Analysis of actual versus permitted driving speed: a case study from Glasgow, Scotland.

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Summary

With a lack of consistent information about actual driving speed on the majority of roads in the UK we propose a method to determine car speeds from a sample of movement data from a GPS-based travel survey. Furthermore, we identify potential road links within a road network where speeding incidents take place. Speed at which a car travels is a strong determinant in the potential risk of a crash as well as the severity of the crash. Using the GPS movement data we can detect areas in the city of Glasgow where the driving speed exceeds the permitted limits and thus identifying possible areas of higher crash risk.

KEYWORDS: GPS movement data, OpenStreetMap, speed limits, speeding incidents, crash risk

1. Introduction

Driving speed is an important factor in road safety, and reducing speed is crucial in increasing survival rate from collisions involving pedestrians and cars. 98% of pedestrians would survive a collision if from a car with a speed not exceeding 20mph and only 60% with a speed equal to 40mph (Box 2012). Speed limits are set to ensure road safety as well as to prevent costly environmental damages. In recent years, traffic cameras have come to be the most popular sensor for traffic estimation in transportation systems. Nevertheless, there are insufficient numbers of these and therefore urban and transport planners have to estimate the actual road speeds for the majority of roads in a city (Shan and Zhu 2015). Transport planners require road link speed information for travel demand analysis (Pinjari and Bhat 2011), accessibility modelling (Farber and Fu 2017) or route planning (Chang et al. 2013). With new forms of data such as GPS movement data there are increased possibilities for predicting speed averages on road links (Oshyani et al. 2014). Therefore, the purpose of this study is to use vehicle GPS trajectories to detect actual speed on road links and then calculate the differences between the actual and permitted speed on these links in order to map sample areas of potential crash risks when cars are speeding.

2. Using vehicle trajectories for detecting actual speed on road links

Our approach spans three parts:

- GPS movement data preparation
- Map-matching a sample of GPS data points to the OpenStreetMap road network
- Identifying road links where the actual speed exceeds the permitted road speed

The GPS-based travel survey used in this study was designed as a part of the Integrated Multimedia City Data (iMCD) project where, in 2015, a sample of 330 people from a total of 2,095 who completed a socio-demographical survey, carried a GPS device recording location, speed and acceleration every

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5 seconds for seven consecutive days (more about the project in Thakuriah et al. (2016)). The collected GPS movement data were first cleaned and filtered to reduce the number of inaccurate GPS locations and incorrect speed readings. The trajectories were then segmented into homogeneous sub-trajectories using a Spatio-Temporal Kernel Window - a statistical measure developed by Sila-Nowicka et al. (2016). Consequently, a feedforward neural network with a general backpropagation algorithm for segment classification was applied to classify movement segments into pre-defined travel modes (driving, walking, bus and train). For this study we used only the driving trajectories (other travel modes, stop locations as well as user identifiers were deleted).

The GPS data classified as being in driving travel mode were map-matched to the OpenStreetMap road network using an existing Java-based library, Barefoot[†], which uses a Hidden Markov Model (HMM) method to deduce information about the object's movement on the map.

As this is an exploratory study we used only a sample of the iMCD GPS data (192318 map matched driving locations - presented in Table 1) restricted to a binding box of 9x7 km^2 including 12,588 road links (Figure 1). Road data are categorised according to the OSM classification[‡] and not all of the road links have a speed limit attribute associated with the link.

Figure 1 OpenStreetMap road network with speed limit information. The map presents Glasgow city centre with surrounding areas in 2017 (for analysis the city centre was treated as 30mph-48km/h as the "20mph zone" in the city centre was introduced in March 2016). Note that not all the road links have this information.

As a result of the map-matching, the GPS data points were enriched by ascribing attribute information (e.g. maxspeed[§] per road link) according to the road network link. Consequently the differences

[†] https://github.com/bmwcarit/barefoot/wiki

[‡] https://wiki.openstreetmap.org/wiki/Key:highway

[§] Attribute reflecting the speed limit in the OSM road network between the actual (obtained from GPS) and permitted road speed were calculated, multiplied by "-1" and stored as speed differences (Figure 2). In built-up areas in the UK the speed limit is set to 30mph (48km/h) except for cases where other external conditions dictate a different limit. Hence, we assigned the speed limit to 30mph for the remaining unclassified roads inside the study area.

Table 1 Road links in the study area

OSM highway class	Number of map matched GPS data points
motorway	32501
primary	53043
secondary	4699
tertiary	36438
unclassified	147924
residential	21243

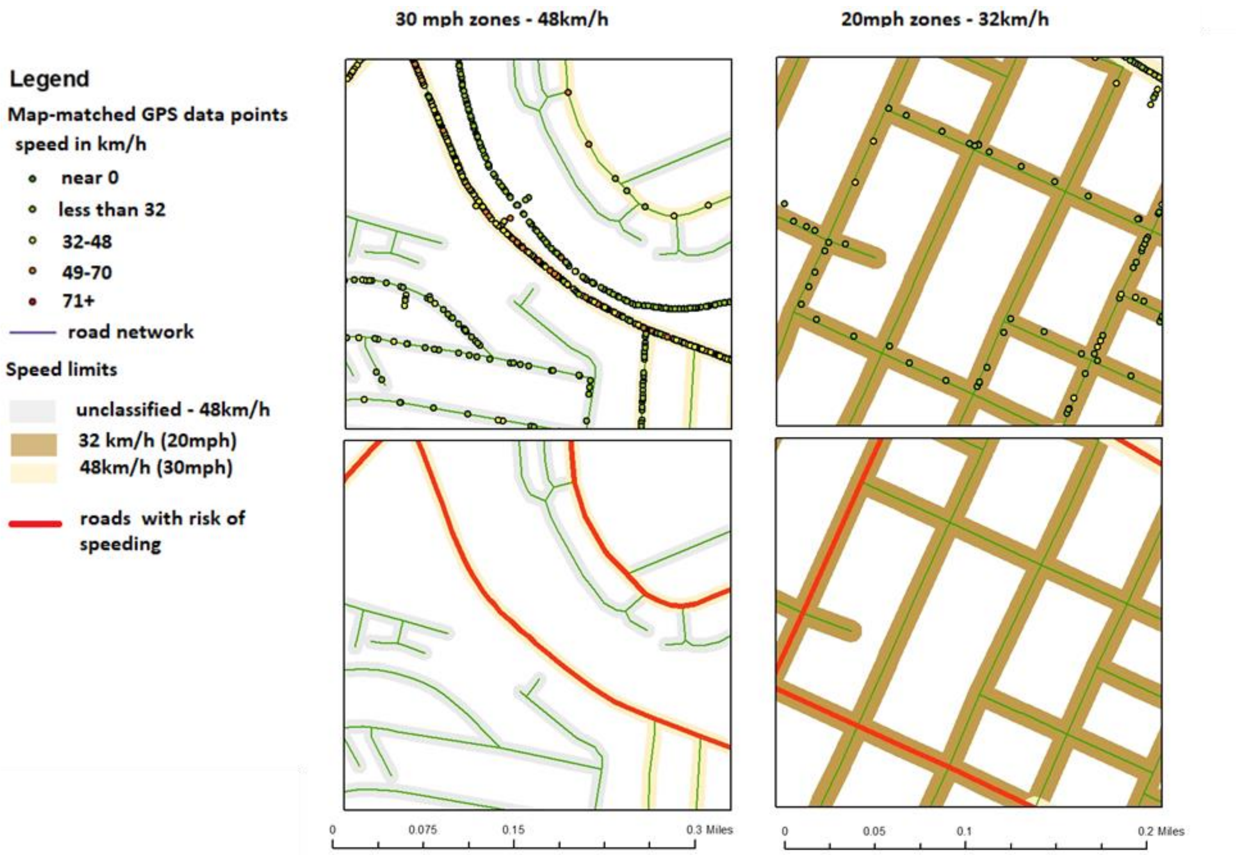

Figure 2 Identification of road links with speeding incidents. The left images show speeding on roads with a 30mph limit and the right images show speeding incidents within the "20mph zone".

3. Results

The initial results show that the majority of the calculated speed differences are negative which means that people tend to drive slower than the speed limit allows for (Figure 3). This could be related to the type of road (Figure 4), traffic congestion at different times of day (Figure 5 and Figure 6) as well as characteristics of a driver.

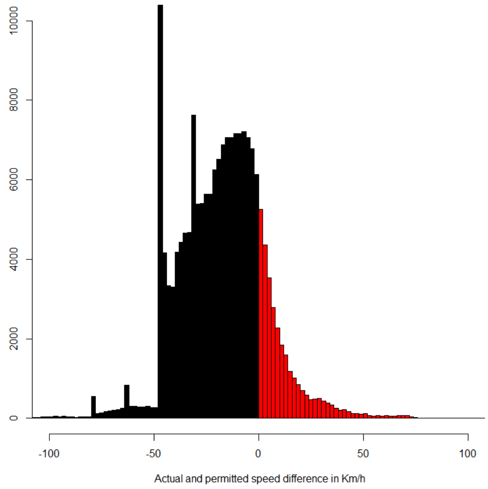

Figure 3 The distribution of speed differences where black shows speed difference values below the permitted ones and red are values of speed differences when a driver was speeding. The two outlying peaks probably identify stopping or driving with speed near to zero in certain speed limits zones.

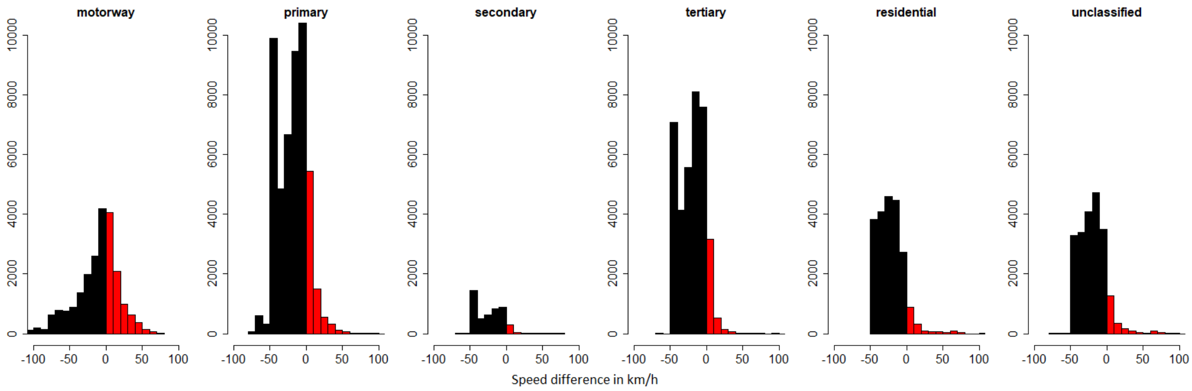

Figure 4 The distribution of speed differences [km/h] for different road types.

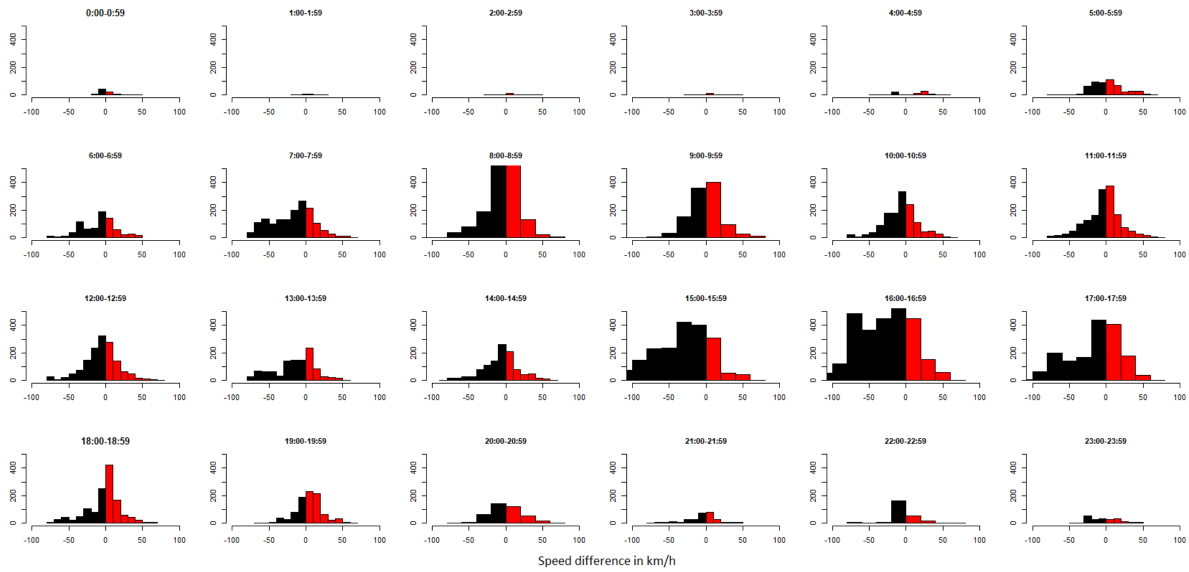

Figure 5 The distribution of speed differences [km/h] for motorways according to time of day.

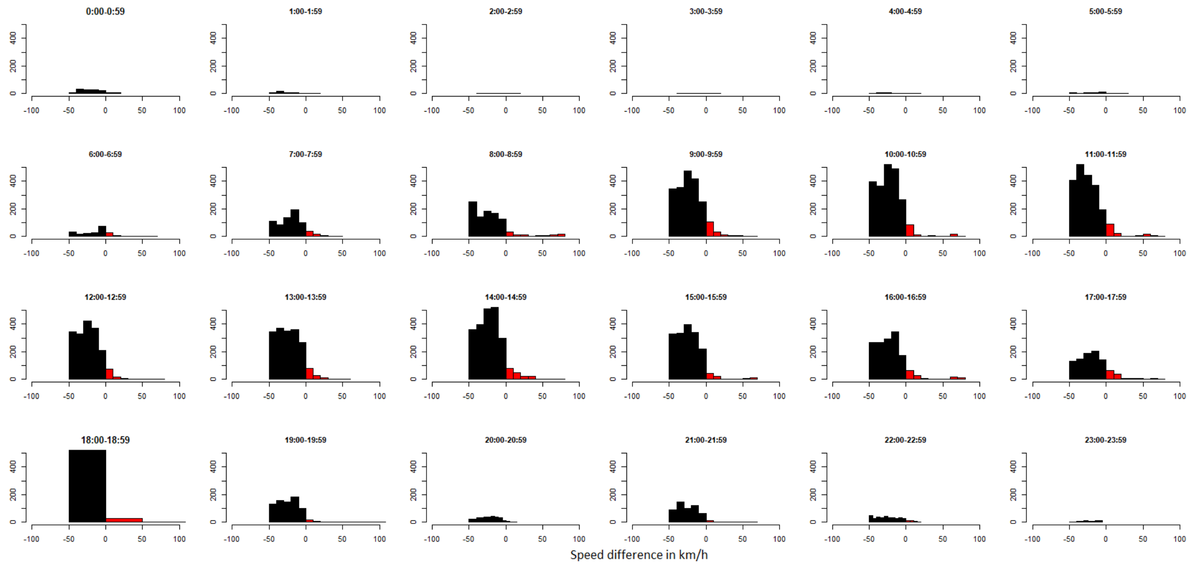

Figure 6 The distribution of speed differences [km/h] for residential roads according to time of day. Note that 30mph is approximately equal to 48km/h.

We can observe that people tend to speed more often and more significantly on main roads such as motorways or primary roads. The influence of congestion levels at different times of day on motorways is visible and shows that during rush hours the actual speeds of cars are significantly lower, whereas outside the peak hours the level of speeding increases, potentially intensifying crash risks on roads.

Even though there are fewer speeding incidents on lower ranked types of roads (residential or unclassified), it is worth investigating driving behaviour in the "20mph zones" which are the important dimension of road safety management in Britain. About 27% of the GPS data points indicate speeds in the 20mph zones exceeding the limit in our study area (Figure 7).

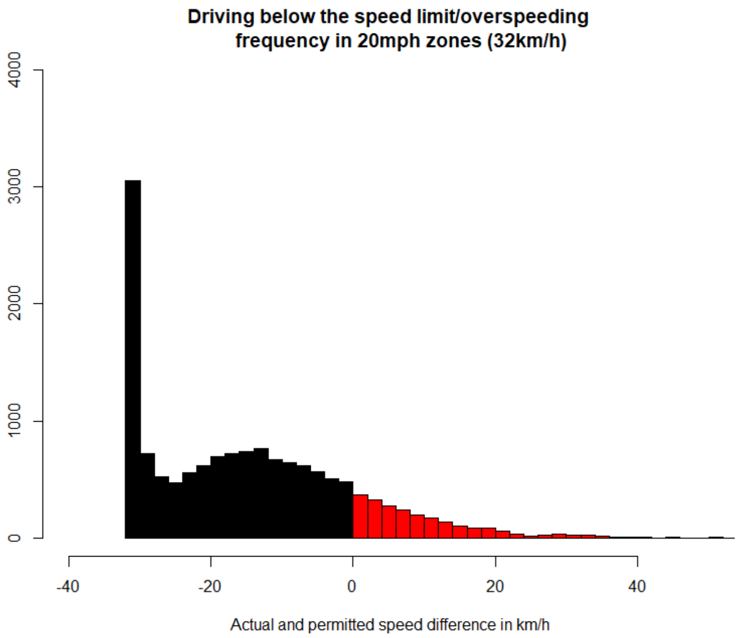

Figure 7 The distribution of speed differences (actual speed minus permitted speed) for roads in a "20mph zone" (32 km/h).

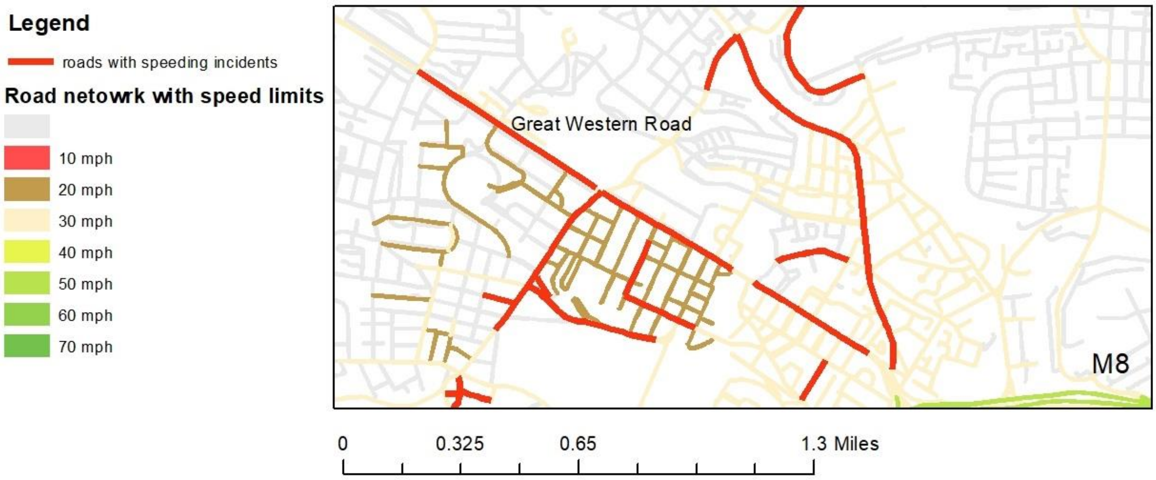

Figure 8. Speeding incidents in the North West area of Glasgow city centre.

Mapped speeding incidents linked to actual road links highlight areas of crash risks. In the area of Glasgow where we mapped a sample of speeding incidents, they happen to occur in locations where significant numbers of pedestrians (students as this is a university area) jaywalk, potentially increasing accident risk (Figure 8).

4. Conclusions and limitations

This paper shows the importance of speeding mapping across urban areas. Information obtained from a GPS travel survey might be used to inform local authorities and Police Scotland where to modify the number of speed limit signs or use traffic calming devices such as speed bumps or speed tables.

Although speed limits are set for all roads in the UK, they can be varied in response to weather conditions, congestion or time of day whereby the speed limit would be changed accordingly on an electronic road sign. With our method we assume that the speed limits were not changed in this way. Even though, the actual speed information analysed in this study might not be representative of the Glasgow population as a whole since it comes from only 330 individuals who took part in the iMCD survey, with a lack of actual speed data in most of the locations in a city, this study simply aims to show the potential of new forms of data.

5. Future research

In future research, other influencing factors and specific urban areas of interest should be considered for further study. These could include the locations of primary and secondary schools to investigate pupils' walking safety; the locations of past accidents to investigate the possible relationship between numbers, times and types of road accidents with speeding incidents described in this study.

6. Acknowledgements

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7. Biography

Dr Katarzyna Sila-Nowicka (Sila) is a research associate in urban methods, modelling and simulations at the Urban Big Data Centre at University of Glasgow. Her research interests cover a wide range of areas in GISc, urban studies, geodesy and cartography including spatial analysis, statistics, spatial modelling and urban planning.

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