A City-Wide Safety Analysis of Mobile Speed Enforcement

Ran Li
University of Alberta

Dr. Karim El-Basyouny
University of Alberta

Dr. Amy Kim
University of Alberta

ABSTRACT

This study examined the safety effects of the City of Edmonton's mobile enforcement program. Four years of city-wide monthly collision data, enforcement statistics, and employment rate data was incorporated in a generalized linear Poisson model. It was found that the estimations of the enforcement variables were highly significant with a negative sign. Further analysis was conducted to verify the enforcement effectiveness on the reduction of severe collisions. The marginal effects of increasing deployment hours by 1,000 and issued tickets by 10,000 per month were estimated to be 52 and 68 fewer severe collisions, respectively. The results were compared with previous research and discussions are provided herein.

RÉSUMÉ

Cette étude a examiné l'effet de l'application mobile dans Edmonton. Le programme a débuté en 1993. Quatre années de données de la ville à l'échelle mensuelle collision, les statistiques de l'application et des données de taux d'emploi a été intégré dans un modèle linéaire de Poisson généralisé. On a constaté que les estimations des variables d'application étaient hautement significatives avec un signe négatif. Une analyse plus poussée a été effectuée afin de vérifier l'efficacité de l'application sur la réduction des collisions graves. On estime que les effets marginaux de l'augmentation des heures de déploiement en 1000 et émis des billets de 10.000 par mois pour être 52 et 68 collisions graves moins, respectivement. Les résultats ont été comparés avec les recherches antérieures et des discussions sont fournis ici.

INTRODUCTION

According to the global status report on road safety by the World Health Organization, traffic collisions have become the eighth leading cause of death and the number one threat to young people aged 15-29. More than one million people die on roads each year, which costs billions of dollars [1]. In Canada, 2,006 people died in motor vehicle collisions in 2011 [2]. Many factors contribute to traffic collisions, such as adverse weather conditions, inappropriate roadway design, distracted driving, and, most commonly, speeding. It was estimated that 30% of fatal collisions were related to speeding [3]. Nilsson used a power model to describe the relationship between the increase in mean speed and the growth of traffic collision probability. It was revealed that the degree of power rose with the severity of the collision [4]. Since there is a clear link between speeding and collisions, it is of great importance to develop effective speed management strategies.

According to the Organisation for Economic Cooperation and Development (OECD) report on speed management, speeding countermeasures fall into three categories: engineering, education, and enforcement [5]. Among these, enforcement is considered to be both efficient and effective. The deterrence of Enforcement operations can be attributed to two types: general deterrence and specific deterrence [6]. General deterrence is the impact of the *threat* of legal punishment on the public at large, while specific deterrence is the impact of *actual* legal punishment on those who have been apprehended. Compared with fixed speed camera enforcement, mobile enforcement is more flexible and covert in operation. Many studies have confirmed the effectiveness of mobile enforcement on both speed and safety; most of these studies adopted before-and-after or interrupted time series analysis [7,8,9,10]. Although mobile enforcement is able to bring significant effects at an early stage, the outcomes were reported to diminish over time, and sometimes enforcement operation has been accused of being mainly for revenue purposes [11,12,13]. Thus, it is critical to conduct a safety effectiveness evaluation as the program moves on into its later stages.

The City of Edmonton’s mobile photo radar program was initiated as early as 1993. In April 2012, the City of Edmonton’s Office of Traffic Safety (OTS) was delegated to manage the program. Currently two types of enforcement technologies are applied: photo radar speed detectors and dragon camera speed detection systems. However, during the study period, only photo radar detectors were deployed. In total, there were 10 covert trucks and three overt ones equipped with photo radar devices. More than 700 enforcement sites were selected based on collision, speed and other criteria covering different types of road in the city. Tay [12] conducted a study on this program and revealed its impact on city-wide severe collision reduction using data collected from 2002 to 2005. This study is based on Tay’s research with extended timelines to identify the sustainable, long-term effects of the mobile enforcement program.

LITERATURE REVIEW

France has experienced great success in its automated speed enforcement program. Since the installation of the first photo radar device in 2003, 2,756 speed cameras have been installed nation-wide as of 2010, among which 933 are mobile. From 2000 to 2010, the number of fatalities dropped by 40%. The national average speed for private cars decreased from more than 90 km/h to below 80 km/h and the proportion of cars traveling 10 km/h above the speed limit decreased from 37% to 12% from 2002 to 2009 [7,14]. Australia applied a randomized schedule method in its enforcement program. Instead of focusing only on high collision locations, each police station operated an individual program covering as many routes in the station's territory as possible. The time-of-day and day-of-week of the enforcement schedule at each site was generated randomly, making the operation highly unpredictable. The interactive relationship between police attendance and collision reduction was continuously evaluated, which guided adjustments to the program. The average reduction for major casualty collisions was estimated to be 32% [15]. Austroad conducted a survey about drivers’ attitudes towards speed enforcement, which showed that although drivers generally supported speed enforcement techniques, drivers related enforcement to revenue-seeking behaviour. In addition, drivers preferred manned enforcement to automatic enforcement and the use of covert enforcement was not widely understood [11].

Richards et al. compared different types of police enforcement and non-enforcement techniques. The non-enforcement techniques, such as rumble strips, changeable message signs, and lane width reduction, except for flagging, were found to be less effective in reducing overall vehicle speed. With regards to the form of enforcement, stationary enforcement proved to be better than circulating enforcement [3]. Chen et al. verified the effectiveness of police enforcement in work zones and found the variable message sign to be an effective supplement to the enforcement. It was also suggested to spread police resources to a larger number of locations rather than concentrating resources on limited locations. The authors admitted that the spatial residual effects, or the spatial halo effects, decayed within one mile downstream of the enforcement location [16]. It is natural that drivers tend to speed up after slowing down at enforcement sites. However, Hauer et al. argued this may not always be the case when the percentage of local drivers repeatedly exposed to the enforcement is high. The time halo effect could last as long as one week after enforcement [17].

Elvik developed accident modification functions based on 11 studies to describe the relationship between injury collision reduction and relative enforcement intensity. An assumption of a declining marginal effect with increased enforcement intensity was made. The inverse function and logarithmic function were found to be the ideal model forms, which indicated that doubled enforcement intensity would further reduce injury collisions by 20% [8]. Goldenbeld et al. also conducted research on a mobile enforcement program with increased intensity. The analysis showed that speed decreased greatly in the first year after enforcement implementation and was further reduced in the fourth year when the enforcement effort intensified [9].

DATA

Four years of city-wide monthly data, from April 2005 to March 2009, was used in this study. The data included the number of severe collisions, the deployment hours, the number of issued tickets, and the employment rate. Severe collisions consist of injury and fatal collisions (property damage only collisions were not considered, because many PDO collisions are not reported, which may affect data quality). Deployment hours is the total time of the enforcement operation over one month. It should be noted that the number of issued tickets is less than the number of violations due to practical issues, such as the identification of the vehicle plate number. However, the number of issued tickets accurately represents the number of drivers who were affected by specific deterrence. Usually, drivers receive their ticket approximately one week post-violation, which makes the number of issued tickets reasonably examinable on a monthly basis. The employment rate was collected to account for socio-economic factors.

In total, there were 48 monthly data entries. The summary statistics and the monthly variation is provided in Table 1 and Figures 1 to 4.

	Mean	Standard Deviation	Minimum	Maximum
Severe Collisions	458	69	315	611
Deployment Hours	1388.6	167.3	987.4	1772.4
Issued Tickets	13379	5583	3528	27369
Employment Rate (%)	68.5	1.6	65.9	71.1

Table - 1 Summary Statistics of Data

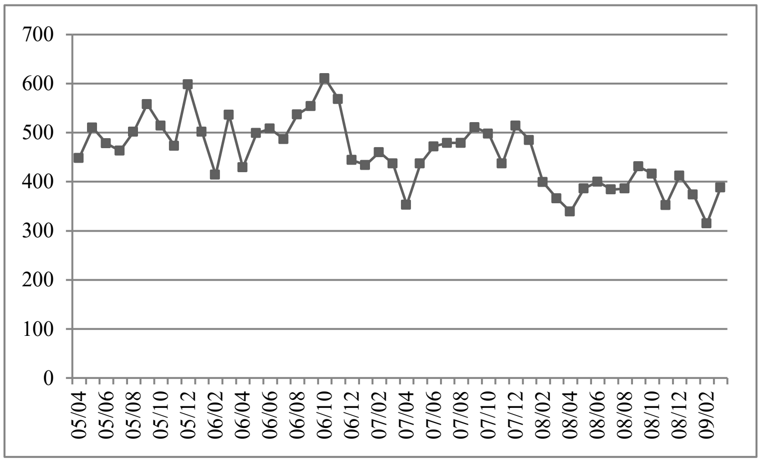

Figure - 1 Number of Severe Collisions per Month

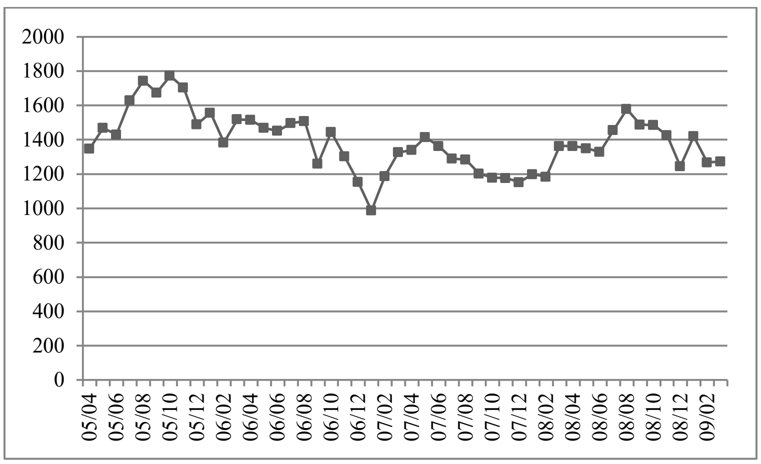

Figure - 2 Deployment Hours per Month

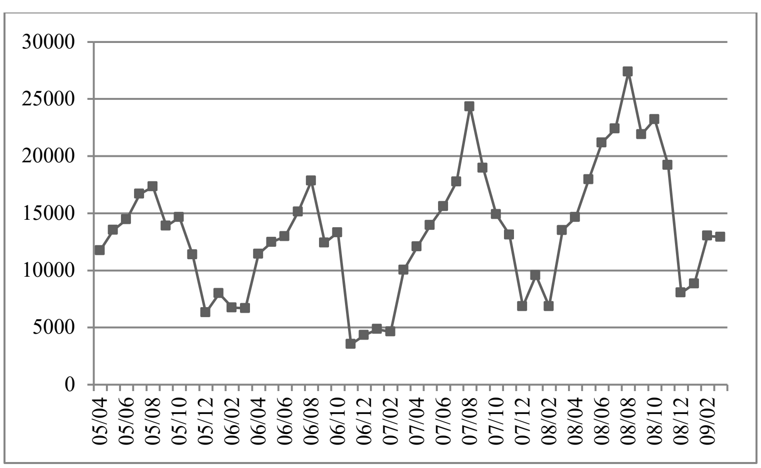

Figure - 3 Number of Issued Tickets per Month

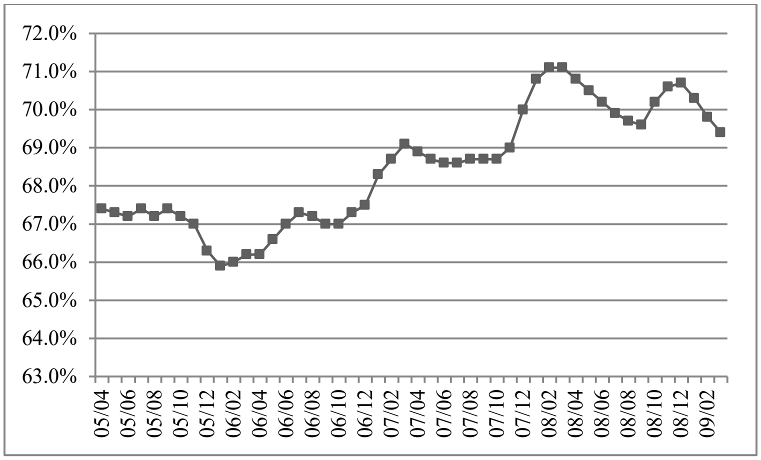

Figure - 4 Employment Rate per Month

From the figures, it can be observed that the monthly severe collisions did not show a specific seasonal pattern. However, there was a clear decline trend in collisions during the analysis period. The monthly deployment hours varied from 1,000 hours to 1,800 hours without any trend. For the number of monthly issued tickets, the peak value always occurred in August, while the low values appeared in winter months. The employment rate increased gradually from 66% to 71%.

METHODOLOGY

In this study, a generalized linear model (GLM) was adopted to examine the relationship between the number of severe collisions and explanatory variables. Compared with traditional linear regression, GLM is able to capture collision distribution. The most commonly used collision distributions are the Poisson distribution and the negative binomial distribution [18,19]. In this study, the Poisson distribution was adopted due to the low dispersion parameter of the data.

In the model, the number of monthly severe collisions is the dependent variable, while the enforcement variables and employment rate were the explanatory variables, or the independent variables. It should be noted that since the deployment hours and the number of issued tickets were generated from the same event, it is impossible for them to be totally independent of each other. However, the correlation coefficient between these two variables was only 0.34. As can be observed in Figures 2 and 3, the deployment hours remained at a relatively stable level, while the number of tickets varied seasonally. Thus, it is acceptable to keep them together in the model to represent the general and specific deterrence effects of speed enforcement.

In addition, monthly dummies and trend variables were also included in the model to account for monthly change factors and the social safety trend. The model form is shown in Equation 1. The parameters were estimated in SAS through the GENMOD procedure [20], which realizes the maximum likelihood estimation with the Newton-Raphson algorithm.

$$\ln(\mu) = \beta_0 + \beta_1 \text{Deployment Hours} + \beta_2 \text{Issued Tickets} + \beta_3 \text{Employmet Rate} + \beta_4 \text{Trend} + \beta_{5-15} \text{Monthly Dummies} \quad (1)$$

Where, μ is the distribution mean, and $\boldsymbol{\beta}$ are the parameters that need to be estimated.

RESULTS

The estimation results are shown in Table 2. The adjusted R-square reached 0.7315, which indicates a sound goodness-of-fit. All of the parameters were highly significant, except for a few monthly dummies. All of the signs were as expected.

A significant declining trend of monthly severe collisions is shown in Table 2 and can be observed in Figure 1. The employment rate was found to be negatively related to the frequency of severe collisions. Both of the enforcement variables showed a significant negative value, which means that the enforcement program reduced severe collisions.

Number of observations	48		
Log-likelihood	-234.7373		
Adjusted R-square	0.7315		
Dependent Variable	Number of severe collisions per month		
Dependent Variables	Estimate	Standard Error	P value
Intercept**	7.8961	0.6334	<.0001
January	-0.0611	0.0329	0.0629
February**	-0.1835	0.0339	<.0001
March	-0.0381	0.035	0.2763
April**	-0.1551	0.0413	0.0002
May	0.0353	0.0435	0.417
June	0.0709	0.0468	0.1297
July	0.089	0.0505	0.0779
August**	0.1987	0.0589	0.0007

September**	0.1911	0.0466	<.0001
October**	0.1926	0.0449	<.0001
November	0.011	0.036	0.7608
Employment Rate*	-0.02	0.0094	0.0337
Trend**	-0.0034	0.0012	0.004
Deployment Hours (1,000 hours)*	-0.1131	0.0575	0.0491
Issued Tickets (10,000 tickets)**	-0.148	0.0344	<.0001

* Significant at 5% level ** Significant at 1% level

Table - 2 Model Estimation Results

To further validate the enforcement effectiveness, restricted models were tested: the enforcement variables were removed from the model to observe the change of Log-likelihood. The results showed that the absence of the deployment hours reduced the Log-likelihood by 1.933; the absence of the number of issued tickets reduced the Log-likelihood by 9.203; the absence of both variables reduced the Log-likelihood by 18.742. It was also found that the absence of trend variables reduced the Log-likelihood by only 4.130, which indicates that the number of issued tickets had a greater impact on the fit of the model than the trend variable. Since the declining trend in severe collisions was substantial, the enforcement variables are believed to be effective. To illustrate the models' capability to describe collision data, the expected monthly numbers of severe collisions are plotted against the actual data in Figure 5. The R-square of the expected data is as high as 0.809.

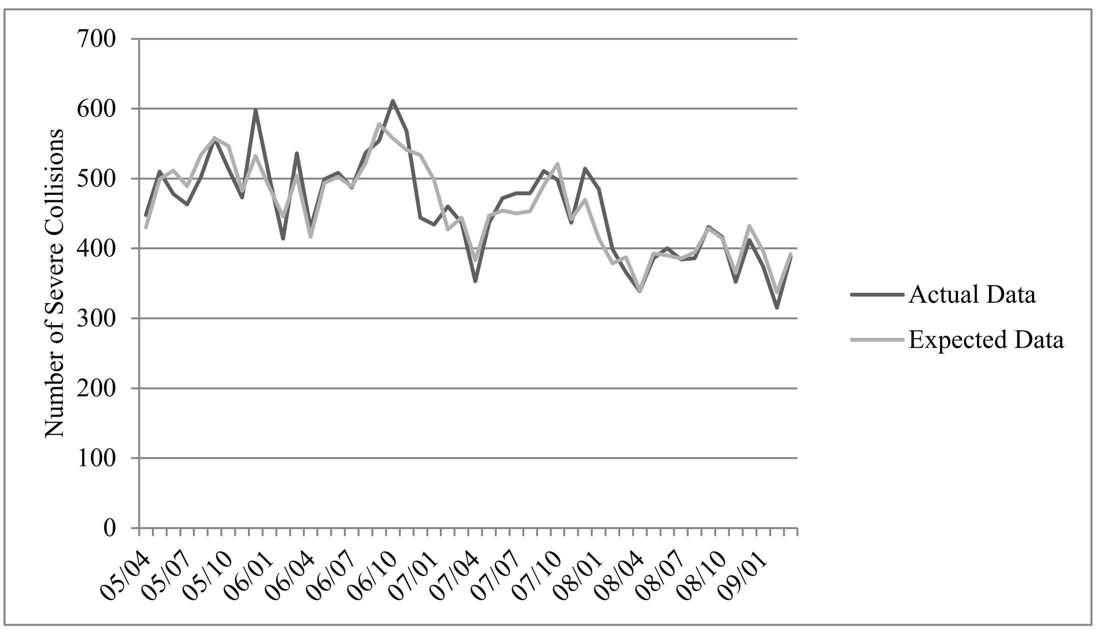

Figure - 5 Expected against Actual Number of Monthly Severe Collisions

For the model with the Log-link function, the marginal effect of one variable is the product of the expected number of collisions and the estimated variable parameter. Thus, the magnitude of the parameter can be seen as the reduction ratio. If the mean of the actual monthly severe collisions is used to represent the general expected number of collisions, the marginal effects of increasing 1,000 deployment hours and 10,000 issued tickets per month were estimated to be 52 and 68 fewer severe collisions, respectively.

DISCUSSIONS AND CONCLUSIONS

This study validated the effectiveness of mobile speed enforcement on the reduction of severe collisions. Monthly collision data, enforcement data, and employment rate data was incorporated in a generalized linear model. Unlike most safety studies, the analysis target here was city-wide collisions, rather than road segment or intersection collisions. The dispersion parameter was calculated to be only 0.0018, which indicates the suitability of using the Poisson distribution. In addition, it was found that the distribution selection did not have obvious influence on parameter estimation.

The estimated parameters of the enforcement variables had significantly negative values. To further verify the effectiveness of the enforcement variables, they were removed from the model to observe changes in the model's fit. It was found that any missing variable led to an increase of the Log-likelihood and the number of issued tickets had a greater impact on model's fit than the trend variable. Since the decline trend was highly significant and can be observed from the Figure 1, it was concluded that enforcement affects safety in terms of severe collision reduction. In addition, the expected data had an R-square of 0.8 and fit well to the actual data.

The marginal effects of increasing 1,000 deployment hours and 10,000 issued tickets per month were estimated to be 52 and 68 fewer severe collisions, respectively. A previous study conducted by Tay estimated the values to be 70 and 57, respectively. The results here are consistent with Tay's study. It can be seen that the marginal effect of issued tickets exceeded the effect of deployment hours. In addition, the number of issued tickets was found to be more significant than the deployment hours in the model. This suggests that, given the long existence of the enforcement program, specific deterrence may become the main source of severe collision reduction.

REFERENCES

[1] World Health Organization, Global status report on road safety: supporting a decade of action, Geneva, 2013.

[2] Transport Canada, Canadian Motor Vehicle Traffic Collision Statistics, Ottawa, 2011.

[3] RICHARDS, S. H., WUNDERLINCH, R. C., and DUDEK, C. L., Field Evaluation of Speed Control Techniques. Transportation Research Record 1035. Transportation Research Board, National 30 Research Council, Washington, DC, pp. 66-78, 1985.

[4] NILSSON, G., Traffic Safety Dimension and the Power Model to describe the Effect of Speed on Safety, Lund Institute of Technology, Sweden, 2004.

[5] Organisation for Economic Cooperation and Development, Speed Management, France, 2006.

[6] ZAAL, D., Traffic law enforcement: a review of the literature, Monash University Accident Research Centre, Report No. 50, Melbourne, 1994.

[7] CARNIS, L., ETIENNE, B., assessment of the safety effects of the French speed camera program, Accident Analysis & Prevention, Volume 51, Pages 301-309, 2013.

[8] ELVIK, R., Developing an accident modification function for speed enforcement, Safety Science, Volume 49, Issue 6, Pages 920-925, 2011.

[9] GOLDENBELD, C., SCHAGEN, I. V., The effects of speed enforcement with mobile radar on speed and accidents: An evaluation study on rural roads in the Dutch province Friesland, Accident Analysis & Prevention, Volume 37, Issue 6, Pages 1135-1144, 2005.

[10] New Zealand Traffic Camera Office, Presentation for the Insurance Council of British Columbia, Unpublished report, New Zealand, 1995.

[11] Austroads. Driver attitudes to speed enforcement, Sydney, 2013, AP-R433-13.

[12] TAY, R., Speed Cameras: Improving Safety or Raising Revenue, Journal of Transport Economics and Policy, Vol. 44, No. 2, pp. 247-257, 2010.

[13] DELANEY, A., DIAMANTOPOULOU, K., CAMERON, M., MUARC's Speed Enforcement Research: Principle Learnt and Implications for Practice, Monash University Accident Research Center, report No.200, 2003.

[14] CARNIS, L., A public policy in evolution: speed enforcement in France 2000-2010, Australasian Road Safety Research, Policing and Education Conference, Perth, Western Australia, Australia, 2011.

[15] LEGGETT, L., Using Police Enforcement to Prevent Road Crashes: the Randomised Scheduled Management System, Crime Prevention Studies, New York CIN Press, 1997.

[16] CHEN, E., TARKO, A. P., Police Enforcement Strategies and Speed Reduction in Work Zones, TRB 92nd Annual Meeting Compendium of Papers, Washington, DC, 2013.

[17] HAUER, E., AHLIN, F. J., and BOWSER, J. S., Speed Enforcement and Speed Choice. Accident Analysis and Prevention, Vol. 14, No. 4, pp. 267-278, 1982.

[18] YE, Z., ZHANG, Y., Lord, D., Goodness-of-fit testing for accident models with low means, Accident Analysis & Prevention, Volume 61, Pages 78-86, 2013.

[19] EL-BASYOUNY, K., SAYED, T., Safety performance functions using traffic conflicts, Safety Science, Volume 51, Issue 1, Pages 160-164, 2013.

[20] SAS Institute Inc., Version 9.3, PROC GENMOD, Cary, USA, 2012.