Summary:

The Power Model of the relationship between speed and road safety

Update and new analyses

The Power Model remains a valid model of the relationship between speed and road safety according to new analyses presented in this report. The effects on road safety of changes in speed are found to vary depending on initial speed. In general, changes in speed have a smaller effect at low speeds than at high speeds.

Background and research problem

In 2004, the Institute of Transport Economics published the report: "Speed and road accidents: an evaluation of the Power Model" (report 740/2004). In 2007, the first author of that report, Rune Elvik, defended it for the degree Ph. D. at Aalborg University. He then announced his intention to update the study.

This report presents an updated analysis of the relationship between speed and road safety. The original analysis was based on 98 studies containing a total of 460 estimates of the effect on road safety of changes in speed. This report is based on 115 studies containing 526 estimates of effect. The following questions are the focus of the study:

1. Does the Power Model adequately describe the relationship between changes in speed and changes in road safety, or should it be replaced by a different model?
2. Is a revision of the Power Model, in particular the values of the exponents that form the core of the model, justified?

In addition to analysing these questions, the report discusses a number of other issues, including the normative basis of speed limits (as opposed to not regulating the choice of speed).

The Power Model

The Power Model was proposed by the Swedish researcher Göran Nilsson. The model describes the relationship between changes in speed and changes in the number of accidents or the number of accident victims in terms of six power functions, all of which have the following form:

$$\frac{Accidents\ after}{Accidents\ before} = \left(\frac{Speed\ after}{Speed\ before}\right)^{Exponent}$$

The relative change in the number of accidents (or killed or injured road users) is estimated by raising the relative change in speed to an exponent. The value of the exponent varies according to accident- or injury severity.

The Power Model is a monotonic function, i.e. the value of the function increases throughout the range. Or to say it more colloquially: The higher the speed, the greater the number of accidents. And conversely: The lower the speed, the lower the number of accidents. Speed refers to the mean speed of traffic.

Re-analysis, update and development

Three re-analyses of the original study have been made. One by Ezra Hauer, one by James Bonneson, and one by Max Cameron and Rune Elvik. All these re-analyses conclude that the effect of a given relative change in speed (e.g. −10 %) depends on the initial level of speed. This is not consistent with the Power Model. A tendency is seen for changes in relatively low speeds (below about 60 km/h) to have smaller effects on safety than changes in relatively high speeds (above about 60 km/h). This suggests that one should either abandon the Power Model in favour of a model which is consistent with varying effects of given relative changes in speed – like the logistic model – or develop several versions of the Power Model adopted to varying levels of initial speed. One type of model that can accommodate varying effects of speed is a Box-Cox model, in which the curvature of the relationships between two variables is permitted to vary continuously.

Although the updated study was not based on a dramatically larger number of studies (115 versus 98) or estimates of effect (526 versus 460) than the original study, the findings do differ from the original study with respect to at least two key factors.

In the first place, the exponents are found to vary depending on initial speed. In order to capture this, two new versions of the Power Model have been developed. One version applies to urban and residential roads, the other version applies to rural roads and freeways. In addition, a version applying to all roads has been kept. In the second place, the values of the exponents have been adjusted. There is tendency for the exponents to become smaller over time, suggesting that the effects of speed are also becoming smaller. It is nevertheless clear that speed remains a very important risk factor both for accident occurrence and injury severity.

The revised Power Model

Table S.1 presents exponents that have been developed for the revised Power Model. Nearly all the exponents are very close to study estimates. The exponents referring to all injury accidents and to all injured road users have been adjusted downwards, in order to be consistent with the exponents referring to specific levels of accident- or injury severity. The exponents are somewhat lower than those found in the original study.

Table S1: Exponents for the revised Power Model

	Summary estimates of exponents by traffic environment					
	Rural roads/freeways		Urban/residential roads		All roads	
Accident or injury severity	Best estimate	95 % confidence interval	Best estimate	95 % confidence interval	Best estimate	95 % confidence interval
Fatal accidents	4.1	(2.9, 5.3)	2.6	(0.3, 4.9)	3.5	(2.4, 4.6)
Fatalities	4.6	(4.0, 5.2)	3.0	(-0.5, 6.5)	4.3	(3.7, 4.9)
Serious injury accidents	2.6	(-2.7, 7.9)	1.5	(0.9, 2.1)	2.0	(1.4, 2.6)
Seriously injured road users	3.5	(0.5, 5.5)	2.0	(0.8, 3.2)	3.0	(2.0, 4.0)
Slight injury accidents	1.1	(0.0, 2.2)	1.0	(0.6, 1.4)	1.0	(0.7, 1.3)
Slightly injured road users	1.4	(0.5, 2.3)	1.1	(0.9, 1.3)	1.3	(1.1, 1.5)
Injury accidents – all	1.6	(0.9, 2.3)	1.2	(0.7, 1.7)	1.5	(1.2, 1.8)
Injured road users – all	2.2	(1.8, 2.6)	1.4	(0.4, 2.4) #	2.0	(1.6, 2.4)
PDO- accidents	1.5	(0.1, 2.9)	0.8	(0.1, 1.5)	1.0	(0.5, 1.5)

Confidence interval specified informally
Source: TØI-report 1034/2009

The normative foundations of speed limits

The report contains an analysis of the normative foundations of speed limits. The starting point of the analysis is the assumption that road users are rational in choosing speed. A distinction is made between subjective and objective rationality. This distinction is very rarely made in modern analyses relying on the theory of rational choice, but it makes perfect sense with respect to the choice of speed. It is argued that if road users are objectively rational in the choice of speed, the outcome will be optimal from a societal point of view and no speed limits are needed. Analysis shows, however, that road user choice of speed does not satisfy the requirements of objective rationality (although it is possible to model the choices as being subjectively rational). On this basis, it is concluded that speed limits are needed in order to guide road users in their choices so as to obtain more optimal outcomes.

It should be noted that the term “optimal outcomes” is equivalent to optimal speed from a socio-economic point of view. The choice of speed can be approached from many perspectives, and the choice of a perspective based on economic welfare theory in this report is clearly not meant to suggest that other perspectives cannot provide useful insights.