Effect of Increases in Speed Limits on Severities of Injuries in Accidents

Nataliya V. Malyshkina and Fred Mannering

The influence of speed limits on roadway safety has been a subject of continuous debate in the state of Indiana and nationwide. In Indiana, highway-related accidents result in about 900 fatalities and 40,000 injuries annually and place an incredible social and economic burden on the state. Still, speed limits posted on highways and other roads are routinely exceeded as drivers try to balance safety, mobility (speed), and the risks and penalties associated with law enforcement efforts. The combined issue of speed limits and safety issue has been a matter of considerable concern in Indiana since the state raised its speed limits on rural Interstates and selected multilane highways on July 1, 2005. In this paper, the influence of the posted speed limit on the severity of vehicle accidents is studied through Indiana accident data from 2004 (the year before speed limits were raised) and 2006 (the year after speed limits were raised on rural Interstates and some multilane non-Interstate routes). Statistical models estimated the injury severity of different types of accidents on various roadway classes. The results of the model estimations showed that, for the speed limit ranges currently used, speed limits did not have a statistically significant effect on the severity of accidents on Interstate highways. However, for some non-Interstate highways, higher speed limits were found to be associated with higher accident severities, suggesting that future speed limit changes, on non-Interstate highways in particular, need to be carefully assessed on a case-by-case basis.

The speed-limit changes that took effect on July 1, 2005, made Indiana the 30th U.S. state to raise Interstate speed limits up to 70 mph (from 65 mph on rural Interstates). Speed limits were also increased on some multilane non-Interstate highways. These changes intensified a statewide debate on the tradeoff between highway mobility (speed) and safety. This debate has raged throughout the United States for more than three decades, since the passage of the Emergency Highway Energy Conservation Act in 1974, which mandated the 55-mph national maximum speed limit on Interstate highways in the United States. State and federal speed limit policy changes have been fueled by various research findings and subsequent legislation, such as the National Highway System Designation Act of 1995 that gave states complete freedom to set Interstate speed limits.

In relation to safety, however, most research efforts have concluded that the 1974-mandated 55-mph Interstate speed limit had saved lives (*1, 2*). This conclusion has been confirmed by some studies that have looked at recent speed limit increases on Interstates. As an example, Kockelman and Bottom (*3*) found that a speed limit increase from 55 to 65 mph resulted in roughly a 3% increase in the accident rate and a 24% increase in the probability of a fatality once an accident occurred. For speed limit increases from 65 to 75 mph, they found a 0.64% increase in the accident rate and in a lower 12% increase in the probability of fatal injury once an accident occurred. The authors speculated that these lower percentage increases resulting from a speed limit change from 65 to 75 mph (relative to the increases from a change from 55 to 65 mph) may have been the result of drivers' heightened awareness of risk at higher speeds or that roads assigned the higher 75 mph in their study's sample may have been inherently safer.

However, other studies have contended that legislation-enabled speed limit increases have actually saved lives. As an example, Lave and Elias (*4*) argued that the increase from 55 to 65 mph saved lives because of shifts in law enforcement resources, the ability of higher–speed limit Interstates to attract riskier drivers away from inherently more dangerous non-Interstate highways, and possible reductions in speed variances.

Understanding the magnitude of the safety impacts of increasing speed limits, or even the direction of safety impacts (whether safety is improved or compromised), remains a contentious subject because research has not been able to unravel convincingly the impacts of speed limit changes from the confounding effects of time-varying changes in factors such as highway enforcement, vehicle miles traveled, vehicle occupancy, seat belt usage, alcohol use and driving, vehicle fleet mix (proportions of passenger cars, minivans, pickup trucks, and sport utility vehicles), vehicle safety features (increasing adoption of air bags, antilock brakes, and other active safety systems), speed limits on other road classes and in other states, driver expectations, and driver adjustment and adaptation to risk.

In this paper, the recent increase in Indiana speed limits was studied by undertaking a statistical analysis to assess the effect that speed limits have on roadway safety through consideration of the relationship between speed limits and observed accident-injury severities. In assessing the impact of speed limits on accident-injury severities, the injury level sustained by the most critically injured individual in an accident was used to conduct appropriate statistical tests to determine whether the posted speed limit had any significant effect on these injury severities and whether the possible effect changed after the speed limits were raised.

METHODOLOGY

Accident severity (the most severe injury sustained by any vehicle occupant in the accident) has discrete outcomes ranging from property damage only to injury and to fatality. Given that these severity data are ordered responses from less severe to more severe, an ordered-probability model would seem to be a natural approach and one that has been successfully applied to accident-severity analysis by many

School of Civil Engineering, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907-2051. Corresponding author: F. Mannering, flm@purdue.edu.

Transportation Research Record: Journal of the Transportation Research Board, No. 2083, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 122–127.
DOI: 10.3141/2083-14

researchers (*5–12*). However, an alternative to an ordered model is the unordered-probability approach that includes multinomial, nested, and mixed logit models (see *13–21*). Relative to ordered-probability models, traditional multinomial, nested, and mixed logit structures do not account for the ordering of injury-severity data. However, multinomial, nested, and mixed logit models do offer a more flexible functional form. For example, the traditional multinomial logit can provide consistent parameter estimates in the presence of the possible underreporting of accidents (for example, a known problem with police-reported data is the underreporting of property damage-only accidents). Furthermore, the unordered models can relax the parameter restriction imposed by ordered-probability models that does not allow a variable to increase (or decrease) simultaneously both high- and low-injury severities. This monotonic effect of variables imposed by ordered probability models and its potential adverse consequences is discussed by Eluru and Bhat (*22*), Bhat and Pulugurta (*23*), and Washington et al. (*24*). In this paper, a multinomial logit model for accident injury–severity outcomes was used.

For the multinomial logit formulation, a linear function of covariates that determine the probability of the accident injury outcome (of the most severely injured person) being reported as property damage only (no injury), injury, or fatality is defined as

$$Z_{in} = \boldsymbol{\beta}_i \boldsymbol{X}_n + \epsilon_{in} \qquad (1)$$

where

- Z_{in} = linear function determining the probability of accident-severity outcome i for accident n,
- $\boldsymbol{X}_n$ = vector of measurable characteristics for accident n that determine outcome i (such as speed limit, driver characteristics, roadway characteristics, environmental conditions, etc.),
- $\boldsymbol{\beta}_i$ = vector of estimable parameters, and
- ϵ_{in} = error term that accounts for unobserved factors influencing resulting outcomes.

McFadden (*25*) has shown that if ϵ_{in} is assumed to follow a generalized extreme-value distribution, the standard multinomial logit model results of

$$P_n(i) = \frac{\exp[\boldsymbol{\beta}_i \boldsymbol{X}_n]}{\sum_I \exp[\boldsymbol{\beta}_I \boldsymbol{X}_n]} \qquad (2)$$

where $P_n(i)$ is the probability that accident n has accident-severity outcome i and I is the set of possible outcomes. This model is estimable by standard maximum likelihood methods (*24*). To assess the effect of the vector of estimated parameters ($\boldsymbol{\beta}_i$), elasticities are computed for each accident n (n subscripting omitted) as

$$E_{x_{ki}}^{P(i)} = \frac{\partial P(i)}{\partial x_{ki}} \times \frac{x_{ki}}{P(i)} \qquad (3)$$

where $P(i)$ is the probability of discrete outcome i and x_{ki} is the value of variable k for outcome i. This gives (from Equations 2 and 3)

$$E_{x_{ki}}^{P(i)} = [1 - P(i)]\ \beta_{ki} x_{ki} \qquad (4)$$

where β_{ki} is the estimated parameter associated with variable x_{ki}. Elasticity values can be roughly interpreted as the percentage effect that a 1% change in x_{ki} has on the accident-severity outcome probability $P(i)$.

The statistical analysis also used multiple statistical tests to determine if the accident data should be split by roadway type (rural Interstate, urban Interstate, rural arterials, etc.) and accident type (single vehicle, car colliding with car, car colliding with truck, etc.). For this analysis, a likelihood ratio test was used. The appropriate test statistic is (*24*)

$$-2\left[\mathrm{LL}(\boldsymbol{\beta}) - \sum_{m=1}^{M} \mathrm{LL}(\boldsymbol{\beta}_m)\right] \sim \chi^2_{df=(M-1)\times K} \qquad (5)$$

where

- $\mathrm{LL}(\boldsymbol{\beta})$ = log likelihood at converged values of $\boldsymbol{\beta}$ for model estimated for whole data sample,
- $\mathrm{LL}(\boldsymbol{\beta}_m)$ = log likelihood of model estimated for observations in mth data subset (road–accident type combinations),
- $\boldsymbol{\beta}_m$ = vector of parameters estimated for this model ($m = 1, 2, 3, \ldots, M$),
- M = number of data subsets, and
- K = number of parameters estimated for each model (i.e., number of estimated parameters in vectors $\boldsymbol{\beta}$ and $\boldsymbol{\beta}_m$).

For Equation 5, there are $(M - 1) \times K$ degrees of freedom. The null hypothesis for Equation 5 is that the $\boldsymbol{\beta}$'s in the M subset models are the same. If this hypothesis can be rejected with high confidence, estimation of separate models for the data subsets is warranted.

DATA

The accident data used in this study were from the Indiana Electronic Vehicle Crash Record System (EVCRS), which was launched in 2004 and includes available information on all accidents investigated by Indiana police. The information on accidents included into the EVCRS can be divided into three major categories: roadway and environmental data (including weather, roadway and traffic conditions, roadway geometrics, posted speed limits, etc.), vehicle data (including information on all vehicles involved in an accident, type and model of each vehicle, vehicle model year, etc.), and occupant data (including information such as age and gender of all people who were involved in the accident and their injury status). These data gave 127 variables for each accident. Data were considered from 204,382 accidents reported in the Indiana State accident databases for 2004 (the year before the speed limits were raised) and from 182,922 accidents that were reported in the Indiana State accident databases for 2006 (the year after the speed limits were raised).

Of the 182,922 accidents in the 2006 database, 65% occurred on locally maintained streets and roads (city and county), 16.7% on state routes, 10.9% on U.S. routes, and 7.4% on urban and rural Interstates. Of these, 52.9% were two-vehicle accidents involving only passenger vehicles (passenger cars and light trucks, which include sport utility vehicles, vans, and pickup trucks), 3.9% were vehicle accidents involving a large truck and a passenger vehicle, 31.1% were single-vehicle accidents, and 12.1% were other accident types (involving three or more vehicles). These figures compare closely with the 2004 database, which showed that 69.3% occurred on locally maintained streets and roads (city and county), 14.8% on state routes, 9.7% on U.S. routes, and 6.2% on urban and rural Interstates. Of these 2004 accidents, 54.7% were two-vehicle accidents involving only passenger vehicles (as defined earlier), 4.8% were vehicle accidents involving a large truck and a passenger vehicle, 28.6% were single-vehicle accidents, and 11.9% were other accident types (as defined earlier).

TABLE 1 Indiana Accident Injury–Severity Distributions by Posted Speed Limits in 2004 and 2006

	Injury Severity Level		
Speed Limit	Property Damage Only	Injury	Fatality
2004, posted 65 mph	81.7%	17.7%	0.6%
2006, posted 65 or 70 mph	81.9%	17.4%	0.7%
2004, posted 55 and 60 mph	76.7%	22.3%	1.1%
2006, posted 55 and 60 mph	77.8%	21.3%	0.9%
2004, posted 35 to 50 mph	74.5%	25.2%	0.4%
2006, posted 35 to 50 mph	75.3%	24.3%	0.4%
2004, posted 30 mph or less	80.6%	19.2%	0.2%
2006, posted 30 mph or less	82.1%	17.8%	0.2%

Of the accidents in 2006, unsafe speed was identified as the primary cause in 5.78% of them. This compares with 7.28% of the 2004 accidents (before the increase in speed limits) that listed unsafe speed as the primary cause. For injury severity levels in 2006, 79.03% were property damage only, 20.56% were injury, and 0.41% were fatality (the numbers for 2004 were 78.53% property damage only, 21.06% injury, and 0.41% fatality).

As to the effect of speed limits, in 2006, unsafe speed was listed as the primary cause in 11.4% of the accidents on roads with 65- and 70-mph speed limits, 7.7% on roads with speed limits of 55 and 60 mph, 6.6% on roads with speed limits from 35 to 50 mph, and 4.6% on roads with speed limits of 30 mph or less. These figures compare with 2004 data showing that unsafe speed was listed as the primary cause in 19.4% of the accidents on roads with 65-mph speed limits (the maximum speed in 2004), 10.6% on roads with speed limits of 55 to 60 mph, 7.5% on roads with speed limits from 35 to 50 mph, and 6.0% on roads with speed limits of 30 mph or less. The corresponding accident-severity levels, by speed limit category, for 2004 and 2006 are presented in Table 1. This table shows some variation but generally similar numbers between the years. However, to unravel this relationship properly, a multivariate analysis was needed to control for the many factors that can potentially affect this relationship.

ESTIMATION RESULTS

Results of the multinomial logit estimation that used the 2006 data are presented in Table 2 for the accident injury–severity models (the most severely injured occupant). The results for the 2004 data are similar and for brevity are not presented here [see Malyshkina et al. (*26*) for the complete 2004 results]. Again, the possible outcomes are property damage only, injury, and fatality. For estimation purposes, the function determining property damage only (given by Equation 1) is set to zero without loss of generality (*24*). On the basis of the results of likelihood ratio tests, 34 injury-severity models were estimated from combinations of roadway type, roadway location, and number and types of vehicles involved in the accident. In addition to the estimates of the speed limit parameter shown in Table 2, the models included a wide variety of variables found to influence injury severity significantly, such as seasonal indicators, day-of-week indicators, peak-hour indicators, other time-of-day indicators, construction zone indicators, lighting conditions, precipitation indictors (snow, rain, clear, etc.), pavement condition indictors (dry, wet, ice, etc.), median type, presence of vertical and horizontal curves, vehicle age, number of vehicle occupants, traffic control indicators, driver age, and driver gender.

When the speed-limit parameter estimates shown in Table 2 are considered, it is found that speed limits did not significantly affect accident-injury severities on Interstate highways (which was also true of the model estimations based on 2004 data). While the reasons for this finding are not known for certain, there could be a number of contributing factors. One is the issue of speed limit compliance on Interstate highways. A survey of Indiana drivers in the fall of 2005 (a few months after Indiana Interstate speed limits were raised) found that under free-flow conditions, drivers reported driving an average of nearly 11 mph over a 55-mph Interstate speed limit, about 9 mph over a 65-mph Interstate speed limit, and less than 8 mph over a 70-mph speed limit (*27*). Thus, it appears that driver behavior was compressing the effect of speed limits (a 15-mph increase in speed limits results in an increase in speeds of less than 15 mph). In addition, this same survey found that the standard deviation of self-reported free-flow speeds declined from roughly 6 mph on Interstates posted 55 mph to about 5 mph on Interstates posted 65 mph or 70 mph. The reduced standard deviation of speed may be mitigating the effect on severity of the higher overall speeds. There could also be behavioral elements involved, such as drivers becoming more alert (perhaps with lower reaction times) at higher speeds and thereby being enabled to take actions to reduce accident severity. Finally, the high design standards of the Interstate system may be mitigating the effects of higher speeds. All these factors seemed to be sufficient to offset the physics involved with higher travel speed. Whether this offset would be true for speed limits above 70 mph is an open question that the data here cannot support.

Contrasting the data for Interstates, Table 2 shows that, for many other highway types, increases in speed limits significantly increases the likelihood that an accident would result in an injury or fatality (this was also true of the model estimations based on 2004 data). And the elasticities show that the effect can be reasonably large. For example, as Table 2 shows, for accidents on rural county roads involving a car or light truck and a heavy truck, a 1% increase in the speed limits results in a 2.77% increase in the probability of fatality and a 2.35% increase in the probability of injury. For accidents on rural state roads involving a car or light truck and another car or light truck, a 1% increase in the speed limit results in an 11.9% increase in the probability of fatality and a 1.32% increase in the probability of injury. The findings on accident-injury severity on non-Interstate highways suggest that extreme caution needs to be exercised when the speed limits on these roads are raised. It is speculated that the lack of access control, lower design standards, and the greater demand placed on driver attention can make these highways quite sensitive to speed limit changes.

TEMPORAL STABILITY: INTERSTATES

The fact that speed limits on Interstates were not found to affect the severity of accidents is worth a closer look. The previous analysis was based on cross-sectional data comparing the effect of different speed limits on a class of roadways for a single year (2004 or 2006). The use of such cross-sectional data is an important consideration because it controls for possible changes in vehicle safety features, enforcement levels, and driver behavior that may vary from one year to the next. Still, it may be of interest to compare 2004 and 2006 Interstate accident-severity models to see if the 2005 speed-limit

TABLE 2 Speed Limit Parameter and Elasticity Estimates (Computed for Statistically Significant Parameters) for Accident-Severity Models Based on 2006 Indiana Accident Data

Model	Speed Limit Parameter Estimate (*t*-ratio) Fatality	Speed Limit Parameter Estimate (*t*-ratio) Injury	Fatality Elasticity	Injury Elasticity
County Road				
Rural				
(C–LT) + (C–LT)	0.0396 (5.48)	0.0396 (5.48)	1.61	1.20
(C–LT) + (HT)	0.0648 (3.06)	0.0648 (3.06)	2.77	2.35
One vehicle	0.00506 (2.04)	0.00506 (2.04)	0.24	0.19
Urban				
(C) + (C)	0.00689 (0.00)	0.00507 (.321)		
(C) + (LT)	0.0231 (0.00)	0.0613 (2.43)		1.80
(LT) + (LT)	.0110 (0.00)	0.0269 (0.84)		
(C–LT) + (HT)	−0.5454 (−.518)	−0.0288 (−0.30)		
One vehicle	−0.0852 (−1.23)	0.000725 (0.07)		
Interstate				
Rural				
(C–LT) + (C–LT)	0.103 (1.28)	0.00872 (0.88)		
(C–LT) + (HT)	0.150 (0.91)	0.00133 (0.06)		
One vehicle	−0.0237 (−1.55)	−0.0237 (−1.55)		
Urban				
(C–LT) + (C–LT)	11.04 (0.00)	−0.00108 (−0.14)		
(C–LT) + (HT)	−0.00188 (−0.01)	0.0120 (0.52)		
One vehicle	0.00776 (0.20)	0.00384 (0.48)		
State Route				
Rural				
(C–LT) + (C–LT)	0.248 (3.48)	0.0416 (3.25)	11.9	1.32
(C–LT) + (HT)	0.127 (2.50)	0.127 (2.50)	5.79	5.36
One vehicle	0.0636 (2.34)	0.0127 (2.25)	3.34	
Urban				
(C–LT) + (C–LT)	0.251 (3.35)	.0290 (7.95)	9.40	0.84
(C–LT) + (HT)	5.60 (0.00)	0.452 (1.73)		
One vehicle	0.0268 (0.42)	−0.0115 (−0.83)		
City Street				
Rural				
(C–LT) + (C–LT)	0.0414 (6.13)	0.0414 (6.13)	1.46	1.12
(C–LT) + (HT)	0.0185 (0.00)	0.540 (1.43)		
One vehicle	−0.0800 (−1.46)	−0.00409 (−0.38)		
Urban				
(C) + (C)	0.0251 (6.33)	0.0251 (6.33)	0.81	0.63
(C) + (LT)	0.0218 (4.65)	0.0218 (4.65)	0.73	0.56
(LT) + (LT)	0.0343 (4.20)	0.0343 (4.20)	1.14	0.87
(C–LT) + (HT)	0.0284 (2.34)	0.0284 (2.34)	0.94	0.83
One vehicle	0.00968 (0.38)	−0.00128 (−0.24)		
U.S. Route				
Rural				
(C–LT) + (C–LT)	0.0644 (1.32)	0.0272 (1.84)		
(C–LT) + (HT)	0.0608 (3.07)	0.0608 (3.07)	3.12	2.28
One vehicle	0.0137 (1.56)	0.0137 (1.56)		
Urban				
(C–LT) + (C–LT)	0.0154 (2.14)	0.0154 (2.14)	0.61	0.44
(C–LT) + (HT)	0.0586 (3.60)	0.0586 (3.60)	2.33	2.02
One vehicle	0.0327 (0.45)	0.0134 (.878)		

NOTE: C = cars, LT = light trucks, HT = heavy trucks.

increase (and the other factors that may have varied over this time period) significantly changed the estimated parameters in the accident-severity models. To address this possibility, the following situations were considered: (*a*) Interstates that had 55-mph speed limits in 2004 and remained at 55 mph in 2006 (which were Interstates in urban areas) and (*b*) Interstates that were 65 mph in 2004 and increased to 70 mph in 2006 (which were those in rural areas). Again, applying the likelihood ratio test, the appropriate statistical test is (*24*)

$$-2\left[\mathrm{LL}(\boldsymbol{\beta}_{\mathrm{all}})-\mathrm{LL}(\boldsymbol{\beta}_{2004})-\mathrm{LL}(\boldsymbol{\beta}_{2006})\right]\sim\chi^2_{df=(K_{2004}+K_{2006})-K_{\mathrm{all}}} \qquad (6)$$

where

$\mathrm{LL}(\boldsymbol{\beta}_{\mathrm{all}})$ = log likelihood at converged values of $\boldsymbol{\beta}$ for model-estimated 2004 and 2006 data for the accident type being considered,
$\mathrm{LL}(\boldsymbol{\beta}_{2004})$ = log likelihood of model estimated for 2004 observations,
$\mathrm{LL}(\boldsymbol{\beta}_{2006})$ = log likelihood of model estimated for 2006 observations,
K_{all} = number of parameters in $\boldsymbol{\beta}_{\mathrm{all}}$,
K_{2004} = number of parameters in $\boldsymbol{\beta}_{2004}$, and
K_{2006} = number of parameters in $\boldsymbol{\beta}_{2006}$.

The null hypothesis for Equation 6 is that the $\boldsymbol{\beta}$'s generated by the 2004 and 2006 data are the same. If this hypothesis can be rejected, it would indicate that the parameters have shifted from 2004 to 2006, suggesting that the increased speed limit and possibly other influences (such as changes in driver behavior, in enforcement levels, and in vehicle safety features) may have changed the effect of factors that determine injury severity.

For Interstates that had the same 55-mph speed limits in 2004 and 2006, the application of this likelihood ratio test to the various models indicated that the estimates of the accident-severity parameter (for single- and multivehicle crashes) did not significantly change from 2004 to 2006. In no case could the null hypothesis be rejected, even at a very modest 70% confidence level. This observation indicates that the halo effect of the increased speed limits (from 65 to 70 mph in rural areas) did not significantly affect those urban Interstates that remained at 55 mph.

For Interstates that were 65 mph in 2004 and increased to 70 mph in 2006, temporal-stability tests again showed that estimates for the accident-severity parameter (for single- and multivehicle crashes) did not significantly change from 2004 to 2006 (the null hypothesis could not be rejected in any of the cases, even at the very modest 70% confidence level). The temporal stability of these Interstate models adds further evidence to support the cross-sectional finding that the higher range of speed limits in effect on Indiana Interstates in 2006 did not significantly affect the severity of accidents.

SUMMARY AND CONCLUSIONS

The findings of this study are drawn from multinomial models of accident severity defined by the injury level of the most severely injured person in the accident. The estimation results found that speed limits did not significantly affect accident-injury severities on Interstate highways. This is an important finding because the July 1, 2005, increase in maximum Interstate speeds from 65 to 70 mph has been the focus of considerable media attention. One can speculate that this finding is a result of a number of factors, including possible reductions in speed variance as speed limits increase, driver responses to higher speed limits, and the high design standards of the Interstate system, which appear to be able to accommodate modest increases in speed limits.

For non-Interstate highways, the results are quite different. For non-Interstate highways, the accident data show that higher speed limits were associated with a greater likelihood of injury, fatality, or both on some (but not all) roadway types (county, state, city, and U.S. routes) and accident types (single- and two-vehicle).

This study's findings have a number of implications for speed limit policies in the State of Indiana. With regard to Interstate speeds, the findings suggest that the effect of speed limits on accident injury severity are not necessarily a cause for concern for the speed-limit ranges that were considered in this study (55 to 70 mph). Whether this finding would hold true if speed limits were increased further to 75 or 80 mph (both of which would exceed the 70-mph Interstate-standard design speed) remains an open question. To be sure, the additional speed would increase stopping distances and the energy that would need to be dissipated in the accident. Furthermore, at some point, higher speed limits may start increasing the variance in driver speeds as some drivers continue to drive at or above the speed limit while others drive below the speed limit because it may have been raised above their "optimum" speed. With these factors considered (along with others that may come into play, such as variations in driver behavior in response to speed limits), there is likely a point beyond which higher speed limits would significantly increase the severity of accidents on Interstates.

For speed limit policies on roadways other than Interstate highways, the results here suggest that considerable caution should be exercised. The findings show that, for some non-Interstate roadway and accident type combinations, higher speed limits significantly increase the likelihood that accidents will result in injuries and fatalities. Thus, changes to speed limits on non-Interstate highways should be done on a case-by-case basis while taken into account is past accident history as well as the specific geometrics and access control of the facility, as these factors can vary widely, even within the same class of highways (non-Interstate).

ACKNOWLEDGMENTS

The authors were supported by the Indiana Department of Transportation–Joint Transportation Research Program (JTRP). The comments and suggestions of Brad Steckler are gratefully acknowledged.

REFERENCES

1. *The Effects of the 65 mph Speed Limit Through 1990: A Report to Congress.* National Highway Traffic Safety Administration, U.S. Department of Transportation, 1992.
2. Farmer, C., R. Retting, and A. Lund. Changes in Motor Vehicle Occupant Fatalities After Repeal of the National Maximum Speed Limit. *Accident Analysis and Prevention,* Vol. 31, No. 5, 1999, pp. 537–543.
3. Kockelman, K., and J. Bottom. Safety Impacts and Other Implications of Raised Speed Limits on High-Speed Roads. National Cooperative Research Program, Project 17-23, Washington, D.C., 2006.
4. Lave, C., and P. Elias. Did the 65 mph Speed Limit Save Lives? *Accident Analysis and Prevention,* Vol. 26, No. 1, 1994, pp. 49–62.
5. O'Donnell, C., and D. Connor. Predicting the Severity of Motor Vehicle Accident Injuries Using Models of Ordered Multiple Choice. *Accident Analysis and Prevention,* Vol. 28, No. 6, 1996, pp. 739–753.
6. Duncan, C. S., A. J. Khattak, and F. M. Council. Applying the Ordered Probit Model to Injury Severity in Truck-Passenger Car Rear-End Colli-

sions. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1635,* TRB, National Research Council, Washington, D.C., 1998, pp. 63–71.
7. Renski, H., A. J. Khattak, and F. M. Council. Effect of Speed Limit Increases on Crash Injury Severity: Analysis of Single-Vehicle Crashes on North Carolina Interstate Highways. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1665,* TRB, National Research Council, Washington, D.C., 1999, pp. 100–108.
8. Khattak, A. J. Injury Severity in Multivehicle Rear-End Crashes. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1746,* TRB, National Research Council, Washington, D.C., 2001, pp. 59–68.
9. Kockelman, K., and Y.-J. Kweon. Driver Injury Severity: An Application of Ordered Probit Models. *Accident Analysis and Prevention,* Vol. 34, No. 4, 2002, pp. 313–321.
10. Khattak, A. J., D. Pawlovich, R. Souleyrette, and S. Hallmark. Factors Related to More Severe Older Driver Traffic Crash Injuries. *Journal of Transportation Engineering,* Vol. 128, No. 3, 2002, pp. 243–249.
11. Kweon, Y.-J., and K. Kockelman. Overall Injury Risk to Different Drivers: Combining Exposure, Frequency, and Severity Models. *Accident Analysis and Prevention,* Vol. 35, No. 3, 2003, pp. 414–450.
12. Abdel-Aty, M. Analysis of Driver Injury Severity Levels at Multiple Locations Using Ordered Probit Models. *Journal of Safety Research,* Vol. 34, No. 5, 2003, pp. 597–603.
13. Shankar, V., and F. Mannering. An Exploratory Multinomial Logit Analysis of Single-Vehicle Motorcycle Accident Severity. *Journal of Safety Research,* Vol. 27, No. 3, 1996, pp. 183–194.
14. Shankar, V., F. Mannering, and W. Barfield. Statistical Analysis of Accident Severity on Rural Freeways. *Accident Analysis and Prevention,* Vol. 28, No. 3, 1996, pp. 391–401.
15. Chang, L.-Y., and F. Mannering. Analysis of Injury Severity and Vehicle Occupancy in Truck- and Non-Truck-Involved Accidents. *Accident Analysis and Prevention,* Vol. 31, No. 5, 1999, pp. 579–592.
16. Carson, J., and F. Mannering. The Effect of Ice Warning Signs on Accident Frequencies and Severities. *Accident Analysis and Prevention,* Vol. 33, No. 1, 2001, pp. 99–109.
17. Lee, J., and F. Mannering. Impact of Roadside Features on the Frequency and Severity of Run-Off-Roadway Accidents: An Empirical Analysis. *Accident Analysis and Prevention,* Vol. 34, No. 2, 2002, pp. 149–161.
18. Ulfarsson, G., and F. Mannering. Differences in Male and Female Injury Severities in Sport-Utility Vehicle, Minivan, Pickup and Passenger Car Accidents. *Accident Analysis and Prevention,* Vol. 36, No. 2, 2004, pp. 135–147.
19. Khorashadi, A., D. Niemeier, V. Shankar, and F. Mannering. Differences in Rural and Urban Driver-Injury Severities in Accidents Involving Large Trucks: An Exploratory Analysis. *Accident Analysis and Prevention,* Vol. 37, No. 5, 2005, pp. 910–921.
20. Savolainen, P., and F. Mannering. Probabilistic Models of Motorcyclists' Injury Severities in Single- and Multi-Vehicle Crashes. *Accident Analysis and Prevention,* Vol. 39, No. 5, 2007, pp. 955–963.
21. Milton, J., V. Shankar, and F. Mannering. Highway Accident Severities and the Mixed Logit Model: An Exploratory Empirical Analysis. *Accident Analysis and Prevention,* Vol. 40, No. 1, 2008, pp. 260–266.
22. Eluru, N., and C. Bhat. A Joint Econometric Analysis of Seat Belt Use and Crash-Related Injury Severity. *Accident Analysis and Prevention,* Vol. 39, No. 5, 2007, pp. 1037–1049.
23. Bhat, C., and V. Pulugurta. A Comparison of Two Alternate Behavioral Choice Mechanisms for Household Auto Ownership Decisions. *Transportation Research B,* Vol. 32, No. 1, 1998, pp. 61–75.
24. Washington, S., M. Karlaftis, and F. Mannering. *Statistical and Econometric Methods for Transportation Data Analysis.* Chapman and Hall/CRC, Boca Raton, Fla., 2003.
25. McFadden, D. Econometric Models of Probabilistic Choice. In *A Structural Analysis of Discrete Data with Econometric Applications* (C. F. Manski and D. McFadden, eds.), MIT Press, Cambridge, Mass., 1981, pp. 198–272.
26. Malyshkina, N., F. Mannering, and S. Labi. *Influence of Speed Limits on Roadway Safety in Indiana.* Prepared for Joint Transportation Research Program, Indiana Department of Transportation, Federal Highway Administration, Project No. C-36-59VV, 2007.
27. Mannering, F. Speed Limits and Safety: Statistical Analysis of Driver Perceptions. Presented at 87th Annual Meeting of the Transportation Research Board, Washington, D.C., 2008.

The Safety Data, Analysis, and Evaluation Committee sponsored publication of this paper.