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Evaluating the safety impact of increased speed limits on rural highways in British Columbia

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ABSTRACT

Maximum speed limits are usually set to inform drivers of the highest speed that it is safe and appropriate for ideal traffic, road and weather conditions. Many previous studies were conducted to investigate the relationship between changed speed limits and safety. The results of these studies generally show that relaxing speed limits can negatively affect safety, especially with regard to fatal and injury crashes.

Despite these results, several road jurisdictions in North America continue to raise the maximum speed limits. In 2013, the British Columbia Ministry of Transportation and Infrastructure initiated a speed limits review. The review found that the 85th percentile speed on many highway segments was 10 km/h higher than corresponding posted speed limits and 1300 km of rural provincial highway segments were recommended for higher speed limits. Most of the highway segments had 10 km/h speed limit increase with a small section having 20 km/h speed limit increase.

As speed limit changes can have a substantial impact on safety, the main objective of this study is to estimate the effect of the increased speed limits on crash occurrence. A before-after evaluation was undertaken with the full Bayesian technique. Overall, the evaluation showed that changed speed limits led to a statistically significant increase in fatal-plus-injury (severe) crashes of 11.1%. A crash modification function that includes changes in the treatment effect over time showed that the initial increase of the first post-implementation period may slightly decrease over time.

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1. Introduction

Maximum speed limits are usually set to inform drivers of the highest speed that it is safe and appropriate for ideal traffic, road and weather conditions. Many previous studies have been conducted to investigate the relationship between the driving speed, changed speed limits and safety (Solomon, 1964; Cirillo, 1967; Garber and Graham, 1990). There is considerable evidence from the literature that speed affects both the frequency and severity of collisions and that the effect is stronger for severe crashes.

Generally, the results indicate that the higher the travel speed, the greater the probability of crashes (crash risk) and the higher their severity. Despite these results, several road jurisdictions in North America continue to raise the maximum speed limits. Several studies have shown that the crash risk, in the vast majorities of cases, grows more rapidly than driving speed when the latter is increased. This behaviour was first modelled by Nilsson (1982) with a power function as:

$$\text{crashes}_{\text{after}} = \text{crashes}_{\text{before}} \left(\frac{\text{speed}_{\text{after}}}{\text{speed}_{\text{before}}} \right)^{\text{exponent}}$$

where the exponent can assume different values between 0.8 up to 4.6 depending on traffic environment (rural versus urban) and the severity of the crash (Elvik, 2009, 2013).

In the US, several researchers investigated the safety effect of relaxing speed limits after the repeal of the national maximum speed limit law. Farmer et al. (1999) focused on the trends in fatalities over 8 years for 24 states that raised interstate speed limits and 7 states that did not. The results showed an increase of 15% in motor vehicle occupant deaths for the 24 states that raised speed limits. After accounting for changes in vehicle miles of travel, fatality rates were 17% higher following the speed limit increases. A National Cooperative Highway Research Program (NCHRP) project (Kockelman and CRA International, Inc., 2006) found that a 10 mph (16 km/h) speed limit increase on high-speed roads from 55 to 65 mph (88–105 km/h) would result in an increase of 3.3% in total

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crashes and 28% in fatal injury crashes. However, the same speed limit increase from 65 to 75 mph (105–121 km/h) would only increase total crashes of 0.64% and fatal injury crashes of 13%. The methodology used for the evaluation was an autoregressive integrative moving average (ARIMA) intervention time series analysis. Another study from Shafi and Gentilello (2007) reported that, after the repeal of the national maximum speed limit law, there was a 13% increase in the risk of traffic fatalities in the 29 states that increased speed limits on roadways with speed limits greater than 65 mph compared to states that did not increase speed limits. The study estimated that approximately 2985 lives may be saved per year with a nationwide speed limit of 65 mph or less. More recently, Farmer (2016) investigated the effect of speed limit increases focusing on a longer time frame (1993–2013) and using a cross-sectional modeling approach. By means of a Poisson regression, it was found that a 5 mph (8 km/h) increase in the maximum state speed limit was associated with an 8% increase in fatality rates on interstates and freeways and a 4% increase on other highways. Moreover, the study estimated 33,000 more traffic fatalities during the years 1995–2013 than would have been expected if maximum speed limits had not increased.

Outside of North America, a study from Hong Kong evaluated the increase of speed limits that occurred from 1999 to 2002 on different highways with a before-after study (Wong et al., 2005). Nineteen sections were major roadways with increases in speed limits from an initial 50 km/h limit to a higher 70 km/h limit. Overall, the change of the speed limit led to an increase of 15% for fatal-plus-injury crashes, and 1% for fatal plus major-injury only crashes on major roadways. The relaxation of speed limits for remaining highways from an initial 70 km/h limit to an 80 km/h limit was found to increase fatal-plus-injury crashes by 18% and fatal plus major-injury only crashes by 36%.

It should be noted that although the results of the previous studies are generally consistent in showing that relaxing speed limits can have a negative impact on safety especially for fatal and injury crashes, many of the studies suffer from some statistical shortcomings. These include the use of cross-sectional analysis (no actual before/after analysis is conducted), and using simple time trend analysis not accounting for potential confounding factors. Problems with the cross-sectional approach include inappropriate functional forms, potential correlation that might exist among variables in the model such that it is difficult to separate their individual effects on safety, and other unforeseen factors whose inclusion in the model was not possible (Sawalha and Sayed, 2001; Hauer, 2010). Observational before-after (BA) studies are perceived by many researchers to be the best way to estimate the safety effect of changes to location or traffic characteristics. The reason for the superiority of a BA study is that it is a longitudinal analysis meaning that it bases its results on actual changes that have occurred in one data set over a period of time extending from the before condition to the after condition (Sawalha and Sayed, 2001). For BA analysis, Bayesian methods are commonly used within an odds-ratio (OR) analysis for their ability to treat unknown parameters such as predicted collision frequency as random variables having their own probability distributions; in doing so, it is possible to control for the regression-to-mean and other confounding factors. Examples of Bayesian evaluation techniques include the Empirical Bayes (EB) (Hauer, 1997; Sayed et al., 2004) and fully Bayes (FB) (El-Basyouny and Sayed, 2010). In comparison to the EB method, the FB approach is appealing for several reasons, which can be categorized into methodological and data advantages. In terms of methodological advantages, the FB approach has the ability to account for most of the uncertainty in the data, to provide more detailed inference, and to allow inference at more than one level for hierarchical models, among others (El-Basyouny and Sayed, 2010). In terms of data requirements, the FB approach efficiently integrates the estimation of the CPM and treatment effects in a single step reducing the data requirement.

British Columbia offers an opportunity to confirm the results reported in previous studies on the effect of speed limits on crashes in rural environments. In 2013, the Ministry of Transportation and Infrastructure (MoTI) of British Columbia (BC) (Canada) initiated a speed limits review. A technical team conducted over 300 speed surveys on approximately 9100 km of highways with measurements of the 85th percentile operating speeds. After these surveys were carried out, it was found that the 85th percentile speed on these highways was 10 km/h higher than corresponding posted speed limits. It was also noticed that, overall, serious crashes were trending down significantly since 2003. These considerations led to the option of increasing speed limits on BC rural highways of 10 km/h. Therefore, after a public consultation process was conducted, approximately 1300 km of rural provincial highway segments were recommended for higher speed limits. The increased speed limits took effect in the second-half of 2014. Most of the highway segments had 10 km/h speed limit increase with a small highway section having 20 km/h speed limit increase. Therefore, the main objective of this study was to estimate the effect of increased speed limits on crash occurrence for BC rural highways. To evaluate the safety impact, state-of-the-art knowledge and experience in field road safety evaluation was employed. In particular, a BA evaluation was undertaken with the full Bayesian (FB) technique, which is a well-established statistical methodology with considerable literature available to provide guidance for its application for safety evaluations (Lan et al., 2009; El-Basyouny and Sayed, 2012c; Sacchi et al., 2015, 2016). Moreover, to benefit from the additional advantages of the FB approach, several researchers have also proposed the use of intervention models (advanced SPFs) where collision occurrence on various road facilities is a function of time, treatment, and interaction effects (Li et al., 2008; El-Basyouny and Sayed, 2012a). These intervention models acknowledge that safety treatment (intervention) effects do not occur instantaneously but are spread over future time periods and are used to capture the effectiveness of safety interventions.

2. Evaluation methodology

Consider an observational BA study where collision data are available for a reasonable period of time before and after the intervention (changed speed limits in this study). In addition, a set of crash data for the same period of time is available for a comparison group similar to the treatment sites (time-series cross sectional modeling). Let Y_{it} denote the collision count recorded at site i (i = 1, 2, . . ., n) during time period t (t = 1,2, . . ., m). Using a hierarchical model, such as Poisson-lognormal, with site-level random effects it is possible to write:

$$Y_{it}|\lambda_{it} \sim \text{Poisson}(\lambda_{it}) \quad (1)$$

$$\ln(\lambda_{it}) = \ln(\mu_{it}) + \varepsilon_i \quad (2)$$

$$\varepsilon_i \sim N(0, \sigma_\varepsilon^2) \quad (3)$$

where σ_ε^2 represents the extra-Poisson variation.

Then, assuming that Y_{it} are independently distributed, it is possible to introduce the non-linear intervention models (El-Basyouny and Sayed, 2012b). To introduce this model, the following notation is used: T_i is a treatment indicator (equals 1 for treated sites, zero for comparison sites), t_{0i} is the intervention time period for the i^{th} treated site and its matching comparison group, I_{it} is a time indicator (equals 1 in the after period, 0 in the before period), V_{it} denotes the total traffic flow in the form of annual average daily traffic (AADT), and L_i is the length of the stretch of highway analyzed.

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