The final publication is available in: Accident Analysis and Prevention, 59, 2013, 64-70. 10.1016/j.aap.2013.05.011

Factors influencing safety in a sample of marked pedestrian crossings selected for safety inspections in the city of Oslo

Rune Elvik, Michael W. J. Sørensen, Tor-Olav Nævestad

Institute of Transport Economics

Gaustadalleen 21, No-0349 Oslo, Norway

E-mail: re@toi.no, mis@toi.no, ton@toi.no

ABSTRACT

This paper reports an analysis of factors influencing safety in a sample of marked pedestrian crossings in the city of Oslo, Norway. The sample consists of 159 marked pedestrian crossings where a total of 316 accidents were recorded during a period of five years. The crossings were selected for inspection because of they were, for various reasons, regarded as sub-standard. The sample of crossings is therefore not representative of all pedestrian crossings in Oslo. Factors influencing the number of accidents were studied by means of negative binomial regression. Factors that were studied included the volume of pedestrians and vehicles, the number of traffic lanes at the crossing, the location of the crossing (midblock or junction), the type of traffic control, the share of pedestrians using the crossing and the speed of approaching vehicles. The analysis confirmed the presence of a "safety-in-numbers" effect, meaning that an increase in the number of pedestrians is associated with a lower risk of accident for each pedestrian. Crossings located in four-leg junctions or roundabouts had more accidents than crossings located in three-leg junctions or on sections between junctions. A high share of pedestrians crossing the road outside the marked crossing was associated with a high number of accidents. Increased speed was associated with an increased number of accidents.

Key words: marked pedestrian crossing, safety-in-numbers, negative binomial regression

1 INTRODUCTION

Marked pedestrian crossings are very common in urban areas. Such crossings are not always associated with improved safety for pedestrians. The effects of marked pedestrian crossings on safety have been found to be highly variable (Elvik, Høye, Vaa and Sørensen 2009) and many studies do not control very well for potentially confounding variables. The objective of this study is to identify some factors that influence safety in a sample of pedestrian crossings in the city of Oslo, Norway that were inspected in detail. The sample is not representative of all pedestrian crossings in the city. Moreover, it consists of marked pedestrian crossings only. It is therefore not possible to compare the safety of pedestrian crossings to the safety of informal crossing locations. On the other hand, a large number of variables were recorded for each pedestrian crossing. It should therefore be possible to estimate the relationship between these variables and the safety of the pedestrian crossings. The main research problems addressed in this paper are:

1. What are the principal factors influencing safety at pedestrian crossings?
2. Are the results of this study consistent with previous studies?

2 SAMPLE OF CROSSINGS AND DATA RECORDED FOR EACH CROSSING

The sample of marked pedestrian crossings was obtained by selecting crossings for detailed inspection based on one or more of the following criteria (Sørensen, Mosslemi and Akhtar 2010, Sørensen and Nævestad 2012):

1. Accident history: crossings with a history of accidents were selected.
2. Accident severity: crossing where accidents were severe, in particular where fatal accidents had occurred, were selected.
3. Speed limit: crossings located on roads with a speed limit of 50 or 60 km/h were selected.
4. Complaints: crossings for which the public had made complaints were selected.

The selected crossings were inspected in detail and measures designed to improve safety were proposed for each crossing. The first set of inspections (Sørensen, Mosslemi and Akhtar 2010) comprised 85 crossings. The second set of inspections (Sørensen and Nævestad 2012) comprised 75 crossings. These two samples were combined. One crossing was on a street that had been closed for motor vehicles. This crossing was omitted, leaving a total of 159 crossings for analysis. Accident data covered a period of 5 years, 2004-2008 in the first sample; 2006-2010 in the second sample. Crossings that had recorded at least one accident were over-represented. Nevertheless a total of 47 of the 159 crossings did not record any accidents. Table 1 shows the variables that were recorded for each crossing.

Table 1 about here

The two first variables listed were used as dependent variables in the analysis. The total number of accidents refers to all accidents recorded within 50 metres of each pedestrian crossing in each direction (i.e. covering a total road length of 100 metres). The mean number of accidents was 1.987. The total number was 316. Some accidents were judged to be related to the pedestrian crossing. There were a total of

149 of these accidents (mean 0.937 per crossing). Most of the other variables listed in Table 1 are independent variables that may influence the number of accidents.

3 NEGATIVE BINOMIAL REGRESSION MODELS

3.1 Exploratory analysis

There are few examples in the literature of studies resembling this study. The study that perhaps resembles this study the most is a study by Zegeer et al. (2005). In that study, the following accident prediction model was fitted to a sample consisting of marked pedestrian crossings and unmarked crossing locations:

$$\text{Expected number of accidents} = e^{\beta_0}(ADP)^{\beta_1}(ADT)^{\beta_2}e^{\beta_3 L_2}e^{\beta_4 L_4} \qquad (1)$$

Here, $e^{\beta 0}$ is the constant term, ADP is average daily pedestrian volume, ADT is average daily motor vehicle volume, L_2 refers to two-lane roads and L_4 refers to four-lane roads. Model parameters were determined by means of negative binomial regression analysis.

The model presented in equation 1 is common in studies that rely on composite exposure data, i.e. data on traffic volume for at least two groups of road users or two streams of traffic (e.g. vehicles entering junctions from the major and minor approaches). In order to develop a model that fits the data as closely as possible, an exploratory analysis of functional forms as suggested by Hauer and Bamfo (1997) is useful. In this paper, the cumulative residuals algorithm was applied to test two functional forms relating the number of accidents to traffic volume, which tends to exert a stronger influence on the number of accidents than many other variables included in a model. The following functional forms were compared:

Expected number of accidents = $e^{\beta_0}(PED)^{\beta_1}(MV)^{\beta_2}$ (2)

Expected number of accidents = = $e^{\beta_0}(PED)^{\beta_1}(MV)^{\beta_2}e^{\beta_3(PED \cdot MV)}$ (3)

The function in equation 2 has the same form as that used by Zegeer et al. (2005). PED denotes pedestrian volume, MV denotes motor vehicle volume. The function in equation 3 includes an interaction term, which is the product of pedestrian volume and motor vehicle volume.

The two functions were compared by examining the cumulative residuals plots (cureplots). When the total number of accidents was used as dependent variable, the function in equation 2 had positive cumulative residuals for most of the range of traffic volume (traffic volume was defined as the sum of pedestrians and vehicles). The function in equation 3 had a mixture of positive and negative cumulative residuals, suggesting a better fit to the data than the function in equation 2. The cureplot for equation 3 is shown in Figure 1.

Figure 1 about here

The results were very similar when the number of accidents related to the pedestrian crossing was used as dependent variable. The function in equation 3 once again produced the best fit and is shown in Figure 2.

Figure 2 about here

Based on this analysis, the functional form of equation 3 was used in the main analysis that included several independent variables in addition to traffic volume.

3.2 Choice of variables to include in accident prediction models

Table 1 lists the variables that were recorded for each pedestrian crossing. In order to identify factors influencing safety at these crossings, it was regarded as desirable to develop an accident prediction model containing as many independent variables as possible. However, since the sample consists of only 159 crossings, it is not possible to include more than about 15 independent variables in a model, based on the rule-of-thumb that the ratio between the number of units of observation and the number of variables should never be less than about 10:1. The following independent variables were included in the models fitted:

1. The natural logarithm of the total number of road users crossing at pedestrian crossings
2. The natural logarithm of annual average daily traffic (AADT)
3. The product of the number of road users crossing at pedestrian crossings and AADT
4. The number of legs at the crossing location (an indicator of the number of directions from which traffic that may conflict with crossing pedestrians enters)
5. The number of driving lanes at the crossing location (a count variable varying from 1 to 6)
6. The type of traffic control (none or traffic signals; coded as 0 or 1)
7. The percentage of road users crossing outside the marked crossing
8. The mean speed of motor vehicles approaching a marked crossing (km/h)

9. Whether formal warrants for the use of marked pedestrian crossings were satisfied or not (1 if satisfied, 0 otherwise).

Some descriptive statistics about these variables are provided in Table 2.

Table 2 about here

The first three of these variables are intended to capture the effect of traffic volume (both pedestrians and vehicles) on the number of accidents. The number of legs is intended as an indicator of the complexity of the traffic environment. The number of driving lanes indicates the width of the road at the pedestrian crossing. Formal warrants for the use of marked pedestrian crossings in Norway are defined in terms of the number of pedestrians crossing in the maximum hour and the number of motor vehicles. It is well known, however, that these warrants are not applied strictly and that a number of pedestrian crossings have been marked at locations where the warrants are not satisfied.

Two accident prediction models were developed; one using the total number of accidents as dependent variable, the other using accidents related to the pedestrian crossing as dependent variable. The models were fitted by means of negative binomial regression, applying SPSS version 18 software.

3.3 Comparing the effects of the independent variables

Models are stated in terms of a set of coefficients. The numerical values of these coefficients are not directly comparable and do not necessarily represents effects of similar magnitude. To be able to compare the coefficients, and determine which of the independent variables has the strongest relationship to the dependent variable it is useful to estimate elasticities. An elasticity shows the percentage change in the dependent variable associated with a 1 percent change in the independent variable. Elasticities can be calculated on the basis of the coefficients produced by negative binomial regression. A distinction can be made between three different cases (Fridstrøm et al. 1995, Washington, Karlaftis and Mannering 2011):

1. When a variable has been transformed to logarithmic scale, the model coefficient associated with the variable can be interpreted as an elasticity, i.e. as showing the percentage change in the number of accidents associated with a 1 percent increase in the value of the independent variable.
2. When a variable is measured as a count or numerical scale, the elasticity associated with the variable is calculated as: $\beta_k x_{ik}$, in which β_k is the coefficient associated with the kth independent variable and x_{ik} is the value of the kth independent variable for observation i. Elasticities are computed for each observation, but it is common to report only the average elasticity for all observations.
3. For dummy variables (variables taking on the values of 0 or 1), the elasticity is calculated as: $\frac{e^{\beta_i - 1}}{e^{\beta_i}}$ in which e denotes the exponential function and β_i is the coefficient for the dummy variable.

All three cases are represented in this study.

3.4 Goodness of fit of accident prediction models

Model goodness-of-fit was assessed in terms of the Elvik-index of goodness-of-fit (Fridstrøm et al. 1995). The Elvik-index is based on the over-dispersion parameter. The amount of over-dispersion found in a data set can be described in terms of the over-dispersion parameter, which is estimated as follows:

$$\mathrm{Var}(x) = \lambda \cdot (1 + \mu\lambda) \qquad (4)$$

In equation 4 μ denotes the over-dispersion parameter. Solving equation 1 with respect to the over-dispersion parameter gives:

$$\mu = \frac{\frac{Var(x)}{\lambda} - 1}{\lambda} \qquad (5)$$

If the mean (λ) and variance (Var(x)) of the raw data (i.e. the empirical distribution of the count of accidents per marked crossing) are known, the over-dispersion parameter of the crude data can be estimated by applying equation 5. Denoting the over-dispersion parameter of the raw data as μ_{crude} and the over-dispersion parameter of the fitted model as μ_{model} the Elvik index is defined as follows:

$$\text{Elvik-index of goodness-of-fit} = 1 - \frac{\mu_{model}}{\mu_{crude}} \qquad (6)$$

4 RESULTS

Table 3 shows estimated model coefficients, the standard errors of the coefficients and their P-values.

Table 3 about here

A majority of the coefficients estimated for the model using the total number of accidents as dependent variable are statistically significant at the 5 percent level. The coefficients indicate that the number of accidents is positively related to both pedestrian volume and vehicle volume, but negatively related to the product of pedestrian and vehicle volume. The value of the coefficient for pedestrian volume suggests the presence of a strong "safety-in-numbers" effect (Elvik 2009), meaning that the number of accidents increases far less than proportional to pedestrian volume, which in turn implies that each pedestrian faces a lower risk of accident the more pedestrians there are.

The coefficient for the number of legs (number of traffic movements) is positive, but far from statistically significant. The coefficient for number of driving lanes is, perhaps surprisingly, negative but again far from statistically significant. The coefficient for type of traffic control is also positive, suggesting that traffic signal control is associated with more accidents than other types of traffic control. The number of accidents is positively related to the percentage of road users crossing the road outside the pedestrian crossing. Increased speed is associated with an increased number of accidents. Crossings that satisfy the warrant for marking a pedestrian crossing are not safer than those that do not satisfy the warrants, although the difference is very far from being statistically significant.

The coefficients in the model using accidents related to the pedestrian crossing as dependent variable are to some extent inconsistent with those found when the total number of accidents was dependent variable. The "safety-in-numbers" effect is considerably weaker, whereas the influence of the percentage of road users crossing outside the crossing is stronger. The coefficient for warrant now indicates that crossings satisfying the warrant are (non-significantly) safer than those that do not satisfy the warrant. The value of the over-dispersion parameter is remarkably low, but the software issued a warning of a matrix singularity, which indicates a problem of co-linearity between the independent variables. An attempt was made to identify the source of the problem by re-running the model omitting one variable at a time. The only omissions that made a large difference were when the logarithm of road users crossing was omitted and when the interaction term between pedestrian and motor vehicle volume was omitted. However, the correlation between these variables was not very high (r = 0.501) and the coefficients were very stable in all the runs where one variable was omitted. It was therefore concluded that co-linearity does not appear to have influenced the model coefficients very much.

Which of the variables is most strongly related to the number of accidents? One way of answering this question is to compare the elasticities calculated for each of the independent variables. Elasticities are provided in Table 4.

Table 4 about here

The elasticities can be compared directly: the larger the value, the larger the effect of a one percent change in the variable on the number of accidents. It should be noted, however, that the notion of a one percent change does not make equally good sense for all variables. It makes best sense for the continuous variables like the number of pedestrians, the number of motor vehicles and the mean speed of motor vehicles. As can be seen from Table 4, a one percent increase in any of the independent variables is, in general, associated with a less than one percent change in the predicted number of accidents. The total number of accidents appears to be most sensitive to motor vehicle traffic volume, number of legs at the crossing location, type of traffic control and the mean speed of motor vehicles. Crossing-related accidents are most sensitive to pedestrian volume, motor vehicle volume and the mean speed of traffic.

Some of the relationships that have been studied in this paper have been studied in a number of previous studies. This applies in particular to the "safety-in-numbers" effect, the effect on accident risk of the percentage of pedestrians crossing outside the pedestrian crossing and the mean speed of traffic. Elvik (2009) summarised a number of studies that have assessed the safety-in-numbers effect. These studies applied accident prediction models of the form shown in equation 1. The relationship between the volume of pedestrians and motor vehicles and the number of accidents is described in terms of a pair of exponents. If the value of these exponents is less than 1, a safety-in-numbers effect exists. All the studies reviewed by Elvik (2009) indicated a safety-in-numbers effect with respect to pedestrian volume. The mean value (unweighted) of the exponents was 0.50. The lowest value found in the studies that included information on both pedestrian and vehicle volume was 0.33; the highest value was 0.72. Zegeer et al. (2005) in a study that was not included among those reviewed by Elvik (2009) estimated an exponent of 0.38 for pedestrian volume at marked crossings and 0.60 for pedestrian volume at unmarked crossings. This is consistent with an increased risk when crossing outside a marked crossing. The value of the exponent found in this study, based on the total number of accidents, 0.31, is on the low end of the estimates found in previous studies. The estimate based on accidents related to the pedestrian crossing, on the other hand, was 0.76, which is higher than any previous study.

A series of studies (Mackie and Older 1965, Jacobs and Wilson 1967, Jørgensen and Rabani 1970, Cameron and Milne 1978, Vodahl and Giæver 1986, Ekman 1988) compared the risk to pedestrians when crossing the road at different locations. These studies included comparisons of the risk to pedestrians when crossing the road in or near marked crossings. In some of the studies, a tendency was seen for risk to be higher when crossing the road outside a marked crossing than when crossing the road at the crossing. This finding is consistent with the positive coefficient found in this study for the share of pedestrians crossing outside the pedestrian crossing, but within 50 metres from it.

It is, however, difficult to compare the results of the current study with the results of the previous studies. In the current study, it is not possible to develop separate estimates of accident risk for pedestrians using and not using marked crossings. Only overall estimates of risk applying both to pedestrians using crossings and pedestrians not using them can be developed and compared between groups of pedestrian crossings where the share of pedestrians not using the crossings varies. The previous studies included only pedestrian volume and did not apply a multivariate model to estimate risk. Estimates of risk made in different countries are not comparable. Finally, the previous studies were somewhat inconsistent in their findings.

An attempt was nevertheless made to try to compare the results of the previous studies to this study. Four groups of crossings were formed with respect to the share of pedestrians not using them: (1) Less than 10 percent; (2) Between 10 and 29.9 percent; (3) Between 30 and 49.9 percent; (4) More than 50 percent. Risk was estimated as the total number of accidents per 1,000 pedestrians crossing. The count of pedestrians crossing included both those crossing in the marked crossings and those crossing outside. It was found that overall risk was lowest in the group with the smallest share of pedestrians not using the marked crossings and increased as this share increased. Table 5 gives a summary of the results.

Table 5 about here

It was not possible to include all previous studies; only studies that compared locations with varying shares of use of pedestrian crossings within the same country were included. The percentage not using the crossings is stated as a percentage of those using them; thus, if 100 pedestrians use the crossings and 200 do not, the percentage not using is 200 percent. The results are not entirely consistent. While the current study shows a clear dose-response pattern for the increase in risk as the share of pedestrians not using marked crossings increases, the results of the other studies included in Table 5 are inconsistent. The majority of findings indicate, however, that as more pedestrians cross the road outside marked crossings, overall risk increases.

A third variable which has been studied in other studies is the mean speed of traffic. The coefficient for this variable has a small value, suggesting that the number of accidents is not very much influenced by speed. However, the effect of speed is not as small as the value of the coefficient might lead one to believe. In the model using crossing-related accidents as dependent variable, the coefficient is 0.021. Applying this coefficient, one can estimate that the predicted number of accidents is 80 percent higher at a mean speed of 56 km/h than at a mean speed of 28 km/h (the latter value was the actual mean speed for all 159 crossings). In a recent paper, Elvik (2013) estimated a coefficient of 0.034 for injury accidents in a similar (exponential) model. This coefficient suggests that the number of accidents is 159 percent higher at a speed of 56 km/h than at a speed of 28 km/h. It is likely that the coefficient for mean speed estimated in this study is too low. Hauer (2013) gives examples of cross-section studies in which the coefficient for speed was negative, suggesting that increased speed is associated with fewer accidents, which is certainly wrong. In this study, at least the sign, if not the magnitude, of the coefficient for speed was correct.

5 DISCUSSION

The study presented in this paper has a number of weaknesses: (1) It relies on a small and not representative sample of pedestrian crossings; (2) Due to the low sample size, it was only possible to include a limited number of variables in the accident prediction models developed; (3) Accident data did not permit an analysis of factors influencing accident severity, because there were too few accidents with fatal or serious injury.

Despite these weaknesses, the study produced meaningful results. The coefficients estimated in the model based on the total number of accidents are plausible and broadly consistent with those found in previous studies. The study may be subject to a small sample size/low mean problem, as discussed by Lord (2006). However, as part of exploratory analysis, a number of different models were tested. The over-dispersion parameter for these models varied between 0.229 and 0.211, both of which are close to the value in final model (0.203). The values of the coefficients were also similar in the different models. This indicates that the results are fairly robust with respect to model specification and not mere artefacts of a small sample size.

6 CONCLUSIONS

The main findings of the study presented in this paper can be summarised as follows:

1. The factors that have the largest influence on the number of accidents in marked pedestrian crossings are the volume of pedestrians, the volume of motor vehicles, the complexity of the traffic environment, the type of traffic control and the speed of motor vehicles.
2. There was evidence of a safety-in-numbers effect, which means that each pedestrian faces a lower accident risk the more pedestrians there are.
3. The more pedestrians cross outside marked crossings, the higher becomes the risk of accident.
4. The number of accidents increases as the speed of motor vehicles approaching pedestrian crossings increases.

ACKNOWLEDGEMENT

This study was funded by the City of Oslo (Oslo kommune).

REFERENCES

Cameron, M. H., Milne, P. W. 1978. Pedestrian Exposure and Risk in New South Wales. Proceedings of Joint ARRB/DoT Pedestrian Conference, 1978. Department of Transport, Sydney, Australia.

Ekman, L. 1988. Fotgängeres risker på markerat overgångsställe jämfört med andre korsningspunkter. Bulletin 76. Tekniska Högskolan i Lund, Institutionen för trafikteknik, Lund.

Elvik, R. 2009. The non-linearity of risk and the promotion of environmentally sustainable transport. Accident Analysis and Prevention, 41, 849-855.

Elvik, R. 2013. A re-parametrisation of the Power Model of the relationship between the speed of traffic and the number of accidents and accident victims. Accident Analysis and Prevention, 50, 854-860.

Elvik, R., Høye, A., Vaa, T., Sørensen, M. 2009. The handbook of road safety measures. Second edition. Bingley, Emerald.

Fridstrøm, L., Ifver, J., Ingebrigtsen, S., Kulmala, R., Krogsgård Thomsen, L. 1995. Measuring the contribution of randomness, exposure, weather, and daylight to the variation in road accident counts. Accident Analysis and Prevention, 27, 1-20.

Hauer, E. 2013. Even perfect regressions may not tell the effect of interventions. Paper presented at 2013 Transportation research Board Annual Meeting, Washington D. C.

Hauer, E., Bamfo, J. 1997. Two tools for finding what function links the dependent variable to the explanatory variable. Proceedings of ICTCT workshop 1997 in Lund, Sweden.

Jacobs, G. D., Wilson, D. G. 1967. A Study of Pedestrian Risk in Crossing Busy Roads in Four Towns. RRL Report LR 106. Road Research Laboratory, Crowthorne, Berkshire.

Jørgensen, N. O., Rabani, Z. 1971. Fotgængeres sikkerhed i og ved fodgænger-overgange. RfT-rapport 7. Rådet for trafikksikkerhedsforskning (RfT), København.

Lord, D. 2006. Modeling motor vehicle crashes using Poisson-gamma models: examining the effects of low sample mean values and small sample size on the estimation of the fixed dispersion parameter. Accident Analysis and Prevention, 38, 751-766.

Mackie, A. M., Older, S. J. 1965. Study of pedestrian risk in crossing busy roads in London inner suburbs. Traffic Engineering and Control, 7, 376-380.

Sørensen, M. W. J., Mosslemi, M., Akhtar, J. 2010. Kvalitetssikring av gangfelt i 50-soner i Oslo. TØI rapport 1058. Oslo, Transportøkonomisk institutt.

Sørensen, M. W. J., Nævestad, T-O. 2012. Kvalitetssikring av 75 gangfelt i Oslo. TØI rapport 1231. Oslo, Transportøkonomisk institutt.

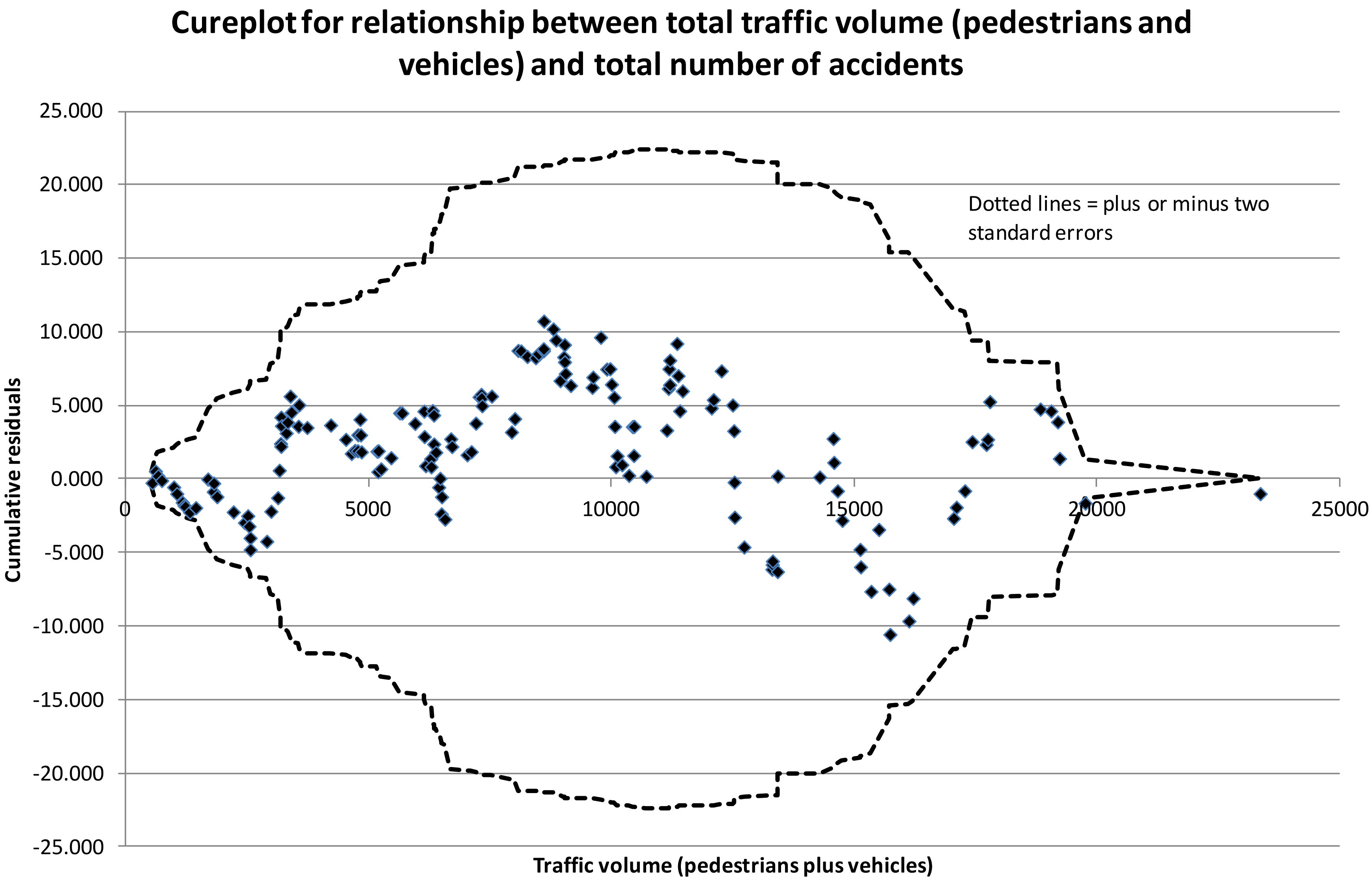
Vodahl, S. B.,Giæver, T. 1986. Risiko ved fotgjengerkryssinger. STF63 A86025. SINTEF Samferdselsteknikk, Trondheim.

Washington, S. P., Karlaftis, M. G., Mannering, F. L. 2011. Statistical and econometric methods for transportation data analysis. Second edition. Boca Raton, CRC Press.

Zegeer, C. V., Stewart, J. R., Huang, H. H., Lagerwey, P. A., Feaganes, J., Campbell, B. J. 2005. Safety effects of marked versus unmarked crosswalks at uncontrolled locations: final report and recommended guidelines. Report FHWA-HRT-04-100. Georgetown Pike, Federal Highway Administration.

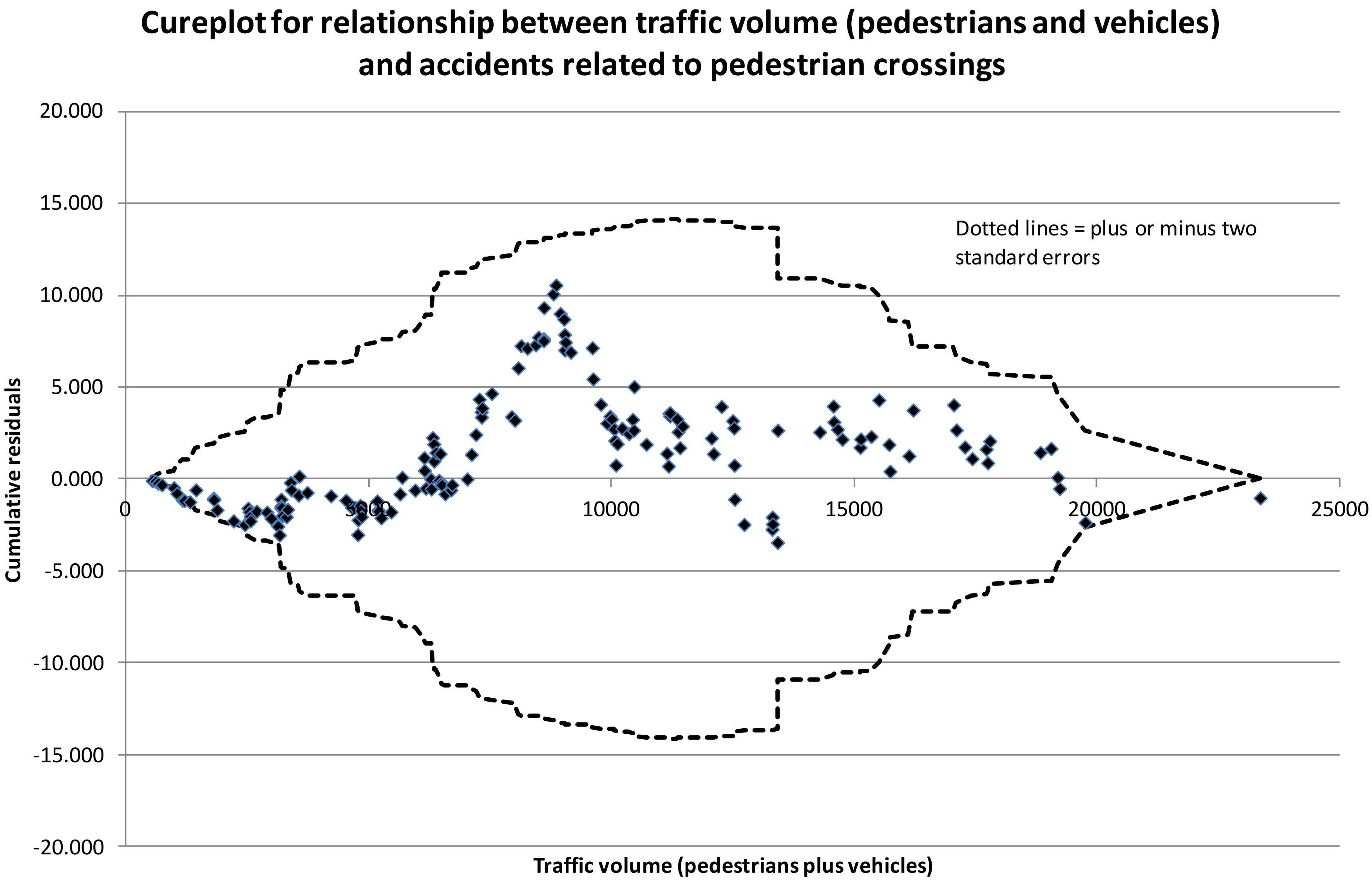
LIST OF FIGURES AND TABLES

Figure 1:



Cureplot for relationship between total traffic volume (pedestrians and vehicles) and total number of accidents
25.000
20.000
15.000
10.000
5.000
0.000
-5.000
-10.000
-15.000
-20.000
-25.000
Cumulative residuals
0
5000
10000
15000
20000
25000
Dotted lines = plus or minus two standard errors
Traffic volume (pedestrians plus vehicles)

Figure 2:



Cureplot for relationship between traffic volume (pedestrians and vehicles) and accidents related to pedestrian crossings
Dotted lines = plus or minus two standard errors
Cumulative residuals
20.000
15.000
10.000
5.000
0.000
-5.000
-10.000
-15.000
-20.000
0
5000
10000
15000
20000
25000
Traffic volume (pedestrians plus vehicles)

Table 1:

Variable number	Name of variable	Values of variable
1	Total number of accidents within 50 metres in both directions from marked pedestrian crossing	Integers (0, 1, ... 10) Mean: 1.987
2	Number of accidents related to pedestrian crossing	Integers (0, 1, ... 8) Mean: 0.937
3	Number of legs (directions from traffic is entering) at crossing location	2 = between junctions; 3 = three leg junction; 4 = four leg junction
4	Number of driving lanes at crossing location	Count (1 to 6)
5	Type of traffic control	0 = no signals; 1 = traffic signals
6	Speed limit in km/h	30, 40, 50, 60 km/h
7	Reason for selecting crossing for inspection	Accident history; accident severity; speed limit; complaints
8	Number of pedestrians crossing in marked crossing	Count
9	Number of other road users crossing in marked crossing	Count
10	Total number of road users crossing in marked crossing	Count
11	Number of pedestrians crossing in marked crossing in maximum hour	Count
12	Number of other road users crossing in marked crossing in maximum hour	Count
13	Total number of road users crossing in marked crossing in maximum hour	Count
14	Number of pedestrians crossing outside marked crossing (within 50 metres from it)	Count
15	Number of other road users crossing outside marked crossing (within 50 metres from it)	Count
16	Total number of road users crossing outside marked crossing (within 50 metres from it)	Count
17	Number of pedestrians crossing outside marked crossing in maximum hour	Count
18	Number of other road users crossing outside marked crossing in maximum hour	Count
19	Total number of road users crossing outside marked crossing in maximum hour	Count
20	Percentage of road users crossing outside marked crossing (as percentage of those using crossing)	Percentage
21	Annual average daily traffic (AADT – motor vehicles only)	Count
22	Count of vehicles during the period each marked crossing was inspected	Count
23	Mean speed of motor vehicles (km/h)	Kilometres per hour
24	85-percentile speed of motor vehicles	Kilometres per hour

Table 1, continued:

Variable number	Name of variable	Values of variable
25	Maximum speed of motor vehicles	Kilometres per hour
26	Years accident data refer to	2004-2008 or 2006-2010 (5 years in all marked crossings)
27	Number of injured road users in total	Integers
28	Number of slightly injured road users in total	Integers
29	Number of seriously injured road users in total	Integers
30	Number of fatally injured road users in total	Integers
31	Number of slightly injured road users in accidents in pedestrian crossing	Integers
32	Number of seriously injured road users in accidents in pedestrian crossing	Integers
33	Number of fatally injured road users in accidents in pedestrian crossing	Integers
34	Number of traffic conflicts in total	Count
35	Formal warrant for use of marked crossing satisfied or not	1 = satisfied; 0 = not satisfied
36	Rating of risk level	1 = low risk; 2 = medium risk; 3 = high risk

Table 2:

Variable	Mean value	Standard deviation	Minimum	Maximum
Ln(road users crossing in marked crossing)	4.87	1.53	0.69	8.53
Ln(AADT)	8.76	0.82	5.99	9.88
Road users crossing in crossing	340	611	2	5058
AADT (motor vehicles)	8186	4874	400	19500
Number of legs (traffic directions)	3.21	0.69	2	4
Number of driving lanes	2.25	0.83	1	6
Type of traffic regulation (dummy; 1 if traffic signals)	0.11	0.31	0	1
Percentage of pedestrians crossing outside crossing	15.2	42.0	0.0	327.3
Speed of motor vehicles approaching crossing (km/h)	28.72	10.09	13	64
Satisfaction of formal warrant for pedestrian crossing (1 if yes, 0 if no)	0.64	0.48	0	1

Table 3:

	Total number of accidents as dependent variable			Accidents related to pedestrian crossing as dependent variable		
Variables	**Coefficient**	**Standard error**	**P-value**	**Coefficient**	**Standard error**	**P-value**
Constant term	-6.879	1.192	0.000	-9.346	1.686	0.000
Ln(road users crossing in marked crossing)	0.312	0.077	0.000	0.761	0.108	0.000
Ln(AADT)	0.591	0.132	0.000	0.533	0.173	0.002
Road users crossing in marked crossing · AADT	1.266E-80	8.695E-9	0.145	1.983E-8	8.671E-9	0.022
Number of legs at crossing location	0.105	0.106	0.323	-0.008	0.122	0.946
Number of driving lanes at crossing location	-0.063	0.100	0.529	0.013	0.115	0.910
Type of traffic control	0.480	0.214	0.025	-0.062	0.273	0.819
Percentage crossing outside marked crossing	0.422	0.180	0.019	0.678	0.248	0.006
Mean speed of motor vehicles	0.012	0.010	0.205	0.021	0.014	0.131
Warrant for marked crossing satisfied	0.066	0.217	0.760	-0.272	0.285	0.339
Dispersion parameter	0.203	0.088	0.010	0.015	Not output	Not output
Elvik index of goodness of fit	0.630			0.983		

Table 4:

	Elasticities for all accidents and crossing-related accidents	
Variables	**All accidents**	**Crossing-related accidents**
Ln(road users crossing in marked crossing)	0.312	0.761
Ln(AADT)	0.591	0.533
Road users crossing in marked crossing · AADT	-0.042	-0.066
Number of legs at crossing location	0.337	-0.026
Number of driving lanes at crossing location	-0.141	0.029
Type of traffic control (dummy; 1 = traffic signals)	0.381	-0.064
Percentage crossing outside marked crossing	0.064	0.103
Mean speed of motor vehicles	0.345	0.603
Warrant for marked crossing satisfied (1 = yes; 0 = no)	0.064	-0.313

Table 5:

Study	Share of pedestrians crossing outside marked crossing (as percentage of those using the crossing)	Relative risk of accident (accidents per 1,000 pedestrians = 1.00 for group with lowest share crossing outside marked crossing)
This study	3.3 %	1.00
	14.4 %	1.41
	42.8 %	1.42
	74.9 %	2.51
Mackie and Older 1965	17.8 %	1.00
	150.8 %	1.57
Jacobs and Wilson 1967	41.6 %	1.00
	85.0 %	0.34
Vodahl and Giæver 1986	15.7 %	1.00
	459.3 %	1.63
Ekman 1988	11.6 %	1.00
	86.2 %	0.69