Smeed's Law: some further thoughts

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In his contribution to this journal entitled "Linking deaths with vehicles and population" Andreassen[1] says that Smeed[2] 'looked at deaths per vehicle plotted against vehicles per capita and espied an apparent relationship.' He argues that the relationship found by Smeed between these variables is spurious, and that 'the Smeed equation was an analysis of 20 countries for one year of data [1938]; it should not be interpreted to mean anything more than just that.' He concludes: 'There is no excuse for the continuation of [such] faulty thinking to this day.' Figure 1, taken from Smeed's original article, illustrates the relationship that Smeed actually found. Figure 2 and 3 (from Adams[3], page 20) show how well this 'apparent relationship' has stood the test of time — despite a three-fold increase in the range of the data for vehicles/population, and the passage of 42 years.

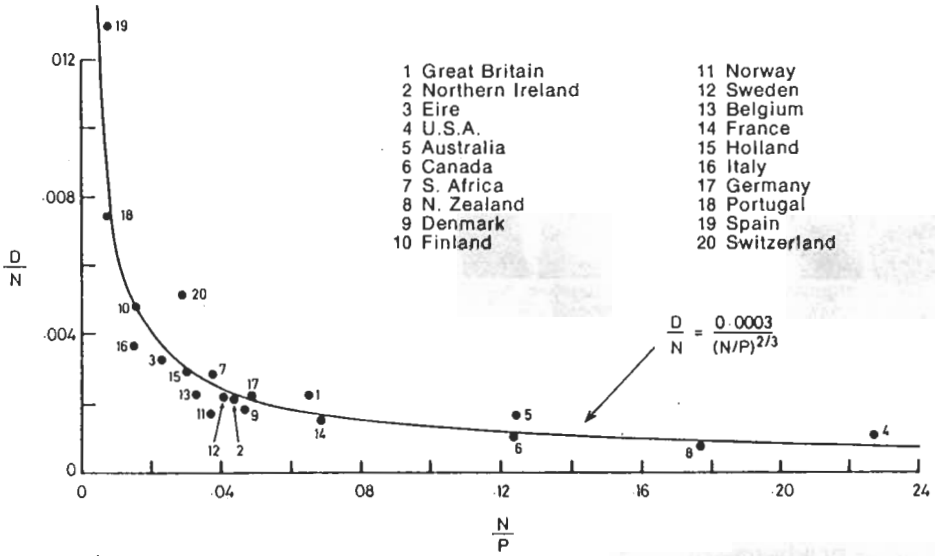


Fig 1 (upper right). Relation between number of deaths per 10 000 registered motor vehicles and number of vehicles per person for 1938 (from Smeed[2]).

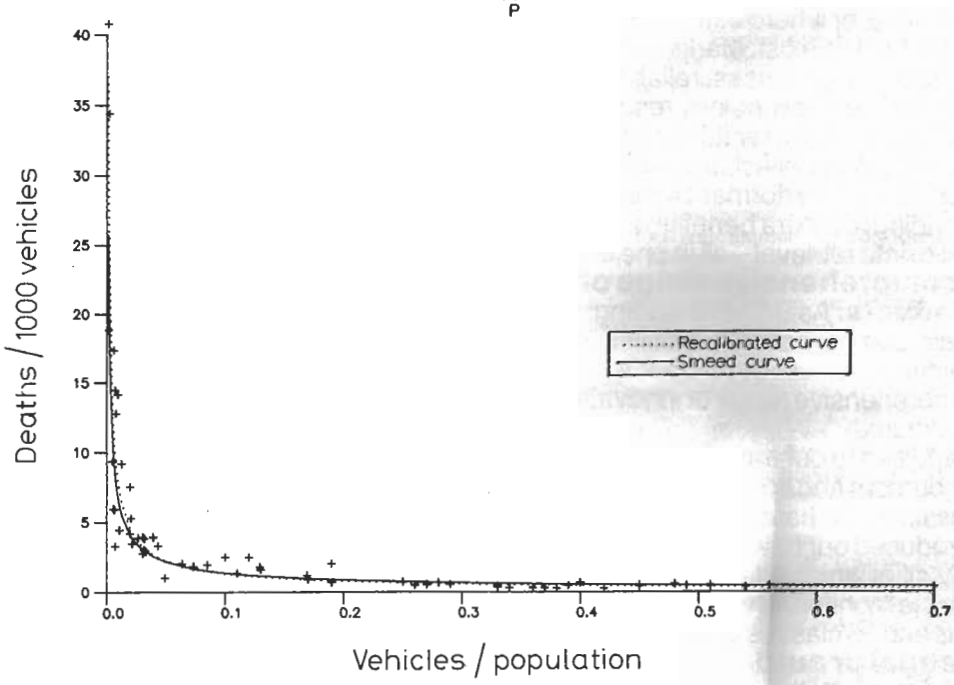


Fig 2 (centre right). The relationship between levels of motorisation and road accident death rates per 1 000 vehicles for 62 countries for the most recent year (1978-80), from Adams[3], p. 20.

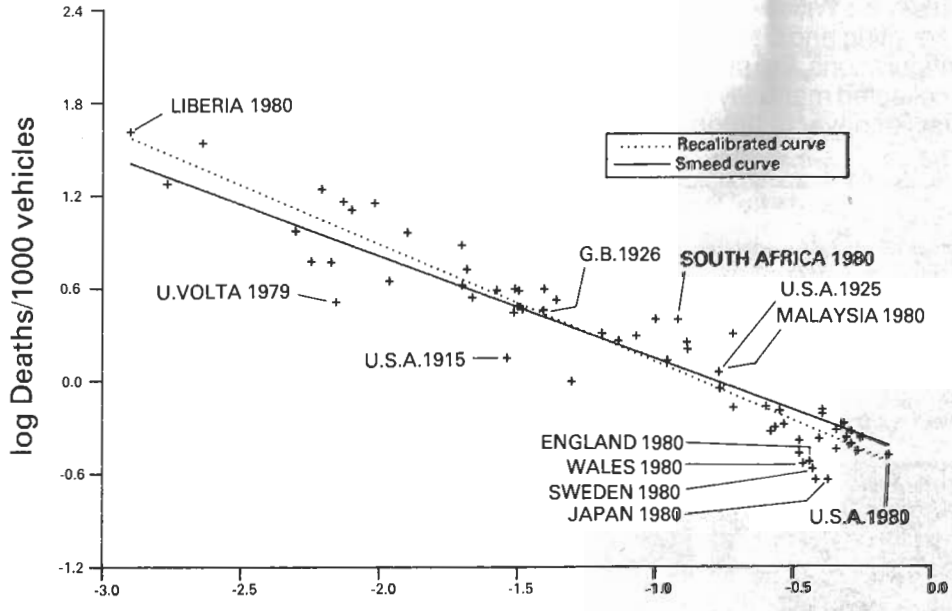


Fig 3 (lower right). Data displayed in Fig 2 transformed into logarithms.

Andreassen is insistent that the relationship discovered by Smeed should not be used as a basis for comparing road accident death rates for different countries at different levels of motorisation. Certainly it is not a perfect standard of comparison (such standards are very hard to find in road accident research), but it does help to put accident rates into perspective. For example, in 1980 Malaysia had a death rate per vehicle about 3.5 times higher than that of the United States; but it had almost exactly the same death rate, and the same car ownership level, as the U.S. in 1925. Viewed in the context of Smeed's curve Malaysia would appear to be more or less 'on course'.

Andreassen notes that Smeed used an alternative formulation of the relationship described in Figs 1, 2 and 3 in an attempt to model deaths/population. This formulation

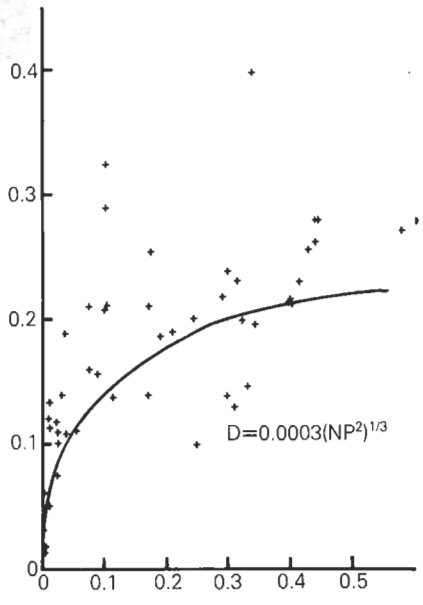


Fig 4. Alternative formulation of the Smeed relationship applied to the most recent data (1970-73) for 46 countries (from Adams[3], p. 27).

looks much less successful. Figure 4 illustrates Smeed's attempt to apply it to data for 46 countries in the early 1970's Vehicles per capita appears to be a very poor predictor of deaths/population. A method for improving the accuracy of the moddeling of deaths will be discussed below, but for the moment it should be noted that even Fig 4 yields relatively accurate predictions compared to those based on the expectation of a constant death rate per vehicle. If, for example, the death rate per vehicle for Liberia, at the top end of the curves in Figs 2 and 3, were to be transposed to the vehicle fleet of the U.S., at the bottom end of the curves, it would yield an estimate of more than 6m. traffic accident deaths per year — compared to the actual number of about 50 000.

A constant death rate per vehicle, or per vehicle-mile, is a standard against which the progress of road safety regulation is frequently measured. Figure 5, taken from an Anniversary Issue of the Insurance Institute for Highway Safety's *Status Report* (September 9, 1986)[4], provides a good example. The anniversary being celebrated was the passage of the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act on September 9, 1966. The IIHS notes that in 1985 43 555 people were killed in highway traffic and that 'had the death rate [per vehicle mile] continued at the 1966 level, there would have been more than 100 000 deaths last year.' Figure 5 — which depicts a rising trend, breaking and turning down with the passage of the 1966 Acts — is offered by the IIHS as convincing evidence of the efficacy of the Acts.

Figure 6 places Fig 5 in a longer historial perspective. Figure 7 shows that since 1925 there has been a 14-fold increase in traffic. If the death rate per vehicle-mile had remained constant since 1925 there would have been over 300 000 deaths in 1985. The downward trend in Fig 5 which the IIHS is attributing to the effect of the 1966 Acts appears, in this wider perspective, to be merely a continuation of a very well established trend.

In following this downward trend the U.S. has had a lot of company. In a 1974 paper, which Andreassen does not cite, Smeed[5] demonstrates with data for 23 countries that the tendency (illustrated in Figs 1, 2 and 3) for the death rate per vehicle to fall as vehicle ownership increases can also be found in time series data for individual countries. He continued his work of data collection and shortly before he died he had graphs ready for publication illustrating this tendency for a total of 46 countries. These graphs have been published in Adams[3] (pp.25-28). Figure 8 reproduces those for Britain and the U.S., the two countries for which he had the greatest number of years' data. The curves shown are not lines of best fit for the two time series; they represent the fit from the original curve fitting exercise shown in Fig 1. The full set of Smeed's graphs shows conclusively that in all countries which have achieved substantial levels of motorisation the death rate per vehicle has fallen *enormously* as exposure to traffic has increased. The parameters of his original model do not fit the experience of every country exactly, but the model still represents a very useful generalisation of the relationship between death rates and exposure.

Fig 5. U.S. fatalities per 100m. miles, 1960-85 (from IIHS Status Report[4]).

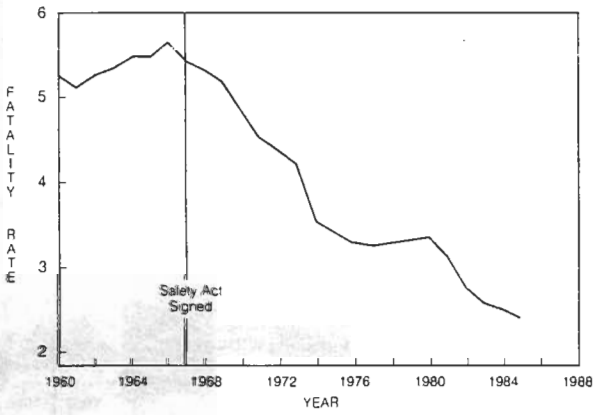


Fig 6. U.S. fatalities per 100m. miles, 1925-84. (Sources: Statistical Abstract of the United States, 1976, 1981, 1985 and 1986, and Historical Statistics of the United States: Colonial Times to 1970 (U.S. Bureau of the Census, 1975).

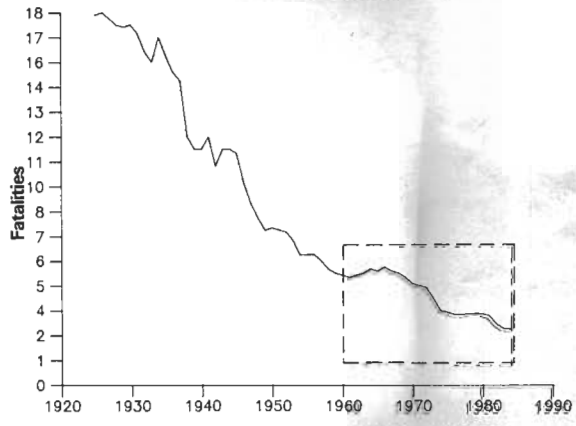


Fig 7. U.S. traffic, 100m. vehicle miles, 1925-84. (Sources as for Fig 6).

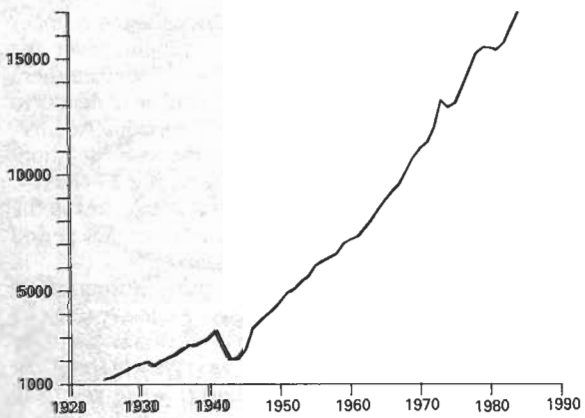
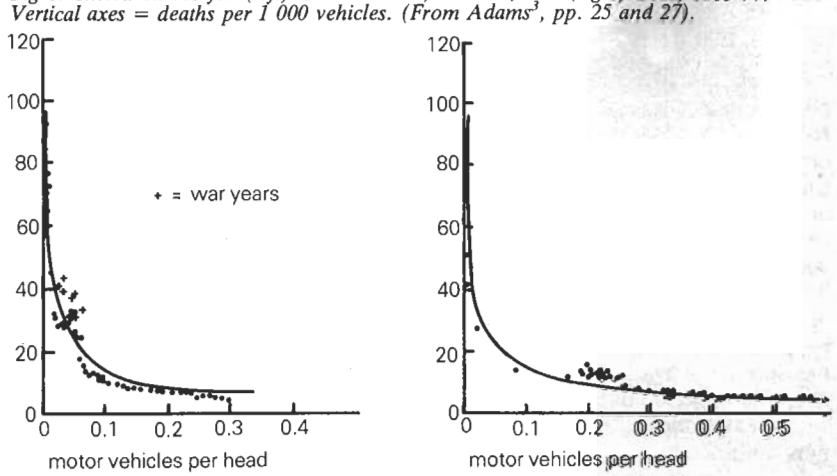


Fig 8. Smeed curves for (left) Great Britain, 1909-73, and (right) U.S., 1905-72. Vertical axes = deaths per 1 000 vehicles. (From Adams[3], pp. 25 and 27).



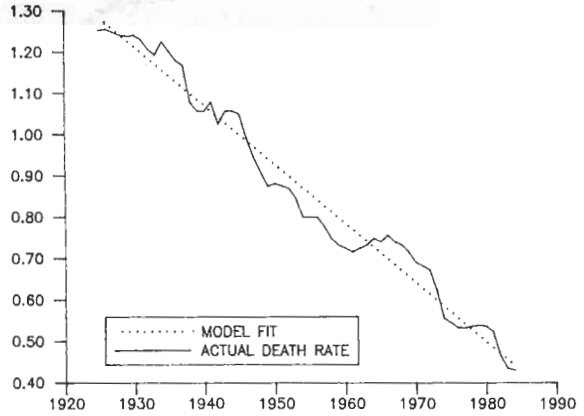


Fig 9. Logarithm of deaths per 100m. miles, U.S., 1925-84. (Sources as for Fig 6).

Fig 10. Motor vehicle traffic in the U.S., percentage change over previous year. (Sources as for Fig 6).

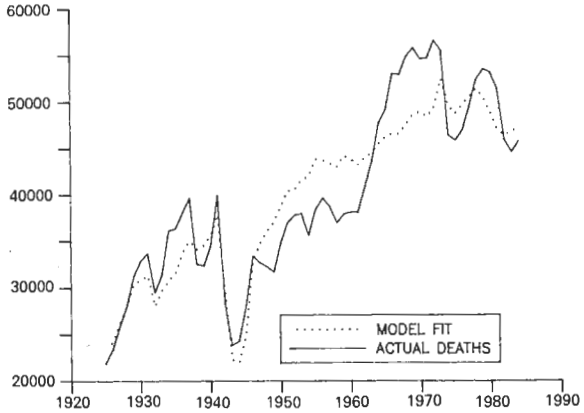


Fig 11. Road deaths in U.S., 1925-84, and estimate (dotted line) calculated by multiplying the annual number of deaths per vehicle mile (estimated from the straight line in Fig 9) by the volume of traffic shown in Fig 7.

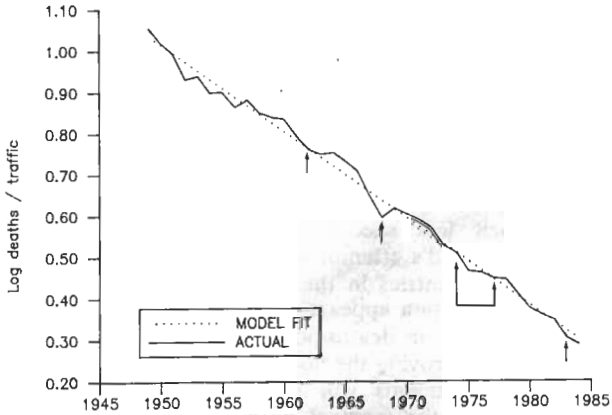


Fig 12. Logarithm of deaths per 100m. vehicle km, G.B., 1949-84 (from Adams[3], p. 106).

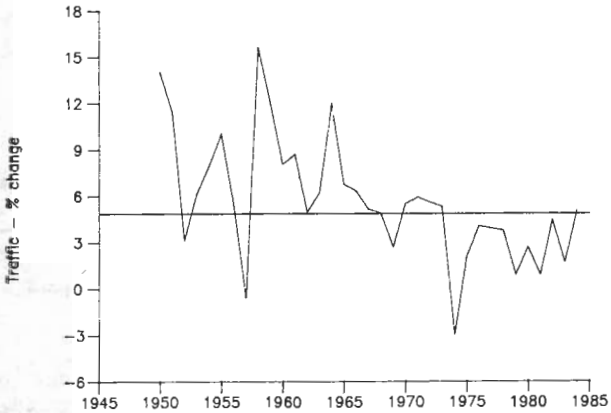


Fig 13. Motor vehicle traffic in Britain, percentage change over previous year (from Adams[3], p. 106).

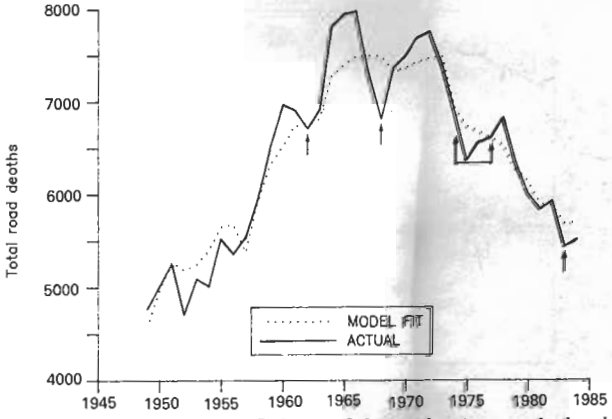


Fig 14. Road deaths in G.B., 1949-84, and estimate calculated by multiplying the annual number of deaths per 100m. vehicle km (estimated from the straight line in Fig 12) by the volume of traffic. (From Adams[3], p. 107.)

Smeed employed the ratio of cars/population as a measure of exposure to the risk of a road accident. He noted[5] that, *other things being equal,* the number of single-vehicle accidents ought to increase in proportion to the number of vehicles, and that the number of collisions between vehicles ought to increase in proportion to the square of the number of vehicles. A more accurate measure of exposure would be vehicle-miles (kilometres). Since this measure is not available for many countries over a long period of time Smeed made do with the best measure available — vehicles per capita.

But vehicle mile series are published for the U.S. going back as far as 1925 and permit closer scrutiny of the phenomenon described by 'Smeed's Law'. Figure 9 illustrates the logarithm of deaths per 100m. miles since 1925. The slope of the linear trend line indicates that over the whole of this period the death rate per mile decreased by 3.3 per cent per year. Figure 10 illustrates the annual percentage rate of change of traffic over this period, with the horizontal line marking the 3.3 per cent level. Figure 11 shows that whenever the rate of exposure (traffic) growth exceeded the long-term rate of decline in deaths per mile there was a tendency for the number of deaths to increase, and whenever the rate of growth was below 3.3 per cent there was a tendency for the number of deaths to fall. Figures 12, 13 and 14 (from Adams[3], pp. 106-107) illustrates the same relationships for Britain for the period 1949-1984. In Britain the average rate of decline in the death rate per kilometre over this period was greater — 4.7 per cent.

For both countries this elaboration of the relationship first identified by Smeed produces fits to the data which might be described as suggestive. They identify the underlying trend fairly well and call

attention to interesting departures from it. Figures 9 and 12 might be considered national learning curves. They suggest that the U.S. and Britain have learned to cope as the threat of traffic has grown. Whenever the threat has grown faster than the long-term rate of learning the numbers killed have tended to increase, and whenever the threat has grown more slowly they have tended to decrease.

It is often argued that the long-term decline in death rates per vehicle (or per vehicle-kilometre) ought to be attributed not to learning but to the large number of safety measures which have been implemented as traffic has increased. There are a number of reasons to doubt this. An examination of departures from the trend in Fig 14 suggests that major road safety initiatives (shown by arrows) deserve little credit for the long-term decrease in the death rate per kilometre (Adams[3], pp. 105-125). Similarly, a detailed examination of the implementation of the 1966 Acts in the U.S. reveals no perceptible effect (Adams[3], pp. 30-36). It would not be appropriate to review here the whole of the protracted argument over the efficacy of road safety measures, but two of the most important pieces of evidence deserve a brief mention.

Firstly, a large part of the variance unaccounted for by the models illustrated by Figs 11 and 14 has been accounted for by simple models employing economic variables (Partyka[6], Cooper[7], Adams[3], pp. 108-109); there appears to be very little variance left for safety interventions to explain. Secondly, the Smeed curve calls into question in a very direct way the claims made for the beneficial effects of the 1966 vehicle safety regulations. The same curve fits both time series data for a large number of countries over many years, and cross-section data for a large number of countries in 1980. Most of the vehicle safety standards adopted in the U.S. in 1966 have been implemented worldwide. Most vehicles in use in 1980 were manufactured after 1966 — especially in most Third World countries where both vehicle population growth rates and accident attrition rates are high. Yet, when driven in Third World countries, these modern vehicles, incorporating 80 years of safety technology, are achieving kill rates per vehicle as high as or higher than those achieved in Britain and the U.S. in the early years of this century with Model T Fords.

The long-term decrease in death rates per measure of exposure is much more plausibly attributable to myriad behavioural adjustments in response to perceived increases in the threat of traffic (Wilde[8], Adams[3], pp. 128-145, Adams[9]).

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