Reduction of the speed limit at highways: An evaluation of the traffic safety effect

Ellen De Pauw, Stijn Daniels, Melissa Thierie, Tom Brijs
Transportation Research Institute, Hasselt University, Belgium
Contact: ellen.depauw@uhasselt.be

Abstract

Speed is one of the main risk factors in traffic safety, as it increases both the chances and the severity of a crash. In order to achieve improved traffic safety by influencing the speed of travel, road authorities may decide to lower the legally imposed speed limits. In 2001 the Flemish government decided to lower speed limits from 90 km/h (56mph) to 70 km/h (43mph) on a considerable number of highways.

The present study examines the effectiveness of this measure by using a comparison group before- and after study to account for general trend effects in road safety. Sixty-one road sections with a total length of 116 km (72 miles) were included. The speed limits for those locations were restricted in 2001 and 2002. The comparison group consisted of 19 road sections with a total length of 53 km (33 miles) and an unchanged speed limit of 90 km/h (56mph) throughout the research period.

Taking trend into account, the analyses showed a 5% decrease [0.88; 1.03] in the crash rates after the speed limit restriction. A greater effect was identified in the case of crashes involving serious injuries and fatalities, which showed a decrease of 33% [0.57; 0.79]. Separate analyses between crashes at intersections and at road sections showed a higher effectiveness at road sections.

It can be concluded from this study that speed limit restrictions do have a favorable effect on traffic safety, especially on severe crashes. Future research should examine the cause for the difference in the effect between road sections and intersections that was identified, taking vehicle speeds into account.

1. Introduction

Speed is defined as an important risk factor in traffic safety[1]. Although crashes are caused by different factors and it is difficult to examine the role of speed[2], higher speeds are proven to increase the likelihood of getting involved in a crash. At higher speeds, drivers have less time to take in information and react, and the vehicle covers a greater distance before it stops. Crash severity also increases with speed, as the degree of kinetic energy at the time of the collision is higher[3].

In order to improve traffic safety, the Flemish government decided to lower the speed limits from 90 km/h to 70 km/h (56mph to 43mph) on a large number of highways. Highways were selected based on four main criteria, at least one of which had to be met:

- road sections without cycle paths or with cycle lanes close to the roadway;
- road sections with obstacles close to the roadways with a high risk of collision;

- road sections outside urban areas but with a high building density, and a high number of vulnerable road users; or
- road sections on which several severe crashes occurred in the past.

The speed limit was often only restricted at specific sections of roads, for example at sections between two intersections or at sections between two parts of an urban environment. The speed limit reduction was introduced for the majority of the locations in 2001-2002. No enforcement and educational efforts were combined with this change; only the traffic signs were adapted.

2. Background

Previous studies examining speed limit restrictions commonly show a favorable effect on traffic safety. A review of Elvik[4], who analyzed 115 studies with 526 estimates, generally found a decrease in crash numbers when the speed limit was reduced. A small number of studies (accounting for 5.7% in the fixed-effect statistical weight) did find unfavorable effects on traffic safety, but these were mostly small-scale and the results are considered unreliable.

The effect on crashes is often expressed through a power function to which the difference in speed has to be raised[2, 5]. Elvik[4] revised this Power Model and made a distinction between rural roads and freeways on the one hand and urban and residential roads on the other hand. For the category of freeways/rural roads, which are also the type of roads that are included in the present study, a power estimate of 4.1 was found for fatal crashes. For serious injury crashes he found a power of 2.60. The analysis of all injury crashes, without a distinction to the severity of the crash, resulted in a power of 1.6.

When these powers are applied to the change in speed from 90 km/h to 70km/h this would lead to a decrease of 64% in the number of fatal crashes, 48% in the severe injury crashes and 33% in all injury crashes. In addition, Elvik [6] analyzed this relationship, according to the initial speed limit, through the application of two models: (1) an exponential function; (2) the Power Model. A slightly higher support was given to the exponential function, which showed an increase of 1.58 in the number of fatal crashes if speed increased with 1km/h from an initial speed of 85km/h. The number of injury crashes was estimated to increase with 1.21. Starting from an initial speed of 75 km/h an increase of 0.79 fatal crashes with an increase by 1 km/h was found, for the injury crashes this was 0.86.

A restriction in the obeyed speed limit will not necessarily lead to a proportional effect on driving speeds. McCarthy[7] showed that a lot of factors can mediate the effect of speed limits on traffic safety; in particular, the driver’s chosen speed is important. In turn, this choice is influenced by different elements, such as socio-economic factors, personal risk perception and the extent of enforcement. In addition, road conditions and the vehicle have an effect. When a speed limit is not in accordance with the road conditions, this limit will not be maintained or it will barely be maintained.

3. Data

The treated group included all road sections that had a reduction in the speed limit from 90 km/h to 70 km/h during 2001 and 2002, located in Limburg, one of five provinces in Flanders, Belgium. Road sections on which other measures were performed during the research period that could have had an effect on travel speeds or traffic safety were excluded. Therefore, local authorities were asked to report whether, in addition to lowering the speed limit, other measures were implemented during the research period. Examples of possible other treatments are changes to traffic regulations such as the right-of-way rules and changes in the infrastructure, such as narrowing or broadening roads. Locations that only had some small changes in infrastructure, such as repair and maintenance works, were not excluded.

Eventually, 61 road sections were included with a total length of 116 km, located in 16 different municipalities in the province of Limburg. The length of the sections ranged from 0.1 to 6.04 km. For most of the road sections a speed limit restriction was applied in 2002, 13 had an adaptation in 2001. The comparison group consisted of 19 sections, with a total length of 53 km. The comparison locations were all located in the province of Limburg. As shown in Table 1, most of the road sections (80%) are situated at local roads, 15% are secondary roads that connect, collect and distribute at the local and intercity level, 5% are primary roads which have the function of connection, collection and distribution at the Flemish level. The majority of road sections were situated outside the urban area (72%), and have 2x1 lanes (92%). Figure 1 shows examples of roads that were adapted.

	Treated group	**Comparison group**
	Number of locations (%)	
Road category:		
- Primary	3 (5%)	1 (5%)
- Secondary	9 (15%)	5 (26%)
- Local	49 (80%)	13 (68%)
Urban area		
- Inside	17 (28%)	2 (10%)
- Outside	44 (72%)	17 (90%)
Number of lanes		
- 2x1	56 (92%)	16 (84%)
- 2x2	4 (7%)	0 (0%)
- 3x1	1 (2%)	3 (16%)

Table 1: Main characteristics of the treated and comparison locations (Agency of Roads and Traffic, Ministry of Mobility and Public Works)

Figure 1: Examples of roads at which the speed limit was restricted from 90 km/h to 70km/h (Source: Google Street View)

At the time of the study, crash data for Belgium was available up until 2009 (Federal Public Service Economy, Statistics Department). However, geo-coded crash data was required, in order to select the crashes at the treated locations. This data was available from 1996 until 2007 (Ministry of Mobility and Public Works, Agency of Roads and Traffic). As a result, the before period starts from 1996 to 2000/2001, the after period from 2002/2003 to 2007.

The year during which the speed limit was adapted, 2001 or 2002, was excluded from the research period. Two groups of crash data were used, based on the severity of crashes. The first group included all injury crashes, in which at least one person was slightly injured. Crashes with property damage only were not included, as data on these crashes is not gathered systematically. The second group only included crashes with seriously injured persons (defined as any person involved in a traffic crash and needing hospitalization for more than 24 hours) and fatally injured persons (any person who, as a result of a traffic crash, died on the spot or within 30 days of the crash).

The spatial analysis program ArcGIS version 9.3 was used to select the crashes. A buffer of 10 metres was applied to make sure all crashes at the selected locations were included. A distinction was made between crashes on road sections and crashes at intersections.

On average, 322 injury crashes per annum occurred at the treated locations. 55% took place at intersections, 45% at road sections. The comparison group consisted of 64 injury crashes per year, with an occurrence of 44% at intersections. In the case of severe crashes an average of 74 crashes per annum were selected for the treated group, with a proportion of 48% at intersections. On average, the comparison group comprised 21 severe crashes, with 37% occurring at intersections. An initial view is given by Figure 2, which shows the mean crash rates per km, both for all injury crashes and the more severe crashes in the treated and comparison group. A decrease can be observed for all groups and in the case of severe crashes in particular, this is stronger in the treated group, when compared to the comparison group.

No data was available in relation to traffic volumes or travel speeds at the treated and comparison locations.

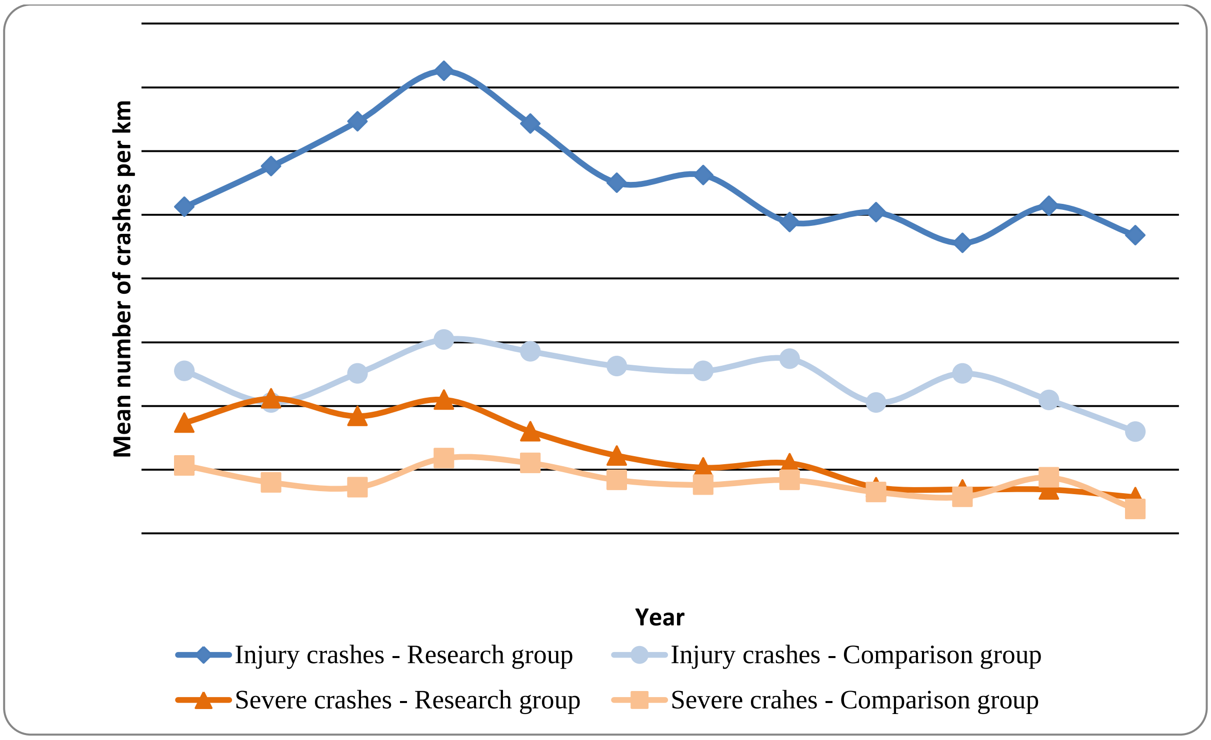

Figure 2: Mean crash numbers per km in the treated and comparison group from 1996 to 2007, both for injury crashes and more severe crashes

4. Method

To evaluate the effectiveness of a traffic safety measure, the most commonly used study design is a before and after (B&A) study[8,9], which compares the number of crashes after the implementation of a measure with the number of crashes at the same location before implementation. In the present study the number of crashes after the speed limit reduction is compared with the number of crashes before this reduction.

As different elements may have been changed during the study period and could have had an autonomous effect on the occurrence of crashes, it is important to take those effects into account. These elements can include traffic safety campaigns, stronger enforcement, adaptations of infrastructure, or changes in traffic volume. In order to control for this general trend effect, comparison locations were selected which were similar to the treated locations (for example in geometric design, traffic volumes and vehicle fleet[10]), but differed in that the speed limit remained 90 km/h during the whole research period.

Evaluation per location

The effectiveness of lowering the speed limit is first calculated per location, and can be expressed in an index of effectiveness (Eff)[11], which shows the relative change in the crash rates from before to after. When the index is lower than 1, this shows that the crashes decreased and the measure had a favorable effect on traffic safety. An index higher than 1 indicates a higher crash rate after the implementation of the measure, compared to before. The equation has to be adapted for trend effects. Therefore, it is assumed that the treated locations followed the same trend as the comparison group. This trend is reflected by the evolution of the crash rates from before to after in the comparison group. Consequently, the effect estimate can be expressed as:

$$\text{Eff} = \frac{L_{after}}{L_{before} * \frac{C_{after}}{C_{before}}} = \frac{L_{after}/L_{before}}{C_{after}/C_{before}} \qquad [3]$$

L_{after}= number of crashes on location L after the measure
L_{before}= number of crashes on location L before the measure
C_{after}= number of crashes in the comparison group after the measure
C_{before}= number of crashes in the comparison group before the measure

The reliability of this estimate is assessed by the 95% confidence interval (CI):
95% CI, lower limit = exp[ln(eff) – 1.96 * s]
95% CI, upper limit = exp[ln(eff) + 1.96 * s] [4]

The standard deviation (s) is the root of the variance (s^2)

$$s^2 = \frac{1}{L_{after}} + \frac{1}{L_{before}} + \frac{1}{C_{after}} + \frac{1}{C_{before}} \qquad [5]$$

Effectiveness across different locations
In addition to an individual analysis per location, a meta-analysis – which calculates the overall effect of all locations with an adapted speed limit – can be carried out[12]. To count the overall effect, every location is given a value that is inversely proportional to the variance:

$$w = \frac{1}{S^2} \qquad [6]$$

Suppose that the measure was implemented at m different locations, the weighted mean index of effectiveness of the measure over all locations (EFF) is:

$$\text{EFF} = \exp\left[\frac{\sum_{l=1}^{m} w_l * \ln(effl)}{\sum_{l=1}^{m} w_l}\right] \qquad [7]$$

The estimation of a 95% confidence interval is

$$95\%\ \text{CI EFF} = \exp\left[\frac{\sum_{l=1}^{m} wl * \ln(effl)}{\sum_{l=1}^{m} wl} \pm 1.96 * \frac{1}{\sqrt{\sum_{l=1}^{m} wl}}\right] \qquad [8]$$

5. Results

The results of the analyses are shown in Table 2. When each location is analyzed separately, a decrease in injury crashes is found at 62% of the locations after lowering the speed limit from 90 km/h to 70 km/h. Furthermore, a separate analysis is carried out for crashes that occurred at intersections and at road sections. There was a decrease in crash rates at intersections at 43% of the locations. At road sections a decrease is found at 70% of the locations. In the case of the fatal and serious injury crashes, a decrease is found at 67%

of the locations. A distinction between road sections and intersections showed a decrease in severe crashes at 49% and 67% of the locations, respectively. At the road sections 7 locations (12%) also had an index equal to 1.

The meta-analysis for the total number of injury crashes showed a decrease in crash rates of 5% after lowering the speed limit. This decrease was only significant at the 25% level. For crashes that occurred at intersections, an increase of 11% is found, significant at the 10% level. On the contrary, analysis of crashes at road sections resulted in a significant decrease of 11%. A meta-analysis for the more severe crashes showed a significant decrease of 33% at all treated locations. This strong decrease was mainly found for crashes that occurred at road sections, for which a significant decrease of 36% was found. The severe crashes at intersections showed a decrease of 6%, which was non-significant. These results clearly show a more favorable effect was found for the severe crashes, compared to the total number of injury crashes. Higher effectiveness is found for the occurrence of crashes at road sections compared to intersections.

Analysis per location						
	Total		**Intersections**		**Road sections**	
	# eff < 1	**# eff >1**	**# eff < 1**	**# eff >1**	**# eff < 1**	**# eff >1**
Injury crashes	38 (62%)	23 (38%)	26 (43%)	35 (57%)	43 (70%)	18 (30%)
Severe crashes	41 (67%)	20 (33%)	30 (49%)	31 (51%)	41 (67%)	13 (21%)
Meta-analysis						
	Total		**Intersections**		**Road sections**	
	Eff [95% CI]		**Eff [95% CI]**		**Eff [95% CI]**	
Injury crashes	0.95 [0.88; 1.03]		1.11 [1.00; 1.23]		0.89 [0.80; 0.99]	
Severe crashes	0.67 [0.57; 0.79]		0.94 [0.73; 1.20]		0.64 [0.52; 0.73]	

Table 2: Results of the B&A study with correction for trend effects

6. Discussion

The analyses clearly showed a higher effectiveness for more severe crashes with serious injuries and fatalities compared to all injury crashes. This can be ascribed to the fact that speed is directly related to injury severity in a crash. This is different than the probability of being involved in a crash, which is more complex, as the occurrence of crashes can seldom be attributed to a single factor[13]. The analyses also showed a stronger effectiveness at road sections compared to intersections, both for injury crashes, for which even a contradictory was found, and the more severe crashes. This is more difficult to explain. Crashes that occur at intersections may be less influenced by speed compared to road stretches, and causation might rather be related to maneuvers, for example turning left. This explains why no decrease was found, but this does not explain why an increase is found. A possible cause for this increase in the number of crashes is increase in the variance of travel speeds.

Lowering the speed limit will not automatically lead to a change in travel speeds by all drivers. Factors such as habits, non-acceptance of the new measure or inattentiveness might explain why the actual speed adaptation is lower than the required speed adaptation[7]. Furthermore, the speed limit change was only communicated by adapting traffic signs. Parker[14] stated that changing posted speed limits alone, without additional enforcement, educational programs or other engineering measures, only has a minor effect on driver behavior. The infrastructure of the road was also not adapted, which makes it less appealing for drivers to adapt their behavior, whereas others will strictly follow the rules. This can lead to an increase in the variance in travel speeds, which is an important risk factor for the occurrence of crashes[15].

Changes in speed behavior will not necessarily result in an equivalent effect on traffic safety. As formulated by Nilsson[2] and Elvik[2,4,6] , this relationship can be expressed by power estimations of the difference in speeds. In a back-of-the-envelope calculation this theory can be compared with the results from the present study, and the power estimations can be applied to observed travel speeds at Flemish roads. For this calculation the power estimations are used that resulted from the study by Elvik[4], from which we applied the power estimations for rural roads and freeways, as these are also the type of roads that are included in the present study. In 2007 the mean speed at 70 km/h roads was 75 km/h, at roads with a limit of 90 km/h this was 82.5 km/h. The V_{85} was respectively 95.1 km/h and 85.6 km/h[16]. Using the power estimations on these speeds resulted in an estimated decrease in crash rates between 14% and 35%, as shown in Table 3.

	Mean speeds 82.5 → 75 km/h	V85 speeds 95.1→85.6 km/h
Fatal injury crashes	-32%	-35%
Serious injury crashes	-22%	-24%
Injury crashes	-14%	-15%

Table 3: Estimation of effect in number of crashes using power estimations by Elvik (2009) for mean and V85 speeds at 90 and 70 km/h roads in Flanders in 2007

The results from our analyses are less favorable with respect to all injury crashes. In the case of severe crashes the results are more in line with these theoretically expected results. However, this reasoning lacks validity due to its non-experimental setting. We would recommend a more detailed analysis of the speed behavior on the roads in question.

7. Conclusions

The data for the study sample suggests that the restriction of the speed limit from 90 km/h to 70 km/h at highways in Flanders has a favorable effect on crashes, mainly the most severe ones.

With respect to injury crashes, a more favorable effect was found for crashes that occurred at road sections, for which a decrease was found, whereas an increase was identified for crashes at intersections. Changes in variances of travel speeds may be a causal factor. However, future research should examine this in a more in-depth manner.

This study was unable to obtain data on travel speeds. Future research is required to examine the relationship between the speed limit and the travel speeds of the driver, and the effect on traffic volumes.

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