Accident Analysis and Prevention 103 (2017) 20–28

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Changes in speed distribution: Applying aggregated safety effect models to individual vehicle speeds

Anna Vadeby*, Åsa Forsman

The Swedish National Road and Transport Research Institute, SE-581 95 Linköping, Sweden

ARTICLE INFO

Article history:
Received 2 December 2016
Received in revised form 3 March 2017
Accepted 13 March 2017

Keywords:
Speed distribution
Mean speed
Power model
Speed compliance
Traffic safety

ABSTRACT

This study investigated the effect of applying two aggregated models (the Power model and the Exponential model) to individual vehicle speeds instead of mean speeds. This is of particular interest when the measure introduced affects different parts of the speed distribution differently. The aim was to examine how the estimated overall risk was affected when assuming the models are valid on an individual vehicle level. Speed data from two applications of speed measurements were used in the study: an evaluation of movable speed cameras and a national evaluation of new speed limits in Sweden.

The results showed that when applied on individual vehicle speed level compared with aggregated level, there was essentially no difference between these for the Power model in the case of injury accidents. However, for fatalities the difference was greater, especially for roads with new cameras where those driving fastest reduced their speed the most. For the case with new speed limits, the individual approach estimated a somewhat smaller effect, reflecting that changes in the 15th percentile (P15) were somewhat larger than changes in P85 in this case. For the Exponential model there was also a clear, although small, difference between applying the model to mean speed changes and individual vehicle speed changes when speed cameras were used. This applied both for injury accidents and fatalities. There were also larger effects for the Exponential model than for the Power model, especially for injury accidents.

In conclusion, applying the Power or Exponential model to individual vehicle speeds is an alternative that provides reasonable results in relation to the original Power and Exponential models, but more research is needed to clarify the shape of the individual risk curve. It is not surprising that the impact on severe traffic crashes was larger in situations where those driving fastest reduced their speed the most. Further investigations on use of the Power and/or the Exponential model at individual vehicle level would require more data on the individual level from a range of international studies.

1. Introduction and background

Driving speed is one of the most important features of road transport and traffic safety. Many safety measures implemented aim to induce road users to reduce their speed and comply with speed limits. In Sweden, 'Vision Zero' is the overall road safety philosophy, established by parliamentary resolution in October 1997. The long-term goal is that no-one should be killed or seriously injured in road traffic (Johansson, 2009; Belin et al., 2011). The interim targets for 2020 are that no more than 220 people per year should be killed in road traffic accidents and that the number of seriously injured people in traffic accidents should not exceed 4100. To reach these targets, better speed compliance and lower mean speeds are some of the main requirements. Two measures with great potential to reduce road users' speed and increase traffic safety are speed limit changes and increased number of speed cameras (Amin et al., 2015). These measures have been widely introduced in Sweden. Evaluations of the Swedish speed cameras (STA, 2009; Larsson and Brüde, 2010) have shown that they decrease mean speed by 4.4% (−3.6 km/h) and that they decrease the 85th percentile (P85) even more, by 5.9% (−5.5 km/h). Similar patterns, with larger decreases for higher speeds, have been found in terms of speed compliance, meaning that those who drive the fastest are most influenced by speed cameras. This indicates that the shape of the speed distribution changes to a more upright configuration. As regards traffic safety, Larsson and Brüde (2010) showed that the number of fatalities was reduced by 30% and the

* Corresponding author.
E-mail addresses: anna.vadeby@vti.se (A. Vadeby), asa.forsman@vti.se (Å. Forsman).

http://dx.doi.org/10.1016/j.aap.2017.03.012

number of people killed or seriously injured (KSI) by 25%. Studies on the effects of speed limit changes by Vadeby and Forsman (2014a, 2016) showed that a decrease in the speed limit of 10 km/h led to a decrease in mean speed of around 2–3 km/h, while an increase in the speed limit of 10 km/h resulted in an increase in mean speed of 3 km/h and P85 changed by the same amount, resulting in no change in the shape of the speed distribution.

A recent literature review by Soole et al. (2013) concluded that section control is effective in reducing mean speed, P85 and speed variations between vehicles. In many of the studies referred to in Soole et al. (2013), the decrease in P85 was greater than the decrease in mean speed, which agrees well with the Swedish experience and suggests a change in the shape of the speed distribution. Gains et al. (2005) studied the effects on vehicle speed following introduction of speed cameras in the UK and found that mean speed decreased by 6% (3.7 km/h) and P85 by 7% (5.0 km/h). Moreover, the number of speeding offences decreased by 30% and the proportion of serious offences (more than 24 km/h over the speed limit) by 43%.

Shin et al. (2009) studied the effects of speed cameras on a road (SR 1010) in Arizona and found that mean speed decreased by 11.9%, while P75 decreased by 14.7% and P25 by 9%, illustrating a change in the shape of the speed distribution. Montella et al. (2015) analysed the effects of section control (Tutor) on the Italian motorway (A56) and reported that mean speed decreased by 8 km/h (−10%), P85 by 14%, the proportion of speeding offences by 45 percentage points and the standard deviation by 26%. In conclusion, it appears when speed cameras are introduced, they result in a larger decrease in high speeds than in low speeds, thus changing the shape of the speed distribution. Overall, P85 decreases more than the average speed and the proportion of serious offences decreases more than total offences. Other measures that have a similar effect are ISA (In-vehicle Speed Adaption) and "Pay-as-you-speed" (Stigson et al., 2013).

Shinar (1998) and Aarts and van Schagen (2006) present different views on how speed distribution affects accident risk. In somewhat simplified terms, one approach claims that the speed itself is most important, while the other claims that speed variations between vehicles on the same road is most important. The main evidence supporting the first approach is that increased speed causes longer reaction times and stopping distances if something unexpected happens, and also leads to more serious consequences if an accident does occur. A finding supporting the second approach is that large variations in speed between adjacent vehicles give rise to conflicts, which in turn can lead to accidents. One aspect highlighted in several studies is that speed variations are probably relevant only to certain types of accidents, while absolute speed affects every accident. Another difficulty when distinguishing between the effects of mean speed and speed variations is that these variables are highly correlated (Finch et al., 1994; Nilsson and Andersson, 1997; Shinar, 1998), making it difficult to isolate the effects of speed from those of speed variation.

Based on the first approach, this study investigated how speed itself affects accident risk when the speed distribution changes. Models that describe the relationship between speed and crash risk can be divided in two main groups: those applied to aggregate data from a road site and those that estimate how speed affects accident risk at the individual level (Aarts and van Schagen, 2006). Examples of aggregated risk models are the Power model (Nilsson, 2004; Elvik, 2009) and the Exponential model (Elvik, 2013, 2014).

The Power model estimates how a change in mean speed affects the outcome of both the number of injury accidents and the number of fatalities and injured. The model can be used both when new measures are planned and when implemented measures are evaluated. The Exponential model is a newer, but similar, model developed by Elvik (2013, 2014). It has an equally good fit to the data as the Power model, but the curve is steeper at high speeds. One limitation of both the Power model and the Exponential model is that they only take into account changes in average speed, and thus ignore possible changes in the shape of the speed distribution.

Studies in the 1960s analysed individual risks in relation to the choice of speed and found a U-shaped relationship between speed and accident risk (Solomon, 1964; Cirillo, 1968). More recent studies suggest that the relationship increases fairly monotonically, the slope becoming steeper at higher speeds (Maycock et al., 1998; Quimby et al., 1999; Kloeden et al., 2001). This means that the higher the driving speed, the higher the risk of being involved in an accident. However, overall risk does not increase when driving below the average speed on the road. Different studies have reported quite different values for the increase in risk when driving above the average speed, and there is still considerable uncertainty as to the actual appearance of the individual risk curve.

2. Objective

The overall aim of this study was to investigate the effect of applying aggregated models to individual vehicle speeds instead of mean speeds. This is of particular interest when the measure introduced affects different parts of the speed distribution differently. Specific objectives of the study were to:

- Gain a better understanding of the changes in speed distribution when speed cameras and new speed limits are introduced
- Evaluate the estimated outcome when the Power and Exponential models are applied to individual vehicle speeds instead of mean speeds.

3. Methods

3.1. Data

Speed data from two applications of speed measurements were used in the study: an evaluation of movable speed cameras and a national evaluation of new speed limits in Sweden. The speeds of all vehicles were considered in the analyses. In general, the speed measurements are conducted on straight road stretches with visibility distance more than 300 m, at least one km away from any intersection or entrance/exit and not within any local speed limits. The data sources are briefly described below, but for a more detailed description see Vadeby and Forsman (2014a,b).

Movable speed cameras were trialled on five road stretches in Sweden in 2010. This study used speed data from 11 sites on rural roads, 10 sites with a speed limit of 90 km/h (six sites at cameras and four sites between cameras) and one site with a speed limit of 80 km/h (at camera). Speed data were collected using pneumatic tubes stretched across the road. The speed measurements used here were made before (August/September 2010) and after (September/October 2010) the speed cameras were installed. At each site and on each measurement occasion, the speeds of passing vehicles were recorded for one week. In total, speeds of more than 300 000 vehicles were recorded per measurement occasion (before and after). Only speeds of vehicles travelling in the direction of the camera orientation were considered.

Starting in 2008, a new set of speed limits (80, 100 and 120 km/h) was introduced on rural roads in Sweden to complement the previous limits of 70, 90 and 110 km/h. The long-term vision was that speed limits should be adapted to the safety classification of each road and be in line with the ideas of Vision Zero. A core principle of Vision Zero is that road system design should take into account how much force a body can tolerate and still survive. This means