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Safety and operational impacts of setting speed limits below engineering recommendations

Vikash V. Gayah*, Eric T. Donnell, Zhengyao Yu, Lingyu Li

Department of Civil and Environmental Engineering, The Pennsylvania State University, 231 Sackett Building, University Park, PA, 16802, United States

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ABSTRACT

This study quantifies the operational and safety impacts of setting posted speed limits below engineering recommendations using field data from rural roads in Montana. Vehicle operating speeds and historical crash data were collected at multiple sites with posted speed limits set equal to engineering recommendations and sites with posted speed limits set lower than engineering recommendations. Linear, quantile and logistic regression models were estimated to predict mean operating speed, 85th percentile operating speed and speed limit compliance, respectively, as a function of various roadway characteristics and level of speed enforcement. The Empirical-Bayes before-after approach was also used to develop crash modification factors (CMFs) that describe the expected change in total and fatal + injury crash frequency when setting posted speed limits lower than engineering recommendations. Because safety data were collected over a long time period, temporal adjustments were incorporated to account for yearly changes in crash reporting, traffic characteristics and other variables. The results revealed that speed limit compliance worsened as the difference between the engineering recommended and posted speed limits increased. The presence of verified heavy police enforcement reduced both mean and 85th-percentile operating speeds by approximately 4 mph and increased speed limit compliance. The safety analysis found a statistically significant reduction in total, fatal + injury, and property damage only (PDO) crash frequency at locations with posted speed limits set 5 mph lower than engineering recommendations. Locations with posted speed limits set 10 mph lower than engineering recommendations experienced a decrease in total and PDO crash frequency, but an increase in fatal + injury crash frequency. The safety effects of setting speed limits 15 to 25 mph lower than engineering recommendations were less clear, as the results were not statistically significant, likely due to the small sample of sites included in the evaluation. Overall, the results suggest that setting posted speed limits 5 mph lower than the engineering recommended practice may result in operating speeds that are more consistent with the posted speed limits and overall safety benefits.

1. Introduction

Posted speed limits are often set based on the results of an engineering study, which involves collecting a sample of free-flow vehicle operating speeds in favorable conditions (e.g., daylight with no adverse weather) and selecting an appropriate speed (usually the 85th percentile value) given the speed distribution. However, for a variety of reasons, including the presence of school zones, citizen requests, political pressure, and perceived safety issues, posted speed limits are sometimes lowered to values below engineering recommendations. In fact, a recent survey of state highway transportation agencies found that this practice is fairly common throughout the United States (Donnell et al., 2016). Unfortunately, a review of the research literature suggests that the operational and safety impacts of this practice are not well-understood on moderate- to high-speed rural highways. Posted speed limits were lowered from 50 km/h (30 mph) to 40 km/h (25 mph) in six residential communities in the City of Edmonton, Alberta, Canada. Before-after studies found that the mean speed declined by approximately 3.5 to 5.3 km/h (2.1 to 3.2 mph), depending on the vehicle type, road type, time-of-day and evaluation method used (Islam et al., 2014; Islam and El-Basyouny, 2015a, b), while total, severe, and property damage only crashes declined (Islam and El-Basyouny, 2015; Islam et al., 2016)[1].

With regards to moderate- to high-speed rural highways, the most closely related studies actually consider the opposite practice: raising

* Corresponding author.
E-mail addresses: gayah@engr.psu.edu (V.V. Gayah), edonnell@engr.psu.edu (E.T. Donnell), zuy107@psu.edu (Z. Yu), lul165@psu.edu (L. Li).

[1] A comparison of the Empirical Bayes and Full Bayes before-after methodologies showed that the magnitude of the total, severe injury, and property damage only crash reductions were similar, but the Full Bayes methodology produced smaller standard errors. The authors' (Islam and El-Basyouny, 2015) concurred with other safety research that additional investigations are needed when the safety effects are small and the standard deviation of the safety effect estimates are large.

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posted speed limits (Farmer, 2016; Kockelman and Bottom, 2006). The findings from these studies suggest that vehicle operating speeds increase as posted speed limits are raised, but do so by an amount less than the speed limit increase. Furthermore, these studies find that increased speed limits are associated with a higher frequency of crashes and an increase in crash severity. However, opposite trends cannot necessarily be expected when posting speed limits lower than engineering recommendations.

Operating speed models may provide a clue as to how lower posted speed limits are associated with driver speed choice. A large body of work has attempted to model the relationship between operating speeds and roadway features such as radius or degree of curvature, superelevation, tangent lengths, access density and traffic volumes, among others. However, relatively few studies incorporate posted speed limits into these models due to the belief that significant correlation exists between the posted speed limit and other roadway characteristics (e.g., radius of curvature), although more recent work finds that omission of posted speed limits from an operating speed model might actually bias model estimates (Himes et al., 2013). Those models that do consider the posted speed limit as an independent variable found positive correlations between posted speed limits and observed operating speeds (Aljanahi et al., 1999; Figueroa and Tarko, 2004; Jessen et al., 2001; Polus et al., 2000). The existing research also highlights the impact of speed enforcement on observed operating speeds and speed limit compliance (Hauer et al., 1982; Shinar and Stiebel, 1986). Thus, lowering posted speed limits may reduce operating speeds, especially if enforced.

From a safety perspective, although the relationship between speed and crash severity is well-known (Lee and Li, 2014; Renski et al., 1999), the relationship between posted speed limits and crash frequency is less understood. Several crash modification factors have been developed that suggest reductions in mean and 85th percentile speeds are expected to decrease crash frequency, although the magnitudes of this reduction vary significantly (Dell'Acqua and Russo, 2011; Elvik et al., 2004; Ksaibati and Evans, 2009). A few CMFs also exist for changes in posted speed limit, and these generally find a reduction in crash frequency when posted speed limits are lowered (Chen et al., 2002; Jaarsma et al., 2011; Park et al., 2010; Parker, 1997). However, the relationship between the posted speed limit and engineering recommended values were not discussed in these works.

In light of the above, the objective of this paper is to quantify the operational and safety impacts of setting speed limits below engineering recommendations. Operating speed and reported crash data were collected from various sites in Montana, United States, which currently implements these lower than engineering recommended speed limits. Operating speed data were analyzed using a variety of regression models to assess speed limit compliance and the effects of speed enforcement in speed zones with posted speed limits set lower than engineering recommendations. The Empirical-Bayes (EB) before-after approach was used to develop crash modification factors to describe safety performance. The results will provide highway engineers with guidance regarding how to implement speed limits lower than engineering recommended values.

2. Data collection

2.1. Operating speed data

Operating speed data were collected from 12 unique roadway segments within Montana. Most of these were rural locations with two travel lanes (one in each direction), although three had four travel lanes (two in each direction). Eight of the sites, designated as treatment sites, had posted speed limits set lower than engineering recommendations. These eight treatment sites were selected to maintain diversity in the difference between the engineering recommended and posted speed limits. Three sites had a posted speed limit 5 mph lower than the engineering recommended speed limit, two sites had a posted speed limit that was 10 mph lower than the engineering recommended speed limit, two sites had a posted speed limit that was 15 mph lower than the engineering recommended speed limit, and one site had a posted speed limit that was 25 mph lower than the engineering recommended speed limit. The remaining four sites were comparison sites that had posted speed limits set equal to engineering recommendations.

Speed data were collected using Nu-metrics, Hi-star on-pavement sensors, which were used because they are less conspicuous than other data collection equipment. A previous study compared the potential measurement errors of various speed collection devices and found these on-pavement sensors to provide accurate average speeds (Poe et al., 1996). All sensors were temporarily fastened to the asphalt pavement surface using a 22-caliber nail gun and covered using a black, rubber mat to further conceal it and protect it from traffic. Four sensors were installed at each treatment site: two within the segment with a posted speed limit set lower than engineering recommendations and two outside of these segments. Sensors within the segment were placed at the least-restrictive geometric feature (i.e., on tangent sections) to capture the highest operating speeds in both travel directions and eliminate the impact of horizontal curvature on speed choice. Sensors within the reduced speed limit zones were designated as "treatment" sensors. The two sensors placed outside of the segment were designated as "control" sensors and used to capture operating speeds in both directions on the same roadway to account for daily fluctuations in the speed data. Speed data were also collected on roadways that did not have any speed limits set lower than engineering recommendations. These were designated as "comparison" locations and at these sites a single detector was installed at the least-restrictive geometric feature to capture the highest speeds at these locations. Details on the speed sites in which speed data were collected, include the site type and speed limit are provided in Table 1.

Speed data were collected at three different time periods at each site. During each of the three data collection periods, a different level of speed enforcement present at each of the sites:

- July 20–23, 2015: no enforcement period
- August 10–13, 2015: light enforcement period
- October 26–29, 2015: heavy enforcement period.

The research team coordinated closely with the Montana Highway Patrol to ensure that the level of enforcement was consistent across all sites during these periods. During the no enforcement period, marked enforcement vehicles were not present at any of the treatment, control or comparison locations during the data collection period. During the light enforcement period, regular speed patrols were made at the treatment and control sites by marked enforcement vehicles during the data collection period. Enforcement vehicles were asked to stay clear of the comparison locations to confirm that operating speeds did not differ during the data collection periods at locations where speeds were not enforced. The heavy enforcement period consisted of either very frequent patrols by enforcement vehicles or the presence of manned or unmanned vehicles parked within the study area at the treatment and control sites. The enforcement vehicles were not positioned in the traveled way, but were positioned adjacent to the roadway in order to be visible to drivers. Data collected during this period were used to assess the effects of a targeted enforcement campaign. Again, enforcement vehicles were asked to stay clear of the comparison locations to confirm that operating speeds did not change during the data collection periods at locations where speeds were not enforced. The research team only received verification of the presence of enforcement vehicles during the heavy enforcement period at a few sites during the third data collection trip. These known heavy enforcement periods were differentiated from other heavy enforcement periods (and denoted "verified heavy enforcement") to see if there was a difference in operating speeds between the two periods. The different speed enforcement levels were only applied to the sites during the data collection periods. To the best of the