number of road fatalities in the category "motorcycle, moped" is higher than in the categories of "passenger car", "bus, goods vehicle", "other". This may be due to the combination of increased mobility of two-wheelers in cities, and the high risk exposure that such vehicles have, also due to their less protection compared to motorists.

Model development (cont.)

- Two city characteristics were found to explain fatality rates, namely the urban population density, and the rate of private to public passenger travel.
- Urban density appears to be negatively correlated with fatality rates, and this may be attributed to the fact that cities with higher urban density may be also more congested, resulting in fewer fatal accidents due to lower vehicle speeds.
- A higher private-to-public passenger kilometres rate is associated with higher fatality rates, which is rather intuitive; indeed, private passenger transport is more dangerous than public transport, and private cars, two-wheelers etc. have significantly higher fatality rates than public transport vehicles.
- The interaction graph between the variable road user type and the model predictions for the dependent variable (i.e. road fatalities per length of road per 1.000 inhabitants) for each capital city shows that the fatality rate is higher for pedestrians in all of the capital cities, confirming that pedestrians are among the most vulnerable road users.
- However, the city of Athens is the only one that differs from this case and has a higher rate in the driver than the pedestrian category. This may be due to the particularly increased private vehicle traffic in the city of Athens, in relation to pedestrian traffic.



- Comparing the capital cities, it appears that the city of Lisbon holds the lowest road safety position among all cities in all road user types.
- The cities of Athens, London, Brussels and Paris follow in the driver category and London, Bucharest, Brussels and Paris in the pedestrian category.
- These cities have the lower values of length of road per 1.000 inhabitants, whereas capital cities such as Madrid, Prague and Budapest, which have lower predictions of fatality rates, have higher values of the length of road per 1.000 inhabitants.

Discussion

- Multilevel Poisson statistical models were developed, taking into account of the **hierarchical structure of road safety data**, and they led to the identification of several factors affecting road safety level in the selected European capital cities, including both accident, road user and city characteristics.
- The results of the research indicated that the capital cities with the highest road fatalities per **road length** have the lowest values of the indicator length of road per 1.000 inhabitants, suggesting that the larger the city's road network is, the higher the level of road safety is in this city.
- It was found that when **urban population density** (persons/ha) increases, the number of road fatalities decreases.
- The indicator "**annual private motorised passenger kilometres / annual public transport passenger kilometres**" has a positive correlation with road fatalities.
- As the results of this research suggest, **creating a safe road environment** for all road users, but especially for the most vulnerable ones i.e. pedestrians and motorcyclists in cities can be quite challenging.
- Given the effect that urban population density can have on road accidents, it seems to be highly significant to consider road safety in **urban mobility plans**.
- Moreover, given the effect of a low proportion of public passenger transport on the road safety level of different cities, it is confirmed that the promotion of public transport and the shift from private transport to safer modes may be of considerable contribution to road safety.
- Overall, the analysis of road safety at city level becomes a priority, when considering the increasing and continuous urbanization globally, and the increased share of road fatalities occurring at cities, especially for vulnerable groups.
- Observing and following road safety data and policies of cities with good road safety level might assist in the better understanding of the factors that contribute to a good safety performance.

Key references

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