60 kph minimum speed limit on rural interstate freeways: is it relevant?

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Abstract

The State of Florida, USA, has a practice of posting a maximum speed limit of 105 kilometers per hour (kph) and a minimum speed limit of 60 kph on rural interstate freeways. The results of safety and operational evaluation on these freeways showed that while only 0.14% of recorded vehicles had speeds below the 60 kph posted minimum speed limit, 9% of crash-involved vehicles were estimated to have speeds below 60 kph. The overrepresentation of slow moving vehicles in the crash data suggests that even a small proportion of under 60 kph vehicles can have negative implications on safety. Thus, regulation of vehicle speeds at the lower end of speed distribution is equally important. The Poisson regression modeling indicated that the difference between the 85th and 15th percentile speeds had a positive effect on crashes.
Keywords: speed limit, polynomial modeling, Poisson modeling, freeway operations, traffic crashes.

1 Introduction

The posting of minimum speed limit signs on roadways is based on the desire to reduce speed variance among vehicles, particularly on high speed roadways. Numerous studies have shown that there is a relationship between crash occurrence and speed variability [1,2,3,4,5]. The State of Florida currently posts a maximum speed limit sign of 105 kph and a minimum speed limit sign of 60 kph on rural Interstate freeways. It seems logical to question the relevance of such a wide gap (45 kph) between the two speed limits thus leading to the assessment of safety and traffic operating characteristics on these sections. Based on the review of previous literature, it could be hypothesized that a wider gap between maximum and minimum speed limits might be creating a number of

www.witpress.com, ISSN 1743-3509 (on-line)

negative effects associated with large speed differentials which include increase in passing maneuvers (and the attendant consequences of improper lane changing); tailgating (driving too close to the slow vehicle in front); frustrations to fast drivers; and formation of platoons of traffic.

Because of lack of control sites, the research reported herein was limited to reviewing the operational and safety characteristics on Florida rural interstate freeway system in relation to the posting of maximum and minimum speed limits. Of interest in the review was the operating speeds at the lower end of the speed distribution and the variances resulting therefrom. The safety review was focused on the analysis of crashes in terms of speed of involvement and crash type occurrences that might be associated with the difference in speeds among the involved vehicles. The research efforts were also directed at conducting a regression analysis to determine the relationship between speed and frequency of crashes while testing a number of hypotheses related to the speed distribution.

2 Analysis of speeds

Speed data were collected from seven sites scattered around the Florida interstate freeway system. Of these seven sites, two were located on sections having six lanes (three in each direction) and five were located on 4-lane sections (two lanes in each direction). Table 1 shows the results of the analysis of the speed characteristics.

The analysis showed that on the average, the mean speed of all vehicles on these sections was 110 kph which is 5 kph above the posted maximum speed limit. Specifically, the percentages of vehicles exceeding the posted maximum speed limit were 56% and 57% on 4-lane and 6-lane sections, respectively. The average speeds on 4-lane sections ranged from 99 kph to 111 kph, and 101 kph to 128 kph on the shoulder and the median lanes, respectively. On the 6-lane sections, the average speeds of the vehicles on the shoulder, middle, and median lanes ranged from 101 kph to 105 kph, 108 kph to 113 kph, and 113 kph to 122 kph, respectively.

The analysis of speed data collected in these sites further showed that the 15th percentile speed—which some engineering texts (e.g. McShane *et al.* [6]) suggests as the measure of slow driving—was 92 kph to 116 kph depending on the lane of travel (i.e., inside lanes had higher 15th percentile speeds than outside lanes). The average of the 15th percentile speed across all sites was 98 kph. Table 1 further shows that only 0.18% and 0.10% of the vehicles had speeds below the posted minimum speed limit (60 KPH) on 4-lane and 6-lane sections, respectively. The review of individual vehicle records did not reveal which type of vehicles predominate at the low end of the speed distribution. This is because the automatic data recorders in the field categorize vehicles in the Federal Highway Administration “F-scheme” which does not prudently capture recreational and vehicles that tow trailers. It is these type of vehicles that were casually observed in the field to be traveling with speeds below 83 kph. In terms of lane usage, this analysis showed that on both 6-lane and 4-lane sections most of the slow vehicles used the outside lane in conformance with Florida State Statutes requiring slow vehicles to use outside lane.

Table 1: Summary of speed statistics.

Statistic	4-lane sections	6-lane sections
Level of service	A	B
15^{th} percentile speed (kph)	101	98
Mean speed (kph)	110	110
85^{th} percentile speed (kph)	120	120
Pace speed (kph)	104-119	104-119
Percent traveling in pace	65	66
Standard deviation (kph)	9.3	8.1
Coefficient of variation	8.5	6.8
Percent traveling above 105 kph	56	57
Percent traveling below 60 kph	0.18	0.10

The examination of the standard deviation of speeds showed a minimum of 6 kph to a maximum of 15 kph. The average standard deviations of speeds were 9.3 kph and 8.1 kph on four-lane and six-lane sections, respectively. The coefficients of variation which measure the relative dispersion between vehicles were calculated as the ratio of the standard deviation to the mean speed. The results showed that the coefficient of variations were between 5% and 14%. The comparison of the coefficient of variations between adjacent lanes on each site showed that the differences were less than 3%. These results indicate that the dispersion of the vehicle speeds from the mean speed is relatively small thus indicating the sufficient uniformity of traffic flow in these sections. Further examination of speed characteristics indicated that the pace speed, which is the 15 kph speed range with the highest number of observations, was between 104 kph and 119 kph. About two thirds of recorded vehicles were traveling in pace.

3 Analysis of crashes

The next step in the research was to acquire data on traffic crashes. In order to have a sufficient sample size that represents crashes which occur on these highway sections, 4-year crash data were acquired. The crash data were collected from January 1, 1998 to December 31, 2001 on the 2-mile segment length on each of the seven sites from which speed data were collected. A total of 169 crashes were reported in these sections in the 4-year analysis period. Crash attributes of interest were the severity level, type of crash, and the estimated pre-crash speed.

3.1 Types of crashes

Of the 169 crashes that occurred on these sections in the 4-year period, 8 (4.7%) were fatal crashes, 99 (58.6%) were injury crashes, and 62 (36.7%) were PDO crashes. There were four major types of crashes that were frequently reported in the crash forms—these were hit roadside object and ran-off road, rear end crashes, angle/sideswipe crashes, and overturned vehicles. Two crash types—rear end and sideswipe/angle—were of particular interest for further analysis given that one study suggested that these crash types are mostly associated with speed differentials between vehicles in the traffic stream [4]. The results further showed that about 41% of the total crashes involved a vehicle hitting roadside object. The rear end and sideswipe crashes were the second and third most occurring crashes, respectively. All other crash types accounted for 12% of the crashes and are categorized as other.

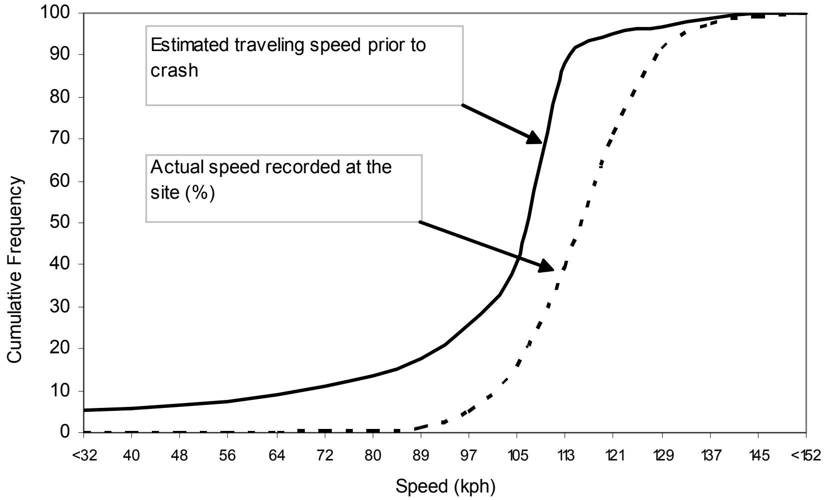

Figure 1. Cumulative distribution of speeds for crash involved vehicles and control vehicles.

3.2 Crash involvement speed

The speed of crash involvement is defined as the estimated vehicle speed when the crash occurred. The responding police officer to the crash scene generally estimates a vehicle speed using accident reconstruction techniques involving measuring skid marks and the degree of vehicle damage. The estimated vehicle speeds of the 244 vehicles involved in crashes were extracted from the crash report forms. Figure 1 shows the cumulative distribution of the estimated speed of vehicles before crash. In addition, the cumulative distribution of actual speed of the vehicles recorded from the permanent count stations is superimposed on the figure in 7.5 kph bins because crash speeds are estimated to the nearest 7.5 kph. Comparison of the two distributions shows that the estimated traveling speed of the vehicle prior to the crash is skewed to the left of the actual vehicle speeds collected at the site.

Looking at the 15-kph speed range with the highest number of crashes, Figure 1 shows that the majority of the vehicles involved in the crashes were traveling with speed between 90 kph to 105 kph. This 90 kph to 105 kph speed range encompasses 66 percent of the vehicles reported to be involved in crashes. However, the curve representing actual field data of vehicle speeds shows that the majority of the vehicles, as defined by the pace, were traveling between 104 kph and 119 kph. At the lower end of speed distribution, the results presented Figure 2 show an overinvolvement of low speed vehicles. For example, percent of vehicles involved in the crashes with speeds below 83 kph were significantly higher than the overall percents of vehicles observed in the field to be traveling below 83 kph.

Furthermore, while the field data showed that only 0.14 percent of the observed vehicles were traveling with speeds below 60 kph (the posted minimum speed limit) averaged across all sites, Figure 2 reveals that about 9 percent of vehicles were involved in the crashes with speeds below 60 kph. This analysis suggests that slow driving is dangerous and poses a bigger risk of crashing even when the proportion of slow moving vehicles in the traffic stream on these freeway sections is low.

4 Modeling crashes

The Poisson regression model was used to test hypotheses on the effect of speed characteristics recorded from the sites on frequency of crashes. The analysis assumed that the crashes occurring in these freeway sections follow a count distribution. The theory behind this assumption was that crashes occurring on these freeway sections were rare and countable events occurring independently. A generalized log-linear model was then used to fit the data to the Poisson distribution. The procedure used was to model crash counts as the exponential function of the independent variables. The generalized crash model took the following form

$$\lambda_i = e^{\beta_i x_i} + \varepsilon \qquad (1)$$

where λ_i is the number of crashes for site i and x_i's are the vectors of geometric and traffic variables with coefficients β_i's which are estimated by the model. The parameter ε is the error term for uncorrelated random variables and intrinsic randomness whose variance increases as the mean increases. This model is estimable by the method of maximum likelihood. The significance of the estimated parameters is tested by the asymptotic normality of maximum likelihood estimates. The model evaluation is performed by assessing the goodness-of-fit using scaled deviance statistic.

Four log-linear models were tested in this study—the models were differentiated by the response variable, i.e., the total number of crashes, the number of fatal crashes, the number of injury crashes, and the number of property damage only crashes. The number of crashes was used as a response variable instead of the crash rate to avoid confounding the effect of traffic volume on occurance of crashes. The inclusion of the volume as an independent variable in the model was inspired by the results of the prior research which revealed that traffic volume and crashes vary in a nonlinear function [7]. Other independent variables that were used in the modeling were the 50th percentile speed, the 15th percentile speed, and the differencce between the 85th and the 15th percentile speed. The difference between the 85th and 15th percentile speed was used as the proxy for the speed variation. In addition, the percent of vehicles traveling below 90 kph was included as a variable to represent the amount of traffic traveling at the lower end of the speed distribution.

4.1 Results of the parameter estimates

The calculation of the scaled deviance resulted in a value equal to one confirming that the assumption of Poisson distribution was appropriate. The results of the parameter estimates are presented in Table 2. These results show that all covariates were very significant ($p \leq 0.0001$) in influencing crash occurrence. All variables included in the model, except the median speed, positively influenced the crash frequency. Closer examination of the parameter estimates of the total crash model revealed the following pointers. The estimated coefficients for volume, the 15th percentile speed, the percentage of vehicles traveling below 90 kph, and the percent difference between 85th and 15th percentile speeds were positive and statistically significant implying that as the values of these variables increase the frequency of crashes also increases significantly. However, the frequency of crashes was found to decrease with the increase of the median speed.

The results presented in Table 2 further show that the frequency of fatal and injury crashes increased significantly as the volume of traffic, the 15th percentile speed, the percent of vehicles with speed below 90 kph, and the difference between 85th and 15th percentile speeds increased. However, the increase of the median speed was found to significantly decrease the likelihood of fatal crashes. For the property damage only crashes, the model results showed that the traffic volume, the 15th percentile speed, and the percentile difference increased the likelihood of property damage crashes significantly. The median speed and the percent of vehicle traveling with speed below 90 kph were found to significantly decrease the frequency of property damage only crashes. The results also show that the intercept coefficient for the property damage only crashes was insignificant ($p=0.1974$).

The modeling exercise discussed above shows some mixed results in interpreting the overall effect of the speed distribution on crash involvement on rural interstate freeways in Florida. A constant theme in all four models is that as the 15th percentile speed increases, the frequency of all crashes (regardless of severity level) increases. This seems counterintuitive since operationally as the 15th percentile speed increases, speeds become more uniform thus reducing conflicts caused by speed variability. One can also speculate that the drivers whose speeds are at the lower end of the speed distribution are not regular commuters hence they choose to travel slow on these freeways and increasing their speed beyond their comfort levels or may eventually increase the incidences of driver error and lead to an increase of crashes. Also, older drivers may choose to drive slow due to their large reaction times or reduced visual capabilities.

Table 2: Poisson regression parameter estimates.

Model	Variable	Coefficient	χ^2	*p*-value
Total crashes	Intercept	-7.7461	32.86	<.0001
	Median	-1.8648	848.82	<.0001
	AADT	0.000055	2860.75	<.0001
	15th Percentile	2.0844	746.63	<.0001
	% below 90 KPH	29.4506	235.77	<.0001
	85th-15th percentile	0.5113	829.37	<.0001
Fatality	Intercept	-1408.76	7.63E12	<.0001
	Median	-31.5887	5.53E13	<.0001
	AADT	0.0011	1.26E13	<.0001
	15th Percentile	53.2955	2.23E13	<.0001
	% below 90 KPH	2016.463	9.08E12	<.0001
	85th-15th percentile	6.3620	7.63E12	<.0001
Injuries	Intercept	-18.8898	2.56	0.1093
	Median	-1.7713	10.15	0.0014
	AADT	0.0001	33.49	<.0001
	15th Percentile	2.1444	10.57	0.0012
	% below 90 KPH	41.0773	6.01	0.0142
	85th-15th percentile	0.4712	9.34	0.0022
PDOs	Intercept	19.4417	1.66	0.1974
	Median	-1.9239	7.27	0.0070
	AADT	0.0001	25.28	<.0001
	15th Percentile	1.7256	4.07	0.0436
	% below 90 KPH	-2.9454	0.02	0.8886
	85th-15th percentile	0.5884	8.68	0.0032

5 Conclusions

The operational and safety characteristics of rural freeways in Florida were reviewed in relation to the posting of the minimum speed limit. The field data on speed and traffic volume were reviewed in conjunction with historical crash data. The approach used in the research was to correlate speed characteristics with reported crashes while attempting to quantify the level of importance that various speed characteristics had on safety of operations on the selected rural freeway sections.

The operational analysis showed that 57% of the recorded vehicles exceeded the posted maximum speed limit of 105 kph while only 0.14% of the vehicles had speeds below the posted minimum speed limit of 60 kph. The 85th and 15th percentile speeds, which some literature suggested should be used as a guide in setting maximum and minimum speed limits, were 120 kph and 98 kph, respectively. A combined analysis of speed and crash data revealed that while only 0.14% of the vehicles had field-recorded speeds below 60 kph, 9% of the crash-involved vehicles were estimated to have speeds below 60 kph. The overrepresentation of slow vehicles in the crashes shows that even a few vehicles with speed characteristics unlike the mainstream can still cause deterioration of safety of travel on highways. This result may perhaps be underscoring the need to regulate speeds on the lower end of speed distribution.

The safety modeling results have indicated that the speed variation has a negative impact on the frequency of crashes, thus measures to reduce the difference between fast and slow moving vehicles could improve the overall safety of operation of these freeways sections. Furthermore, the model results indicated that the presence of significant amount of vehicles which are traveling below 90 kph increases the likelihood of crashes. This calls for the need to restrict the number of vehicles driving slowly relative to the mean speed of the traffic stream. Should the minimum speed be raised to 98 kph which is equivalent to the 15th percentile of operating speeds observed in the field? Further research is needed to answer this question but it can be presumed that higher minimum speed might increase incidences of driver error particularly for vulnerable drivers—e.g., older drivers, reactional vehicle drivers, and drivers driving vehicles towing trailers—who are probably comfortable with speeds below 98 kph but above 60 kph.

It should be noted that additional work is needed to increase the confidence in the results reported herein. A detailed study is desirable in which operational and safety review on sites with minimum speed posted are compared to those without minimum speed posted. The survey study conducted by Mussa [8] indicated that 25 states do not post minimum speed limit signs on interstate freeways. Thus, a multistate study is recommended. In addition, the safety modeling discussed above would benefit from additional sample size that would enable other covariates such as the number of lanes to be incorporated in the model.

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