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Summary:

Speed and road accidents: an evaluation of the Power Model

The relationship between speed and road safety is a controversial topic. In this report, the relationship between speed and road safety has been evaluated by means of a meta-analysis of studies that provide estimates of how changes in speed affect the number of road accidents and the number and severity of injuries to road users.

The Power Model

This study was designed to evaluate the Power Model of the relationship between speed and road safety. This model has been proposed by the Swedish road safety researcher Göran Nilsson. According to the Power Model, the effects of changes in speed on the number of accidents and the severity of injuries can be estimated by means of a set of power functions.

A power function is a mathematical function that relates two variables to each other by raising values of one of the variables to a power in order to obtain values for the other variable. Any function in which a variable is raised to a certain exponent is called a power function (not to be mixed up with an exponential function, which is e (e = 2.71828) raised to an exponent). The Power Model describes the relationship between speed and road safety in terms of six equations. As an example, the equation referring to fatal accidents is:

$$\frac{\text{Fatal accidents after}}{\text{Fatal accidents before}} = \left(\frac{\text{Speed after}}{\text{Speed before}}\right)^4$$

If speed is reduced from 100 km/h to 90 km/h, the ratio speed after/speed before equals 90/100 = 0.9. Raising 0.9 to a power of 4 gives (0.9 · 0.9 · 0.9 · 0.9) 0.656. This means that the number of fatal accidents is estimated to go down to 0.656 times the initial number, corresponding to a reduction of 34.4 percent.

The Power Model consists of one equation for fatalities, one for fatal and serious injuries and one for all injured road users. Moreover, there is one equation for fatal accidents, one for accidents involving fatal or serious injury, and one for all injury accidents. An exponent of 4 is proposed for fatal accidents, an exponent of 3 for accidents involving fatal or serious injury, and an exponent of 2 for all injury accidents. For fatalities an exponent larger than 4, but smaller than 8 is proposed.

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For fatal and serious injuries, the exponent is between 3 and 6. For all injured road users, the exponent is between 2 and 4. Changes in the number of accidents or accident victims are modelled as a function of the relative change in the mean speed of traffic.

The Power Model has been widely employed to estimate the expected effects of changes in speed. The objective of the research presented in this report was to evaluate the validity of the model by means of a systematic review and meta-analysis of relevant studies.

Systematic literature search and meta-analysis

A systematic search for relevant studies was made by accessing the TRANSPORT literature database. "Speed and accidents" was used as search terms. A total of 1.469 entries were found. The computer search was supplemented by a manual search of selected scientific journals and previous reviews of the relationship between speed and road safety. A total of 175 studies were identified as relevant. The results of these studies were summarised by means of a meta-analysis. To be included in the meta-analysis, a study had to state the relative change in speed and the relative change in the number of accidents or accident victims. 98 studies, containing 460 estimates of the effects of changes in speed were included in the meta-analysis. 77 studies identified as relevant could not be included in the meta-analysis, mostly because they did not report the information needed.

Summary estimates of exponents were developed by means of meta-analysis. These analyses were performed by means of traditional techniques as well as techniques for meta-regression (multivariate models). Six models were developed. In addition, several versions of these models were employed in sensitivity analyses. The possible presence of publication bias was tested for by means of the trim-and-fill technique.

Results and interpretation of them

The results give clear support to the Power Model. The values of the exponents are not perfectly identical to those proposed by the Power Model, but they are close to them and exhibit a pattern that conforms to the Power Model.

The Power Model, as stated, contains an element of inconsistency. To explain this, consider the following. The exponent for fatal accidents is 4. The exponent for accidents involving fatal or serious injury is 3. The exponent for all injury accidents, including fatal accidents, is 2. Thus, fatal accidents are represented by an exponent of 4 when considered exclusively, but by an exponent of 3 when merged with serious injury accidents, and an exponent of 2 when merged with all injury accidents. The exponents of 4, 3 and 2 cannot all be true at the same time for the same category of accidents. The Power Model was therefore reformulated, so that the various levels of accident- or injury severity do not overlap, but are treated as mutually exclusive categories. The following exponents are the best estimates for the modified version of the Power Model:

	Best estimate of	95% confidence

Accident or injury severity	exponent	interval
Fatalities	4.5	(4.1 – 4.9)
Seriously injured road user	3.0	(2.2 – 3.8)
Slightly injured road user	1.5	(1.0 – 2.0)
All injured road users (severity not stated)	2.7	(0.9 – 4.5)
Fatal accidents	3.6	(2.4 – 4.8)
Serious injury accidents	2.4	(1.1 – 3.7)
Slight injury accidents	1.2	(0.1 – 2.3)
All injury accidents (severity not stated)	2.0	(1.3 – 2.7)
Property-damage-only accidents	1.0	(0.2 – 1.8)

Source: TØI report 740/2004

These results show that there is a strong statistical association between speed and road safety. As an example, it can be estimated that a 10 percent reduction in the mean speed of traffic will result in a 37.8 reduction of the number of fatalities.

The results show the statistical relationship between speed and road safety. Correlation does not necessarily imply causation. Is there a causal relationship between changes in speed and changes in road safety? The report concludes that the relationship is indeed causal. This is based on the following arguments:

1. There is a very strong statistical relationship between speed and road safety. It is difficult to think of any other risk factor that has a more powerful impact on accidents or injuries than speed.
2. The statistical relationship between speed and road safety is very consistent. When speed goes down, the number of accidents or injured road users also goes down in 95% of the cases. When speed goes up, the number of accidents or injured road users goes up in 71% of the cases. While it may to some extent be possible to offset the impacts of higher speed by introducing other road safety measures, a reduction in speed will almost always improve road safety.
3. The causal direction between speed and road safety is clear. Most of the evidence reviewed in this report comes from before-and-after studies, in which there can be no doubt about the fact that the cause comes before the effect in time.
4. The relationship between speed and road safety holds up when potentially confounding factors are controlled for. There is no evidence of a weaker relationship between speed and road safety in well-controlled studies than in less well-controlled studies.
5. There is a clear dose-response relationship between changes in speed and changes in road safety. The larger the change in speed, the larger the impact on accidents or accident victims.

6. The relationship between speed and road safety appears to hold universally and is not influenced by, for example, the country in which it has been evaluated, when it was evaluated or the type of traffic environment in which it was evaluated.
7. The relationship between speed and road safety can be explained in terms of elementary laws of physics. These laws of physics determine the stopping distance of a vehicle and the amount of energy released when an impact occurs.

It is concluded that there is a law-like and causal relationship between speed and road safety. This relationship is adequately described by means of the Power Model.

Some limitations of the study

The study has a number of limitations. The most important of these can be summarised as follows:

1. A fairly high proportion of the relevant studies, 77 out of 175, could not be included in the meta-analysis. An assessment has been made of whether exclusion of these studies has influenced the results of the study. It is concluded that exclusion of these studies from the meta-analysis is unlikely to have affected its results materially.
2. There is a possibility of publication bias in the data, meaning that studies that are regarded as useless, or whose findings are difficult to interpret, are less likely to be published than other studies. A formal tests for publication bias was conducted and no evidence of it was found.
3. The results may to some extent reflect the effects of other road safety measures, not just changes in speed. This is true as far as individual studies are concerned. It is, however, not true as far as the results of the meta-analyses are concerned. In these studies, the effects of other road safety measures were controlled for statistically by means of multivariate analyses. Hence, the summary estimates of power show the effects of speed only.
4. Data concerning speed and/or accidents can be unreliable. This is obviously correct. However, the impact of unreliable data is always to attenuate statistical relationships, never to reinforce them. It is therefore highly likely that the true effects of speed on road safety are underestimated in this study.
5. A number of studies contain multiple estimates of effect. If these estimates are statistically dependent on each other, variance is reduced and a spuriously strong relationship between speed and road safety can be found. The variance of study findings was assessed, and no evidence of any within-study statistical dependency was found.

6. The study does not state what the relationship between speed and accidents is for specific types of accidents or in specific types of traffic environment. Unfortunately, the data did not allow the relationship between speed and accidents to be estimated for specific types of accidents. As far as different types of traffic environment are concerned, the analyses gave no indication of any differences with respect to the impacts of speed on road safety.
7. The study has evaluated the Power Model only. Very many other models can be imagined to summarise the relationship between speed and road safety. Only two alternative models have been examined. One of these is a linear model, according to which it is the absolute change in speed, not the relative change, that produces changes in road safety. The other model is a logistic model, according to which the effects of changes in speed depend on the initial level of speed. The linear model is highly implausible. The logistic model is somewhat more plausible, but the data did not permit it to be tested in a sufficiently stringent manner. It is concluded that the Power Model is to be preferred to other models because of its generality and simplicity.

The overall conclusion is that the limitations of the study are unlikely to have influenced its findings.

Practical implications

Speed has been found to have a very large effect on road safety, probably larger than any other known risk factor. Speed is a risk factor for absolutely all accidents, ranging from the smallest fender-bender to fatal accidents. The effect of speed is greater for serious injury accidents and fatal accidents than for property-damage-only accidents.

If government wants to develop a road transport system in which nobody is killed or permanently injured, speed is the most important factor to regulate. The report argues that driver speed choice may not always be perfectly rational; hence, a legitimate basis exists for limiting the freedom of choice with respect to speed. The need for such regulation is very widely recognised, as nearly all motorised countries have an extensive system of speed limits and a programme of enforcement. Speed limits and their enforcement are very important road safety measures.