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How can the notion of optimal speed limits best be applied in urban areas?

Rune Elvik

Institute of Transport Economics, Gaustadalleen 21, 0349 Oslo, Norway

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ABSTRACT

This paper reviews estimates of optimal speed limits made in the past 30 years. A tendency is seen for optimal speed limits to become higher. In the most recent estimates made for Norway, the optimal speed limit was in no case lower than 60 km/h. Adopting a speed limit of 60 km/h on roads in urban areas now having speed limits of 30, 40 or 50 km/h would most likely lead to an increase in the number of accidents and killed or injured road users. It is a political objective in Norway to reduce the number of killed or injured road users and to encourage more walking and cycling. Raising speed limits would conflict with both these objectives. This paper discusses if a re-interpretation of the notion of optimal speed limits can applied to justify low speed limits in urban areas. Traditionally, analyses of optimal speed limits have included motorised travel only. It is shown by means of simple numerical examples, that by including the effects of motorised travel speed on walking and cycling, optimal speed limits tend to be lower than when only motorised travel is included.

1. Introduction

The setting of speed limits is a compromise between considerations pulling in opposite directions. Keeping travel time short favours high speed limits. Keeping roads safe favours low speed limits. Keeping vehicle operating cost low favours a speed of around 70 km/h, not much higher and not much lower. Emissions of pollution tend, broadly speaking, to have the same relationship to speed as vehicle operating costs. Traffic noise tends, like accidents, to increase monotonically as speed increases.

Economic theory proposes that the best speed limit is the optimal speed limit (Crouch, 1976). An optimal speed limit minimises the total costs of travel, i.e. the sum of costs of travel time, accidents, vehicle operation and environmental impacts. As applied up to now, the concept of optimal speed limits applies to motorised travel, not to travel by foot or bicycle. To determine the optimal speed limit, one needs to know the physical relationship between speed and the various impacts of speed and assign monetary values to these impacts.

Optimal speed limits, or optimal driving speeds, have been estimated in many studies. Some of these studies are reviewed in section 3 of the paper. Until recently, studies have shown that optimal speed limits tend to be lower than current speed limits. This means that if current speed limits were replaced by optimal speed limits, there would be a reduction of the number and severity of road accidents. However, a recent analysis for Norway (Elvik, 2017) suggests that optimal speed limits are higher than most current speed limits. This finding implies that there are too few traffic fatalities and injuries, and that it would bring a net societal benefit to increase their number. Clearly, this implication would widely be regarded as problematic and conflicts with a political objective of reducing traffic injury. This raises doubts about the applicability of the idea of optimal speed limits, particularly in urban areas.

It should be noted that the notion of optimal speed limits is just one of several principles that have been proposed for setting speed limits (Elvik, 2017). Other principles include biomechanical tolerance for impacts, as proposed in Vision Zero (Tingvall, 1997), road geometry, roadside development, and the 85th percentile of driving speeds. As far as is known, a system of optimal speed limits has not been implemented anywhere. The objectives of this paper are:

1. To review previous studies of optimal speed limits or optimal driving speeds,
2. To discuss reasons why optimal speed limits have tended to become higher recently, illustrated by results for Norway and Sweden, two of the safest highly motorised countries in the world,
3. To discuss whether an alternative framework, embedded in economic theory, can be developed for setting optimal speed limits in urban areas.

2. The theory and estimation of optimal speed limits

Crouch (1976), in developing a framework for determining optimal speed limits included four impacts of speed: travel time, accidents, vehicle operating costs, and enforcement costs. He proposed that the

E-mail address: re@toi.no.

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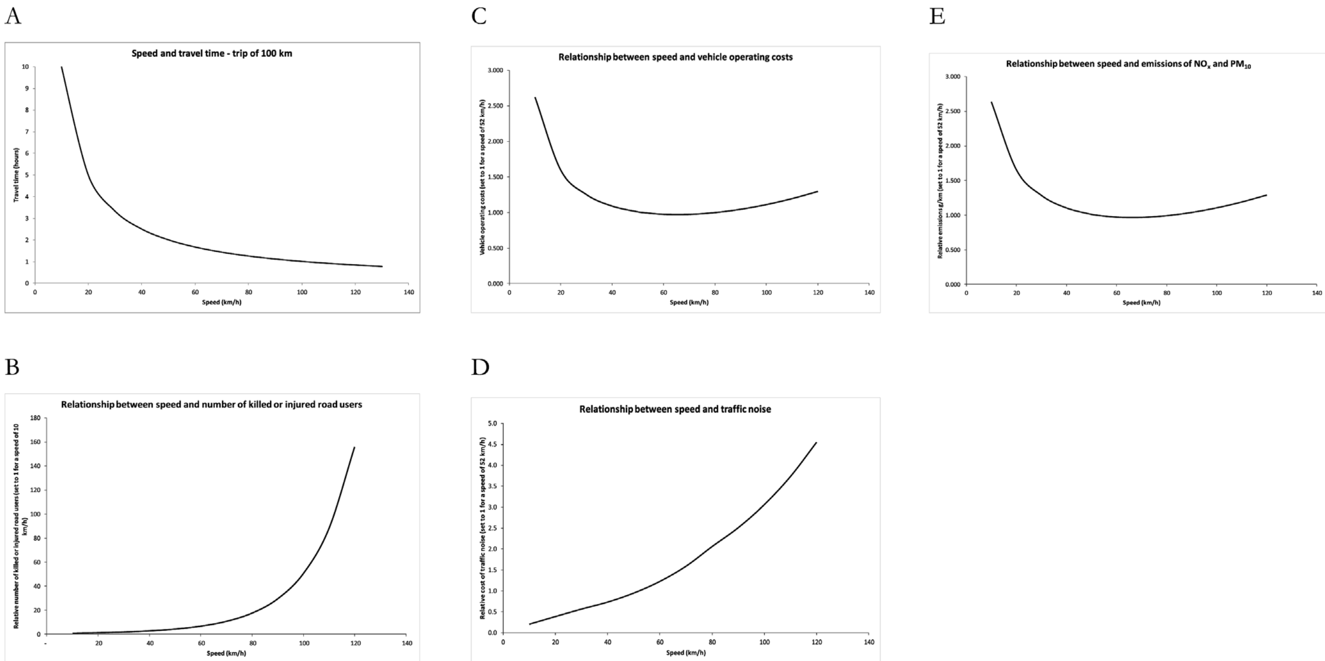

Fig. 1. The relationship between speed and the principal impacts of speed.

relationship between speed and the sum of these costs was U-shaped and would have a minimum, which would be the optimal speed limit. He further noted that drivers may not perceive all costs correctly. The optimal speed from a private point of view might therefore be different from the optimal speed from a societal perspective. He recognised that speed limits need to be enforced and that the costs of enforcement should therefore be included when optimal speed limits are determined.

Most subsequent studies of optimal speed limits have ignored the costs of enforcement, but have included environmental impacts (noise, pollution), which were not discussed by Crouch. The recent analysis for Norway (Elvik, 2017) included:

1. Travel time
2. Accidents
3. Vehicle operating costs
4. Emissions of NO_x and PM_{10}
5. Emissions of CO_2
6. Traffic noise

Fig. 1 shows the relationship between speed and these impacts of speed. Panel A and B show that travel time and accidents move in opposite directions and represent the main trade-off to be made in setting speed limits. Vehicle operating costs (panel C) were assumed to be proportional to fuel consumption, as was emissions of CO_2. Traffic noise increases monotonically as speed increases (panel D). The curve for emissions of NO_x and PM_{10} greatly resembles that for vehicle operating costs, but the curves are not identical (panel E) (Jung et al., 2011; Marner, 2016).

Not all impacts of speed count equally in determining optimal speed limit. Fig. 2 shows the estimated optimal speed limit for roads in Norway that currently have a speed limit of 80 km/h (which happens to be identical to the optimal speed limit). As can be seen from Fig. 2, travel time, accidents and vehicle operation make major contributions, whereas the other impacts of speed are barely visible in the diagram.

The contributions of the different impacts of speed in determining optimal speed limits obviously depend on the monetary valuations of those impacts. The effects of different monetary valuations are discussed in section 5 of the paper.

3. A review of previous estimates

Several studies have estimated optimal speed limits or optimal driving speeds. Kamerud (1983) analysed the impacts of the national 55 miles per hour speed limit in the United States on traffic fatalities and injuries, energy consumption, and time consumption of trucks. He found that the economic impacts of 55 mph speed limit were very small, meaning that the total costs of travel changed very little. However, the monetary valuation of a traffic fatality was just around 12,000 US dollars and Kamerud noted (page 56) that: "there has been no attempt to include a dollar value of human life in the fatal accident cost." Had even a low value, like 200,000 US dollars per fatality prevented, been used, benefits would have been greater than costs.

Andersson et al. (1991) estimated optimal driving speeds for roads with different speed limits in Sweden (based on data for 1986–88). Optimal driving speeds were in all cases lower than actual speed limits, by between 3 km/h and 27 km/h. Optimal driving speeds were also lower than the mean speed of traffic.

Rietveld et al. (1998) estimated optimal speed limits for various types of road in the Netherlands. Optimal speed limits were in all cases lower than actual speed limits and lower than the mean speed of traffic in nearly all cases. The differences were largest for roads that had speed limits of 120 or 100 km/h.

Elvik (2002) estimated optimal speed limits for Norway and Sweden. For Norway, results were mixed. Some speed limits were below the optimal speed limit, others were above. See Table 1 for details. Mixed results were obtained for Sweden as well. The optimal speed limit was lower than the actual speed limit in three cases, higher than the actual speed limit in two cases and identical to it in one case.

Cameron (2000, 2012) estimated optimal driving speed on residential streets with a speed limit of 60 km/h and on rural highways with a speed limit of 110 or 100 km/h. For residential streets, optimal speed was found to be 55 or 50 km/h, depending on whether the monetary valuation of traffic injury was based on the human capital approach or the willingness-to-pay approach. For rural highways, optimal speeds were 10–15 km/h below actual speed limits. Adopting optimal speed was estimated to reduce accident costs by 34%.

Hosseinlou et al. (2015) estimated optimal driving speed for a six-lane freeway in Iran with a speed limit of 110 km/h. They found that