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A before-after study of the effects on safety of environmental speed limits in the city of Oslo, Norway

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ABSTRACT

Starting in the winter of 2004-05, a temporary speed limit of 60 km/h (ordinary speed limit: 80 km/h) was introduced on one of the major arterial roads in the city of Oslo, Norway as a measure to reduce air pollution, in particular the spread of micro-particles torn from the road surface by studded tyres. The speed limit, referred to as an environmental speed limit, was in force from November 1 to March 31. Similar speed limits were later introduced on other arterial roads in Oslo. This paper presents a before-and-after study of the effects of these speed limits on accidents. Four study designs were employed: (1) A simple before-after study; (2) A before-after study using the rest of Oslo as comparison group; (3) A before-after study based on accident rates; (4) An empirical Bayes before-after study. The latter design is widely regarded as the best, but its implementation in the current study was not straightforward. The number of injury accidents was reduced by about 25-35 percent according to all study designs. The estimate of effect did not differ much between the different study designs. It is reasonable to rule out confounding by chance variation, long-term trends, changes in traffic volume and regression-to-the-mean. It cannot be claimed, however, that the entire accident reduction was attributable to the environmental speed limits exclusively.

Key words: speed limit, before-after study, empirical Bayes method, city of Oslo

1 INTRODUCTION

Air pollution in winter has attracted considerable attention as a health hazard in the city of Oslo, Norway. There are many sources of pollution, but two of the most important are cars and the heating of houses. An important component of the pollution attributable to cars is the spread of micro-particles torn off the road surface by cars using studded tyres. These particles can be inhaled and may worsen respiratory problems in susceptible individuals. The amount of particles spread in the air depends on many factors. One of them is the speed of traffic. More particles are spread at a high speed than at a low speed.

Starting in the winter season from November 1, 2004 to March 31, 2005 a so called "environmental speed limit" was introduced on one of the arterial roads in the city of Oslo, national road number 4. This road passes through several suburbs in the northeast of Oslo. The speed limit was lowered from 80 to 60 km/h for a length of about 7.4 km. Annual average daily traffic volume (AADT) on the road varies from 42,000 vehicles at the start of the road (closest to the city centre) to about 28,000 vehicles at the end of the section subject to the environmental speed limit. An evaluation study published in 2005 (Hagen, Larssen and Schaug 2005) concluded that the spread of particles had been reduced. The mean speed of traffic was reduced from 76.8 to 67.2 km/h (more recent data on speed are used subsequently in this paper). The pilot project was regarded as a success and environmental speed limits in the period from November 1 to March 31 have now been introduced on two more arterial roads in the city of Oslo: (1) The ring 3 road, going around the city mainly through suburban residential areas, with a length of about 15.6 km and a daily traffic volume varying from about 50,000 vehicles (Western end) to about 70,000 vehicles (Eastern end); (2) European road 18, the main arterial in the West of the City, carrying a daily traffic volume of 70,000-80,000 vehicles and extending for about 4.7 km. Thus, three main roads in Oslo now have a speed limit of 60 km/h between November 1 and March 31 and a speed limit of 80 km/h the rest of the year. All these roads are multilane divided highways with no access points to adjacent properties and no at-grade junctions. The map in Figure 1 shows the roads that have the environmental speed limit.

Figure 1 about here

The objective of this paper is to evaluate the effects of the environmental speed limits on road safety. Although improving safety was not the chief reason for introducing the speed limits, lowered speed limits tend to be associated with a lower mean speed of traffic, which in turn very often leads to fewer accidents (Elvik 2009, Cameron and Elvik 2010). The study is based on data on accidents, speed and traffic volume provided by the Public Roads Administration, Region East.

2 DATA AND METHOD

2.1 Sources of data

For national road 4, the before-period was from 1998-99 to 2003-04 (six years). The after-period was from 2004-05 to 2009-10 (six years). The before-period for the ring 3 road was from 2002-03 to 2005-06 (four years) and the after-period from 2006-07 to 2009-10 (four years). For European road 18, the before-period was from 2004-05 to 2006-07 (three years) and the after-period from 2007-08 to 2009-10 (three years). Data were provided for these periods by the Public Roads Administration, although for the ring 3 road and European road 18 data for longer before-periods are likely to be available. Table 1 shows the number of accidents recorded in the before- and after-periods for each of the three arterial roads. The number of accidents refers to the period from November 1 to March 31.

Table 1 about here

For national road 4, the annual number of accidents varied between 5 and 21. All these accidents were police-reported injury accidents. Property-damage-only accidents are not reported in official accident statistics in Norway. For the ring 3 road, the annual count of accidents varied between 9 and 31. For European road 18, the annual count of accidents varied between 1 and 11. A declining trend over time was discernible on all three roads, although there were large fluctuations around the trend. Table 1 also shows traffic volume in million vehicle kilometres of driving before and after the environmental speed limits were introduced and the number of accidents in the rest of Oslo in the before- and after-periods.

2.2 Assessing the possible presence of selection bias

Although the environmental speed limits were not introduced for safety reasons, it is appropriate to check for the possible presence of selection bias. Selection bias would be present if the roads had an abnormally high or low number of accidents in the period before environmental speed limits were introduced (an abnormally high number of accidents is the more common problem). To determine if this was the case or not, one must compare the recorded number of accidents to an estimate of the expected number of accidents for similar roads. To assess whether the count of accidents in the before-period was abnormally high or low, a multivariate accident prediction model based on data for six years (2000-2005) for all national roads in Norway (about 27,000 km of road with an annual accident count of about 4,500 to 5,000 at the time the model was fitted) was applied to predict the number of accidents typically expected to occur on the roads. The accident prediction model predicted the number of accidents per kilometre of road per year. The model was of the form:

Predicted number of accidents = $e^{\sum_{i=1}^{n}(coefficients_i \,.\, variables_i)}$

The number of accidents was predicted by taking the exponential function of a sum of products of coefficients and variables. The model was fitted by means of negative binomial regression. Details of model coefficients are given in Table 2.

Table 2 about here

Table 2 shows the model coefficients, the standard errors of these coefficients and their P-values. Nearly all coefficients were highly statistically significant. The rightmost three columns of Table 2 show the coefficients that were used to estimate the model-predicted number of accidents for the three roads where environmental speed limits were introduced. All these roads (but not all roads that were used to develop the model) had a speed limit (in the before-period) of 80 km/h. All the treated roads also had status as trunk roads. Thus, only traffic volume and the number of lanes varied from road to road and between different sections of the same road.

A check of model predictions for all national roads in Oslo revealed that model predictions were systematically too low. The total recorded number of accidents on national roads in Oslo from 2000 to 2005 was 2481. The model-predicted number of accidents was 1870. A calibration factor (Highway Safety Manual 2010, part C, equation A-1 in Appendix A) of 2481/1870 = 1.327 was therefore applied to model predictions. A further problem was that the period used for fitting the model (2000-2005) was not identical to the before-periods for the three treated roads. Further calibration factors were therefore estimated to adjust for differences in the mean annual number of accidents during the actual before-periods for each of the treated roads and the period from 2000 to 2005. The calibration factor was 1.041 for national road 4, 0.972 for the Ring 3 road and 0.958 for European road 18.

As mentioned above, model output were estimates of the annual number of accidents per kilometre of road. However, neither accident data nor data on traffic volume for the treated roads were specified per kilometre per year. Thus, accident data for each of the three roads referred to the entire length of the road. Data on traffic volume in general referred to shorter sections. There were two sections on national road 4, three sections on the ring 3 road and two sections on European road 18. These sections had different lengths.

Model estimates were therefore re-scaled to refer to the actual lengths of the road sections and to the period from November 1 to March 31. To help convert model estimates to the relevant part of the year, month-by-month variation in the number of injury accidents in Oslo from 1998 to 2010 was studied. Figure 2 shows the curves for these years as well as a mean curve based on all years.

Figure 2 about here

The month-by-month fluctuations are highly consistent from year to year. The mean number of accidents per month for the whole period was used as an estimate of the typical month-to-month variation. The months of November, December, January, February and March had 35 percent of all injury accidents occurring during a year. The scaling factor for period was therefore 0.350.

The scaling factor for the length of road sections was section length in kilometres. Model estimates were thus adjusted as follows:

Adjusted expected number of accidents = $Pred_{model} \cdot C_M \cdot C_P \cdot C_L \cdot C_S$

The first term is the number of accidents predicted by the model. This is the number of accidents per kilometre of road per year. The first calibration factor, C_M, adjusts for the tendency of the model to predict too few accidents in Oslo. This calibration factor, 1.327, is identical for all roads. The second calibration factor, C_P, adjusts for differences between the period used to fit the accident prediction model and the actual before-period for each road. This calibration factor differs between the three roads. The third calibration factor, C_L, adjusts for the length of each road section. There are two sections on national road 4, three sections on the Ring 3 road and two sections on European road 18. The fourth calibration factor, C_S, adjusts for the season in which environmental speed limits are in force. This factor, 0.35, is identical for all roads.

To illustrate, the first section of national road 4 will be used as example:

Adjusted expected number of accidents = 2.73 · 1.327 · 1.041 · 3.00 · 0.35 = 3.96

The first of these numbers, 2.73, is the predicted number of accidents per kilometre of road per year. The second number, 1.327 is the model calibration factor adjusting for a too low predicted number of accidents. The third number, 1.041, adjusts for the difference in the number of accidents between the period used for model development (2000-2005) and the actual before period (1998-2003). The fourth number, 3.00 is the length of the road section in kilometres. The fifth number, 0.35, is the share of accidents typically occurring between November 1 and March 31.

The adjusted estimates of the predicted number of accidents turned out to be very stable from year-to-year. As an example, for national road 4 (both sections added), the adjusted predicted number of accidents was, respectively, 8.40, 8.38, 8.36, 8.34, 8.41 and 8.46 during the six years making up the before-period. These minor annual variations provide no information of analytic interest; moreover, the chief concern was whether the entire before-period had an abnormally high or low number of accidents, not whether the count of accidents in any particular year of the before-period deviated from the predicted number. It was therefore decided to add the predicted number of accidents for all years of the before period. For national road 4, the sum of the predicted number of accidents for six years in the before-period was 50.34.

2.3 Application of model predictions in empirical Bayes estimation

The recorded number of accidents in the before-period on national road 4 was 78, which is considerably higher than the predicted number of accidents. In the empirical Bayes method, the long-term expected number of accidents at a particular site is estimated as the weighted mean of the model-predicted number of accidents and the recorded number of accidents. The weight given to the model-predicted number of accidents is:

$$\text{Weight} = \alpha = \frac{1}{1+\frac{\lambda}{k}}$$

Here, λ is the model-predicted number of accidents and k is the inverse value of the over-dispersion parameter of the negative binomial regression model. In the model used in this study, k had a value of 2.41 (this equals 1/0.415 in which 0.415 is the over-dispersion parameter listed at the bottom of Table 2). This value refers to one kilometre of road and one year. The EB-estimate of the expected number of accidents is:

$$\text{EB-estimate of the expected number of accidents} = E(\lambda|r) = \alpha \cdot \lambda + (1 - \alpha) \cdot r$$

Here, α refers to the weight defined above, λ is the model-predicted number of accidents, adjusted as explained above, and r is the recorded number of accidents.

As noted by Hauer (2001) and Hauer et al. (2002), the weight assigned to the model-predicted number of accidents is sensitive both to the number of years model predictions refer to and to the length of the road sections. More specifically Hauer (2001) suggests that the over-dispersion parameter could be proportional to road length, i.e. $k \cdot L$. To obtain the EB-estimate of the expected number of accidents in the current study, the following approach was taken:

1. The adjusted predicted number of accidents per section of road per year was summed for all sections and all years to obtain a single estimate of the adjusted predicted number of accidents for the before-period for each of the three roads: national road 4, ring 3 road and European road 18. The adjusted predicted number of accidents included all calibration parameters discussed above.
2. The over-dispersion parameter, k, was adjusted according to road length. Road length was 7.39 km for national road 4, 15.59 km for the ring 3 road and 4.73 km for European road 18.
3. The weight, α, was thus estimated as follows:
    a. National road 4: $1/[(1 + 50.34)/(2.41 \cdot 7.39)] = 0.347$.
    b. Ring 3 road: $1/[(1 + 94.64)/(2.41 \cdot 15.59)] = 0.393$.
    c. European road 18: $1/[(1 + 32.96)/(2.41 \cdot 4.73)] = 0.336$.
4. The EB-estimates of the number of accidents expected to occur before introduction of the environmental speed limits were thus:
    a. National road 4: $(0.347 \cdot 50.34) + (0.653 \cdot 78) = 68.4$.
    b. Ring 3 road: $(0.393 \cdot 94.64) + (0.607 \cdot 83) = 87.6$.

    c. European road 18: $(0.336 \cdot 32.96) + (0.664 \cdot 22) = 25.7$.

5. The EB-estimates of the number of accidents expected to occur after introduction of environmental speed limits were obtained as follows:
    a. National road 4: $68.4 \cdot (1968/2222) = 60.6$.
    b. Ring 3 road: $87.6 \cdot (1267/1292) = 85.9$.
    c. European road 18: $25.7 \cdot (931/1048) = 22.8$.

It is seen that national road 4 had a considerably higher recorded number of accidents in the before-period than the model-predicted number of accidents. The Ring 3 road and European road 18 had a lower recorded number of accidents in the before-period than the model-predicted number of accidents. The EB-estimates of the number of accidents for the after-period were obtained by using the count of accidents in the rest of Oslo (i.e. not including the count of accidents on the treated roads) in the period from November 1 to March 31 each year as comparison group (see Table 1). As can be seen, the number of accidents in the rest of Oslo tended to be lower in the after-period than in the before-period.

2.4 Estimates of safety effects and their standard errors

Estimates of safety effects and the standard errors of these estimates were, to the extent possible, based on Hauer (1997). Denote by:

K = count of accidents on treated roads in the before-period

L = count of accidents on treated roads in the after-period

M = count of accidents in comparison group in the before-period

N = count of accidents in comparison group in the after-period

EA = expected number of accidents after on treated roads using the comparison group method = (N/M) · K

EB = empirical Bayes estimate of expected number of accidents in the after-period on treated roads

VEB = variance of empirical Bayes estimate of expected number of accidents

TB = traffic volume before

TA = traffic volume after

VT = variance of change in traffic volume from before to after

The best estimate of effect and the standard error of the estimate were estimated as follows in the various study designs:

Best estimate of effect in simple before-after = θ = (L/K)/(1+1/K)

Standard error in simple-before-after = $\theta \cdot \sqrt{(\frac{1}{K}+\frac{1}{L})/(1+\frac{1}{K})}$

Best estimate of effect in comparison group method = θ = [(L/K)/(N/M)]/(1+1/K+1/M+1/N)

Standard error in comparison group method = $\theta \cdot \sqrt{(\frac{1}{K}+\frac{1}{EA}+\frac{1}{M}+\frac{1}{N})/(1+\frac{1}{EA})}$

Best estimate relying on accident rates = θ = [(L/TA)/(K/TB)]/(1+VT/K^2)

Standard error in accident rate method = $\theta \cdot \sqrt{(\frac{1}{K}+\frac{1}{L})/(1+\frac{VT}{K \cdot K})}$

Best estimate in empirical Bayes method = θ = (L/EB)/(1+1/L+1/VEB+1/M+1/N)

Standard error in empirical Bayes method = $\theta \cdot \sqrt{(\frac{1}{K} + \frac{1}{VEB} + \frac{1}{M} + \frac{1}{N})/(1 + \frac{1}{VEB})}$

In general, an estimate of effect is regarded as statistically significant if the 95 % confidence interval (best estimate plus or minus 1.96 times the standard error) does not include the value of 1.00 (i.e. no change in the number of accidents). For further details, see Hauer (1997).

3 RESULTS

Estimated effects on accidents are shown in Table 3. The estimates are stated as accident modification factors. An accident modification factor of 0.80 corresponds to an accident reduction of 20 percent. Estimates shown in bold are statistically significant at the 5 percent level.

Table 3 about here

Estimates of effect based on the simple before-after study were obtained by dividing the count of accidents after by the count of accidents before. The estimates indicate that the number of accidents was reduced on all three roads, but only two of these reductions were statistically significant at the 5 percent level. For all roads as a group, the number of accidents was reduced by almost 33 percent. This reduction was statistically significant at the 5 percent level.

When the rest of Oslo was used as a comparison group, all estimates of effect became slightly smaller than in the simple before-after study. The overall accident reduction was about 27 percent and this was statistically significant at the 5 percent level. In the study relying on accident rates, the number of accidents before and after was divided by million kilometres of driving and the change in accident rate from before to after treatment was estimated. A reduction of accident rate was found on all roads. The overall reduction was 34 percent. This reduction was statistically significant at the 5 percent level.

In the empirical Bayes (EB) study, an estimate of the expected number of accidents was first obtained for the before-period, applying the adjustment factors explained in section 2.2. Then, an EB-estimate of the number of accidents expected to occur in the after-period was obtained by adjusting the before-period EB-estimate using the rest of Oslo as comparison group. The overall estimate of effect according to the EB-study was an accident reduction of 28 percent. This reduction was statistically significant at the 5 percent level.

An interesting question is whether the changes in the number of accidents are related to changes in the speed of traffic. On national road 4, the mean speed of traffic was reduced from 76.7 to 70.2 km/h during the period when environmental speed limits applied. On the ring 3 road, the mean speed of traffic was reduced from 76.3 to 69.9 km/h when environmental speed limits applied. On European road 18, the speed of traffic was reduced from 76.0 to 72.9 km/h when environmental speed limits applied. Thus, the smallest change in speed was found for European road 18, which had the largest percentage reduction in the number of accidents according to the EB-estimate of effect. The largest speed reduction was found for national road 4, which had the smallest percentage accident reduction according to the EB-estimate of effect. The size of the accident reduction does therefore not seem to be related to the size of the speed reduction in a simple positive manner. This suggests that the changes in the number of accidents are attributable not only to the environmental speed limits but also to other factors.

4 DISCUSSION

Environmental speed limits on major roads in the city of Oslo have been introduced to reduce air pollution. In general, however, lowering speed limits leads to lower mean speeds, which in turn improves road safety. It is therefore of interest to examine whether the speed limits of 60 km/h, which apply from November 1 to March 31 on three major roads in Oslo have had an effect on the number of accidents.

The results of the study presented in this paper suggest that the number of accidents has been reduced on the treated roads. When all treated roads are seen as one group the accident reduction is statistically significant in all study designs, but the confidence intervals are very wide and span from an accident reduction of about 48 percent (lower 95 % confidence limit in study using accident rates as estimator of effect) to an accident reduction about 10 percent (upper 95 % confidence limit in comparison group study). Thus the overall accident reduction found cannot be attributed to chance variation. It also cannot be attributed to long-term trends. Two of the study designs (before-after with comparison group and empirical Bayes before-after) controlled for this confounding factor, but still found an accident reduction. Changes in traffic volume were minor and cannot explain the changes in the number of accidents. Finally, regression-to-the-mean was present, but its overall influence on estimates of effect was small. For all roads as a group, regression-to-the-mean was associated with an accident reduction of 7.5 percent (from 183 accidents before to an estimated number of accidents of 169.3 after). Thus, it is reasonable to conclude that the accident reduction cannot be attributed to chance variation, long-term trends, changes in traffic volume or regression-to-the-mean.

Still, the absence of a relationship between the size of the accident reduction and the size of the speed reduction raises doubt as to whether the accident reduction can be attributed to the environmental speed limits only. On the other hand, there were only three roads and the speed data for the roads are not complete, in the sense that annual data on speed per road section is available. The overall mean speed reduction for all three roads as a group was from 76.3 to 70.6 km/h. According to the Power Model of the relationship between changes in the mean speed of traffic and changes in the number of accidents (Cameron and Elvik 2010), such a change is expected to reduce the number of injury accidents by close to 12 percent. If the relationship between speed and the number of injury accidents is modelled in terms of an exponential function (Elvik 2013), an accident reduction of 18 percent is predicted. The EB-estimate of the accident reduction, 27 percent, is slightly larger than these predictions, but it should be remembered that the 95 % confidence interval of the EB-estimate spans from an accident reduction of 44 percent to an accident reduction of 13 percent. Strictly speaking, one cannot therefore claim that the EB-estimate of effect is inconsistent with the predictions of the exponential model.

The empirical Bayes (EB) approach was used to control for regression-to-the-mean. A conservative interpretation of the EB-approach was adopted in this paper. Model predictions of the number of accidents were developed for each kilometre of road and each year. These predictions were added for all years in the before-period and all kilometres of road, as there was no meaningful variation in model predictions from year-to-year and because data on the recorded number of accidents were only available for the entire treated road, not kilometre-by-kilometre. The over-dispersion parameter used to compute the weight assigned to the model-predictions when estimating the site-specific expected number of accidents was adjusted by road length, based on Hauer (2001).

These analytic choices resulted in a somewhat conservative adjustment for regression-to-the-mean. The results are nevertheless judged to be reasonable. The count of accidents in the before-period was 183 in total and one would not expect such an accident count to be associated with large regression-to-the-mean effects. The standard error of an accident count of 183 is about 13.5, which corresponds to 7.4 percent of the count.

All non-treated roads in Oslo were used as a comparison group to control for long-term trends. This was regarded as appropriate, since the data clearly indicated that there was a downward trend in the number of accidents.

5 CONCLUSIONS

The following main conclusions can be drawn from the study reported in this paper:

1. The introduction of environmental speed limits during winter (November 1 – March 31) on major arterial roads in the city of Oslo, Norway, was associated with a reduction in the mean speed of traffic of about 7.5 percent. Speed was reduced on all three roads that had the temporary speed limit.
2. The number of injury accidents was reduced by about 25-35 percent. Estimates of effect based on different study designs are highly consistent, suggesting that the influence of various confounding factors is small.
3. The accident reduction cannot be attributed to chance variation, long-term trends, changes in traffic volume or regression-to-the-mean. It is, on the other hand, not entirely clear that the accident reduction was caused by the environmental speed limits exclusively.

ACKNOWLEDGEMENT

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Map of roads in Oslo with environmental speed limits in winter

Figure 2:

Month-by-month variation in the number of injury accidents in Oslo from 1998 to 2010

Table 1:

Accidents on treated roads, traffic volume and accidents in rest of Oslo before and after introduction of environmental speed limits

Table 2:

Accident prediction model used in the empirical Bayes study. Model coefficients, standard errors and P-values

Table 3:

Estimates of effect (accident modification factors) based on four study designs

Figure 1:

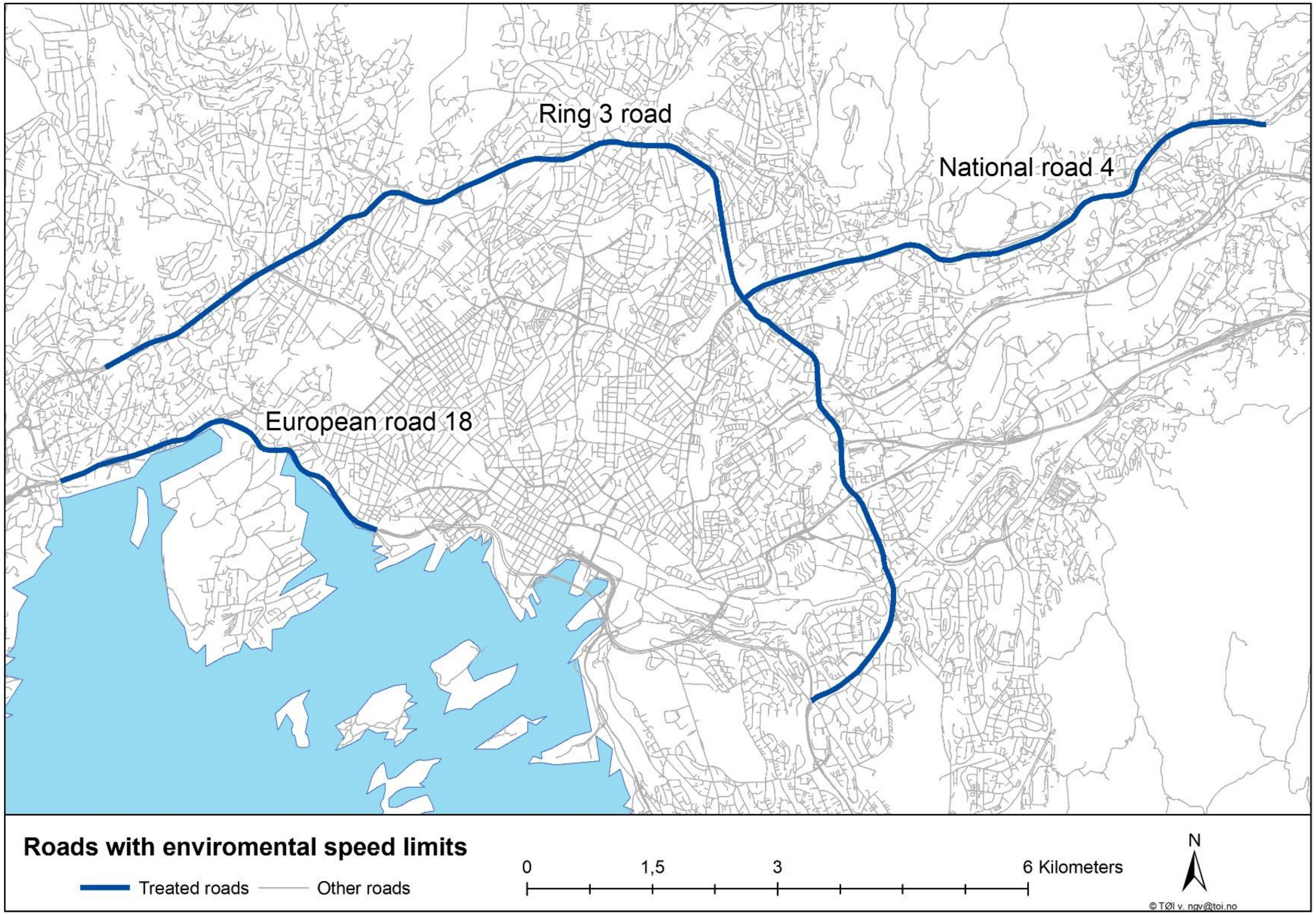
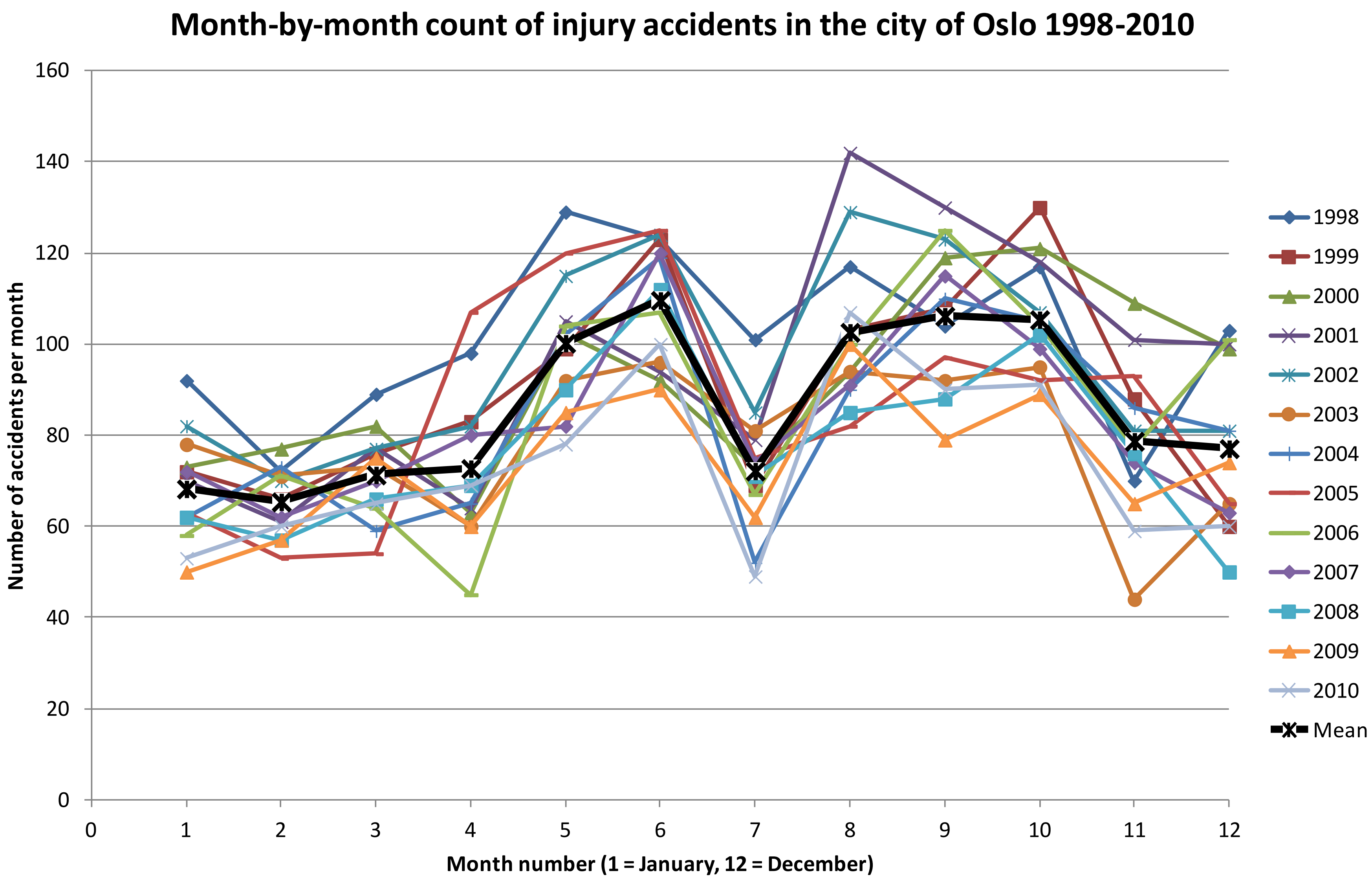

Ring 3 road
National road 4
European road 18
Roads with enviromental speed limits
Treated roads
Other roads
0
1,5
3
6 Kilometers
N
© TØI v. ngv@toi.no

Figure 2:



Month-by-month count of injury accidents in the city of Oslo 1998-2010
Number of accidents per month
Month number (1 = January, 12 = December)
0
20
40
60
80
100
120
140
160
0
1
2
3
4
5
6
7
8
9
10
11
12
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Mean

Table 1:

Site	Length (km)	Before-period	After-period	Count of accidents before	Count of accidents after	Million vehicle km before	Million vehicle km after	Accidents in rest of Oslo before	Accidents in rest of Oslo after
National road 4	7.39	1998/99-2003/04	2004/05-2009/10	78	49	229.84	223.32	2222	1968
Ring 3 around Oslo	15.59	2002/03-2005/06	2006/07-2009/10	83	62	533.30	554.93	1292	1267
European road 18	4.73	2004/05-2006/07	2007/08-2009/10	22	16	174.39	166.44	1048	931
Total	27.51			183	127	937.53	944.69		

Table 2:

Variable	Coefficient	Standard error	P-value	Coefficients applied to estimate model-predicted number of accidents (indicated by X): National road 4	Ring 3 road	European road 18
Constant term	-8.493	0.066	0.000	X	X	X
Natural logarithm of AADT	0.895	0.008	0.000	X	X	X
Dummy for speed limit 50 km/h	Reference	Reference	Reference			
Dummy for speed limit 60 km/h	-0.476	0.024	0.000			
Dummy for speed limit 70 km/h	-0.518	0.031	0.000			
Dummy for speed limit 80 km/h	-0.686	0.022	0.000	X	X	X
Dummy for speed limit 90 km/h	-0.891	0.051	0.000			
Dummy for speed limit 90 and class B motorway	-1.042	0.065	0.000			
Dummy for speed limit 90 and class A motorway	-1.626	0.071	0.000			
Dummy for speed limit 100 km/h	-1.863	0.101	0.000			
Dummy for speed limit change 80 to 70 km/h	-0.328	0.050	0.000			
Dummy for speed limit change 90 to 80 km/h	-0.0005	0.0002	0.028			
Dummy for speed limit change 90 to 80 km/h on class B motorways	0.279	0.095	0.003			
Dummy for speed limit change 80 to 70 km/h on European roads	-0.269	0.074	0.000			
Dummy for speed limit change 90 to 80 km/h on European roads	-1.114	0.192	0.000			
Dummy for speed limit change 90 to 80 km/h on European roads that are class B motorways	-0.607	0.133	0.000			
Natural logarithm of number of lanes + 1	0.443	0.052	0.000	X	X	X
Natural logarithm of junctions per km + 1	0.182	0.013	0.000			
Dummy for trunk road status	-0.173	0.015	0.000	X	X	X
Over-dispersion parameter	0.415	0.017	0.000			

Table 3:

	Accident modification factors and their standard errors according to study design							
	Simple before-after design		Before-after with comparison group		Before-after accident rates		Empirical Bayes before-after	
Site	**Best estimate**	**Standard error**	**Best estimate**	**Standard error**	**Best estimate**	**Standard error**	**Best estimate**	**Standard error**
National road 4	**0.62**	0.11	**0.70**	0.13	**0.63**	0.11	0.78	0.14
Ring 3 road	**0.74**	0.12	0.75	0.13	**0.69**	0.11	**0.71**	0.11
European road 18	0.70	0.22	0.78	0.26	0.72	0.23	0.64	0.19
All roads	**0.67**	0.08	**0.73**	0.09	**0.66**	0.08	**0.72**	0.08

Estimates shown in bold are statistically significant at the 5 percent level