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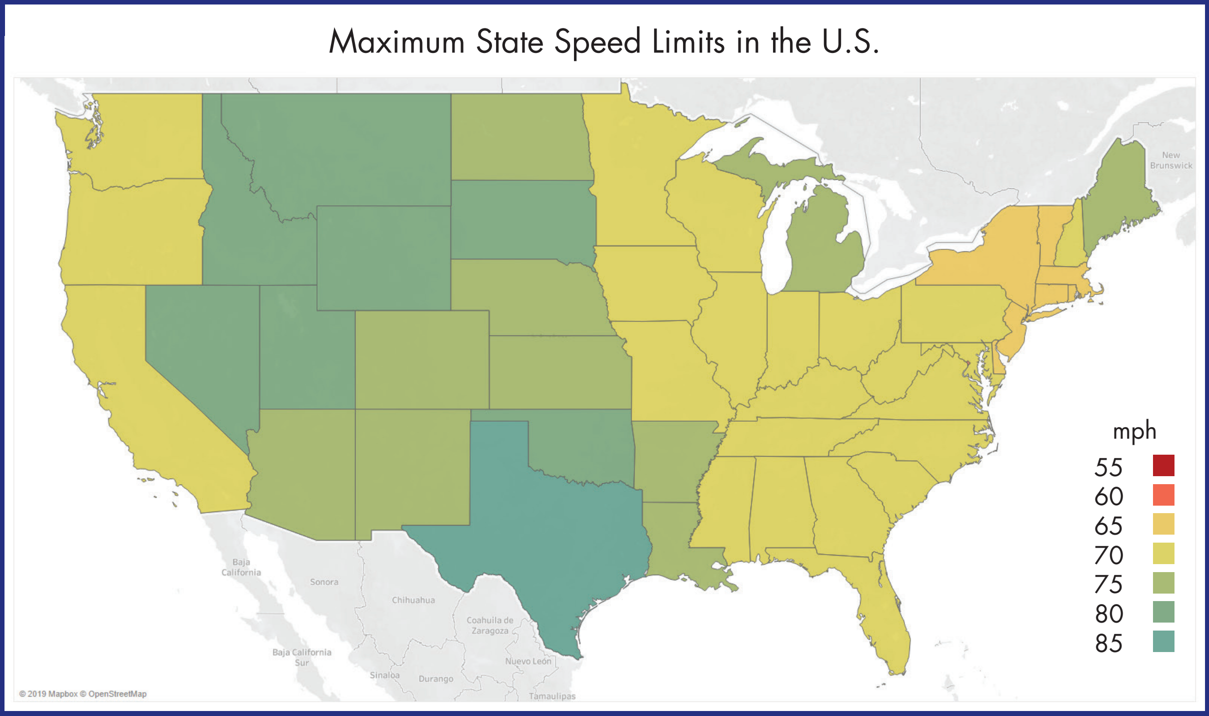
Predicting the Impact of Changing Speed Limits on Traffic Safety and Mobility on Indiana Freeways



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16. Abstract

After repeal of the National Maximum Speed Limit Law, states were allowed to set individual speed limits on their interstate roads. Several states opted for a uniform speed limit while others implemented differential speed limits. The current speed limit on Indiana rural freeways limits speed of passenger cars to 70 mph and restricts to 65 mph speed of vehicles with a gross weight of 26,000 pounds or more. Indiana's speed limit on urban freeways is mostly 55 mph, but varies from 50 mph on certain downtown sections to 65 mph on some suburban sections. Previous studies comparing uniform and differential speed limit settings as to safety and mobility produced inconclusive or conflicting results.

This study evaluates the safety and mobility effects of alternative speed limit scenarios on Indiana interstate freeways. Differences in travel time, vehicle operation, and traffic safety were used to compare the speed-limit scenarios. The effect of speed limit was evaluated in hourly periods. The traffic conditions in these periods were classified as uncongested, intermediate, and congested and the speed limit effects were analyzed in relation to these conditions. Rural and urban freeways were analyzed separately and distinct speed models were developed for cars and trucks. Safety was estimated by probability of crash and the conditional probability of crash injury severity.

Speed limit was found to affect mobility and safety mostly in non-congested traffic conditions, while no significant effects were found in congested conditions. A limited effect was detected in intermediate traffic conditions on rural freeways. Results indicate that replacing the differential 70/65 mph speed limit on Indiana rural roads with the uniform speed limit of 70 mph may be beneficial for both safety and mobility. Increasing speed limits on urban interstates is confirmed to be beneficial for mobility but detrimental to safety.

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JOINT TRANSPORTATION RESEARCH PROGRAM

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NOTICE

EXECUTIVE SUMMARY

PREDICTING THE IMPACT OF CHANGING SPEED LIMITS ON TRAFFIC SAFETY AND MOBILITY ON INDIANA FREEWAYS

Introduction

Speed is one of the strongest factors influencing road safety and is the primary measure of mobility. The repeal of the National Maximum Speed Limit Law in 1995 allowed state administrations to set their own speed limits on freeways. Some states adopted a uniform speed limit, while others implemented differential speed limit policies, explicitly, a lower speed limit for heavy vehicles and a higher speed limit for lighter vehicles.

The current speed limits on Indiana's rural freeways are 70 mph for cars and 65 mph for trucks with a gross vehicular weight of 26,000 pounds or greater. On Indiana's urban freeways, the speed limit range is wider. Most urban freeways post the speed limit at 55 mph, while their suburban sections tend to post speed limits of 65 mph.

This study investigates the potential effect of changing the speed limits on Indiana freeways. Safety and mobility are estimated under the current dual 70/65-mph rural speed limit and compared to estimates under uniform 70-mph limits. The studied changes on urban freeways include reducing the existing 65-mph suburban limit to 55 or 60 mph, and increasing the existing urban 55-mph limit to 60 or 65 mph. The differences in travel time, vehicle operating costs, and crash frequency and severity are considered.

Findings

Speed limit was found to affect mobility and safety mostly in non-congested traffic conditions, while no significant effects were found in congested conditions. A limited effect was detected in intermediate traffic conditions on rural freeways.

The effect of replacing the existing differential 70/65-mph speed limit on rural freeways with a uniform 65-mph limit could not be estimated confidently due to insufficient suitable data. Converting to a uniform 70-mph speed limit, however, could be expected to

- increase car speeds by 1.4 mph and increase truck speeds by 0.6 mph;
- reduce crash frequency by approximately 20% at all severity levels;
- produce an economic loss of $21.6 million per year, mostly due to higher vehicle operation costs; and
- result in a $479.3 million annual net benefit if the comprehensive cost of crashes is considered.

A 5-mph increase from the current typical 55-mph to a 60-mph speed limit on urban freeways would be expected to

- increase the average speed of cars by 1.4 mph and increase average truck speed by 1.0 mph;
- increase the expected number of crashes by 4% and the fatal and injury crash proportion by 18%;
- produce an economic savings of $37.2 million per year; and
- result in a loss of $275.0 million per year when considering the comprehensive cost of crashes.

Implementation

Comparisons of various speed limit scenarios for rural and urban freeways are summarized in tables that include changes in travel time, vehicle operation, and crash frequencies and severities with their corresponding costs. The economic effects are presented as economic loss and comprehensive cost. These results are intended to be among the essential elements of discussion for changes in the current speed limits on Indiana freeways.

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1. INTRODUCTION

In January 1974, the federal government passed the Emergency Highway Energy Conservation Act. One of its provisions, the National Maximum Speed Law (NMSL), set the maximum speed limit on U.S. highways to 55 mph; speed limits prior to 1974 were as high as 75 mph in some Midwestern states such as Kansas. In April 1987, Congress passed the Surface Transportation and Uniform Relocation Assistance Act, allowing states to raise speed limits up to 65 mph on rural interstates and other non-interstate roads that were designed and built to freeway standards. The states of California, Florida, Illinois, Iowa, Kansas, Kentucky, and Oklahoma raised their speed limits without much delay. Eventually, the repeal of the NMSL in December 1995 transferred the setting of freeway speed limits back to the authority of state governments. Most states immediately readopted their original pre-1974 speed limit policies.

1.1 State-wide Speed Limits

The repeal of the NMSL promoted diversity in state speed limits. While some states adopted a uniform speed limit policy (USL), others implemented a differential speed limit (DSL)—that is, lower posted speeds for heavy trucks and higher speeds for lighter vehicles. States typically varied the speed limit of urban freeways according to section, e.g., downtown or suburban. Some states posted a minimum speed on rural interstates (e.g., 45 mph in Illinois), and other states opted for speed limits by time of day, such as Texas set for certain freeway segments. More recently, variable speed limits (VSL) based on changing conditions were introduced in selected interstate sections in Ohio.

Figure 1.1 presents the current maximum speed limit allowed in each state. There is a clear pattern that higher speed limits are found in places with a low population density. In Indiana and its adjacent states, the predominant maximum freeway speed limit is 70 mph, with Michigan being the only exception at 75 mph.

Table 1.1 presents a summary of the current speed limits in Indiana and its neighboring states. Indiana and Michigan are the only states in the region that currently maintain DSL on rural freeways. Michigan uses a 10-mph differential between cars and trucks while Indiana uses a 5-mph speed differential. On urban freeways, USLs are predominant. Urban posted speed limits range from 45 mph in some interstate segments of Illinois to 70 mph in most interstate segments in Michigan.

In Indiana, the maximum speed limit prior to the NMSL was 70 mph. After the law's repeal, Indiana adopted a differential speed limit on rural interstates of 65 mph for light vehicles and 60 mph for heavy vehicles. In 2005, the speed limits were upgraded to 70 mph for cars and 65 mph for trucks with a gross vehicular weight of 26,000 pounds or greater. The 2005 upgrade also allowed urban freeway speed limits to range from 50 to 65 mph. Since the 2005 change, some efforts have been made to remove the differential speed limit on rural freeways, but the state has maintained its DSL policy to date.

TABLE 1.1
Speed Limit Policies for Freeways in Proximity to Indiana

State	Rural		Urban
	Non-Trucks	Trucks	
Illinois	70	70	45–70
Indiana	70	65	50–65
Kentucky	70	70	55–65
Michigan	70–75	60–65	55–70
Ohio	70	70	50–65
Wisconsin	70	70	55–65

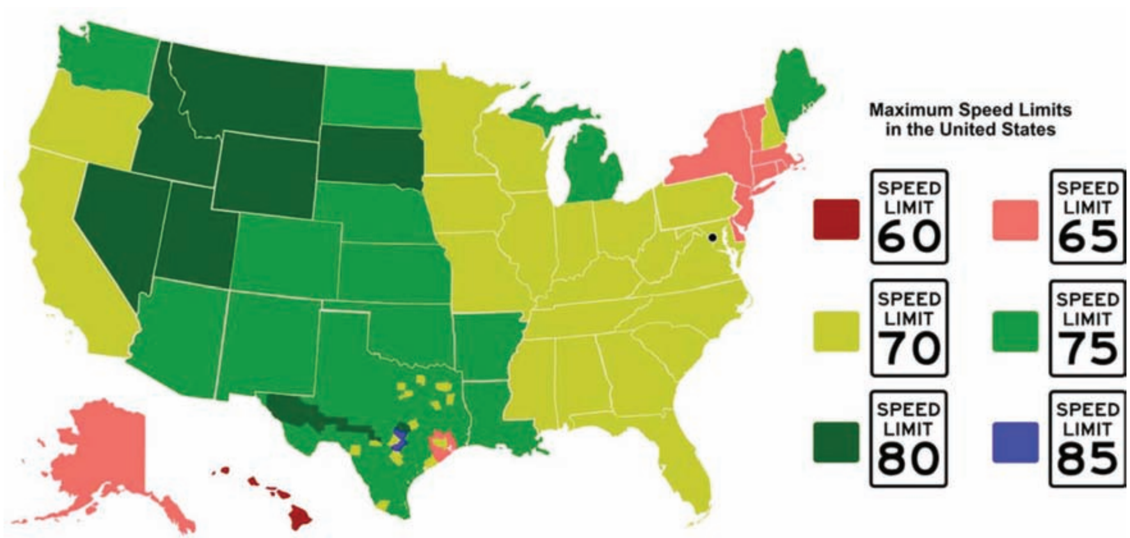

Figure 1.1 Maximum state speed limits in the United States as of April 2019. (Source: Insurance Institute for Highway Safety (IIHS).)

Illinois raised the maximum allowed speed limit on rural freeways from 65 mph to 70 mph in June 2013, with the change taking effect in January 2014. Urban interstate limits can range from 45 up to 70 mph.

Ohio reformed its interstate speed limits in July 2013. Selected rural freeways were permitted to increase limits from 65 to 70 mph. Over the last several years, Ohio has made several attempts to raise speed limits to 75 mph. The state has also adopted other strategies such as winter and variable speed limits.

Michigan raised its speed limits on May 2017, maintaining the 10-mph speed differential on rural freeways and increasing the speed limit by 5 mph on selected freeway sections. The current speed limit in Michigan is 65 mph for trucks and 75 mph for non-trucks on rural freeways, and 55 to 70 mph on urban freeways with 70 mph being the predominant limit.

1.2 Speed Factors

Changes in state-wide speed limits are usually preceded by the evaluation of the mobility (travel time) and safety effects of the proposed changes (Iowa Highway Safety Management System, 2002; Monsere et al., 2004; Savolainen et al., 2014; Skszek, 2004). Posted speed limits on individual roads are additionally set based on engineering studies of drivers' speed behavior and crash history, which prompt deviation from the statutory limits. Despite the setting of speed limits grounded in observed driver behavior and preferences, drivers frequently exceed the posted speed limit in response to their perceived crash risk and level of speed enforcement (Tarko, 2009).

Drivers' speed selection in non-congested traffic is affected by many factors not yet fully understood. For example, freeways are used by both local and long-distance drivers who may have different speed preferences and perceptions of speed limit enforcement. In addition, the presence of heavy trucks may cause stronger interactions between vehicles because truck drivers are more likely to comply with the posted speed limit. It is also plausible that the effect of the speed limit on speed selection diminishes in the presence of congestion, where drivers are heavily influenced by other drivers and traffic flow dynamics dominate individual speed preferences. Herman and Prigogine proposed a two-state fluid model for describing urban traffic (Herman & Prigogine, 1979). The model addresses two distinct situations: (1) vehicles move rather freely on non-congested roads and change lanes to pass slower vehicles, and (2) vehicles are slowed down considerably in congested traffic and lack the possibility of passing slower vehicles. Typically, traffic conditions are a mix of the two states, which leads to an intermediate level of congestion. The mobility is determined by the proportion of the two distinct states. This perspective on traffic, sometimes called two-fluid flow, has been successfully tested in urban scenarios by several researchers (Chakraborty & Srinivasan, 2016; Dixit, 2013; Dixit, Pande, Abdel-Aty, Das, & Radwan, 2011; Mahmassani, Jayakrishnan, & Herman, 1990; Mahmassani, Williams, & Herman, 1984), and may be applied to estimate average speeds and the effects of speed limits.

1.3 Study Objectives

The tendency since 1974 has been towards continuously increasing the speed limits on freeways, but mobility and safety effects need to be considered before making any major change in speed limit policies. Specifically, it is necessary to evaluate the possible implications of changing the Indiana speed limit policy in accord with different scenarios. This study is intended to

1. determine the effect on mobility (travel time) of the speed limits for heavy trucks and passenger cars;
2. estimate the speed limit's effect on crash risk;
3. calculate the impact of removing the DSL on rural freeways; and
4. estimate the effect of raising the speed limit on urban freeways.

The maximum effect of each speed limit is expected to be observed under non-congested traffic conditions, as no significant effect is expected under congested conditions. However, an intermediate effect is expected in the mix of the two traffic states. This study's two-fluid flow approach to evaluating the effect of a speed limit will be more adequate than the common practice of focusing only on free-flow conditions.

The relatively recent availability of massive travel-time data from GPS and smartphones has created an opportunity to analyze the effect of speed limits from an area-wide perspective, that is, the statutory speed limits evidenced on freeways and other high-standard roads. The analysis is conducted for rural and urban freeways separately due to differences in driver behavior, roadway features, and speed limit settings.

This study is focused on freeway roads categorized as interstates. Other restricted access highways are not included in the analysis.

2. LITERATURE REVIEW

The relationship between posted speed limits and operating speed has been a matter of study for a few decades. Multiple authors have addressed this relationship using a variety of approaches including before-after studies related to speed limit changes, cross-sectional analyses investigating correlations between speed limits and speed characteristics, and lately, human behavior studies that focus on driver perception of enforcement and driver response to speed limits.

As related to traffic safety, researchers have confirmed the relationship between speed and crash rate and severity. The connections between average speed, speed variance, crash risk, crash frequency, and crash severity have been studied and numerous explanatory models have been calibrated. However, researchers who have studied the direct relationship between traffic safety and posted speed limits have only found inconclusive and conflicting results.

The existing literature on the mobility and safety effects of speed limit has been updated. A compilation of some of the most relevant studies is presented below.

2.1 Speed Limits and Operating Speed

Modeling speed behavior as a dependent variable, some researchers have included speed limit as a predictor, and have found a strong correlation between the two. In 1997, Parker found that drivers respond to 5-mph changes in speed limits by increasing or decreasing speed by 1.5 mph; it was concluded, however, that the small degree of change may not be of practical significance (Parker, 1997). Fitzpatrick et al. studied the relationship between design speed, operating speed, and posted speed limit in free-flow conditions at 79 sites in six states. They found that operating speed and speed limit have the highest correlation of the three: a 1-mph change in speed limit was associated with a 0.963-mph change in speed (Fitzpatrick, Miaou, Brewer, Carlson, & Wooldridge, 2005). Most recent studies (Bassani, Dalmazzo, Marinelli, & Cirillo, 2014; Eluru, Chakour, Chamberlain, & Miranda-Moreno, 2013), confirm speed limit to affect speed. However, the magnitude of the impact decreases significantly after including other attributes such as temporal indicators, light conditions, roadway geometry, and pavement characteristics.

Survey-based studies give us drivers' perception towards speed limits. Results from the National Survey of Speeding and Unsafe Driving Attitudes and Behaviors suggest that drivers believe they can drive 7 to 8 mph above the speed limit before they get a ticket (The Gallup Organization, 2003). Also of interest is that younger and male drivers are more likely to speed and that most drivers seem to believe speed limits inappropriately reflects road capacity. Of surveyed drivers, 35% said that the speed limits on interstate roads are too low. Four out of ten drivers will still drive above the speed limit on freeways even when it is increased by 10 mph.

To supplement survey-based studies of drivers' speed choices, Tarko proposed modeling driver-preferred speeds as a trade-off behavior between safety, travel time, and enforcement (Tarko, 2009). Using free-flow speed measurements (headways of 5 s or larger) and after including roadway characteristics, surrounding environmental conditions, and time indicators, a 0.485-mph increase in speed was linked to a 1-mph increase in posted speed limit. Another interesting finding from the model is that speed limits seem to encourage slow drivers to drive faster and fast drivers to drive slower.

Finally, area-wide changes in speed limit policies have been examined. In 2002, state-wide changes in Iowa speed limits were studied by observing changes in the distribution of speed and crash patterns (Iowa Highway Safety Management System, 2002). In terms of mobility, a 10-mph rise in speed limit was found to result in an 8.2-mph increase in the 85th percentile of speed distribution. Safety was also affected. Increases in crash frequency at multiple severity levels were observed on road segments posted with 10-mph speed limit increases. In 2004, Oregon authorities suggested that a 5-mph rise in interstate speed limits was likely to produce a 2- to 4-mph increase in the 85th percentile of speed distribution (Monsere et al., 2004; Taylor, Woolley, & Zito, 2000).

2.2 Speed and Safety

Increasing the speed of a motor vehicle reduces the available time that the driver has to respond to an emergency stop, and it increases the braking distance. Researchers have observed that average speed has a strong impact on the number of crashes and their severity (Elvik, 2009, 2013; Elvik, Christensen, & Amundsen, 2004), and other studies have found a direct relationship between crash risk and speed variance (Garber & Gadiraju, 1989).

Various models have been proposed that relate speed with traffic safety, the most relevant of which are the exponential and the power models. In 1982, Nilsson proposed a power model relationship between speed change and traffic safety (Nilsson, 1982). The relationship can be defined as in Equation 2.1 and Equation 2.2.

$$Y_1 = \left(\frac{V_1}{V_0}\right)^{\alpha} Y_0 \qquad \text{(Equation 2.1)}$$

where, Y_1 is the number of crashes at a certain severity level after the speed change, V_1 is the average speed after the change, Y_0 is the number of crashes at a certain severity level before the change, V_0 is the average speed before the change, and α is the coefficient of the relation between the speed change ratio and the number of crashes before the change.

$$Z_1 = \left(\frac{V_1}{V_0}\right)^{\alpha_1} Y_0 + \left(\frac{V_1}{V_0}\right)^{\alpha_2} (Z_0 - Y_0) \qquad \text{(Equation 2.2)}$$

where, Z_1 is the number of causalities after the speed change, Z_0 is the number of causalities before the change, V_1 is the average speed after the change, V_0 is the average speed before the change, α_1 is the coefficient of the relation between speed change ratio and number of causalities before the change, and α_2 is the coefficient of the relation between the speed change ratio and the number of causalities minus the total number of crashes before the change.

Elvik has used meta-data analysis to evaluate Nilsson's power model and, based on 526 studies, he confirmed a power relationship between speed and safety (Elvik, 2009, 2013; Elvik et al., 2004).

In addition to the power model, the exponential model proposed by Hauer (2009) has been used widely to address changes in average speed and their effect on safety. A simplified equation for the exponential model in terms of speed is presented in Equation 2.3.

$$\left(\frac{Y_1}{Y_0}\right) = e^{\beta}\left[V_0 - V_1 + \left(\frac{\mu}{2}\right)(V_0^2 - V_1^2)\right] \qquad \text{(Equation 2.3)}$$

where Y_0, Y_1 are the number of crashes at a certain severity level before and after the speed change, β is the exponential coefficient of the relationship between speed change and crash ratio, and μ is a parameter that depends on the form of $f(v)$.

Elvik compared the exponential and power models and found that the two approaches yielded distinct results, particularly at high speeds. A much larger increase in the number of fatal accidents was predicted by the exponential function as compared to the power function. He also observed that the exponential function's dependence on the vehicle's initial speed for fatal accidents is much stronger than that of the power function. In other words, the curvature of the exponential function is more sensitive over the range of initial speeds than the power function (Elvik, 2013).

Many studies have shown the relationship between speed variance and traffic safety. In 1964, Solomon proposed a U-shaped relationship between the crash involvement rate and the degree of deviation from the average speed. The crash-involvement, injury, and property-damage rates were highest at very low speeds, lowest at the approximate average speed of all traffic, and increased again at very high speeds, particularly at night. Solomon thus concluded that the greater a vehicle's variation in speed from the average speed of all traffic, the greater its chance of being involved in an accident (Solomon, 1964). The U-shaped pattern has been confirmed for vehicles moving above the average speed but is still under debate for vehicles moving below average speed (Aarts & van Schagen, 2006).

Taylor et al. found that speed variance was related to total crash frequency, and that speed variance increases with an increase in average speed (Taylor et al., 2000). Other studies have confirmed that driving close to the average traffic speed reduces crash risk (Johnson & Pawar, 2007).

2.3 Speed Limit and Safety

Different approaches have been used to investigate the relationship between the speed limit and traffic safety. Using statistical regression, the connection between speed limit, safety, and speed under free-flow conditions has been studied widely (Deardoff, Wiesner, & Fazio, 2011; Figueroa Medina & Tarko, 2005; Garber & Gadiraju, 1989).

Before and after studies have also been implemented to test the relationship between the speed limit and traffic safety. Using data from 1993 to 2013, Farmer found that an increase of 5 mph in the posted maximum speed limit was linked to an 8% rise in accident rates (Farmer, 2017). In 1997, Parker analyzed the effects of speed limit change on selected roadway sections. His evidence led him to conclude that crash frequency changed when posted speed limits were either lowered or raised (Parker, 1997). Farmer et al. conducted a before-after study to investigate changes in maximum state speed limits after the repeal of the National Maximum Speed Law (NMSL). They found that fatalities on interstates increased 15% in the 24 states that raised speed limits. After accounting for changes in vehicle miles traveled (VMT), fatality rates were 17% higher than before the repeal, while deaths on roads unaffected by the repeal were unchanged (Farmer, Retting, & Lund, 1999).

In 2008, Malyshkina and Mannering evaluated speed limits in Indiana and their effect on crash frequency and severity by examining crash records. They found that higher speed limits on freeways had no statistically significant effect on the probability of "unsafe speed" being listed as the main cause of a crash, nor did speed limit influence crash severity. However, for some non-freeway highways, higher speed limits did significantly raise the likelihood of the "unsafe speed" assessment, while in other road categories (including county road and city street), higher speed limits, in fact, decreased the likelihood. Higher crash severity levels were associated with higher speed limits on some non-freeway highways (Malyshkina & Mannering, 2008).

2.4 Differential Speed Limits (DSL)

It has been found that differential speed limits (DSL) increase the actual difference in mean speed between light and heavy vehicles. However, this difference is not as large as the difference between mean speeds for different uniform speed limits (USL) (Dixon, Abdel-Rahim, & Elbassuoni, 2012; Garber & Gadiraju, 1991; Hall & Dickinson, 1974; Harkey & Mera, 1994; Johnson & Murray, 2010).

In 1992, Freedman and Williams analyzed speed data from 11 northeastern states to determine the effect of DSL on the mean and 85th percentile of speed distribution. They found that for passenger cars, speed parameters in DSL states were not significantly different from those in states with USL policies (Freedman & Williams, 1992). Similarly, in 1994 Harkey and Mera found no significant differences for truck as well as non-truck mean speeds when comparing DSL and USL (Harkey & Mera, 1994). In contrast, Garber and Gadiraju did find a statistical difference between USL and DSL roads in non-truck mean speed, though the degree of change was less than anticipated. The average speed increases were about 1 to 4 mph in response to a 10-mph differential in the speed limit (Garber & Gadiraju, 1991).

More recently, Russo et al. studied speed during free-flow conditions under different posted speed limits on Midwest rural and urban freeways. They found that passenger vehicle speeds were consistent across the states of Indiana, Michigan, and Ohio, where a common 70-mph limit was in effect on rural interstates. Similarly to Johnson and Pawar, they found that speeds varied more at locations with lower posted limits. Russo et al., along with other researchers, also found that speeds varied more for all vehicles on freeways with DSL, although almost as much variation was evident on urban freeways with USL of 55 mph (Russo, Rista, Savolainen, Gates, & Frazier, 2015).

Studies that aim to compare uniform versus differential speed limits have consistently found that regardless of the posted speed limits, trucks and non-truck vehicles exhibit different speed behavior (Johnson & Murray, 2010). Inspection of their separate speed distributions reveals that trucks tend to travel at considerably lower speeds than passenger cars.

2.5 DSL and Safety

The relationship between differential speed limit and safety has been researched using different methodologies such as cross-sectional, before-and-after, and case studies. The research, however, has led to inconclusive and in some cases contradictory results.

In 1974, Hall and Dickinson investigated crash data from 83 sites in Maryland to study truck speed and safety (Hall & Dickinson, 1974). They concluded that having different speed limits for trucks and non-trucks contributes to lane-changing and specific types of crash, largely rear-end. A reduction in truck-involved rear-end accidents was related to higher operating speeds.

Pfefer et al. conducted a time series analysis to determine the traffic safety impact of differential speed limits in Illinois after the speed limit on rural interstate roads had been changed from 55 mph to 65/55 mph (Pfefer, Stenzel, & Lee, 1991). Monthly crash counts and vehicle-miles-traveled data were gathered for the January 1983–July 1988 period. Although the frequency of total crashes rose by 14.2% after the speed limit change, no statistically significant increase in the frequency of fatal and injury crashes was found. In terms of crash rates, no change was detected in total crashes, but an 18.5% increase in the fatal and injury crash rate. A significant 27.3% reduction in the car-truck fatal and injury crash rate was found, but there was no conclusive change in the car-truck total crash rate when all accidents were considered.

Garber et al. compared DSL and USL using crash records from 17 states and employing multiple traditional and Bayesian methods (Garber & Gadiraju, 1991; Garber & Gadiraju, 1992; Garber, Miller, Sun, & Yuan, 2006; Garber, Miller, Yuan, & Sun, 2005). A differential speed limit of 65/55 mph, compared with a uniform speed limit of 65 mph, produced no significant decrease in the non-truck-truck crash rate, or in the rate of any two-vehicle collisions. Although no conclusive results were found for the crash rate, an increase in fatality frequency was evidenced. As Hall and Dickinson had observed in 1974, the frequency of rear-end collisions was also relatively higher in DSL states than in USL states, suggesting that the 65/55-mph speed differential may cause more rear-end accidents, especially between cars and trucks. The researchers concluded that DSL does not provide any safety benefit over USL.

In 2004, the Virginia Transportation Research Council of the Federal Highway Administration (FHWA) compiled studies comparing DSL with USL regarding their mobility and safety effects (FHWA, 2004). Among their main findings, it was observed that DSL increases some types of crash rates while reducing others, and that speed characteristics were not affected by the implementation of a USL or DSL policy. Additionally, the Empirical Bayes methodology suggested that crash risk during the study period increased for all four policy groups studied.

Like Garber et al., Neeley and Richardson modeled the safety effect of changes in speed limit using data from several DSL states (Neeley & Richardson, 2009). They, too, found that a higher speed limit for trucks promoted significantly higher fatality rates, but the difference in speed limit between cars and trucks had no significant effect. Results from a second model demonstrated that car speed limits had positive and significant effects on the truck-involved crash fatality rate.

Dixon et al. found that implementing DSL on Idaho rural interstate freeways produced a decrease in crash rates, but this effect was linked to a significant reduction in trucks' mean speed (Dixon et al., 2012), similar to the observation made in other studies. Korkut et al. used statistical regression to determine the combined effect of DSL and truck lane restriction. A positive impact was found on overall safety, but the specific effect of DSL-only was not found statistically significant (Korkut, Ishak, & Wolshon, 2010). Indeed, Monsere et al. examined DSL in Oregon and determined that except for travel time savings and economic development benefits, all other issues (such as crashes, enforcement, health, and environment) will be negatively impacted by the proposed change of speed limit from 65/55 to 70/65 mph (Monsere, Kothuri, & Razmpa, 2017).

The discrepancies between findings regarding DSL's safety effects were analyzed by Johnson and Pawar (Johnson & Pawar, 2007), who attributed the inconsistencies to two opposing factors: (1) the positive effect that results from the improved vehicle dynamics (braking and maneuvering) for trucks moving at lower speeds; and (2) the negative effect on the number of interactions among overall traffic that results from increased speed variation. These two effects of DSL counter each other and ultimately result in no consistently observable effect on highway safety data. Additionally, the researchers concluded that four methodological issues contributed to the inconclusive results: (1) the use of fatal crashes and crash rates; to the contrary, Wilmot and Khanal's review concluded that the main effect of speed limits is on the severity of injury (Wilmot & Khanal, 1999); (2) differences in results due to using frequencies or rates; (3) various lengths of analysis period, which has been shown to produce differing results; and (4) driver use of speed limiters, or governors, that may limit drivers' responses to posted speed limits.

2.6 Driver Behavior

A driver survey conducted in Indiana showed that drivers' perception of the extent to which they could drive above the speed limit without receiving a speeding ticket was a critical determinant of their idea of a safe speed (Mannering, 2009). Of the surveyed drivers, 21% said that driving 5 mph over the posted speed limit was safe, 44% indicated 10 mph, and 35% felt as much as 20 mph was safe. Other variables found to be significant included age, gender, being previously stopped for speeding, and driver ethnicity.

As previously noted, speed limiters for trucks play a significant role in describing the interaction between speed, posted speed limits, and safety. Hanowski et al. found strong positive safety benefits for the use of speed limiters (Hanowski et al., 2012). The crash rate for trucks with speed limiters was approximately 50% lower than for trucks without limiters.

As part of their 2005 study, Johnson and Pawar surveyed truck drivers on their opinion of DSL vs USL (Johnson & Pawar, 2005). Most drivers stated that DSL increased interactions among vehicles and increased the probability of rear-end, side-swipe, and on-ramp accidents. Three scenarios concerned the drivers: (1) truck being trapped in the right lane and continuously needing to yield to merging traffic from entrance ramps; (2) truck not being able to reach traffic speed when merging into traffic low; and (3) congestion, clustering of traffic, and bottleneck situations on freeways as the result of lower truck speeds. The preferred speed limit for the surveyed truck drivers was a USL of 70 mph on rural freeways.

2.7 Identification of Research Need

Despite evidence that safety decreases as driving speed increases, the trend toward raising speed limits continues. Differential speed limits are a commonly employed solution but multiple attempts to establish a clear comparison between uniform and differential speed limits have had contradictory and inconclusive results. The current study addresses this problem by assessing the effect of speed limit under multiple traffic regimes. The developed models and their implementation is meant to improve the realism of evaluating the effects of alternative area-wide speed limit policies on safety and mobility in road networks. The study will contribute to the field in three aspects.

First, we will use highly disaggregated massive travel time data from the National Performance Management Research Data Set (NPMRDS), obtained from probes such as phones and GPS devices. This type of data has not yet been used to analyze area-wide speed limit settings such as DSL or USL.

Second, the effects will be estimated separately for congested and non-congested traffic conditions using the congestion index. By separating these conditions, we expect to find a highly significant relationship between the speed limit and travel speed under non-congested free-flow conditions, and inconclusive or unrealistic results will be limited to congested conditions.

Third, this study will focus on the macro level mobility effect of different speed limit policies. Changes in travel time and the expected number of crashes due to different types of speed limit policies will be estimated and simulated based on past conditions. It is assumed that the effects in the past will continue to be valid in the future.

3. DATA DESCRIPTION

3.1 Available Data

Several factors influence drivers' speed selection. Among the most relevant are road user characteristics, vehicle attributes, roadway elements, weather conditions, and time-related variables. These elements were gathered from multiple data sources.

Travel time data was obtained from the National Performance Management Research Data Set (NPMRDS). Travel times are measured along segments defined by the data provider. On interstates, these segments are usually defined between two consecutive entering ramps. For each road segment, of which the average length is 2.5 miles, the average travel times for all vehicles, passenger cars, and heavy trucks, are reported in five-minute intervals. Currently, NPMRDS does not provide information related to the number of vehicles used to calculate the average travel time, which is the main constraint of this data source.

Geometry and other road characteristics were extracted from the Highway Performance Monitoring System (HPMS). The system provides a comprehensive set of variables that are reported by state agencies on an annual basis, which include cross-sectional elements, pavement condition, posted speed limit, and annual average daily traffic (AADT) by vehicle type. The HPMS road sections are smaller than the NPMRDS segments, with an average length of 0.1 miles, and are displayed in a shapefile.

Daily weather variables were obtained from the National Oceanic and Atmospheric Administration (NOAA) server. The available data, aggregated at the county level, included precipitation intensity and snow accumulation. Other variables such as wind speed and temperature were only available at urban areas and therefore were not included in the final analysis.

Crash records from the states of Illinois and Indiana were obtained from Illinois DOT and in-house datasets available at the Purdue University Center for Road Safety. The location, severity, number of vehicles involved, and number of people injured at each severity level were connected to each crash.

3.2 Sample

Data from 2014 was compiled for the states of Illinois and Indiana, and data validation and cleaning procedures were performed. Due to the vast amount of data, a random sample of 30% of the freeway segments was selected overall, but all rural freeways sections with a 65-mph speed limit were selected for the safety analysis due to their low frequency as compared to 70-mph and 70/65-mph segments. The distribution of segments by road type and speed limit is presented in

Table 3.1. The spatial distribution of the segments included in the sample is displayed in Figure 3.1.

It was found that several Indiana freeway sections that used the differential speed limit setting were defined as urban by the HPMS. These segments are located within the city limits but their road geometry is more similar to rural freeways. These segments were thus reclassified for the study as suburban and were included in the rural freeway speed and safety models.

3.3 Speed Data

Table 3.2 and Table 3.3 present the summary statistics of the urban and rural speed datasets. The datasets include information on speed characteristics, roadway features, weather conditions, and spatial and temporal attributes. Each variable's mean, standard deviation, and maximum and minimum values are provided for the 1,451,312 valid observations in the urban dataset and 1,243,748 in the rural dataset. Seventy-nine percent of the observations in the urban dataset were on 55-mph posted speed limit sections while 21% were on 65-mph limit sections. In the rural dataset, 1% of observations were on 65-mph sections, 25% on 70-mph sections, and 74% were on 70/65-mph differential speed limit sections. On average, the speeds for passenger cars were 2.34 mph higher than heavy trucks on urban freeways and 4.23 mph higher on rural freeways.

The distributions of speed for passenger cars and heavy trucks are presented in the boxplots in Figure 3.2, which reflect the distribution under all traffic conditions. We can see a trend toward higher mean and median speeds when the speed limit is increased. The data presents a larger left tail that may reflect congestion.

3.4 Safety Data

The number of crashes for each combination of road type and speed limit is presented by severity level in Table 3.4. Crash records were available for all

TABLE 3.1
Distribution of Segments in the Random Sample

State	Road Type	Speed Limit (mph)	Total Number of Segments	Number of Segments in Sample
Illinois	Rural	65	9	9
Illinois	Rural	70	128	39
Illinois	Urban	55	197	76
Illinois	Urban	65	49	19
Indiana	Rural	70/65	389	108
Indiana	Urban	55	211	59
Indiana	Urban	65	63	17

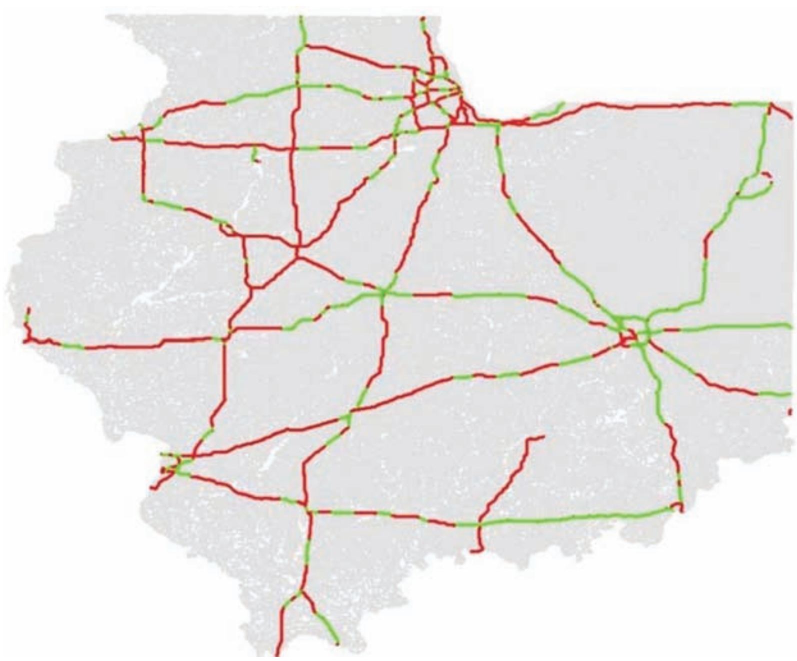

Figure 3.1 Freeway segments included in the random sample: green segments = included; red segments = excluded.

TABLE 3.2
Summary Statistics for Urban Speed Dataset

Variable Name	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
Speed Characteristics					
Mean Speed—All Vehicles (mph)	1,451,312	55.42	9.88	0.61	87.48
Mean Speed—Heavy Trucks (mph)	1,358,335	54.20	9.77	0.62	77.63
Mean Speed—Passenger Cars (mph)	1,418,542	56.54	10.61	0.61	89.04
Roadway Features					
AADT (1,000 vehicles/day)	1,451,312	111.85	55.47	21.91	288.45
IRI* (inches/mile)	1,451,312	91.95	32.98	37.21	250.00
Median Width (ft)	1,451,312	39.95	19.14	1.60	99.00
Number of Lanes = 2	1,451,312	0.23	0.42	0.00	1.00
Number of Lanes = 3	1,451,312	0.52	0.50	0.00	1.00
Number of Lanes > 3	1,451,312	0.25	0.43	0.00	1.00
Number of Ramps	1,451,312	1.96	0.99	0.00	5.00
Proportion of Trucks	1,451,312	0.10	0.06	0.00	0.37
Ramp Frequency (#/mile)	1,451,312	1.76	1.29	0.00	7.90
Segment Length (mi)	1,451,312	1.58	1.15	0.12	6.90
Shoulder Width (ft)	1,451,312	7.88	3.96	0.80	21.77
Speed Limit = 55 mph	1,451,312	0.79	0.41	0.00	1.00
Speed Limit = 65 mph	1,451,312	0.21	0.41	0.00	1.00
Weather Conditions					
Precipitation (in)	1,451,312	0.12	0.34	0.00	4.46
Snow	1,451,312	0.06	0.23	0.00	1.00
Spatial Attributes					
Distance to City Center (mi)	1,451,312	14.46	9.71	1.34	56.66
Illinois	1,451,312	0.56	0.50	0.00	1.00
Indiana	1,451,312	0.44	0.50	0.00	1.00
Temporal Attributes					
Daylight	1,451,312	0.51	0.50	0.00	1.00
Fall	1,451,312	0.25	0.43	0.00	1.00
Spring	1,451,312	0.25	0.43	0.00	1.00
Summer	1,451,312	0.25	0.43	0.00	1.00
Winter	1,451,312	0.24	0.43	0.00	1.00
Weekend	1,451,312	0.28	0.45	0.00	1.00

*IRI, International Roughness Index.

combinations at all severities except fatal on rural roads with 65-mph posted speed. To overcome this issue, the crash severity levels for rural roads were ultimately recategorized into two: property damage only was combined with possible injury (CO, or C-injury, and O-property damage only), and evident injury and disabling injury were combined with fatal crashes (KAB, or Killed, A-injury, and B-injury).

Table 3.5 and Table 3.6 present summary statistics for the urban and rural safety datasets. The information is similar to the speed statistics tables, but with the addition of crash characteristics and supplemental speed characteristics to provide a better understanding of the relation between speed and safety. These supplemental characteristics are the hourly speed range, hourly speed trend, and difference in average speed between the current and the upstream segments. The focus of these tables on crashes reduced the number of observations: 5,453 crashes were reported on urban freeways and 3,773 on rural freeways. Eighty-six percent of urban road crashes occurred under 55-mph posted speed limits, while just 14% were observed under 65-mph limits. On rural freeways, 85% of the crashes were observed in segments with differential speed limits and 15% of the crashes were under uniform limits.

TABLE 3.3
Summary Statistics for Rural Speed Dataset

Variable Name	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
Speed Characteristics					
Mean Speed—All Vehicles (mph)	1,243,748	62.99	3.91	0.59	88.20
Mean Speed—Heavy Trucks (mph)	1,228,153	61.36	3.39	0.59	76.36
Mean Speed—Passenger Cars (mph)	1,193,299	65.59	4.96	0.62	89.97
Roadway Features					
AADT (1,000 vehicles/day)	1,243,748	30.19	16.54	2.46	77.37
IRI (inches/mile)	1,243,748	75.16	34.48	32.00	247.55
Median Width (ft)	1,243,748	58.07	18.35	4.00	99.00
Number of Lanes = 2	1,243,748	0.88	0.33	0.00	1.00
Number of Lanes = 3	1,243,748	0.11	0.31	0.00	1.00
Number of Lanes > 3	1,243,748	0.01	0.12	0.00	1.00
Number of Ramps	1,226,455	2.00	1.13	0.00	6.00
Proportion of Trucks	1,243,748	0.25	0.10	0.00	0.47
Ramp Frequency (#/mile)	1,226,455	0.56	0.57	0.00	3.40
Segment Length (mi)	1,243,748	5.39	3.31	0.29	18.23
Shoulder Width (ft)	1,211,037	6.23	2.80	1.79	15.00
Speed Limit = 65 mph	1,243,748	0.01	0.08	0.00	1.00
Speed Limit = 70 mph	1,243,748	0.74	0.44	0.00	1.00
Speed Limit = 70/65 mph	1,243,748	0.25	0.43	0.00	1.00
Weather Conditions					
Precipitation (in)	1,243,748	0.11	0.32	0.00	6.10
Snow	1,243,748	0.06	0.24	0.00	1.00
Spatial Attributes					
Distance to City Center (mi)	1,243,748	23.60	17.32	0.75	82.28
Illinois	1,243,748	0.26	0.44	0.00	1.00
Indiana	1,243,748	0.74	0.44	0.00	1.00
Suburban	1,243,748	0.23	0.42	0.00	1.00
Temporal Attributes					
Daylight	1,243,748	0.51	0.50	0.00	1.00
Fall	1,243,748	0.25	0.43	0.00	1.00
Spring	1,243,748	0.25	0.43	0.00	1.00
Summer	1,243,748	0.25	0.44	0.00	1.00
Winter	1,243,748	0.24	0.43	0.00	1.00
Weekend	1,243,748	0.28	0.45	0.00	1.00

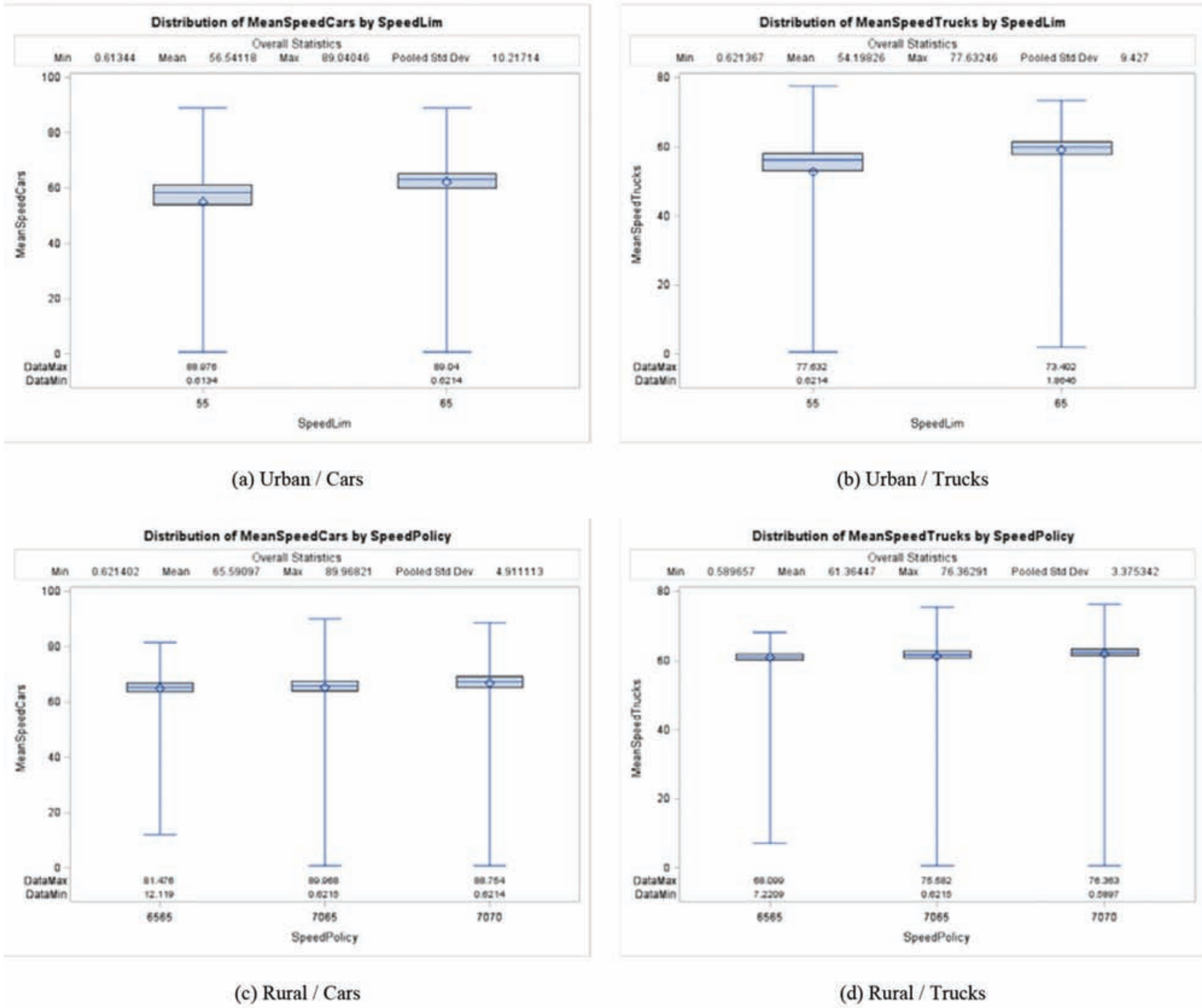

Figure 3.2 Distribution of car and truck speed by road environment and speed limit.

TABLE 3.4
Distribution of Crashes by Level of Severity, Road Type, and Speed Limit

Road Type	Speed Limit (mph)	Crash Severity	Number of Crashes
Urban	55	Property damage only	4,021
Urban	55	Possible injury	97
Urban	55	Evident injury	499
Urban	55	Disabling injury	86
Urban	55	Fatal	11
Urban	65	Property damage only	595
Urban	65	Possible injury	22
Urban	65	Evident injury	98
Urban	65	Disabling injury	19
Urban	65	Fatal	5
Rural	65	Property damage only	227
Rural	65	Possible injury	11
Rural	65	Evident injury	25
Rural	65	Disabling injury	8
Rural	70	Property damage only	254
Rural	70	Possible injury	10
Rural	70	Evident injury	26
Rural	70	Disabling injury	8
Rural	70	Fatal	2
Rural	70/65	Property damage only	2,673
Rural	70/65	Possible injury	30
Rural	70/65	Evident injury	390
Rural	70/65	Disabling injury	79
Rural	70/65	Fatal	22

TABLE 3.5
Summary Statistics for Urban Safety Dataset

Variable Name	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
Speed Characteristics					
Mean Speed (mph)	5,453	48.14	15.27	3.60	71.53
Speed Range (mph)	5,453	18.37	11.69	0.00	68.58
Speed Trend (mph)	5,453	-0.38	2.02	-36.95	19.65
Upstream Difference (mph)	5,453	2.11	10.90	-49.78	56.97
Roadway Features					
AADT (1,000 vehicles/day)	5,453	130.48	55.14	21.91	288.45
IRI (inches/mile)	5,453	92.21	28.07	37.21	225.33
Median Width (ft)	5,453	35.88	17.52	1.60	99.00
Number of Lanes = 2	5,453	0.14	0.34	0.00	1.00
Number of Lanes = 3	5,453	0.54	0.50	0.00	1.00
Number of Lanes > 3	5,453	0.33	0.47	0.00	1.00
Number of Ramps	5,453	2.30	1.04	0.00	5.00
Proportion of Trucks	5,453	0.10	0.06	0.00	0.37
Ramp Frequency (#/mile)	5,453	1.59	1.13	0.00	7.90
Segment Length (mi)	5,453	1.96	1.19	0.12	6.90
Shoulder Width (ft)	5,453	7.31	3.89	0.80	20.00
Speed Limit = 55 mph	5,453	0.86	0.34	0.00	1.00
Speed Limit = 65 mph	5,453	0.14	0.34	0.00	1.00
Weather Conditions					
Precipitation (in)	5,453	0.14	0.34	0.00	4.10
Snow	5,453	0.13	0.34	0.00	1.00
Spatial Attributes					
Distance to City Center (mi)	5,453	14.77	10.36	1.34	56.66
Illinois	5,453	0.46	0.50	0.00	1.00
Indiana	5,453	0.54	0.50	0.00	1.00
Temporal Attributes					
Daylight	5,453	0.66	0.47	0.00	1.00
Fall	5,453	0.24	0.42	0.00	1.00
Spring	5,453	0.21	0.41	0.00	1.00
Summer	5,453	0.23	0.42	0.00	1.00
Weekend	5,453	0.21	0.41	0.00	1.00
Winter	5,453	0.33	0.47	0.00	1.00
Crash Characteristics					
Property Damage Only	5,453	0.85	0.36	0.00	1.00
Possible Injury	5,453	0.02	0.15	0.00	1.00
Evident Injury	5,453	0.11	0.31	0.00	1.00
Disabling Injury	5,453	0.02	0.14	0.00	1.00
Fatal	5,453	0.003	0.05	0.00	1.00

TABLE 3.6
Summary Statistics for Rural Safety Dataset

Variable Name	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
Speed Characteristics					
Mean Speed (mph)	3,773	57.36	10.01	3.74	72.37
Speed Range (mph)	3,502	14.42	9.56	0.00	67.23
Speed Trend (mph)	3,502	-0.29	1.46	-18.34	18.00
Upstream Difference (mph)	3,502	1.77	8.07	-49.62	60.63
Roadway Features					
AADT (1,000 vehicles/day)	3,773	36.06	14.06	3.16	77.37
IRI (inches/mile)	3,773	74.29	29.53	32.00	247.55
Median Width (ft)	3,690	59.17	14.36	9.67	99.00
Number of Lanes = 2	3,773	0.87	0.33	0.00	1.00
Number of Lanes = 3	3,773	0.10	0.30	0.00	1.00
Number of Lanes > 3	3,773	0.03	0.16	0.00	1.00
Number of Ramps	3,773	2.14	1.36	0.00	6.00
Proportion of Trucks	3,773	0.24	0.09	0.08	0.47
Ramp Frequency (#/mile)	3,773	0.39	0.37	0.00	3.40
Segment Length (mi)	3,773	7.12	3.55	0.07	18.23
Shoulder Width (ft)	3,690	5.60	2.84	1.79	15.00
Speed Limit = 65 mph	3,773	0.07	0.26	0.00	1.00
Speed Limit = 70 mph	3,773	0.08	0.27	0.00	1.00
Weather Conditions					
Precipitation (in)	3,773	0.15	0.36	0.00	5.54
Snow	3,773	0.20	0.40	0.00	1.00
Spatial Attributes					
Distance to City Center (mi)	3,773	20.04	13.75	0.75	66.21
Illinois	3,773	0.15	0.36	0.00	1.00
Indiana	3,773	0.85	0.36	0.00	1.00
Temporal Attributes					
Daylight	3,773	0.57	0.50	0.00	1.00
Fall	3,773	0.25	0.44	0.00	1.00
Spring	3,773	0.19	0.39	0.00	1.00
Summer	3,773	0.17	0.38	0.00	1.00
Weekend	3,773	0.31	0.46	0.00	1.00
Winter	3,773	0.38	0.49	0.00	1.00
Crash Characteristics					
Property Damage Only	3,773	0.84	0.37	0.00	1.00
Possible Injury	3,773	0.01	0.12	0.00	1.00
Evident Injury	3,773	0.12	0.32	0.00	1.00
Disabling Injury	3,773	0.03	0.16	0.00	1.00
Fatal	3,773	0.01	0.08	0.00	1.00

4. METHODOLOGY

4.1 General Considerations

To determine the mobility and safety effects of changes in speed limits, several assumptions and considerations are made in regard to traffic conditions and types of vehicles.

Speed limits are assumed to have their major effect on low-density traffic conditions when speeds are close to free-flow speeds. In high-density traffic conditions, the speed limit effect diminishes, as it does in congested conditions when speeds are low. Thus, the effect of speed limit will be estimated consistent with the two-fluid model proposed by Herman and Prigogine (Herman & Prigogine, 1979). Long freeway segments may experience a mix of congested and non-congested conditions, and average speeds along these segments reflect the conditions by taking intermediate values.

Rural and urban roads are analyzed separately because of differences in speed limit settings, driving behavior, nature of the trip, and potentially different levels of speed limit enforcement. Many rural interstates have differential speed limits, while urban freeways typically have uniform speed limits. Drivers on urban freeways tend to be daily commuters familiar with the road, and tend to be more aggressive when changing lanes to maintain preferred speeds; and the higher number of police officers in urban areas may lead to their greater visibility and, thus, their influence on driver speed.

Passenger cars and trucks are considered separately for several reasons. First, trucks tend to move more slowly than cars regardless of the speed limit policy (Hanowski et al., 2012; Johnson & Pawar, 2007). This tendency can be linked to the different dynamic capabilities of trucks and cars, the use of speed limiters in trucks, and oversight from truck companies. Second, drivers of trucks and cars might respond to the posted speed limit in dissimilar ways because of their different perception of enforcement, that is, truck drivers are at higher risk if they are ticketed for speeding. Finally, the value of time and fuel economy differs for the two types of vehicle. For instance, the average cost of one hour of truck operation in 2014 was $46.10 while the cost for cars was $21.31 (Sinha & Labi, 2007).

Six speed limit changes are studied for their effects on mobility and safety.

1. Rural freeways (eliminating existing differential speed limit)
    a. 70/65 mph to 70 mph,
    b. 70/65 mph to 65 mph.
2. Urban freeways
    a. 55 mph to 60 mph,
    b. 55 mph to 65 mph,
    c. 65 mph to 60 mph,
    d. 65 mph to 55 mph.

4.2 Proposed Approach

Predicting future speeds and safety consequences requires predicting the future conditions that affect them. To simplify the task, this study focuses on estimating the effects of these conditions and applying the gained knowledge to the entire system of Indiana interstate roads in a "what if" analysis. Determining the system-wide effect of various speed limit policies in a recent year is a good basis for deciding which among the evaluated policies is most promising and should be implemented.

A methodology for evaluating alternative state-wide statutory speed limits on Indiana interstate roads was devised to follow the proposed overall approach. The general methodology, applied in three consecutive steps, is depicted in Figure 4.1. First, traffic conditions were classified based on the congestion index. Second, the mobility and safety effects of speed limit were estimated with regression models. Third, the alternative scenarios and corresponding economic effects were evaluated by statistical simulation of speed and safety in the analysis year. Each step is described in detail in the following subsections.

4.3 Classification of Traffic Conditions

This first step classifies traffic conditions into three states based on hourly speed observations:

1. Non-congested: Drivers operate at speeds close to their preferred speed. The range of traffic flow in this state is wide since drivers try to maintain their preferred speeds as long as passing slower vehicles is possible. Occasional blocking somewhat reduces the speed.
2. Congested: All vehicles move collectively at speeds determined by the road geometry, road capacity, and drivers' selection of spacing.
3. Intermediate. The coexistence of non-congested and congested conditions. This state is common in long freeway segments that may have single or multiple bottlenecks. Extended duration of this state is particularly likely on urban freeways.

The relative reduction of speed below free-flow speed, known as the congestion index, is used to measure the extent of free-flow operation remaining in

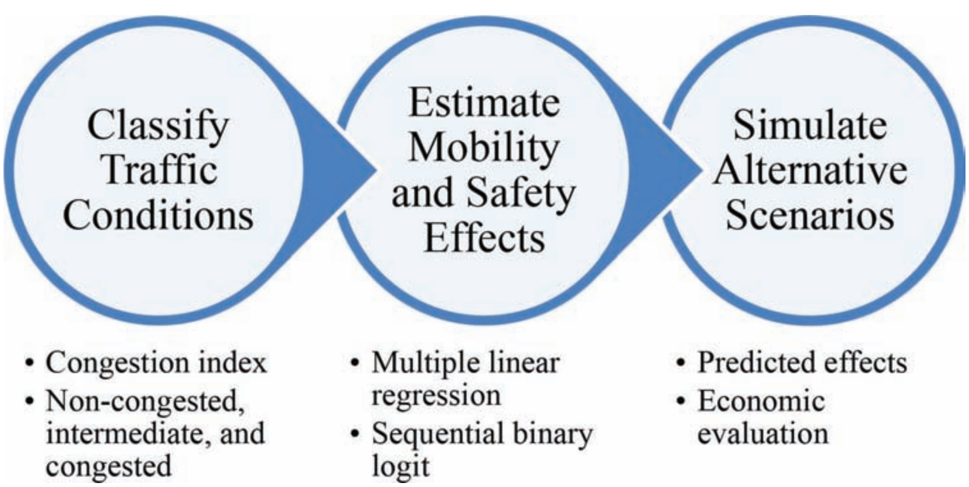

Figure 4.1 Overall methodology.

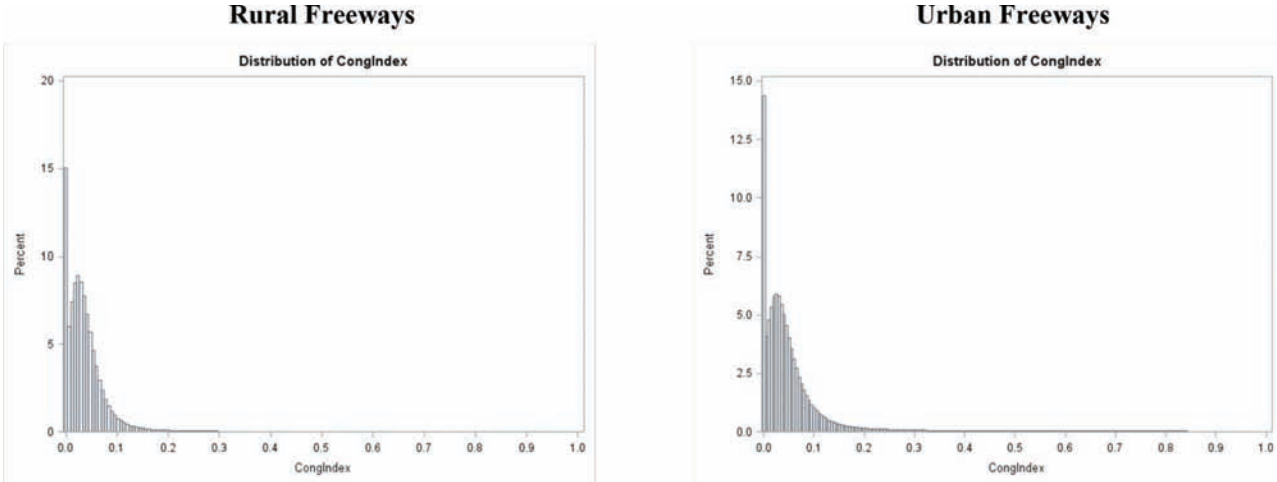

Figure 4.2 Distribution of congestion index.

the flow (Equation 4.1).

$$CI_i = \begin{cases} \frac{v_f - v_i}{v_f} \times 100, \, if \; v_i \leq v_f \\ 0, \text{otherwise} \end{cases} \qquad \text{(Equation 4.1)}$$

where CI_i is the congestion index for the ith observation, v_i is the hourly speed observation, and v_f is the free-flow speed defined as the 90th percentile of the distribution of speed for a given date and road segment.

The thresholds that separate the three traffic conditions are defined based on the distribution of the congestion index and the effect of traffic volume on speed. Figure 4.2 presents histograms of the congestion index for rural and urban freeways. Most of the observations have values equal to or lower than 0.1, which correspond to observations that are greater than or equal to 90% of the free-flow speed. The regression analysis of speed factors presented later in this report indicates the effect of traffic volume is negligible. Consequently, traffic conditions during hours with congestion indexes 0.1 and lower are classified as non-congested, while traffic conditions during hours with speeds equal to or lower than half of the free flow speed (congestion index 0.5 or higher) are classified as congested. Traffic conditions with a congestion index between 0.1 and 0.5 are classified as intermediate.

4.4 Estimation of Effect on Mobility

Linear regression models were estimated to provide insight into the relationship between the speed limit and the average speed. The models were calibrated with the PROC GLM function in Statistical Analysis Software SAS 9.4 (SAS Institute Inc., 2013). The PROC GLM uses the ordinary least-squares estimation method. The goodness of fit of the calibrated models was assessed using the F statistic combined with the adjusted sum of squares. Variables were retained in the models based on both the statistical and practical significance of the coefficients. The statistical significance is demonstrated by low p-values, while the practical significance is demonstrated by the considerable marginal effects. Separate models for passenger cars and trucks were calibrated for rural and urban roads under non-congested and congested traffic conditions. A total of eight models were used to represent the speed relationships. Equation 4.2 presents the general form of the multiple linear regression models.

$$v_i = \beta_0 + \beta_1 X_{1i} + \cdots + \beta_m X_{mi} + \varepsilon_i \qquad \text{(Equation 4.2)}$$

where v_i is the expected speed estimate in hour i, β_j is the estimated coefficient corresponding to variable j, X_{ji} is the value of explanatory variables in hour i, and ε_i is the normally distributed error term with zero mean and standard deviation σ. Significant variables j (j=1…m) are confirmed speed factors (e.g., AADT, precipitation, speed limit), while β_j values express the strength of these factors.

4.5 Estimation of Effect on Safety

The safety observations were obtained from the 2014 crash records for Indiana and Illinois, and as in the speed dataset, these observations were randomly sampled. The final safety dataset was composed of hourly observations with a binary crash indicator; the severity level was recorded if a crash occurred.

A sequential binary logit model was used to estimate the probability of a crash and the conditional probability of crash severity. The proposed approach was divided into two binary logit models. First, we obtained the probability of a crash. Second, after eliminating the non-crash observations, crash severity was modeled as the probability of being involved in an injury or fatal crash. The modeling procedure was applied separately to rural and urban roads and to each of the three traffic congestion conditions.

The ratio of crash to non-crash observations is very low, which reflects the small probability of crash. This unbalanced data could decrease the coefficients of factors affecting crash frequency, so to mitigate the problem, the 1:10 crash to non-crash ratio was adjusted by selecting all crash observations and 10 times the number crash observations of randomly selected non-crash observations. This distortion was later eliminated by adjusting the estimated intercept properly (Washington, Karlaftis, & Mannering, 2011). The other model parameters did not require adjustments.

Additional calculations were required to obtain the actual probability of a PDO or possible injury (CO), and injury or fatal crash (KAB). Let A be the event of being involved in a crash, B the event of being involved in a KAC crash. The sequential binary logit model provides the probabilities $P(A)$ and $P(B|A)$. The remaining probabilities are calculated as follows (Equation 4.3):

$$P(KAB) = P(B|A) \times P(A)$$

$$P(CO) = P(A) - P(B|A) \times P(A) \qquad \text{(Equation 4.3)}$$

4.6 Simulation and Economic Evaluation

The six scenarios of speed limit change were evaluated for their effects on mobility and safety. Simulations of speed, crash frequency, and severity were conducted for each hour of the 2014 year on 319 randomly selected segments. The obtained speeds for these segments were converted to travel times and combined according to the speed limit. Similarly, the number of crashes at the three severity levels were estimated and then combined. All 319 segments, including those with traffic conditions not sensitive to change in speed limit, contributed to the cumulative numbers of observed speeds and crashes. These cumulative numbers were expanded by a factor of 3 from the random sample to the actual number of Indiana interstate segments operating in 2014 under corresponding speed limits. The total travel times and total number of crashes were then used to estimate the cost components: the value of time, vehicle operation costs, economic losses caused by crashes, and the comprehensive costs of the crashes. The difference between cost components for the existing and assumed speed limits was calculated. The following sections present the methodology details.

4.6.1 Value of time

The value of time represents the amount of money that a user could earn by working instead of traveling. It includes both in-vehicle and out-of-vehicle travel time (e.g., walking to parking facility, waiting for a bus to arrive), and can also include the cost of delays in the traffic due to speed restricted by the posted speed limit. After estimating the average speed under the studied speed limit (Section 4.4), the travel time and corresponding value of time for passenger cars and trucks are calculated. The travel time can be obtained using the predicted speed and the segment length as $t=s/v$, where t is the travel time in hours, s is the length of the freeway segment, and v is the predicted average hourly speed along the segment.

Since travel time represents the average condition during one hour for all cars (and separately for all trucks), the value must be multiplied by the number of vehicles in the traffic flow to obtain the total travel time in the hour. However, the traffic volume associated with the observed speed was not available in the original speed dataset. This limitation was overcome by using the car and truck AADT with hourly adjustment factors. Using the speed and volume data available at INDOT's Traffic Count Database System (TCDS), hourly adjustment factors for rural and urban freeways were developed. The detectors used include all permanent non-ramp freeway speed and volume detectors available during 2014 and are presented in Figure 4.3.

The adjustment factors for rural and urban freeways were calculated for each day of the week and month of the year, which represent the average proportion of the AADT for each type of road and time. A total of 4,032 hourly traffic volume adjustment factors were calculated (see Appendix E). Figure 4.4 and Figure 4.5 display rural and urban freeway profiles using the hourly adjustment factors for a sample weekday and weekend during November 2014. The urban profile presents two peak periods on weekdays, but a constantly increasing trend during weekends that is more similar to the rural profile.

The total estimated hourly volume is divided into car and truck volumes using the proportion of the AADT that corresponds to heavy vehicles (u_t). This is shown in Equation 4.4:

$$T_{c_i} = t_{c_i} \cdot q_i \cdot (1 - u_t)$$

$$T_{t_i} = t_{t_i} \cdot q_i \cdot (u_t) \qquad \text{(Equation 4.4)}$$

where T_{c_i} is the total travel time for passenger cars during the ith hour, T_{t_i} is the total travel time for heavy trucks during the ith hour, t_{c_i} is the average travel time of cars during the ith hour, t_{t_i} is the average time of trucks during the ith hour, q_i is the hourly volume calculated from the product of AADT and the adjustment factors, and u_t is the proportion of trucks in the segment's traffic.

Hourly travel time costs for passenger cars and heavy trucks were obtained from (Sinha & Labi, 2007) (Table 5.3) and the values were converted to 2014 dollars using the change in the Consumer Price Index. The hourly 2014 travel time cost for passenger cars was \$21.31 per occupant, the number of which was based on the average of 1.7 occupants/vehicle suggested by the Federal Highway Administration (FHWA, 2018). The average hourly travel time cost for heavy trucks was \$46.10, which does not require adjustment by number of occupants.

4.6.2 Vehicle operating costs

Vehicle operating costs include fuel-related costs, which depend on the vehicle's fuel consumption and

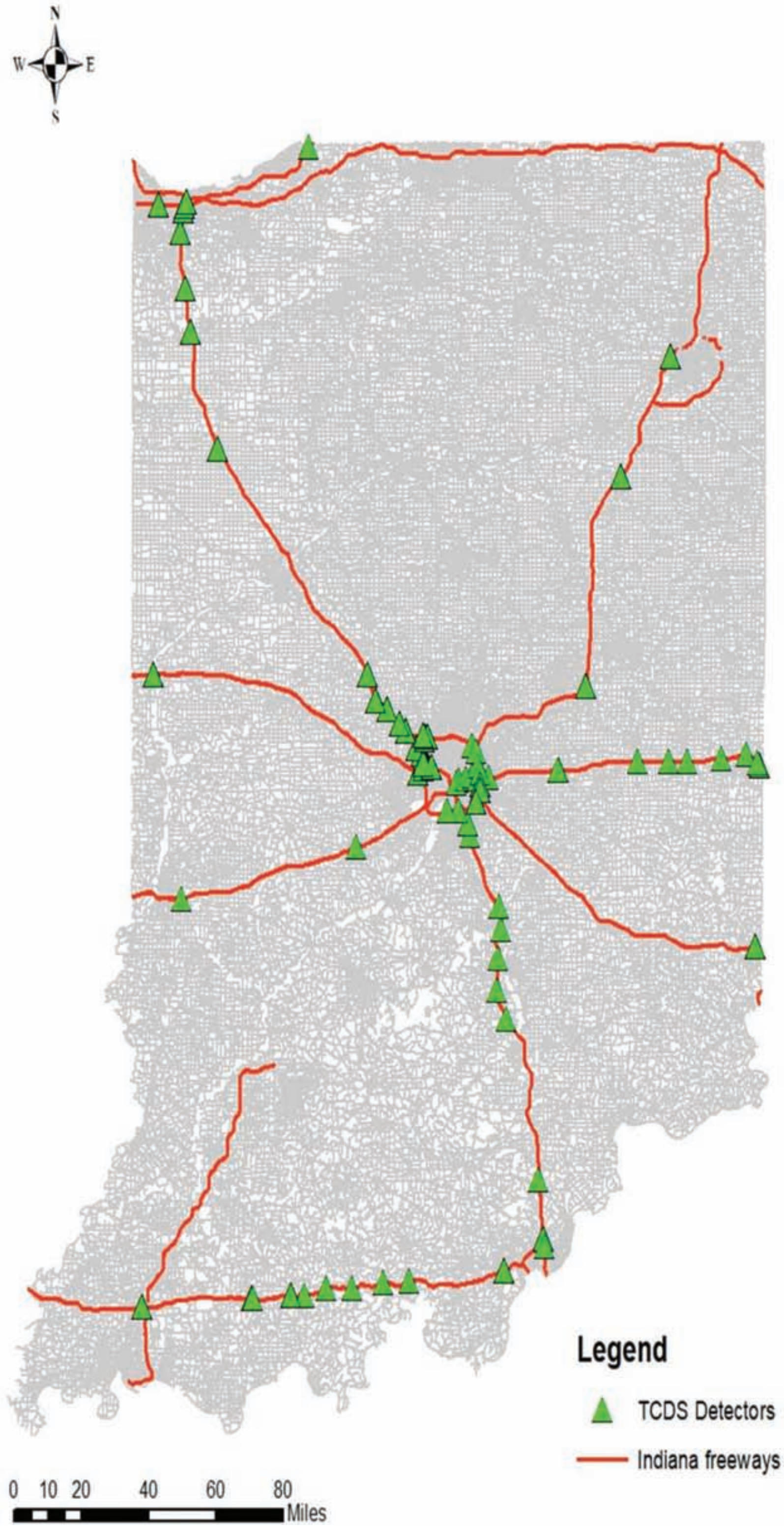

Figure 4.3 TCDS detector locations.

operating speed, and other costs, which include the cost of oil, tires, maintenance, and depreciation.

Fuel consumption for passenger cars and heavy trucks as a function of speed was based on data from the California Department of Transportation, which is used in the Highway Economic Evaluation Model (HEEM). Two polynomial curves were fit to the data, and their equations are presented in Figure 4.6. These

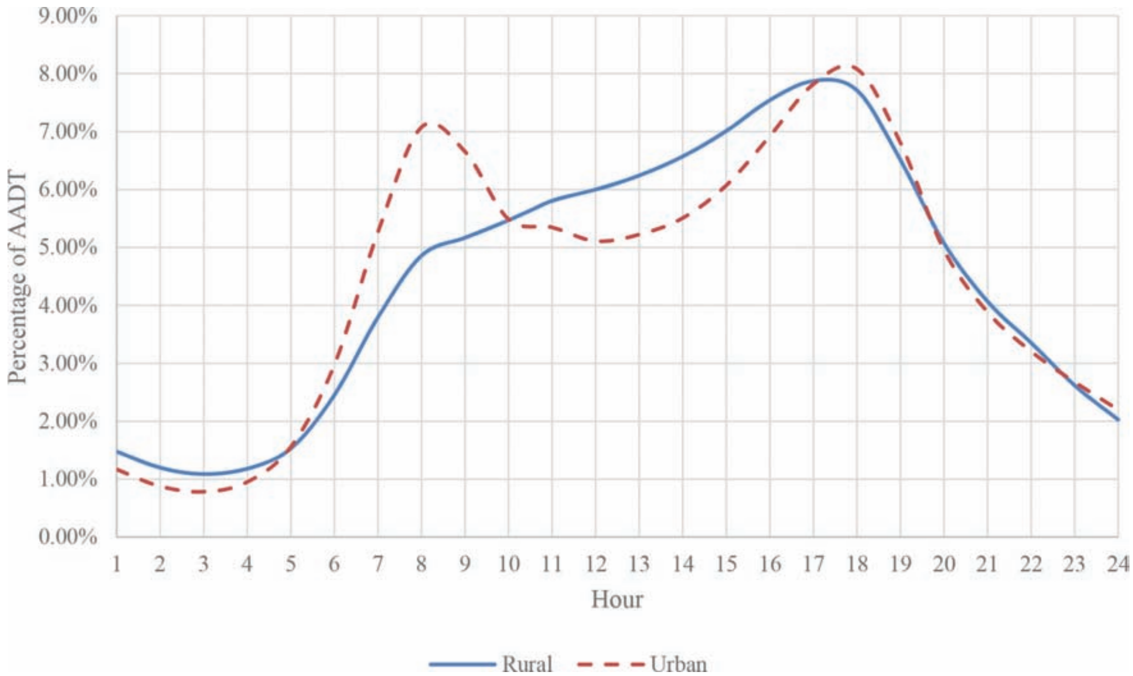

Figure 4.4 Example AADT adjustment factors on a weekday.

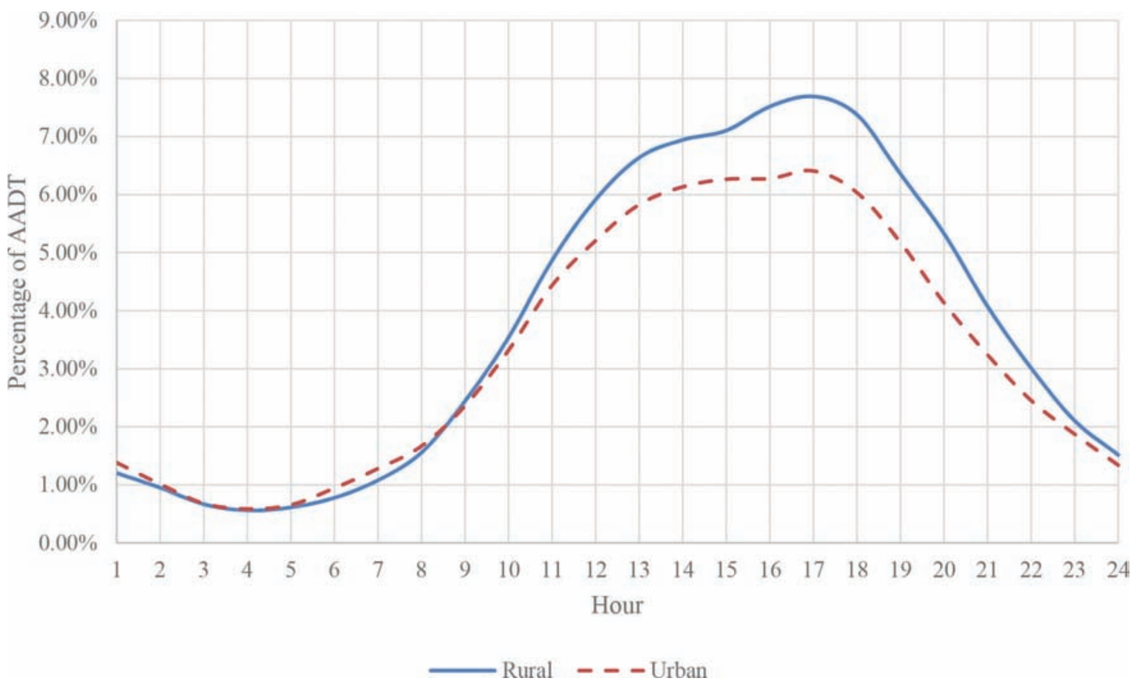

Figure 4.5 Example AADT adjustment factors on a weekend.

equations help us to evaluate changes the fuel-related costs that are due to changes in speed. Trucks were found to have minimum fuel consumption at 30.3 mph, while cars' optimal speed was 50.7 mph. Any speed higher produced an increase in the fuel needed to operate the vehicle.

The average cost of fuel for regular gasoline and diesel was obtained from the U.S. Energy Information Administration (EIA). In 2014, the average cost of one gallon of regular gasoline in the Midwest was $3.303. The average cost of a gallon of diesel was $3.806. These costs were used along with fuel consumption to obtain fuel-related vehicle operating costs.

Other operating costs (oil, tires, etc.) are usually presented as a function of miles traveled. The average other operating costs per mile were obtained from the Surface Transportation Efficiency Model (STEAM).

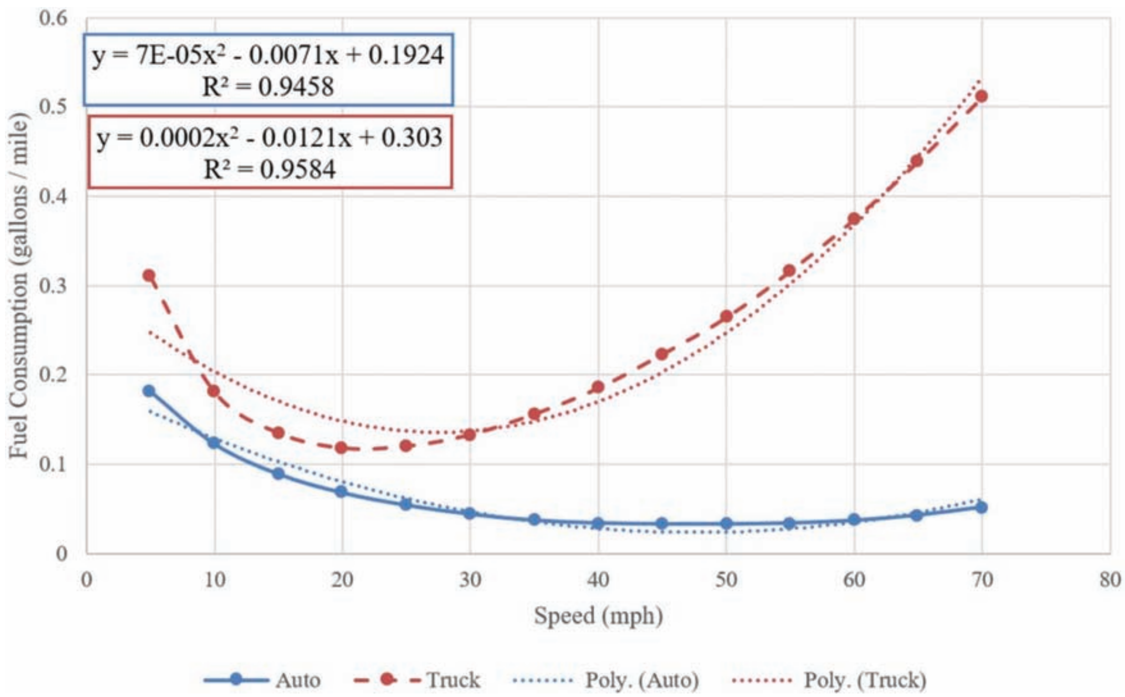

Figure 4.6 Fuel consumption for cars and trucks.

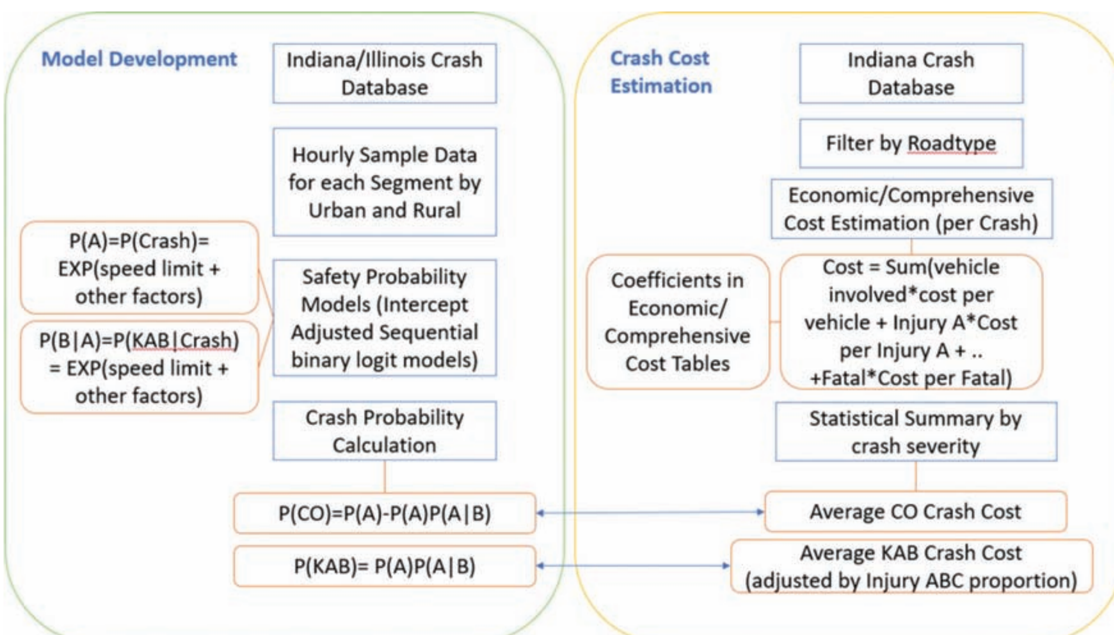

Figure 4.7 Safety impact simulation methodology.

The 2014 costs for cars and trucks were \$0.227/mile and \$0.392/mile, respectively.

4.6.3 Traffic safety

Figure 4.7 shows the flow chart for obtaining safety simulation results. The methodology employed included two parts: model development and crash cost estimation.

The average crash costs for Indiana were estimated based on the 2014 Indiana crash database and on the unit crash cost estimates from the National Safety Council (National Safety Council, 2015). The number of vehicles involved and the number of people injured were used to estimate individual crash costs. Costs were obtained separately for rural and urban freeways and for each crash severity level. The average economic and comprehensive costs for a single crash in Indiana in

TABLE 4.1
Average Economic Cost of a Crash (2014 USD)

	Crash Severity		
Road Type	**PDO ($)**	**Injury ($)**	**Fatal ($)**
Urban	7,305	50,183	1,579,949
Rural	5,726	65,110	1,586,886

TABLE 4.2
Average Comprehensive Cost of a Crash (2014 USD)

	Crash Severity		
Road Type	**PDO ($)**	**Injury ($)**	**Fatal ($)**
Urban	34,315	516,341	10,470,196
Rural	29,381	632,653	10,555,870

2014 are presented in Table 4.1 and Table 4.2, respectively. The comprehensive values are much higher than economic losses since they reflect what people are willing to pay to avoid a crash. The amounts were converted to 2014 dollars using the change in the Consumer Price Index.

5. RESULTS AND DISCUSSION

5.1 Speed Limit Effect on Operating Speed

Average hourly speeds were estimated with regression models using 2014 data from Illinois and Indiana. Individual models were applied to specific types of road, vehicle, and traffic condition; the full summary tables for the obtained speed models are presented in Appendix A. Due to the large sample size, most of the variables were found statistically significant with the 95% confidence level. Therefore, variables were selected for analysis also based on their marginal effects on speed, which reveals whether or not their effects are large enough to be considered.

The R-square values suggest that most of the models for non-congested conditions perform better than the models for congested conditions, as the non-congested model explains a larger portion of the variability in speed. This is not a surprise. Speeds in congested conditions are affected by complex and unstable factors, such as bottleneck capacity and traffic flow on ramps, which are difficult to include due to data limitations. Nevertheless, the majority of the estimated coefficients are intuitive. Although the following discussion of the results is phrased in terms of causal effects, it should be kept in mind that the estimates reflect statistical association and may not fully reflect causality.

Changing the rural freeway 70/65-mph differential speed limit (DSL) to a uniform speed limit (USL) of 70 mph is associated with an increase of 1.42 mph in passenger car average hourly speed, and an increase of 0.63 mph in heavy truck speed. Changing the DSL to a USL of 65 mph was found to reduce the average hourly speed of passenger cars by 0.74 mph and the heavy truck speed by 0.67 mph. These values represent changes on long freeway segments in non-congested conditions. Larger changes are expected on individual vehicle speeds. In the congested traffic models, the speed limit effect on driving speed was found insignificant.

On urban freeways, increasing the speed limit from 55 mph to 60 mph was linked to a 1.40-mph increase in the average speed of passenger cars and a 1.02-mph increase in the average speed of heavy trucks. Likewise, a 10-mph increase in speed limit was linked to a 2.80-mph increase in passenger car average hourly speed and a 2.04-mph increase in the heavy truck speed. Heavy trucks were found to be less responsive to the speed limit changes, possibly because they already tend to operate below the speed limit. As on rural roads, after accounting for the correlation between the speed limit and the number of lanes, the change in the speed limit under congested traffic conditions showed no practical effect.

Other variables also affected the average speed. They are included in the models to help isolate the effect of the speed limit from their confounding effects. An increase in the annual average daily traffic (AADT) was found to reduce the average hourly speed of passenger cars and trucks on rural freeways. Higher AADT also reduced truck speed on urban freeways but had a positive effect on passenger car speed. While rural freeways, and trucks on urban freeways, seem sensitive towards additional traffic volume, passenger cars on urban freeways may more often opt for overtaking slow-moving vehicles because the additional number of lanes allows them to increase their speed.

The proportion of trucks had a negative effect on speed; that is, the AADT corresponding to heavy trucks was found to reduce the average speed of all vehicles on rural freeways. The opposite effect was observed on urban freeways. As with AADT, this effect can be explained by the additional lanes that allow vehicles to overtake slow-moving traffic.

A high value on the pavement International Roughness Index (IRI), which is an indicator of pavement roughness, was found to reduce the speed of passenger cars on rural freeways, but no practical effect for heavy trucks was observed. On urban freeways, a higher IRI reduced the speed of both passenger cars and heavy trucks.

Increases in median width raised the average speed of passenger vehicles on rural freeways, while no practical effect was observed for heavy trucks. On urban freeways, however, an increase in median width was found to reduce the average speed for both vehicle types. The urban freeway results may be associated with the presence of median barriers, locations for which were not available to be included in the model. Shoulder width had an effect similar to that of median width. On rural freeways, speed for all vehicles was found to increase, which can be explained as vehicles having more room to maneuver and therefore accelerate. A decrease of speed was observed on urban freeways, a counterintuitive outcome that may again be explained by the presence of median barriers.

The average speed of all vehicles on urban freeways increased with the number of lanes. On rural freeways, speed increased when going from two lanes to three, but decreased with the addition of a fourth lane. This irregularity could be because four-lane rural roadways are usually located in areas with heavy demand, such as close to the city; their greater frequency of ramps and bottlenecks may lower vehicles' speed. Ramp frequency, or number of ramps per mile, was found to reduce the average speed of all vehicle types on both rural and urban freeways. A larger reduction was observed on urban freeways, which may be explained by the greater complexity and frequency of entering and exiting maneuvers.

The effects on speed of weather-related conditions are largely intuitive. The precipitation intensity and presence of snow were found to reduce the average speed of both vehicle types on urban and rural interstates, though a larger reduction was observed for passenger cars. The previous could be explained as truck drivers are usually exposed to multiple driving environments while car drivers tend to operate locally. The effects of weather did not vary largely between urban and rural freeways.

Figure 5.1 presents profiles of the estimated coefficients of hourly indicators for average speed after all other factors are kept fixed. The effect of the hour of the day on heavy truck speed was found to be similar for rural and urban freeways: trucks increase their speed mainly during early morning hours. On the other hand, passenger cars' maximum speed on rural freeways was found during mid-to-late afternoon hours, while on urban freeways, their main increase was during early morning and secondly, in evening hours.

The presence of daylight was found to increase the average hourly speed of all vehicles on urban and rural interstates, with a larger increase for passenger cars than for heavy trucks. The average speed of passenger cars was higher on weekends than on weekdays on both road types. For heavy trucks, the weekend variable increased the speed on urban freeways but decreased it on rural freeways. Season indicator variables were found to affect passenger car speed, while no significant effect was found for heavy trucks. Passenger car speed is higher in summer and fall; it is reduced in spring, and is lowest in winter. This effect is similar across rural and urban freeways.

An increase in speed associated with greater distance to the city center was found to be statistically, but not practically, significant for all vehicles on rural freeways, and for passenger cars on urban freeways. Lower speeds for passenger cars and heavy trucks were found on suburban freeway segments, segments with rural-like speed limits but located within city limits. This effect was larger for cars than for trucks. Additional interaction with the number of lanes was included to account for unobserved categories on rural freeways.

5.2 Speed Limit Effect on Safety

Because the effect of speed limit on safety performance may differ among traffic congestion conditions, safety models were developed for each condition based on the same congested, intermediate, and non-congested classifications used to categorize the original dataset. Several sets of sequential binary logit (SBL) models were therefore developed to investigate the effect of urban and rural freeway speed limits on the number of crashes at different severity levels.

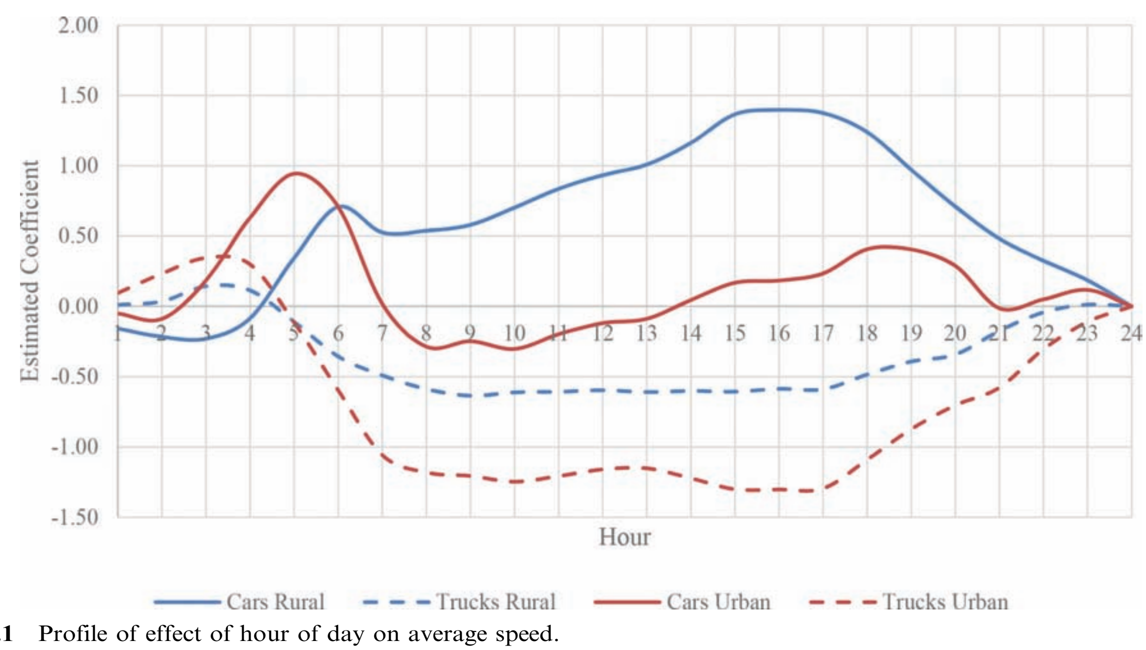

Figure 5.1 Profile of effect of hour of day on average speed.

The number of urban segments in the sample is sufficiently large to divide crashes into three severity levels: fatal or incapacitating injury (KA), non-incapacitating or possible injury (BC), and property damage only (PDO). Due to the lower number of rural segments, crash severity is restricted to two levels: fatal, incapacitating or non-incapacitating injury (KAB); and possible injury or property damage only (CO). The three severity levels under the three traffic conditions could potentially produce nine models for urban freeways, and the two severity levels under three traffic conditions could produce six models for rural freeways. The actual number of models is smaller, however, because the safety effect of speed limit is not always present, particularly in more congested conditions, and also because differences in the urban and rural speed limit policies have different effects on safety. The results are described separately.

The SBL models for urban non-congested conditions are shown in Appendix B. Safety on urban freeways was found affected by changes in speed limits only in non-congested traffic conditions, where increasing the speed limit from 55 mph to 65 mph increased the probability of crash, and increased the probability of injury or fatality, given a crash. While the probability of fatality (vs. injury) in crashes at this severity level is not statistically significant, most likely due to the small number of fatalities in the sample, these results concur with previous findings that an increase of speed limit leads to a higher probability of crash and a rise in crash severity. These effects of speed limit on safety are consistent across the severity levels.

In terms of differential speed limits, rural freeways showed a significant effect from the speed limit for non-congested and intermediate traffic conditions, as shown in Appendix B. The estimated coefficients in the crash risk models indicated that the differential speed limit (70/65 mph) is less safe than the 65-mph uniform speed limit, a finding consistent for both conditions. It should be kept in mind, however, that all the studied DSL segments are in Indiana and all the USL segments are in Illinois. Due to possible differences in crash reporting and safety performance records between Indiana and Illinois, the "state" effect may be included in the estimated speed limit effect. This possibility is confirmed by the non-congested urban interstate model, which indicates different safety outcomes for the two states under similar conditions. We will return to this difference in Section 5.3, but if one applies to rural roads the difference between the two states' urban estimates, even the higher uniform 70-mph speed limit is found slightly safer than the differential 70/65-mph speed limit. This uniform higher speed might be more acceptable than a DSL that can lead to additional collisions.

Applying a similar treatment to transferring the uniform speed limit of 65 mph from Illinois estimates to Indiana is questionable, however, because there is an additional source of concern. The general recommended speed limit in Illinois is 70 mph, but a limit of 65 mph is applied on certain road segments with safety concerns. Applying a reduced speed limit where crashes are more frequent and/or more severe introduces a selection bias to cross-sectional estimates of safety effects. Simply put, if, as is a rather plausible assumption, the reduced speed limit does not fully eliminate safety problems, the reduction would be connected with a road of substandard safety performance, clearly a serious mistake. Indeed, after adjusting Indiana results for the safety difference in Illinois, the results imply that safety under a uniform 65-mph speed limit is poorer than under the current differential 70/65 mph. These results contradict the current evidence and understanding of the effect of speed on safety, and consequently, fail the basic test of reasonableness. An alternative approach could include data from Ohio's rural interstates, which would provide the opportunity to observe both 65-mph and 70-mph uniform speed limits along entire roads, and not only on sporadic freeway segments. However, this analysis was outside of the scope of the presented study.

Other effects considered in the proposed safety models included roadway geometry, weather conditions, temporal variability, and exposure variables, including AADT and segment length. Most of these other effects are intuitive. For example, AADT had a significant positive association with crash risk in the urban non-congested crash probability model and in the rural non-congested and intermediate models. Although coefficients for some of the other factors in the safety models are not intuitive (e.g., increasing the median width increases the crash frequency in rural roads), they reflect the reality of the freeway samples. Since the results are applied to the same population, the non-intuitive coefficients are not expected to influence the safety simulation results and the speed limit effects can be assumed to be estimated correctly.

5.3 Transferability of the Results

The use of data from the states of Illinois and Indiana raise questions about the transferability between the two states of the estimated results. Attaining reliable transferability is imperative for rural freeways where the speed limits are different. On the other hand, speed and safety differences between states are usually greater on urban than rural freeways due to the different nature of the travel: urban freeways are used for a combination of short and long-distance trips while rural freeways are predominantly used for long-distance trips. Yet urban freeway data are more transferable between states because the roads more frequently have speed limits in common. Urban roads thus offer a valuable opportunity to compare the relationships between speed limit, speed, and safety.

Two multiple linear regression models were developed to estimate the average speed of passenger cars and trucks (see Appendix C). The models show the interaction of speed limit and state along with other confounding factors. Table 5.1 lists by speed limit the

TABLE 5.1
Descriptive Statistics for the Average Speed of Passenger Cars

State	Speed Limit	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
Illinois	55 mph	649,202	52.31	13.06	0.61	88.98
Illinois	65 mph	159,871	62.38	5.22	0.62	87.17
Illinois	70 mph	615,512	64.27	6.18	0.61	89.93
Indiana	55 mph	499,904	58.66	6.24	0.62	88.84
Indiana	65 mph	142,335	61.89	6.19	0.62	89.04
Indiana	70 mph	291,934	64.34	5.08	0.62	88.18

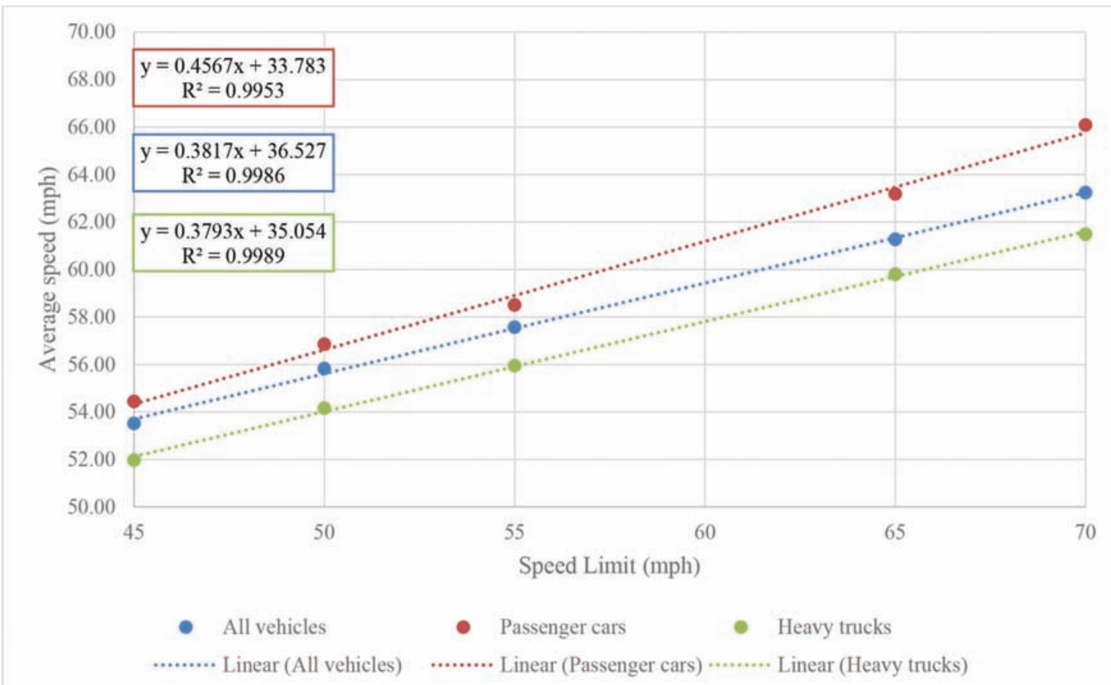

Figure 5.2 Trend lines of average speed by vehicle type.

summary statistics of passenger cars' average speed for Illinois and Indiana. We notice that the difference in mean speed between the two states was at its greatest on roads with a 55-mph speed limit. Under a common posted 55-mph speed limit, passenger cars in Indiana operated more than 6 mph faster than passenger cars in Illinois. The state-to-state differences for 65-mph and 70-mph limits are lower than 0.5 mph and are negligible.

For trucks, the estimated difference in mean speed between the two states was at its greatest on roads with a 70-mph speed limit. In fact, there are no roads with 70-mph speed limits for trucks in Indiana. The calculation, in this case, refers to suburban freeway segments with a 70/65 differential speed limit, making the actual truck speed limit 65 mph. Taking this into account, we found that the state-to-state differences in the effect of speed limit on truck speed was lower than 0.5 mph under both 55-mph and 65-mph posted speeds.

Interaction between the speed limit, state, and safety was estimated for urban freeways. The estimated coefficient was then translated to rural freeways and was used to estimate the crash risk at each severity level. This step was of great importance since the unadjusted models combined the effects of speed limit and state as the speed limit coefficient. Reducing the effect of the speed limit by using the urban indicator brought us closer to the actual effect of the speed limit on rural freeway safety.

5.4 Linear Relationship Between Speed Limit and Operating Speed

The speed limit was assumed to have a proportional effect on driving speed. To test the validity of this assumption, exploratory data and regression analyses were developed.

In Figure 5.2, the average speeds for the different vehicle types are plotted against the speed limit.

TABLE 5.2
Estimated Annual Effects of Increasing Speed Limits on Indiana Rural Interstate Roads to 70-mph Uniform Speed (Eliminating Differential Speed Limit)

Effect	70/65 mph (current)	70 mph
Value of Time		
Predicted travel time for passenger cars (million hours)	431.39	422.44
Predicted travel time for heavy trucks (million hours)	88.01	87.18
Cost of travel time for passenger cars (million 2014 USD)	$9,193.02	$9,002.10
Cost of travel time for heavy trucks (million 2014 USD)	$4,057.32	$4,018.80
Total cost of travel time (million 2014 USD)	*$13,250.34*	*$13,020.90*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$229.44
Vehicle Operating Costs		
Predicted fuel consumption for passenger cars (million gallons)	477.61	526.57
Predicted fuel consumption for heavy trucks (million gallons)	1,635.97	1,676.02
Fuel related costs for passenger cars (million 2014 USD)	$1,577.55	$1,739.25
Fuel related costs for heavy trucks (million 2014 USD)	$6,226.52	$6,378.91
Non-fuel related costs for passenger cars (million 2014 USD)	$3,884.87	$3,884.87
Non-fuel related costs for heavy trucks (million 2014 USD)	$2,119.23	$2,119.23
Total vehicle operating costs (million 2014 USD)	*$13,808.17*	*$14,122.26*
Difference in cost from base scenario (million 2014 USD)	$0.00	$314.09
Traffic Safety—Economic Cost		
Predicted PDO and possible injury crashes	10,931.09	9,067.36
Predicted injury and fatal crashes	2,089.62	1,284.84
Cost of PDO and possible injury crashes (million 2014 USD)	$62.60	$51.90
Cost of injury and fatal crashes (million 2014 USD)	$136.10	$83.70
Total cost of crashes (million 2014 USD)	*$198.70*	*$135.60*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$63.10
Traffic Safety—Comprehensive Cost		
Predicted PDO and possible injury crashes	10,931.09	9,067.36
Predicted injury and fatal crashes	2,089.62	1,284.84
Cost of PDO and possible injury crashes (million 2014 USD)	$321.20	$266.40
Cost of injury and fatal crashes (million 2014 USD)	$1,322.00	$812.90
Total cost of crashes (million 2014 USD)	*$1,643.20*	*$1,079.30*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$563.90
Total difference using safety economic cost (million 2014 USD)	**$0.00**	**$21.60**
Total difference using safety comprehensive cost (million 2014 USD)	**$0.00**	**-$479.30**

Urban freeway segments from Illinois were employed in order to offer a broader set of urban speed limits than those present in Indiana. Three linear trend lines were fit for passenger cars, heavy trucks, and the total of all vehicles. Using these equations, it was found that a 5-mph rise in the speed limit was associated with a 2.28-mph increase in passenger car speed, a 1.90-mph increase in heavy truck speed, and a 1.91-mph overall traffic speed increase.

Complementing the exploratory data analysis described in Figure 5.2, three regression models were fit. The average hourly speeds of all vehicles, passenger cars, and heavy trucks were modeled as functions of road geometry, traffic, weather, and seasonal factors (see Appendix D). Using the estimated coefficients from the models, it was found that a 5-mph rise in the speed limit was associated with a 2.13-mph increase in passenger car speed, a 2.04-mph increase in heavy truck speed, and a 1.27-mph speed increase overall.

5.5 Evaluation of Alternative Speed Limit Scenarios

The effects of changing the speed limit settings on Indiana interstate roads were assessed. The assessment includes estimations, for current and alternative speed limit scenarios, of the value of time, vehicle operating cost, and crash cost. Table 5.2 presents the annual effect of changing the differential speed limit on rural freeways to a uniform 70 mph. Table 5.3 summarizes the annual effects of increasing the speed limit on urban freeway sections that are currently set at 55 mph, and Table 5.4 presents the annual effects of reducing the speed limit on urban freeways sections that are currently set at 65 mph. The number of miles that each speed limit policy covers is presented at the top of each table.

Replacing the differential 70/65-mph speed limit with a uniform speed limit of 70 mph will reduce travel time, and will reduce the total number of crashes by 20% and

TABLE 5.3
Estimated Annual Effects of Changes in the Speed Limits on Indiana Urban 55-mph Interstate Roads

Effect	**55 mph (current)**	**60 mph**	**65 mph**
Value of Time			
Predicted travel time for passenger cars (million hours)	372.84	364.14	355.45
Predicted travel time for heavy trucks (million hours)	27.44	26.97	26.50
Cost of travel time for passenger cars (million 2014 USD)	$7,945.10	$7,759.90	$7,574.60
Cost of travel time for heavy trucks (million 2014 USD)	$1,264.80	$1,243.10	$1,221.50
Total cost of travel time (million 2014 USD)	*$9,209.90*	*$9,003.00*	*$8,796.10*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$206.90	-$413.90
Vehicle Operating Costs			
Predicted fuel consumption for passenger cars (million gallons)	251.20	271.93	292.67
Predicted fuel consumption for heavy trucks (million gallons)	364.04	378.82	393.61
Fuel related costs for passenger cars (million 2014 USD)	$829.70	$898.20	$966.70
Fuel related costs for heavy trucks (million 2014 USD)	$1,385.50	$1,441.80	$1,498.10
Non-fuel related costs for passenger cars (million 2014 USD)	$2,747.30	$2,747.30	$2,747.30
Non-fuel related costs for heavy trucks (million 2014 USD)	$564.10	$564.10	$564.10
Total vehicle operating costs (million 2014 USD)	*$5,526.60*	*$5,651.30*	*$5,776.10*
Difference in cost from base scenario (million 2014 USD)	$0.00	$124.80	$249.50
Traffic Safety—Economic Cost			
Predicted PDO crashes	7,509.58	7,561.49	7,613.39
Predicted injury crashes	1,486.40	1,814.57	2,142.73
Predicted fatal crashes	27.56	45.32	63.09
Cost of PDO crashes (million 2014 USD)	$54.90	$55.20	$55.60
Cost of injury crashes (million 2014 USD)	$74.60	$91.10	$107.50
Cost of fatal crashes (million 2014 USD)	$43.50	$71.60	$99.70
Total cost of crashes (million 2014 USD)	*$173.00*	*$217.90*	*$262.80*
Difference in cost from base scenario (million 2014 USD)	$0.00	$44.90	$89.80
Traffic Safety—Comprehensive Cost			
Predicted PDO crashes	7,509.58	7,561.49	7,613.39
Predicted injury crashes	1,486.40	1,814.57	2,142.73
Predicted fatal crashes	27.56	45.32	63.09
Cost of PDO crashes (million 2014 USD)	$257.70	$259.50	$261.30
Cost of injury crashes (million 2014 USD)	$767.50	$936.90	$1,106.40
Cost of fatal crashes (million 2014 USD)	$288.60	$474.50	$660.50
Total cost of crashes (million 2014 USD)	*$1,313.80*	*$1,671.00*	*$2,028.20*
Difference in cost from base scenario (million 2014 USD)	$0.00	$357.20	$714.40
Total difference using safety economic cost (million 2014 USD)	**$0.00**	**-$37.20**	**-$74.50**
Total difference using safety comprehensive cost (million 2014 USD)	**$0.00**	**$275.00**	**$550.10**

the proportion of severe crashes by 26%. However, these gains come at the expense of increased vehicle operating costs. The overall economic effect is expected to be slightly on the negative side unless the comprehensive cost of crashes is considered.

Urban freeway sections with currently displayed 55-mph speed limits would benefit from reduced travel times by increasing their speed limits. This benefit is moderately larger than the combined vehicle operating costs and economic loss of crashes, but when comprehensive crash costs are incorporated, the higher speed limit alternative becomes unappealing. On the other hand, the analysis indicates that the current 65-mph urban segments may benefit from reducing the speed limit. This conclusion is valid regardless of whether economic loss or comprehensive cost is considered, but is particularly appealing from the perspective of comprehensive cost.

TABLE 5.4
Estimated Annual Effects of Changes in the Speed Limits on Indiana Urban 65-mph Interstate Roads

Effect	65 mph (current)	60 mph	55 mph
Value of Time			
Predicted travel time for passenger cars (million hours)	68.71	70.25	71.78
Predicted travel time for heavy trucks (million hours)	9.15	9.30	9.45
Cost of travel time for passenger cars (million 2014 USD)	$1,464.30	$1,497.00	$1,529.70
Cost of travel time for heavy trucks (million 2014 USD)	$421.70	$428.70	$435.70
Total cost of travel time (million 2014 USD)	*$1,886.00*	*$1,925.70*	*$1,965.30*
Difference in cost from base scenario (million 2014 USD)	$0.00	$39.70	$79.30
Vehicle Operating Costs			
Predicted fuel consumption for passenger cars (million gallons)	60.99	55.84	50.70
Predicted fuel consumption for heavy trucks (million gallons)	153.26	147.43	141.59
Fuel related costs for passenger cars (million 2014 USD)	$201.40	$184.50	$167.50
Fuel related costs for heavy trucks (million 2014 USD)	$583.30	$561.10	$538.90
Non-fuel related costs for passenger cars (million 2014 USD)	$559.70	$559.70	$559.70
Non-fuel related costs for heavy trucks (million 2014 USD)	$206.70	$206.70	$206.70
Total vehicle operating costs (million 2014 USD)	*$1,551.20*	*$1,512.00*	*$1,472.80*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$39.20	-$78.40
Traffic Safety—Economic Cost			
Predicted PDO crashes	1,624.77	1,612.59	1,600.41
Predicted injury crashes	444.73	376.63	308.53
Predicted fatal crashes	15.43	11.10	6.77
Cost of PDO crashes (million 2014 USD)	$11.90	$11.80	$11.70
Cost of injury crashes (million 2014 USD)	$22.30	$18.90	$15.50
Cost of fatal crashes (million 2014 USD)	$24.40	$17.50	$10.70
Total cost of crashes (million 2014 USD)	*$58.60*	*$48.20*	*$37.90*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$10.30	-$20.70
Traffic Safety—Comprehensive Cost			
Predicted PDO crashes	1,624.77	1,612.59	1,600.41
Predicted injury crashes	444.73	376.63	308.53
Predicted fatal crashes	15.43	11.10	6.77
Cost of PDO crashes (million 2014 USD)	$55.80	$55.30	$54.90
Cost of injury crashes (million 2014 USD)	$229.60	$194.50	$159.30
Cost of fatal crashes (million 2014 USD)	$161.50	$116.20	$70.80
Total cost of crashes (million 2014 USD)	*$446.90*	*$366.00*	*$285.10*
Difference in cost from base scenario (million 2014 USD)	$0.00	-$80.90	-$161.90
Total difference using safety economic cost (million 2014 USD)	**$0.00**	**-$9.90**	**-$19.80**
Total difference using safety comprehensive cost (million 2014 USD)	**$0.00**	**-$80.50**	**-$160.90**

6. CONCLUSIONS

The mobility and safety effects of changing the speed limits on Indiana freeways were estimated using a what-if analysis. The evaluation criteria included differences in travel time (mobility), vehicle operating costs, and the cost of crashes (safety).

A lack of suitable data prevented this study from estimating the safety effect of replacing the current 70/65-mph differential speed limit on rural interstates with a uniform 65-mph speed limit setting, but a uniform setting of 70 mph was evaluated. The results suggest a non-beneficial economic performance with the uniform speed limit, but consideration of the comprehensive costs of crashes justify this alternative.

Limitations must be noted, however, in the use of both Illinois and Indiana DSL data. Each state has a separate speed limit policy that only overlaps on certain urban freeway segments, which led to some state-to-state differences in the estimated safety effects on rural freeways. To overcome this issue, urban safety models were calibrated with a state indicator variable. The estimated state coefficient in the urban model was applied to the rural model in order to address the possible bias caused by the difference between Indiana and Illinois.

Considering the economic loss cost of crashes, urban freeways with currently displayed 55-mph speed limits offer an opportunity to test higher speed limits since travel time benefits overcome vehicle operating and traffic safety losses. Results also suggest considering reducing the current 65-mph speed limit on other urban freeway segments. However, the results obtained using the comprehensive cost of crashes identifies the lowest speed limit as the most appealing scenario.

This study tested the assumption that the speed limit has its maximum effect under free-flow conditions. Congestion was defined by the relative difference between an observed hourly speed and the daily free flow (uncongested) speed, and was divided into three levels: non-congestion, intermediate, and congestion. It was confirmed that the effect of speed limit on operating speed and safety diminishes as the traffic condition approaches congestion.

The National Performance Management Research Data Set offered a comprehensive view of speed on all freeway sections in Indiana. However, the NPMRDS estimates of the effects of speed limit on actual speed may be larger than those estimated in the models. NPMRDS estimates are sustained using the average travel times of multiple vehicles over large freeway segments (2.5 miles on average), and over a large period of time. Use of this dataset is warranted, nonetheless, by its largest benefit, which is its coverage.

Observations of the past conditions of travel time, roadway geometry, weather, and crash data were available for this analysis. It can be assumed that their influence on speed, and thus their impact on our estimates of the effect of speed limit, can be applied to the same population from which they were derived. An optimum policy selected from the alternatives based on an analysis such as this should remain desirable for future years without the need to continually predict future temporal conditions such as traffic and weather.

This study is focused on the system-level effect of changes in speed limits. Engineering prudence prompts that implementation of speeds higher than currently posted should consider geometric design of individual road segments and their crash history before the posted speed limit is raised.

REFERENCES

Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, *38*(2), 215–224. https://doi.org/10.1016/j.aap.2005.07.004

Bassani, M., Dalmazzo, D., Marinelli, G., & Cirillo, C. (2014). The effects of road geometrics and traffic regulations on driver-preferred speeds in northern Italy: An exploratory analysis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *25*(Part A), 10–26. https://doi.org/10.1016/j.trf.2014.04.019

Chakraborty, S., & Srinivasan, K. K. (2016). Analysis and application of two-fluid model for mixed traffic conditions. *Transportation Letters: The International Journal of Transportation Research*, 1–13. https://doi.org/10.1080/19427867.2016.1193309

Deardoff, M. D., Wiesner, B. N., & Fazio, J. (2011). Estimating free-flow speed from posted speed limit signs. *Procedia—Social and Behavioral Sciences*, *16*(2011), 306–316. https://doi.org/10.1016/j.sbspro.2011.04.452

Dixit, V. V. (2013). Behavioural foundations of two-fluid model for urban traffic. *Transportation Research Part C: Emerging Technologies*, *35*(2013), 115–126. https://doi.org/10.1016/J.TRC.2013.06.009

Dixit, V. V., Pande, A., Abdel-Aty, M., Das, A., & Radwan, E. (2011). Quality of traffic flow on urban arterial streets and its relationship with safety. *Accident Analysis & Prevention*, *43*(5), 1610–1616. https://doi.org/10.1016/J.AAP.2011.01.006

Dixon, M. P., Abdel-Rahim, A., & Elbassuoni, S. (2012). *Evaluation of the impacts of differential speed limits on interstate highways in Idaho* (Report No. FHWA-ID-13-218). Moscow, ID: University of Idaho. Retrieved from https://rosap.ntl.bts.gov/pdfjs/web/viewer.html?file=https://rosap.ntl.bts.gov/view/dot/25335/dot_25335_DS1.pdf#page=2&zoom=auto,-23,98

Eluru, N., Chakour, V., Chamberlain, M., & Miranda-Moreno, L. F. (2013). Modeling vehicle operating speed on urban roads in Montreal: A panel mixed ordered probit fractional split model. *Accident Analysis and Prevention*, *59*(2013), 125–134. https://doi.org/10.1016/j.aap.2013.05.016

Elvik, R. (2009). *The Power Model of the relationship between speed and road safety*. Oslo, Norway: Institute of Transportaion Economics (TOI).

Elvik, R. (2013). A re-parameterisation of the Power Model of the relationship between the speed of traffic and the number of accidents and accident victims. *Accident Analysis & Prevention*, *50*(2013), 854–860. https://doi.org/10.1016/j.aap.2012.07.012

Elvik, R., Christensen, P., & Amundsen, A. H. (2004). *Speed and road accidents: An evaluation of the Power Model* (Report No. 740/2004). Oslo, Norway: Institute of Transportaion Economics (TOI). Retrieved from https://www.toi.no/getfile.php?mmfileid=1007

Farmer, C. M. (2017). Relationship of traffic fatality rates to maximum state speed limits. *Traffic Injury Prevention*, *18*(4), 375–380. https://doi.org/10.1080/15389588.2016.1213821

Farmer, C. M., Retting, R. A., & Lund, A. K. (1999). Changes in motor vehicle occupant fatalities after repeal of the national maximum speed limit. *Accident Analysis & Prevention*, *31*(5), 537–543. https://doi.org/10.1016/S0001-4575(99)00010-X

FHWA. (2004). *The safety impacts of differential speed limits on rural interstate highways* (Report No. FHWA-HRT-04-156). Washington, DC: U.S. Department of Transportation, Federal Highway Administration. Retrieved from https://www.fhwa.dot.gov/publications/research/safety/04156/04156.pdf

FHWA. (2018). *Average vehicle occupancy factors for computing travel time reliability measures and total peak hour excessive delay metrics*. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. Retrieved from https://www.fhwa.dot.gov/tpm/guidance/avo_factors.pdf

Figueroa Medina, A. M., & Tarko, A. P. (2005). Speed factors on two-lane rural highways in free-flow conditions. *Transportation Research Record: Journal of the Transportation Research Board*, *1912*(1), 39–46. https://doi.org/10.3141/1912-05

Fitzpatrick, K., Miaou, S.-P., Brewer, M., Carlson, P., & Wooldridge, M. D. (2005). Exploration of the relationships between operating speed and roadway features on tangent sections. *Journal of Transportation Engineering*, *131*(4), 261–269. https://doi.org/10.1061/(ASCE)0733-947X(2005)131:4(261)

Freedman, M., & Williams, A. F. (1992). Speeds associated with 55-mph and 65-mph speed limits in northeastern states. *ITE Journal*, *62*(2), 17–21.

Gallup Organization, The. (2003). *National survey of speeding and unsafe driving attitudes and behaviors*: *Vol. II—Findings report* (Report No. DOT HS 809 688). Washington, DC: National Highway Traffic Safety Administration. Retrieved from https://one.nhtsa.gov/people/injury/drowsy_driving1/speed_volII_finding/SpeedVolumeIIFindingsFinal.pdf

Garber, N. J., & Gadiraju, R. (1989). Factors affecting speed variance and its influence on accidents. *Transportation Research Record: Journal of the Transportation Research Board*, 1213, 64–71. Washington, DC: Transportation Research Board. Retrieved from http://onlinepubs.trb.org/Onlinepubs/trr/1989/1213/1213-009.pdf

Garber, N. J., & Gadiraju, R. (1991). *Impact of differential speed limits on highway speeds and accidents*. Charlottesville, VA: University of Virginia, Charlottesville, Center for Transportation Studies. Retrieved from https://trid.trb.org/view.aspx?id=350870

Garber, N. J., & Gadiraju, R. (1992). Impact of differential speed limits on the speed of traffic and the rate of accidents. *Transportation Research Record: Journal of the Transportation Research Board*, *1375*, 44–52. Retrieved from http://onlinepubs.trb.org/Onlinepubs/trr/1992/1375/1375-007.pdf

Garber, N. J., Miller, J. S., Sun, X., & Yuan, B. (2006). Safety impacts of differential speed limits for trucks and passenger cars on rural interstate highways: A modified empirical Bayes approach. *Journal of Transportation Engineering*, *132*(1), 19–29. Retrieved from https://doi.org/10.1061/(ASCE)0733-947X(2006)132:1(19)

Garber, N. J., Miller, J. S., Yuan, B., & Sun, X. (2005). *Safety effects of differential speed limits: Limits on rural interstate highways* (Publication No. FHWA-HRT-05-042). Charlottesville, VA: Virginia Transportation Research Council. Retrieved from https://www.fhwa.dot.gov/publications/research/safety/05042/05042.pdf

Hall, J. W., & Dickinson, V. L. (1974). Truck speeds and accidents on interstate highways. *Transportation Research Record: Journal of the Transportation Research Board*, *486*, 19–32. Washington, DC: Transportation Research Board. Retrieved from https://onlinepubs.trb.org/Onlinepubs/trr/1974/486/486-003.pdf

Hanowski, R. J., Bergoffen, G., Hickman, J. S., Guo, F., Murray, D., Bishop, R., … Camden, M. C. (2012). *Research on the safety impacts of speed limiter device installations on commercial motor vehicles: Phase II* (Report No. FMCSA-RRR-12-006). Fryeburg, ME: MaineWay Services. Retrieved from https://rosap.ntl.bts.gov/pdfjs/web/viewer.html?file=https://rosap.ntl.bts.gov/view/dot/105/dot_105_DS1.pdf#page=1&zoom=auto,-23,792

Harkey, D. L., & Mera, R. (1994). *Safety impacts of different speed limits on cars and trucks* (Report FHWA-RD-93-161). Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

Hauer, E. (2009). Speed and safety. *Transportation Research Record: Journal of the Transportation Research Board*, *2103*(1), 10–17. https://doi.org/10.3141/2103-02

Herman, R., & Prigogine, I. (1979). A two-fluid approach to town traffic. *Science*, *204*(4389), 148–151. https://doi.org/10.1126/science.204.4389.148

Iowa Highway Safety Management System. (2002). *Update report on speed limits in Iowa*. Ames, IA: Iowa Department of Transportation. Retrieved from https://www.iowadot.gov/pdf_files/speed2002.pdf

Johnson, S. L., & Murray, D. (2010). Empirical analysis of truck and automobile speeds on rural interstates: Impact of posted speed limits. In *Transportation Research Board 89th Annual Meeting compendium of papers*. Washington, DC: Transportation Research Board. https://trid.trb.org/view.aspx?id=909664

Johnson, S. L., & Pawar, N. (2005). *Cost-benefit evaluation of large truck-automobile speed limit differentials on rural interstate highways* (Report No. MBTC 2048.) Fayetteville, AR: Mack-Blackwell Transportation Center, University of Arkansas. Retrieved from https://rosap.ntl.bts.gov/pdfjs/web/viewer.html?file=https://rosap.ntl.bts.gov/view/dot/16162/dot_16162_DS1.pdf#page=1&zoom=auto,-23,683

Johnson, S. L., & Pawar, N. (2007). Analysis of heavy-truck and automobile speed distributions for uniform and differential speed limit configurations on rural interstate highways. In *Transportation Research Board 86th Annual Meeting compendium of papers*. Washington, DC: Transportation Research Board. https://trid.trb.org/view.aspx?id=802489

Korkut, M., Ishak, S., & Wolshon, B. (2010). Freeway truck lane restriction and differential speed limits: Crash analysis and traffic characteristics. *Transportation Research Record: Journal of the Transportation Research Board*, *2194*(1), 11–20. https://doi.org/10.3141/2194-02

Mahmassani, H. S., Jayakrishnan, R., & Herman, R. (1990). Network traffic flow theory: Microscopic simulation experiments on supercomputers. *Transportation Research Part A: General*, *24*(2), 149–162. https://doi.org/10.1016/0191-2607(90)90022-X

Mahmassani, H., Williams, J. C., & Herman, R. (1984). Investigation of network-level traffic flow relationships: Some simulation results. *Transportation Research Record: Journal of the Transportation Research Board*, *971*, 121–130.

Retrieved from http://onlinepubs.trb.org/Onlinepubs/trr/1984/971/971-016.pdf
Malyshkina, N. V., & Mannering, F. (2008). Effect of increases in speed limits on severities of injuries in accidents. *Transportation Research Record: Journal of the Transportation Research Board*, *2083*(1), 122–127. https://doi.org/10.3141/2083-14
Mannering, F. (2009). An empirical analysis of driver perceptions of the relationship between speed limits and safety. *Transportation Research Part F: Traffic Psychology and Behaviour*, *12*(2), 99–106. https://doi.org/10.1016/j.trf.2008.08.004
Monsere, C., Kothuri, S., & Razmpa, A. (2017). *Update to issues report for interstate speed changes* (Project 16-110). Salem, OR: Oregon Department of Transportation Research Unit. Retrieved from https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/Truck-Speed-PSU-Issues-Report-2017.pdf
Monsere, C. M., Newgard, C. D., Dill, J., Rufolo, A. M., Wemple, E., Bertini, R. L., & Milliken, C. (2004). *Impacts and issues related to proposed changes in Oregon's interstate speed limits, Final report*. Portland, OR: Oregon Department of Transportation. Retrieved from http://archives.pdx.edu/ds/psu/7994
National Safety Council. (2015). *Estimating the costs of unintentional injuries*. Itasca, IL: National Safety Council. Retrieved from https://www.nsc.org/Portals/0/Documents/NSCDocuments_Corporate/estimating-costs.pdf
Neeley, G. W., & Richardson, L. E. (2009). The effect of state regulations on truck-crash fatalities. *American Journal of Public Health*, *99*(3), 408–415. https://doi.org/10.2105/AJPH.2008.136952
Nilsson, G. (1982). The effects of speed limits on traffic accidents in Sweden. In *Proceedings of the International Symposium on the Effects of Speed Limits on Traffic Accidents and Transport Energy Use*, October 6–8, 1981, Dublin (pp. 1–8). Paris, France: Organization for Economic Cooperation and Development (OECD).
Parker, M. R., Jr. (1997). *Effects of raising and lowering speed limits on selected roadway sections* (Publication No. FHWA-RD-92). Wayne, MI: Martin R. Parker & Associates, Inc. Retrieved from https://www.fhwa.dot.gov/publications/research/safety/97084/97084.pdf
Pfefer, R. C., Stenzel, W. W., & Lee, B. D. (1991). Safety impact of the 65-mph speed limit: A time series analysis. *Transportation Research Record: Journal of the Transportation Research Board*, *1318*, 22–33. Retrieved from http://onlinepubs.trb.org/Onlinepubs/trr/1991/1318/1318-004.pdf
Russo, B. J., Rista, E., Savolainen, P. T., Gates, T. J., & Frazier, S. (2015). Vehicle speed characteristics in states with uniform and differential speed limit policies: Comparative analysis. *Transportation Research Record: Journal of the Transportation Research Board*, *2492*(1), 1–9. https://doi.org/10.3141/2492-01
SAS Institute Inc. (2013). The GLM procedure. In *SAS/STAT 9.2 User's guide* (pp. 2431–2619). Retrieved from https://support.sas.com/documentation/cdl/en/statug/63033/PDF/default/statug.pdf
Savolainen, P., Gates, T., Hacker, E., Davis, A., Frazier, S., Russo, B., … Schneider, W. (2014). *Evaluating the impacts of speed limit policy alternatives* (Report No. RC-1609). Detroit, MI: Wayne State University. Retrieved from https://www.michigan.gov/documents/mdot/RC-1609_478401_7.pdf
Sinha, K. C., & Labi, S. (2007). *Transportation decision making: Principles of project evaluation and programming*. Hoboken, NJ: John Wiley & Sons. Retrieved from https://onlinelibrary.wiley.com/doi/pdf/10.1002/9780470168073
Skszek, S. L. (2004). *Actual speeds on the roads compared to the posted limits* (Report No. FHWA-AZ-04-551). Phoenix, AZ: Arizona Department of Transportation. Retrieved from https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa09028/resources/actual%20speeds%20on%20roadtopostedlimits.pdf
Solomon, D. H. (1964). *Accidents on main rural highways related to speed, driver, and vehicle*. Washington, DC: U.S. Department of Commerce, Bureau of Public Roads. Retrieved from https://safelyhome.westerncape.gov.za/sites/safelyhome.westerncape.gov.za/files/assets/Documents/Solomon.pdf
Tarko, A. P. (2009). Modeling drivers' speed selection as a trade-off behavior. *Accident Analysis and Prevention*, *41*(3), 608–616. https://doi.org/10.1016/j.aap.2009.02.008
Taylor, M. A. P., Woolley, J. E., & Zito, R. (2000). Integration of the global positioning system and geographical information systems for traffic congestion studies. *Transportation Research Part C: Emerging Technologies*, *8*(1–6), 257–285. https://doi.org/10.1016/S0968-090X(00)00015-2
Washington, S. P., Karlaftis, M. G., & Mannering, F. (2011). *Statistical and econometric methods for transportation data analysis* (2nd ed.). Boca Raton, FL: CRC Press.
Wilmot, C. G., & Khanal, M. (1999). Effect of speed limits on speed and safety: A review. *Transport Reviews*, *19*(4), 315–329. https://doi.org/10.1080/014416499295420

APPENDICES

Appendix A. Average Speed Models

Appendix B. Crash Risk Models

Appendix C. Transferability Models

Appendix D. Linearity Models

Appendix E. Hourly Volume Adjustment Factors

Appendix A. Average Speed Models

Table A.1 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Non-Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	67.7030	0.0300	2254.34	<.0001
Speed Limit = 65 mph	-0.7422	0.0416	-17.85	<.0001
Speed Limit = 70 mph	1.4165	0.0094	150.45	<.0001
Speed Limit = 70/65 mph	–	–	–	–
AADT (1,000 vehicles/day)	-0.0139	0.0003	-45.93	<.0001
Proportion of Trucks	-2.7482	0.0397	-69.15	<.0001
IRI (in/mi)	-0.0059	0.0001	-51.87	<.0001
Median Width (ft)	0.0082	0.0002	35.90	<.0001
Shoulder Width (ft)	-0.1630	0.0018	-89.81	<.0001
Number of Lanes = 3	0.6788	0.0257	26.40	<.0001
Number of Lanes = 4	-1.6072	0.0287	-56.03	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.1477	0.0070	-21.23	<.0001
Precipitation Intensity (in)	-0.2021	0.0095	-21.33	<.0001
Snow Accumulation	-0.5793	0.0171	-33.89	<.0001
Precipitation/Snow	-3.0070	0.0587	-51.22	<.0001
01:00–01:59 Travel Hour	-0.1578	0.0216	-7.32	<.0001
02:00–02:59	-0.2168	0.0217	-10.00	<.0001
03:00–03:59	-0.2301	0.0216	-10.64	<.0001
04:00–04:59	-0.0846	0.0215	-3.93	<.0001
05:00–05:59	0.3446	0.0213	16.20	<.0001
06:00–06:59	0.7079	0.0214	33.11	<.0001
07:00–07:59	0.5260	0.0229	22.94	<.0001
08:00–08:59	0.5382	0.0248	21.67	<.0001
09:00–09:59	0.5800	0.0248	23.42	<.0001
10:00–10:59	0.7030	0.0248	28.39	<.0001
11:00–11:59	0.8363	0.0247	33.80	<.0001
12:00–12:59	0.9330	0.0247	37.73	<.0001
13:00–13:59	1.0089	0.0247	40.83	<.0001
14:00–14:59	1.1626	0.0247	47.08	<.0001
15:00–15:59	1.3663	0.0247	55.31	<.0001
16:00–16:59	1.3967	0.0245	57.08	<.0001
17:00–17:59	1.3752	0.0236	58.29	<.0001
18:00–18:59	1.2394	0.0227	54.51	<.0001
19:00–19:59	0.9723	0.0221	44.08	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
20:00–20:59	0.7101	0.0212	33.48	<.0001
21:00–21:59	0.4815	0.0210	22.94	<.0001
22:00–22:59	0.3247	0.0211	15.41	<.0001
23:00–23:59	0.1858	0.0212	8.76	<.0001
00:00–00:59	–	–	–	–
Daylight	0.6047	0.0135	44.86	<.0001
Weekend	0.8883	0.0067	131.83	<.0001
Spring	-0.8083	0.0087	-92.91	<.0001
Summer	-0.1955	0.0086	-22.81	<.0001
Winter	-1.1917	0.0089	-134.04	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0032	0.0002	-15.26	<.0001
Suburban	-0.3257	0.0108	-30.11	<.0001
Suburban*Lanes 3	-1.6398	0.0260	-63.09	<.0001
R-square		0.1892		
F-value		5761.60		
Pr > F		<.0001		

Table A.2 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	31.0112	1.3564	22.86	<.0001
AADT (1,000 vehicles/day)	-0.0656	0.0181	-3.63	0.0003
Proportion of Trucks	-3.0988	2.3346	-1.33	0.1846
Median Width (ft)	-0.0465	0.0168	-2.77	0.0057
Number of Lanes = 3	1.5330	0.9684	1.58	0.1136
Number of Lanes = 4	-1.9312	1.2624	-1.53	0.1263
Number of Lanes = 2	–	–	–	–
Precipitation Intensity (in)	-1.6934	0.9685	-1.75	0.0806
Daylight	-1.4837	0.4364	-3.40	0.0007
Weekend	0.5832	0.4550	1.28	0.2002
Distance to City Center (mi)	-0.0599	0.0133	-4.49	<.0001
R-square		0.0441		
F-value		8.32		
Pr > F		<.0001		

Table A.3 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed Under Non-Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	63.2010	0.0167	3788.62	<.0001
Speed Limit = 65 mph	-0.6732	0.0235	-28.64	<.0001
Speed Limit = 70 mph	0.6305	0.0052	120.11	<.0001
Speed Limit = 70/65 mph	–	–	–	–
AADT (1,000 vehicles/day)	-0.0083	0.0002	-49.14	<.0001
Proportion of Trucks	-0.0736	0.0222	-3.32	0.0009
IRI (in/mi)	0.0004	0.0001	6.54	<.0001
Median Width (ft)	-0.0006	0.0001	-4.97	<.0001
Shoulder Width (ft)	-0.0993	0.0010	-97.73	<.0001
Number of Lanes = 3	0.4391	0.0147	29.95	<.0001
Number of Lanes = 4	-1.2439	0.0161	-77.25	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.1191	0.0039	-30.92	<.0001
Precipitation Intensity (in)	-0.1039	0.0053	-19.70	<.0001
Snow Accumulation	-0.2656	0.0096	-27.76	<.0001
Precipitation/Snow	-1.4308	0.0339	-42.18	<.0001
01:00–01:59 Travel Hour	0.0111	0.0118	0.94	0.3454
02:00–02:59	0.0353	0.0118	2.99	0.0028
03:00–03:59	0.1433	0.0118	12.16	<.0001
04:00–04:59	0.1139	0.0118	9.68	<.0001
05:00–05:59	-0.1098	0.0117	-9.37	<.0001
06:00–06:59	-0.3563	0.0118	-30.11	<.0001
07:00–07:59	-0.4905	0.0127	-38.50	<.0001
08:00–08:59	-0.5882	0.0138	-42.53	<.0001
09:00–09:59	-0.6353	0.0138	-46.03	<.0001
10:00–10:59	-0.6117	0.0138	-44.35	<.0001
11:00–11:59	-0.6077	0.0138	-44.11	<.0001
12:00–12:59	-0.5961	0.0138	-43.29	<.0001
13:00–13:59	-0.6101	0.0138	-44.32	<.0001
14:00–14:59	-0.6009	0.0138	-43.68	<.0001
15:00–15:59	-0.6068	0.0138	-44.10	<.0001
16:00–16:59	-0.5868	0.0136	-43.04	<.0001
17:00–17:59	-0.5895	0.0131	-44.85	<.0001
18:00–18:59	-0.4847	0.0127	-38.31	<.0001
19:00–19:59	-0.3923	0.0123	-32.01	<.0001
20:00–20:59	-0.3424	0.0118	-29.11	<.0001
21:00–21:59	-0.1739	0.0116	-14.94	<.0001
22:00–22:59	-0.0426	0.0117	-3.65	0.0003

Parameter	Estimate	Std. Error	t Value	Pr > |t|
23:00–23:59	0.0126	0.0117	1.08	0.2806
00:00–00:59	–	–	–	–
Daylight	0.1593	0.0075	21.12	<.0001
Weekend	-0.1310	0.0037	-35.08	<.0001
Spring	-0.1664	0.0048	-34.35	<.0001
Summer	-0.0027	0.0048	-0.56	0.577
Winter	0.0066	0.0050	1.32	0.1857
Fall	–	–	–	–
Distance to City Center (mi)	-0.0037	0.0001	-31.23	<.0001
Suburban	-0.1869	0.0060	-30.91	<.0001
Suburban*Lanes 3	-0.8168	0.0147	-55.57	<.0001
R-square		0.0985		
F-value		2757.04		
Pr > F		<.0001		

Table A.4 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed under Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	40.5210	2.0381	19.88	<.0001
AADT (1,000 vehicles/day)	-0.0460	0.0193	-2.38	0.0173
Median Width (ft)	-0.1046	0.0197	-5.32	<.0001
Number of Lanes = 3	0.9383	1.0594	0.89	0.3759
Number of Lanes = 4	-4.2217	1.4192	-2.97	0.003
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-2.1031	0.5118	-4.11	<.0001
Snow Accumulation	1.8011	0.8459	2.13	0.0334
Precipitation/Snow	-6.6411	1.3742	-4.83	<.0001
01:00–01:59 Travel Hour	0.2847	2.0448	0.14	0.8893
02:00–02:59	-0.3526	1.9686	-0.18	0.8579
03:00–03:59	-4.4184	1.8897	-2.34	0.0195
04:00–04:59	-4.7678	2.0744	-2.30	0.0217
05:00–05:59	-1.5006	2.1968	-0.68	0.4947
06:00–06:59	-4.5348	1.9691	-2.30	0.0214
07:00–07:59	-5.3289	1.7111	-3.11	0.0019
08:00–08:59	-6.4751	1.7535	-3.69	0.0002
09:00–09:59	-9.9258	1.9134	-5.19	<.0001
10:00–10:59	-8.2846	1.7503	-4.73	<.0001
11:00–11:59	-10.3573	1.6364	-6.33	<.0001
12:00–12:59	-10.7776	1.5960	-6.75	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
13:00–13:59	-9.9661	1.6419	-6.07	<.0001
14:00–14:59	-10.0511	1.6060	-6.26	<.0001
15:00–15:59	-9.7175	1.5864	-6.13	<.0001
16:00–16:59	-10.3695	1.5217	-6.81	<.0001
17:00–17:59	-9.5638	1.4912	-6.41	<.0001
18:00–18:59	-8.2883	1.4991	-5.53	<.0001
19:00–19:59	-7.6604	1.5910	-4.81	<.0001
20:00–20:59	-8.7279	1.6447	-5.31	<.0001
21:00–21:59	-7.5744	1.6149	-4.69	<.0001
22:00–22:59	-8.5412	1.6691	-5.12	<.0001
23:00–23:59	-4.6977	1.8081	-2.60	0.0095
00:00–00:59	–	–	–	–
Weekend	3.2573	0.5026	6.48	<.0001
Spring	-0.9303	0.7124	-1.31	0.1918
Summer	-1.4950	0.7043	-2.12	0.034
Winter	2.4459	0.6852	3.57	0.0004
Fall	–	–	–	–
Distance to City Center (mi)	-0.1021	0.0145	-7.03	<.0001
R-square		0.2421		
F-value		14.23		
Pr > F		<.0001		

Table A.5 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	59.4568	0.0313	1897.35	<.0001
Speed Limit = 65 mph	2.7989	0.0113	248.05	<.0001
Speed Limit = 55 mph	–	–	–	–
Illinois	-0.5371	0.0089	-60.05	<.0001
Indiana	–	–	–	–
AADT (1,000 vehicles/day)	0.0078	0.0001	68.22	<.0001
Proportion of Trucks	15.8451	0.0801	197.76	<.0001
IRI (in/mi)	-0.0277	0.0001	-245.38	<.0001
Median Width (ft)	-0.0040	0.0002	-18.08	<.0001
Shoulder Width (ft)	0.1035	0.0010	103.42	<.0001
Number of Lanes = 3	0.3748	0.0114	32.95	<.0001
Number of Lanes = 4	0.4333	0.0155	28.04	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.6236	0.0035	-178.01	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Precipitation Intensity (in)	-0.3248	0.0114	-28.45	<.0001
Snow Accumulation	-0.5404	0.0228	-23.68	<.0001
Precipitation/Snow	-3.1284	0.0780	-40.13	<.0001
01:00–01:59 Travel Hour	-0.0507	0.0257	-1.98	0.0481
02:00–02:59	-0.0886	0.0259	-3.42	0.0006
03:00–03:59	0.1842	0.0257	7.16	<.0001
04:00–04:59	0.6319	0.0253	25.01	<.0001
05:00–05:59	0.9436	0.0251	37.65	<.0001
06:00–06:59	0.7075	0.0265	26.70	<.0001
07:00–07:59	0.0176	0.0294	0.60	0.5493
08:00–08:59	-0.2864	0.0308	-9.29	<.0001
09:00–09:59	-0.2484	0.0305	-8.13	<.0001
10:00–10:59	-0.3029	0.0303	-9.99	<.0001
11:00–11:59	-0.1982	0.0302	-6.56	<.0001
12:00–12:59	-0.1195	0.0302	-3.96	<.0001
13:00–13:59	-0.0882	0.0303	-2.91	0.0036
14:00–14:59	0.0447	0.0305	1.46	0.1437
15:00–15:59	0.1680	0.0310	5.43	<.0001
16:00–16:59	0.1837	0.0310	5.93	<.0001
17:00–17:59	0.2345	0.0302	7.77	<.0001
18:00–18:59	0.4066	0.0285	14.24	<.0001
19:00–19:59	0.4041	0.0269	15.00	<.0001
20:00–20:59	0.2885	0.0253	11.40	<.0001
21:00–21:59	-0.0137	0.0251	-0.55	0.5848
22:00–22:59	0.0499	0.0250	1.99	0.0465
23:00–23:59	0.1173	0.0251	4.67	<.0001
00:00–00:59	–	–	–	–
Daylight	1.0892	0.0172	63.38	<.0001
Weekend	1.6529	0.0083	200.29	<.0001
Spring	-1.0183	0.0107	-95.00	<.0001
Summer	-0.4453	0.0106	-42.05	<.0001
Winter	-1.4050	0.0110	-127.28	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	0.0025	0.0004	6.04	<.0001
R-square		0.2857		
F-value		11001.20		
Pr > F		<.0001		

Table A.6 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	17.1994	0.5277	32.59	<.0001
Illinois	-2.2122	0.1443	-15.33	<.0001
Indiana	–	–	–	–
AADT (1,000 vehicles/day)	0.0191	0.0007	25.92	<.0001
Proportion of Trucks	30.2335	1.2662	23.88	<.0001
IRI (in/mi)	-0.0158	0.0012	-13.35	<.0001
Median Width (ft)	0.0046	0.0014	3.26	0.0011
Shoulder Width (ft)	0.0273	0.0120	2.28	0.0227
Number of Lanes = 3	-0.5610	0.1875	-2.99	0.0028
Number of Lanes = 4	1.0308	0.2011	5.13	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.3755	0.0201	-18.69	<.0001
Snow Accumulation	-1.9163	0.1777	-10.78	<.0001
Precipitation/Snow	2.2764	0.5016	4.54	<.0001
01:00–01:59 Travel Hour	0.9536	0.6556	1.45	0.1458
02:00–02:59	2.0363	0.6724	3.03	0.0025
03:00–03:59	2.3082	0.7372	3.13	0.0017
04:00–04:59	3.5487	0.8031	4.42	<.0001
05:00–05:59	4.1996	0.7840	5.36	<.0001
06:00–06:59	5.7734	0.4430	13.03	<.0001
07:00–07:59	1.6281	0.4345	3.75	0.0002
08:00–08:59	-0.1573	0.4353	-0.36	0.7178
09:00–09:59	3.6497	0.4405	8.29	<.0001
10:00–10:59	3.2448	0.4581	7.08	<.0001
11:00–11:59	1.5043	0.4642	3.24	0.0012
12:00–12:59	1.0052	0.4552	2.21	0.0272
13:00–13:59	1.5051	0.4466	3.37	0.0008
14:00–14:59	1.8622	0.4396	4.24	<.0001
15:00–15:59	1.0120	0.4345	2.33	0.0199
16:00–16:59	0.5367	0.4322	1.24	0.2143
17:00–17:59	0.8558	0.4315	1.98	0.0473
18:00–18:59	1.6658	0.4344	3.83	0.0001
19:00–19:59	3.2307	0.4432	7.29	<.0001
20:00–20:59	4.1696	0.4971	8.39	<.0001
21:00–21:59	2.8013	0.5245	5.34	<.0001
22:00–22:59	1.0010	0.5357	1.87	0.0617
23:00–23:59	0.0776	0.6051	0.13	0.898
00:00–00:59	–	–	–	–

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Weekend	1.3059	0.0783	16.69	<.0001
Spring	-0.3243	0.0708	-4.58	<.0001
Summer	-0.1060	0.0701	-1.51	0.1305
Winter	-0.3336	0.0756	-4.41	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0409	0.0064	-6.44	<.0001
R-square		0.1077		
F-value		184.24		
Pr > F		<.0001		

Table A.7 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	58.7421	0.0224	2619.74	<.0001
Speed Limit = 65 mph	2.0348	0.0080	253.15	<.0001
Speed Limit = 55 mph	–	–	–	–
Illinois	-0.0437	0.0064	-6.87	<.0001
Indiana	–	–	–	–
AADT (1,000 vehicles/day)	-0.0114	0.0001	-129.66	<.0001
Proportion of Trucks	10.3593	0.0560	185.04	<.0001
IRI (in/mi)	-0.0186	0.0001	-231.75	<.0001
Median Width (ft)	-0.0047	0.0002	-28.52	<.0001
Shoulder Width (ft)	0.0372	0.0007	51.54	<.0001
Number of Lanes = 3	0.9535	0.0082	115.84	<.0001
Number of Lanes = 4	2.1117	0.0118	179.67	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.5523	0.0028	-196.57	<.0001
Precipitation Intensity (in)	-0.2242	0.0082	-27.22	<.0001
Snow Accumulation	-0.3003	0.0167	-17.94	<.0001
Precipitation/Snow	-1.5684	0.0576	-27.23	<.0001
01:00–01:59 Travel Hour	0.0949	0.0186	5.10	<.0001
02:00–02:59	0.2331	0.0186	12.52	<.0001
03:00–03:59	0.3449	0.0185	18.65	<.0001
04:00–04:59	0.2991	0.0183	16.32	<.0001
05:00–05:59	-0.1148	0.0182	-6.30	<.0001
06:00–06:59	-0.5970	0.0193	-30.96	<.0001
07:00–07:59	-1.0579	0.0214	-49.48	<.0001
08:00–08:59	-1.1813	0.0225	-52.61	<.0001
09:00–09:59	-1.2064	0.0222	-54.30	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
10:00–10:59	-1.2471	0.0221	-56.55	<.0001
11:00–11:59	-1.2074	0.0220	-55.00	<.0001
12:00–12:59	-1.1600	0.0220	-52.82	<.0001
13:00–13:59	-1.1521	0.0220	-52.28	<.0001
14:00–14:59	-1.2225	0.0222	-55.07	<.0001
15:00–15:59	-1.3013	0.0225	-57.87	<.0001
16:00–16:59	-1.3025	0.0225	-57.81	<.0001
17:00–17:59	-1.2956	0.0219	-59.07	<.0001
18:00–18:59	-1.0903	0.0207	-52.58	<.0001
19:00–19:59	-0.8732	0.0196	-44.53	<.0001
20:00–20:59	-0.7036	0.0184	-38.20	<.0001
21:00–21:59	-0.5781	0.0183	-31.56	<.0001
22:00–22:59	-0.3045	0.0183	-16.66	<.0001
23:00–23:59	-0.1100	0.0183	-6.01	<.0001
00:00–00:59	–	–	–	–
Daylight	0.7255	0.0125	58.26	<.0001
Weekend	0.4016	0.0060	66.79	<.0001
Spring	-0.2010	0.0077	-25.96	<.0001
Summer	-0.1471	0.0077	-19.19	<.0001
Winter	-0.1512	0.0080	-18.85	<.0001
Fall	–	–	–	–
R-square		0.3065		
F-value		12069.60		
Pr > F		<.0001		

Table A.8 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed Under Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	27.8364	0.6622	42.04	<.0001
Illinois	-1.9254	0.1655	-11.63	<.0001
Indiana	–	–	–	–
AADT (1,000 vehicles/day)	0.0230	0.0009	24.45	<.0001
Proportion of Trucks	23.6231	1.4239	16.59	<.0001
IRI (in/mi)	-0.0278	0.0014	-20.38	<.0001
Median Width (ft)	-0.0145	0.0016	-9.03	<.0001
Shoulder Width (ft)	0.0372	0.0142	2.62	0.0088
Number of Lanes = 3	-2.5162	0.2165	-11.62	<.0001
Number of Lanes = 4	-0.8861	0.2385	-3.71	0.0002
Number of Lanes = 2	–	–	–	–

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Ramp Frequency (#/mi)	-0.4716	0.0240	-19.62	<.0001
Snow Accumulation	-2.1928	0.2038	-10.76	<.0001
Precipitation/Snow	2.5617	0.6072	4.22	<.0001
01:00–01:59 **Travel Hour**	5.7801	0.8895	6.50	<.0001
02:00–02:59	8.8778	0.9532	9.31	<.0001
03:00–03:59	3.7261	1.0491	3.55	0.0004
04:00–04:59	-0.8347	1.0559	-0.79	0.4292
05:00–05:59	-2.4492	0.9855	-2.49	0.013
06:00–06:59	-3.8092	0.5787	-6.58	<.0001
07:00–07:59	-7.9154	0.5698	-13.89	<.0001
08:00–08:59	-9.2759	0.5704	-16.26	<.0001
09:00–09:59	-5.7922	0.5754	-10.07	<.0001
10:00–10:59	-6.4893	0.5923	-10.96	<.0001
11:00–11:59	-8.7578	0.5979	-14.65	<.0001
12:00–12:59	-9.0560	0.5893	-15.37	<.0001
13:00–13:59	-8.6259	0.5815	-14.83	<.0001
14:00–14:59	-7.7345	0.5749	-13.45	<.0001
15:00–15:59	-8.4923	0.5698	-14.90	<.0001
16:00–16:59	-8.8702	0.5674	-15.63	<.0001
17:00–17:59	-8.7322	0.5667	-15.41	<.0001
18:00–18:59	-8.2292	0.5698	-14.44	<.0001
19:00–19:59	-6.3386	0.5794	-10.94	<.0001
20:00–20:59	-5.2581	0.6468	-8.13	<.0001
21:00–21:59	-6.7706	0.6809	-9.94	<.0001
22:00–22:59	-7.7703	0.6840	-11.36	<.0001
23:00–23:59	-6.9595	0.7784	-8.94	<.0001
00:00–00:59	–	–	–	–
Weekend	0.9638	0.0924	10.43	<.0001
R-square		0.1049		
F-value		189.52		
Pr > F		<.0001		

Appendix B. Crash Risk Models

Table B.1 Binary Logistic Regression of Crash Probability Under Non-Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-6.2088	0.1612	1482.8356	<.0001
Speed Limit = 65 mph	-0.3027	0.1050	8.3125	0.0039
Speed Limit = 70 mph	-0.8211	0.0813	102.0973	<.0001
Speed Limit = 70/65 mph	–	–	–	–
Suburban	-0.7185	0.0621	134.0658	<.0001
AADT (1,000 vehicles/day)	0.0245	0.0019	167.4031	<.0001
IRI (in/mi)	-0.0017	0.0008	4.8441	0.0277
Median Width (ft)	0.0005	0.0015	0.0965	0.7561
Shoulder Width (ft)	-0.0591	0.0093	40.7431	<.0001
Precipitation Intensity (in)	0.2017	0.0566	12.6897	0.0004
Snow Accumulation	0.4089	0.0883	21.4256	<.0001
Weekend	0.0913	0.0461	3.9204	0.0477
Spring	0.0181	0.0378	0.2299	0.6316
Summer	-0.1582	0.0390	16.4785	<.0001
Winter	-0.0228	0.0404	0.3179	0.5729
Fall	–	–	–	–
Daylight	-0.2835	0.0897	9.9833	0.0016
01:00–01:59 Travel Hour	-0.3281	0.1240	6.9988	0.0082
02:00–02:59	-0.6946	0.1414	24.1220	<.0001
03:00–03:59	-0.7591	0.1459	27.0551	<.0001
04:00–04:59	-0.4213	0.1257	11.2307	0.0008
05:00–05:59	-0.3049	0.1199	6.4655	0.0110
06:00–06:59	0.1842	0.0942	3.8292	0.0504
07:00–07:59	0.3240	0.0885	13.4080	0.0003
08:00–08:59	0.3069	0.1031	8.8676	0.0029
09:00–09:59	0.1306	0.1086	1.4478	0.2289
10:00–10:59	0.2434	0.1074	5.1377	0.0234
11:00–11:59	0.2618	0.1053	6.1863	0.0129
12:00–12:59	0.1004	0.1101	0.8309	0.3620
13:00–13:59	0.2134	0.1043	4.1817	0.0409
14:00–14:59	0.2419	0.1051	5.2931	0.0214
15:00–15:59	0.3560	0.1005	12.5426	0.0004
16:00–16:59	0.5851	0.0943	38.4825	<.0001
17:00–17:59	0.2513	0.0954	6.9419	0.0084

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
18:00–18:59	0.1417	0.0941	2.2667	0.1322
19:00–19:59	0.0360	0.0965	0.1393	0.7089
20:00–20:59	0.0342	0.1009	0.1150	0.7345
21:00–21:59	-0.1026	0.1105	0.8620	0.3532
22:00–22:59	-0.2527	0.1158	4.7674	0.0290
23:00–23:59	-0.3230	0.1221	7.0013	0.0081

Table B.2 Binary Logistic Regression of KAB (Fatal, Incapacitating or Non-Incapacitating) Injury Probability Under Non-Congested Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-1.0274	0.3293	9.7371	0.0018
Speed Limit = 65 mph	-0.9238	0.3540	6.8116	0.0091
Speed Limit = 70 mph	-0.2749	0.2146	1.6412	0.2002
Speed Limit = 70/65 mph	–	–	–	–
Shoulder Width (ft)	-0.0405	0.0241	2.8242	0.0929
Median Width (ft)	-0.0061	0.0042	2.1022	0.1471
Spring	-0.0673	0.0961	0.4903	0.4838
Summer	0.2952	0.0945	9.7544	0.0018
Winter	0.0245	0.0953	0.0661	0.7970
Fall	–	–	–	–

Table B.3 Binary Logistic Regression of Crash Probability Under Intermediate Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-5.4002	0.1568	1185.4994	<.0001
Speed Limit = 65 mph	-0.7340	0.1672	19.2738	<.0001
Speed Limit = 70 mph	-0.8866	0.1737	26.0487	<.0001
Speed Limit = 70/65 mph	–	–	–	–
Suburban	-1.4293	0.1289	122.9911	<.0001
AADT (1,000 vehicles/day)	0.0470	0.0040	136.7015	<.0001
Shoulder Width (ft)	-0.1104	0.0159	48.3747	<.0001
Precipitation Intensity (in)	0.4270	0.1509	8.0092	0.0047
Snow Accumulation	0.5375	0.1142	22.1698	<.0001
Spring	-0.2591	0.1253	4.2783	0.0386
Summer	-0.6538	0.1218	28.8317	<.0001
Winter	0.8621	0.0847	103.4932	<.0001
Fall	–	–	–	–

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
01:00–01:59 Travel Hour	-0.9732	0.2190	19.7443	<.0001
02:00–02:59	-1.3700	0.2745	24.9023	<.0001
03:00–03:59	-1.3241	0.2639	25.1830	<.0001
04:00–04:59	-1.0162	0.2419	17.6489	<.0001
05:00–05:59	-0.2457	0.1888	1.6938	0.1931
06:00–06:59	-0.2140	0.1928	1.2322	0.2670
07:00–07:59	0.7064	0.1718	16.9066	<.0001
08:00–08:59	0.2319	0.1754	1.7486	0.1861
09:00–09:59	0.6853	0.1708	16.1048	<.0001
10:00–10:59	0.8438	0.1954	18.6381	<.0001
11:00–11:59	0.7464	0.2094	12.7066	0.0004
12:00–12:59	0.6056	0.2239	7.3197	0.0068
13:00–13:59	0.4077	0.2476	2.7110	0.0997
14:00–14:59	0.9464	0.2716	12.1424	0.0005
15:00–15:59	1.0517	0.2418	18.9243	<.0001
16:00–16:59	0.6006	0.2472	5.9044	0.0151
17:00–17:59	0.2857	0.2215	1.6641	0.1970
18:00–18:59	0.0410	0.2292	0.0320	0.8581
19:00–19:59	-0.2013	0.2234	0.8121	0.3675
20:00–20:59	-0.1645	0.2196	0.5613	0.4537
21:00–21:59	-0.0324	0.2105	0.0236	0.8779
22:00–22:59	-0.4138	0.2259	3.3567	0.0669
23:00–23:59	-0.4043	0.2508	2.5984	0.1070
00:00–00:59	–	–	–	–

Table B.4 Binary Logistic Regression of KAB (Fatal, Incapacitating or Non-Incapacitating) Injury Probability Under Intermediate Traffic Conditions on Rural Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-1.6364	0.3151	26.9633	<.0001
Speed Limit = 65 mph	-0.1186	0.3765	0.0993	0.7527
Speed Limit = 70 mph	-0.4465	0.4232	1.1134	0.2913
Speed Limit = 70/65 mph	–	–	–	–
AADT (1,000 vehicles/day)	-0.0164	0.0081	4.1481	0.0417
Shoulder Width (ft)	0.1004	0.0268	14.0124	0.0002
Snow Accumulation	-0.4534	0.1907	5.6534	0.0174

Table B.5 Binary Logistic Regression of Crash Probability Under Non-Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-6.7437	0.1022	4350.73	<.0001
Speed Limit = 65 mph	0.0849	0.0612	1.92	0.1655
Speed Limit = 55 mph	–	–	–	–
AADT (1,000 vehicles/day)	0.0082	0.0005	310.47	<.0001
Proportion of Trucks	2.6730	0.4257	39.42	<.0001
Median Width (ft)	-0.0081	0.0012	45.23	<.0001
Precipitation Intensity (in)	0.1501	0.0547	7.53	0.0061
Snow Accumulation	0.5619	0.0746	56.81	<.0001
Weekend	-0.3492	0.0461	57.46	<.0001
Fall or Winter	0.1321	0.0404	10.68	0.0011
Illinois	-0.5992	0.0446	180.86	<.0001
Indiana	–	–	–	–
01:00–01:59 Travel Hour	-0.6096	0.1270	23.05	<.0001
02:00–02:59	-0.8574	0.1414	36.77	<.0001
03:00–03:59	-0.6308	0.1289	23.94	<.0001
04:00–04:59	-0.7185	0.1296	30.72	<.0001
05:00–05:59	-0.3483	0.1062	10.77	0.0010
06:00–06:59	0.6655	0.0764	75.95	<.0001
07:00–07:59	0.7732	0.0728	112.93	<.0001
08:00–08:59	0.3951	0.0844	21.91	<.0001
09:00–09:59	0.2085	0.0872	5.72	0.0168
10:00–10:59	0.1054	0.0903	1.36	0.2429
11:00–11:59	-0.0526	0.0934	0.32	0.5738
12:00–12:59	0.2207	0.0851	6.73	0.0095
13:00–13:59	0.3123	0.0828	14.24	0.0002
14:00–14:59	0.4061	0.0803	25.56	<.0001
15:00–15:59	0.6294	0.0746	71.18	<.0001
16:00–16:59	0.6643	0.0789	70.83	<.0001
17:00–17:59	0.6651	0.0796	69.83	<.0001
18:00–18:59	0.2136	0.0928	5.30	0.0213
19:00–19:59	-0.0904	0.1012	0.80	0.3715
20:00–20:59	-0.4260	0.1105	14.87	0.0001
21:00–21:59	-0.1273	0.0967	1.73	0.1881
22:00–22:59	-0.3637	0.1076	11.42	0.0007
23:00–23:59	-0.3961	0.1107	12.80	0.0003
00:00–00:59	–	–	–	–

Table B.6 Binary Logistic Regression of Injury Probability Under Non-Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-1.6105	0.0651	612.02	<.0001
Speed Limit = 65 mph	0.3683	0.1165	9.99	0.0016
Speed Limit = 55 mph	–	–	–	–
Weekend	0.2469	0.1111	4.94	0.0263
01:00–01:59 Travel Hour	0.7728	0.2632	8.62	0.0033
02:00–02:59	0.7188	0.2976	5.83	0.0157
03:00–03:59	0.0474	0.3144	0.02	0.8802
04:00–04:59	0.5212	0.2812	3.44	0.0638
05:00–05:59	-0.2911	0.2920	0.99	0.3186
06:00–06:59	0.0266	0.1826	0.02	0.8844
07:00–07:59	-0.3564	0.1924	3.43	0.0639
08:00–08:59	-0.2688	0.2226	1.46	0.2273
09:00–09:59	-0.2599	0.2281	1.30	0.2546
10:00–10:59	-0.0390	0.2226	0.03	0.8611
11:00–11:59	-0.1973	0.2451	0.65	0.4209
12:00–12:59	-0.1369	0.2162	0.40	0.5266
13:00–13:59	-0.2650	0.2184	1.47	0.2249
14:00–14:59	-0.1392	0.2018	0.48	0.4902
15:00–15:59	-0.0271	0.1793	0.02	0.8801
16:00–16:59	-0.2620	0.2032	1.66	0.1973
17:00–17:59	-0.2714	0.2038	1.77	0.1829
18:00–18:59	-0.2171	0.2396	0.82	0.3649
19:00–19:59	-0.1688	0.2602	0.42	0.5166
20:00–20:59	0.1084	0.2661	0.17	0.6837
21:00–21:59	0.4199	0.2133	3.87	0.0491
22:00–22:59	-0.1812	0.2842	0.41	0.5238
23:00–23:59	0.4848	0.2444	3.94	0.0473
00:00–00:59	–	–	–	–

Table B.7 Binary Logistic Regression of Fatal Probability Under Non-Congested Traffic Conditions on Urban Freeways

Parameter	Estimate	Std. Error	Wald Chi-Square	Pr > ChiSq
Intercept	-4.8367	0.6547	54.57	<.0001
Speed Limit = 65 mph	0.4664	0.6244	0.56	0.4551
Speed Limit = 55 mph	–	–	–	–
Distance to City Center (mi)	0.0487	0.0242	4.04	0.0444

Appendix C. Transferability Models

Table C.1 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways with Interaction Between Speed Limit and State

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	61.0167	0.0241	2536.55	<.0001
SpeedLim 65 mph * Illinois	2.5582	0.0133	191.95	<.0001
SpeedLim 65 mph * Indiana	2.2164	0.0134	165.16	<.0001
SpeedLim 70 mph * Illinois	3.8040	0.0113	337.07	<.0001
SpeedLim 70 mph * Indiana	4.3220	0.0114	379.22	<.0001
SpeedLim 55 mph * Illinois	-0.8621	0.0093	-92.54	<.0001
SpeedLim 55 mph * Indiana	–	–	–	–
AADT (1,000 vehicles/day)	0.0054	0.0001	51.27	<.0001
Proportion of Trucks	9.9620	0.0464	214.89	<.0001
IRI (in/mi)	-0.0251	0.0001	-266.18	<.0001
Median Width (ft)	-0.0020	0.0002	-12.05	<.0001
Shoulder Width (ft)	0.0940	0.0009	105.79	<.0001
Number of Lanes = 3	-0.5494	0.0087	-62.91	<.0001
Number of Lanes = 4	-0.2733	0.0131	-20.94	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.6238	0.0030	-211.21	<.0001
Precipitation Intensity (in)	-0.2963	0.0089	-33.43	<.0001
Snow Accumulation	-0.7362	0.0168	-43.88	<.0001
Precipitation/Snow	-2.7020	0.0590	-45.76	<.0001
01:00–01:59 Travel Hour	-0.0911	0.0201	-4.54	<.0001
02:00–02:59	-0.1024	0.0202	-5.06	<.0001
03:00–03:59	0.1208	0.0201	6.00	<.0001
04:00–04:59	0.5234	0.0198	26.42	<.0001
05:00–05:59	0.9007	0.0196	45.95	<.0001
06:00–06:59	0.8301	0.0204	40.74	<.0001
07:00–07:59	0.2648	0.0225	11.76	<.0001
08:00–08:59	0.0346	0.0235	1.47	0.1409
09:00–09:59	0.0871	0.0233	3.74	0.0002
10:00–10:59	0.0625	0.0232	2.69	0.0071
11:00–11:59	0.1836	0.0231	7.93	<.0001
12:00–12:59	0.2405	0.0231	10.39	<.0001
13:00–13:59	0.3205	0.0232	13.83	<.0001
14:00–14:59	0.4632	0.0233	19.90	<.0001
15:00–15:59	0.5929	0.0235	25.28	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
16:00–16:59	0.6283	0.0232	27.08	<.0001
17:00–17:59	0.6550	0.0225	29.11	<.0001
18:00–18:59	0.7303	0.0215	33.91	<.0001
19:00–19:59	0.6367	0.0206	30.98	<.0001
20:00–20:59	0.4799	0.0196	24.53	<.0001
21:00–21:59	0.1987	0.0195	10.19	<.0001
22:00–22:59	0.2089	0.0195	10.71	<.0001
23:00–23:59	0.1920	0.0196	9.78	<.0001
00:00–00:59	–	–	–	–
Daylight	0.9175	0.0128	71.41	<.0001
Weekend	1.4333	0.0063	226.72	<.0001
Spring	-0.9609	0.0082	-117.39	<.0001
Summer	-0.3236	0.0081	-40.08	<.0001
Winter	-1.3545	0.0084	-161.00	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0151	0.0002	-63.42	<.0001
R-square		0.4152		
F-value		30467.80		
Pr > F		<.0001		

Table C.2 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways with Interaction Between Speed Limit and State

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	59.6620	0.0166	3598.28	<.0001
SpeedLim 65 mph * Illinois	2.1575	0.0091	236.68	<.0001
SpeedLim 65 mph * Indiana	1.7196	0.0092	187.44	<.0001
SpeedLim 70 mph * Illinois	2.4263	0.0077	313.10	<.0001
SpeedLim 70 mph * Indiana	3.2961	0.0078	422.65	<.0001
SpeedLim 55 mph * Illinois	-0.3207	0.0065	-49.10	<.0001
SpeedLim 55 mph * Indiana	–	–	–	–
AADT (1,000 vehicles/day)	-0.0114	0.0001	-147.70	<.0001
Proportion of Trucks	6.8751	0.0318	216.26	<.0001
IRI (in/mi)	-0.0158	0.0001	-244.25	<.0001
Median Width (ft)	-0.0065	0.0001	-55.86	<.0001
Shoulder Width (ft)	0.0484	0.0006	78.71	<.0001
Number of Lanes = 3	0.1664	0.0061	27.49	<.0001
Number of Lanes = 4	1.2637	0.0095	133.39	<.0001
Number of Lanes = 2	–	–	–	–

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Ramp Frequency (#/mi)	-0.4903	0.0022	-222.52	<.0001
Precipitation Intensity (in)	-0.1856	0.0061	-30.51	<.0001
Snow Accumulation	-0.3889	0.0116	-33.40	<.0001
Precipitation/Snow	-1.4101	0.0415	-33.94	<.0001
01:00–01:59 Travel Hour	0.0640	0.0137	4.69	<.0001
02:00–02:59	0.1842	0.0137	13.47	<.0001
03:00–03:59	0.2642	0.0136	19.44	<.0001
04:00–04:59	0.1848	0.0135	13.70	<.0001
05:00–05:59	-0.1419	0.0134	-10.57	<.0001
06:00–06:59	-0.5127	0.0140	-36.62	<.0001
07:00–07:59	-0.8498	0.0155	-54.83	<.0001
08:00–08:59	-0.9456	0.0162	-58.46	<.0001
09:00–09:59	-0.9681	0.0161	-60.28	<.0001
10:00–10:59	-0.9806	0.0160	-61.33	<.0001
11:00–11:59	-0.9469	0.0159	-59.41	<.0001
12:00–12:59	-0.9165	0.0159	-57.51	<.0001
13:00–13:59	-0.9187	0.0160	-57.53	<.0001
14:00–14:59	-0.9672	0.0160	-60.33	<.0001
15:00–15:59	-1.0072	0.0162	-62.36	<.0001
16:00–16:59	-0.9823	0.0160	-61.46	<.0001
17:00–17:59	-0.9780	0.0155	-63.12	<.0001
18:00–18:59	-0.8035	0.0148	-54.22	<.0001
19:00–19:59	-0.6391	0.0141	-45.20	<.0001
20:00–20:59	-0.5447	0.0135	-40.49	<.0001
21:00–21:59	-0.4340	0.0134	-32.35	<.0001
22:00–22:59	-0.2058	0.0134	-15.34	<.0001
23:00–23:59	-0.0483	0.0135	-3.58	0.0003
00:00–00:59	–	–	–	–
Daylight	0.5127	0.0089	57.86	<.0001
Weekend	0.2519	0.0044	57.86	<.0001
Spring	-0.2140	0.0056	-38.10	<.0001
Summer	-0.0808	0.0056	-14.54	<.0001
Winter	-0.0974	0.0058	-16.78	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0147	0.0002	-92.51	<.0001
R-square		0.4433		
F-value		33923.10		
Pr > F		<.0001		

Appendix D. Linearity Models

Table D.1 Multiple Linear Regression of All Vehicles Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways in Illinois

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	55.9292	0.0346	1614.34	<.0001
Speed Limit = 50 mph	3.6786	0.0459	80.23	<.0001
Speed Limit = 55 mph	4.2315	0.0212	199.64	<.0001
Speed Limit = 65 mph	6.8760	0.0254	270.45	<.0001
Speed Limit = 70 mph	8.1422	0.0260	313.26	<.0001
Speed Limit = 45 mph	–	–	–	–
AADT (1,000 vehicles/day)	0.0033	0.0001	34.29	<.0001
Proportion of Trucks	4.4452	0.0354	125.70	<.0001
IRI (in/mi)	-0.0316	0.0001	-252.40	<.0001
Median Width (ft)	-0.0127	0.0001	-89.99	<.0001
Shoulder Width (ft)	0.1925	0.0009	205.29	<.0001
Number of Lanes = 3	-0.4607	0.0082	-55.93	<.0001
Number of Lanes = 4	-0.1543	0.0141	-10.95	<.0001
Number of Lanes = 2	.–	–	–	–
Ramp Frequency (#/mi)	-0.5839	0.0025	-234.13	<.0001
Precipitation Intensity (in)	-0.2165	0.0077	-28.22	<.0001
Snow Accumulation	-0.5596	0.0155	-36.19	<.0001
Precipitation/Snow	-3.4990	0.0602	-58.14	<.0001
01:00–01:59 Travel Hour	-0.0746	0.0175	-4.26	<.0001
02:00–02:59	-0.0426	0.0176	-2.42	0.0154
03:00–03:59	-0.0063	0.0175	-0.36	0.7179
04:00–04:59	0.1565	0.0173	9.06	<.0001
05:00–05:59	0.3583	0.0173	20.69	<.0001
06:00–06:59	0.2432	0.0187	13.01	<.0001
07:00–07:59	0.0114	0.0214	0.53	0.5947
08:00–08:59	-0.0760	0.0213	-3.57	0.0004
09:00–09:59	-0.0670	0.0212	-3.16	0.0016
10:00–10:59	-0.1037	0.0211	-4.92	<.0001
11:00–11:59	-0.0514	0.0210	-2.45	0.0145
12:00–12:59	0.0371	0.0210	1.76	0.0779
13:00–13:59	0.0955	0.0211	4.52	<.0001
14:00–14:59	0.1723	0.0212	8.12	<.0001
15:00–15:59	0.2743	0.0214	12.81	<.0001
16:00–16:59	0.3119	0.0207	15.05	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
17:00–17:59	0.2313	0.0200	11.58	<.0001
18:00–18:59	0.2073	0.0192	10.82	<.0001
19:00–19:59	0.1338	0.0181	7.38	<.0001
20:00–20:59	0.0324	0.0173	1.87	0.0611
21:00–21:59	-0.0209	0.0173	-1.21	0.2253
22:00–22:59	0.1123	0.0172	6.52	<.0001
23:00–23:59	0.1273	0.0173	7.37	<.0001
00:00–00:59	–	–	–	–
Daylight	0.4086	0.0122	33.37	<.0001
Weekend	0.7812	0.0056	138.88	<.0001
Spring	-0.8597	0.0073	-116.99	<.0001
Summer	-0.2032	0.0072	-28.07	<.0001
Winter	-0.8006	0.0075	-107.40	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0035	0.0002	-19.47	<.0001
R-square		0.5050		
F-value		34519.60		
Pr > F		<.0001		

Table D.2 Multiple Linear Regression of Passenger Cars' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways in Illinois

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	58.1286	0.0464	1251.92	<.0001
Speed Limit = 50 mph	3.4592	0.0613	56.46	<.0001
Speed Limit = 55 mph	3.8135	0.0280	136.04	<.0001
Speed Limit = 65 mph	6.8198	0.0337	202.14	<.0001
Speed Limit = 70 mph	8.5211	0.0345	246.91	<.0001
Speed Limit = 45 mph	–	–	–	–
AADT (1,000 vehicles/day)	-0.0005	0.0001	-3.99	<.0001
Proportion of Trucks	6.3677	0.0482	132.13	<.0001
IRI (in/mi)	-0.0406	0.0002	-242.37	<.0001
Median Width (ft)	-0.0089	0.0002	-46.94	<.0001
Shoulder Width (ft)	0.2021	0.0013	161.33	<.0001
Number of Lanes = 3	-0.6434	0.0111	-58.16	<.0001
Number of Lanes = 4	-0.0018	0.0187	-0.10	0.9228
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.6631	0.0033	-199.18	<.0001
Precipitation Intensity (in)	-0.2610	0.0103	-25.35	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Snow Accumulation	-0.9176	0.0208	-44.08	<.0001
Precipitation/Snow	-3.6153	0.0810	-44.61	<.0001
01:00–01:59 Travel Hour	-0.0606	0.0243	-2.49	0.0127
02:00–02:59	-0.0583	0.0245	-2.38	0.0173
03:00–03:59	0.1715	0.0242	7.07	<.0001
04:00–04:59	0.6899	0.0238	29.00	<.0001
05:00–05:59	0.9785	0.0236	41.44	<.0001
06:00–06:59	0.7568	0.0253	29.93	<.0001
07:00–07:59	0.2301	0.0288	7.98	<.0001
08:00–08:59	0.0146	0.0286	0.51	0.6098
09:00–09:59	0.0596	0.0285	2.09	0.0365
10:00–10:59	0.0483	0.0284	1.70	0.0889
11:00–11:59	0.1607	0.0283	5.68	<.0001
12:00–12:59	0.2031	0.0283	7.18	<.0001
13:00–13:59	0.3050	0.0284	10.75	<.0001
14:00–14:59	0.5005	0.0285	17.56	<.0001
15:00–15:59	0.6593	0.0288	22.91	<.0001
16:00–16:59	0.7267	0.0279	26.08	<.0001
17:00–17:59	0.6720	0.0269	25.00	<.0001
18:00–18:59	0.6206	0.0258	24.02	<.0001
19:00–19:59	0.5005	0.0245	20.43	<.0001
20:00–20:59	0.3464	0.0234	14.78	<.0001
21:00–21:59	0.0977	0.0234	4.17	<.0001
22:00–22:59	0.1926	0.0234	8.22	<.0001
23:00–23:59	0.2085	0.0236	8.83	<.0001
00:00–00:59	–	–	–	–
Daylight	0.7158	0.0163	43.86	<.0001
Weekend	1.3055	0.0076	172.06	<.0001
Spring	-0.8961	0.0099	-90.89	<.0001
Summer	-0.2459	0.0097	-25.39	<.0001
Winter	-1.3404	0.0100	-133.97	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0059	0.0003	-23.44	<.0001
R-square		0.5053		
F-value		33174.40		
Pr > F		<.0001		

Table D.3 Multiple Linear Regression of Heavy Trucks' Average Hourly Speed Under Non-Congested Traffic Conditions on Urban Freeways in Illinois

Parameter	Estimate	Std. Error	t Value	Pr > |t|
Intercept	58.1688	0.0313	1857.99	<.0001
Speed Limit = 50 mph	0.1565	0.0415	3.77	0.0002
Speed Limit = 55 mph	2.3529	0.0189	124.42	<.0001
Speed Limit = 65 mph	4.5288	0.0228	198.72	<.0001
Speed Limit = 70 mph	5.0868	0.0234	217.85	<.0001
Speed Limit = 45 mph	–	–	–	–
AADT (1,000 vehicles/day)	-0.0190	0.0001	-203.71	<.0001
Proportion of Trucks	4.8885	0.0320	152.74	<.0001
IRI (in/mi)	-0.0226	0.0001	-202.70	<.0001
Median Width (ft)	-0.0138	0.0001	-107.58	<.0001
Shoulder Width (ft)	0.1012	0.0009	118.91	<.0001
Number of Lanes = 3	0.3400	0.0075	45.59	<.0001
Number of Lanes = 4	2.3146	0.0138	167.91	<.0001
Number of Lanes = 2	–	–	–	–
Ramp Frequency (#/mi)	-0.5189	0.0025	-211.43	<.0001
Precipitation Intensity (in)	-0.1601	0.0068	-23.39	<.0001
Snow Accumulation	-0.4366	0.0140	-31.22	<.0001
Precipitation/Snow	-1.9801	0.0546	-36.27	<.0001
01:00–01:59 Travel Hour	0.0570	0.0159	3.59	0.0003
02:00–02:59	0.1903	0.0159	11.98	<.0001
03:00–03:59	0.2298	0.0158	14.58	<.0001
04:00–04:59	0.1373	0.0156	8.80	<.0001
05:00–05:59	-0.2001	0.0156	-12.82	<.0001
06:00–06:59	-0.5766	0.0168	-34.29	<.0001
07:00–07:59	-0.8270	0.0192	-43.02	<.0001
08:00–08:59	-0.9024	0.0191	-47.24	<.0001
09:00–09:59	-0.9527	0.0190	-50.15	<.0001
10:00–10:59	-0.9677	0.0189	-51.20	<.0001
11:00–11:59	-0.9345	0.0188	-49.63	<.0001
12:00–12:59	-0.8987	0.0188	-47.70	<.0001
13:00–13:59	-0.8866	0.0189	-46.92	<.0001
14:00–14:59	-0.9533	0.0190	-50.22	<.0001
15:00–15:59	-0.9640	0.0192	-50.33	<.0001
16:00–16:59	-0.8982	0.0185	-48.43	<.0001
17:00–17:59	-0.9026	0.0179	-50.48	<.0001
18:00–18:59	-0.7698	0.0172	-44.86	<.0001
19:00–19:59	-0.6598	0.0163	-40.56	<.0001

Parameter	Estimate	Std. Error	t Value	Pr > |t|
20:00–20:59	-0.5393	0.0155	-34.71	<.0001
21:00–21:59	-0.3996	0.0156	-25.70	<.0001
22:00–22:59	-0.1266	0.0156	-8.14	<.0001
23:00–23:59	0.0196	0.0156	1.25	0.2101
00:00–00:59	–	–	–	–
Daylight	0.3867	0.0109	35.48	<.0001
Weekend	0.2285	0.0051	45.17	<.0001
Spring	-0.2185	0.0065	-33.39	<.0001
Summer	-0.0597	0.0065	-9.25	<.0001
Winter	-0.0406	0.0067	-6.07	<.0001
Fall	–	–	–	–
Distance to City Center (mi)	-0.0083	0.0002	-50.87	<.0001
R-square		0.5448		
F-value		38541.10		
Pr > F		<.0001		

Appendix E. Hourly Volume Adjustment Factors

The hourly volume adjustment factors represent the percentage of AADT for a specific month, day of the week, and hour. The following coding is used in the summary tables:

- M: Month. 1-January, 2-February, 3-March, 4-April, 5-May, 6-June, 7-July, 8-August, 9-September, 10-October, 11-November, and 12-December.
- D: Day of the week. 1-Sunday, 2-Monday, 3-Tuesday, 4-Wednesday, 5-Thursday, 6-Friday, and 7-Saturday.
- H: Hour. H0: 00:00–00:59. H1: 01:00–01:59. H2: 02:00–02:59. H3: 03:00–03:59. H4: 04:00–04:59. H5: 05:00–05:59. H6: 06:00–06:59. H7: 07:00–07:59. H8: 08:00–08:59. H9: 09:00–09:59. H10: 10:00–10:59. H11: 11:00–11:59. H12: 12:00–12:59. H13: 13:00–13:59. H14: 14:00–14:59. H15: 15:00–15:59. H16: 16:00–16:59. H17: 17:00–17:59. H18: 18:00–18:59. H19: 19:00–19:59. H20: 20:00–20:59. H21: 21:00–21:59. H22: 22:00–22:59. H23: 23:00–23:59.

Table E.1 AADT Hourly Volume Adjustment Factors for Rural Freeways in Indiana

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
1	1	0.84	0.57	0.45	0.38	0.43	0.56	0.79	1.11	1.64	2.38	3.28	4.04	4.68	4.93	5.07	5.22	5.22	5.17	4.52	3.68	3.04	2.27	1.67	1.19
1	2	0.86	0.67	0.62	0.67	1.00	1.90	2.84	3.79	3.88	4.17	4.43	4.56	4.75	4.91	5.15	5.61	5.91	5.80	4.61	3.41	2.77	2.34	1.87	1.46
1	3	1.06	0.90	0.84	0.87	1.22	2.09	2.96	3.81	3.83	3.95	4.10	4.20	4.30	4.58	4.92	5.40	5.63	5.49	4.25	3.19	2.50	2.21	1.79	1.42
1	4	0.98	0.88	0.78	0.79	1.07	1.77	2.62	3.43	3.58	3.87	4.12	4.33	4.64	4.88	5.17	5.57	5.71	5.51	4.35	3.28	2.61	2.35	1.85	1.45
1	5	1.16	0.98	0.87	0.90	1.25	2.07	2.98	3.90	3.95	4.00	4.08	4.30	4.51	4.98	5.18	5.57	5.90	5.79	4.52	3.44	2.94	2.52	2.02	1.62
1	6	1.23	1.05	0.96	0.99	1.31	2.20	3.09	3.93	4.11	4.41	4.77	5.07	5.44	5.99	6.43	6.95	7.34	7.25	6.01	4.62	3.44	2.92	2.26	1.67
1	7	1.24	0.98	0.83	0.77	0.89	1.27	1.64	2.15	2.88	3.80	4.61	5.06	5.07	5.04	5.03	4.91	4.77	4.42	3.77	3.09	2.62	2.22	1.89	1.39
2	1	0.85	0.60	0.46	0.40	0.40	0.55	0.75	1.07	1.68	2.47	3.43	4.11	4.78	5.08	5.44	5.73	5.76	5.48	4.63	3.67	2.88	2.22	1.65	1.20
2	2	0.84	0.67	0.64	0.69	1.04	2.05	3.12	4.18	4.16	4.40	4.57	4.62	4.80	4.95	5.10	5.50	5.75	5.66	4.43	3.31	2.61	2.25	1.83	1.42
2	3	1.11	0.98	0.90	0.98	1.33	2.28	3.31	4.31	4.40	4.50	4.63	4.62	4.74	4.99	5.21	5.55	5.66	5.46	3.99	3.00	2.42	2.09	1.69	1.31
2	4	0.97	0.84	0.78	0.80	1.15	1.99	2.90	3.87	3.91	3.95	4.06	4.07	4.23	4.43	4.85	5.29	5.66	5.59	4.43	3.32	2.69	2.34	1.91	1.48
2	5	1.18	0.96	0.89	0.98	1.32	2.40	3.57	4.68	4.68	4.71	4.82	4.89	5.06	5.37	5.72	6.26	6.69	6.57	5.10	3.74	3.08	2.62	2.18	1.68
2	6	1.24	1.05	0.97	1.00	1.39	2.42	3.51	4.58	4.62	4.90	5.17	5.43	5.77	6.06	6.63	7.30	7.81	7.83	6.48	5.03	3.78	3.12	2.51	1.88
2	7	1.34	0.98	0.79	0.76	0.94	1.31	1.65	2.29	3.10	3.91	4.59	4.91	4.88	4.79	4.67	4.75	4.74	4.47	3.90	3.21	2.63	2.21	1.76	1.26
3	1	1.30	0.86	0.65	0.59	0.62	0.72	1.05	1.48	2.20	3.23	4.41	5.48	6.07	6.30	6.59	6.68	6.53	6.31	5.57	4.89	3.88	2.95	2.00	1.38
3	2	1.01	0.80	0.70	0.74	1.06	2.02	3.06	3.99	4.05	4.45	4.71	4.90	4.96	5.15	5.39	5.84	6.05	5.98	4.84	3.70	2.97	2.57	2.12	1.63
3	3	1.22	1.04	0.94	0.97	1.32	2.33	3.53	4.54	4.60	4.80	4.87	4.96	5.16	5.37	5.70	6.20	6.46	6.34	5.05	3.86	3.20	2.68	2.16	1.68
3	4	1.29	1.09	1.00	0.99	1.36	2.24	3.31	4.27	4.43	4.69	4.79	4.94	5.19	5.47	5.94	6.32	6.57	6.33	5.05	3.94	3.22	2.74	2.13	1.70
3	5	1.31	1.07	1.02	1.07	1.43	2.38	3.58	4.64	4.93	5.32	5.48	5.68	5.80	6.07	6.49	6.96	7.32	7.25	5.94	4.69	3.73	3.17	2.55	1.95
3	6	1.53	1.25	1.12	1.12	1.52	2.48	3.61	4.68	5.06	5.72	6.11	6.50	6.81	7.27	7.99	8.59	9.01	9.05	7.96	6.33	4.92	4.05	3.06	2.27
3	7	1.60	1.23	1.00	0.94	1.06	1.51	2.12	3.05	4.21	5.26	6.14	6.45	6.25	6.07	6.06	6.12	6.14	5.83	5.19	4.32	3.62	3.03	2.47	1.81
4	1	1.26	1.01	0.68	0.61	0.59	0.74	1.11	1.69	2.60	3.82	5.04	6.27	6.68	6.88	7.22	7.75	8.15	8.24	7.52	6.29	4.94	3.76	2.53	1.70
4	2	1.22	0.95	0.80	0.83	1.21	2.26	3.44	4.52	4.61	5.06	5.43	5.45	5.77	5.81	5.96	6.19	6.19	5.95	4.72	3.90	3.06	2.67	2.16	1.76
4	3	1.32	1.15	1.06	1.14	1.46	2.41	3.56	4.58	4.70	4.93	4.97	4.06	3.73	3.85	4.16	4.65	5.33	5.74	5.51	4.79	4.15	3.57	3.05	3.02
4	4	2.79	2.83	2.87	3.22	3.40	3.64	3.74	4.23	4.07	4.12	4.03	3.98	4.00	4.16	4.49	5.00	5.74	5.98	5.78	5.02	4.15	3.70	3.27	2.91
4	5	3.10	3.15	3.29	3.57	3.75	3.83	4.02	4.20	4.18	4.31	4.06	4.94	5.89	6.39	6.89	7.46	7.74	7.38	6.12	5.02	4.17	3.52	2.77	2.02
4	6	1.51	1.28	1.13	1.19	1.53	2.35	3.52	4.67	5.09	5.83	6.30	6.74	7.00	7.65	8.11	8.70	8.92	8.81	7.60	6.24	4.95	4.01	3.20	2.33
4	7	1.64	1.26	1.00	0.91	1.07	1.54	2.16	3.12	4.38	5.44	6.28	6.40	6.12	5.99	5.97	5.98	5.95	5.66	5.08	4.31	3.75	3.15	2.53	1.91
5	1	1.22	0.83	0.61	0.51	0.54	0.73	1.24	1.88	2.96	4.25	5.51	6.41	6.73	6.94	7.18	7.44	7.75	7.74	6.90	6.06	4.82	3.60	2.59	1.82
5	2	1.26	0.97	0.78	0.78	1.04	1.85	2.86	3.91	4.30	4.84	5.48	5.30	5.50	5.74	5.84	5.52	5.79	5.81	4.97	4.21	3.99	3.88	3.60	2.85
5	3	2.66	2.74	2.92	2.50	2.73	3.44	4.30	5.11	4.83	4.68	4.47	4.48	4.32	4.45	4.74	5.15	5.62	5.74	4.82	3.94	3.79	3.81	3.47	2.94

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
5	4	2.97	3.03	3.08	2.69	2.91	3.46	4.61	5.16	4.83	4.94	4.87	4.94	4.58	4.78	4.94	5.79	6.02	5.87	5.48	4.82	4.15	3.65	3.05	2.50
5	5	1.96	1.82	1.69	1.69	2.04	2.95	4.15	5.09	5.17	5.49	5.59	5.52	5.70	5.97	6.43	7.08	7.39	7.24	6.46	5.54	4.45	3.80	3.02	2.30
5	6	1.77	1.57	1.40	1.48	1.86	2.79	3.81	4.83	5.16	5.81	6.30	6.67	7.42	7.98	8.47	8.91	9.27	9.15	8.10	6.69	5.33	4.36	3.38	2.52
5	7	1.72	1.26	1.02	0.97	1.09	1.56	2.27	3.35	4.71	6.03	6.93	6.98	6.74	6.59	6.41	6.28	6.09	5.71	5.03	4.41	3.87	3.26	2.57	1.88
6	1	1.47	0.99	0.74	0.62	0.61	0.81	1.25	1.99	3.16	4.75	6.39	7.37	7.83	8.04	8.12	8.30	8.28	8.12	7.38	6.45	5.28	4.07	2.83	1.96
6	2	1.36	1.03	0.88	0.93	1.27	2.47	3.87	4.95	5.13	5.78	6.39	6.19	6.19	6.29	6.38	6.74	6.88	6.63	5.58	4.49	3.73	3.29	2.59	2.09
6	3	1.61	1.48	1.28	1.39	1.66	2.74	4.11	5.01	5.14	5.07	5.25	5.03	4.90	5.11	5.55	6.32	6.50	6.51	5.69	4.66	3.99	3.64	3.19	2.80
6	4	2.35	2.29	2.14	2.12	2.25	2.91	4.09	4.83	4.80	5.10	5.38	5.35	5.37	5.62	5.92	6.75	6.92	6.89	5.94	5.01	4.19	3.89	3.45	2.88
6	5	2.46	2.31	2.12	1.99	2.20	3.16	4.16	4.88	5.25	5.93	6.40	6.32	6.80	7.03	7.40	7.93	8.08	7.74	6.48	5.23	4.32	3.75	3.12	2.42
6	6	1.98	1.54	1.40	1.45	1.79	2.78	4.05	5.19	5.68	6.52	7.29	7.70	8.02	8.65	9.23	9.53	9.66	9.38	8.09	6.56	5.40	4.50	3.56	2.66
6	7	1.91	1.39	1.10	1.02	1.15	1.69	2.46	3.56	4.99	6.48	7.58	7.55	7.35	7.13	6.97	6.70	6.61	6.10	5.35	4.66	4.04	3.50	2.94	2.24
7	1	1.54	1.07	0.77	0.64	0.64	0.83	1.34	2.11	3.31	4.99	6.88	8.09	8.57	8.93	9.24	9.47	9.44	9.06	8.43	7.14	5.57	4.30	3.09	2.16
7	2	1.52	1.11	0.97	0.98	1.38	2.53	3.85	4.87	5.18	5.89	6.46	6.42	6.05	6.14	6.34	6.54	6.77	6.27	5.06	4.20	3.59	3.31	3.08	2.86
7	3	2.41	2.34	2.25	2.44	2.83	3.48	4.40	5.15	5.28	5.03	5.25	4.66	3.99	4.06	4.24	4.59	5.08	5.28	5.14	4.78	4.40	4.39	4.11	4.12
7	4	4.08	4.02	3.96	4.33	4.45	4.62	4.97	5.00	4.73	4.87	4.80	4.51	4.26	4.29	4.67	5.12	5.45	6.06	5.74	5.39	4.95	4.76	4.50	4.18
7	5	4.48	4.39	4.26	4.30	4.29	4.77	4.84	4.92	4.66	5.21	5.14	5.28	6.09	6.22	6.99	7.75	8.19	8.35	7.36	6.11	5.19	4.49	3.70	3.02
7	6	2.37	2.11	2.06	2.16	2.39	2.94	3.75	4.58	5.18	6.47	7.28	7.86	8.08	8.38	8.65	8.65	8.70	8.26	7.09	5.86	4.81	3.83	3.18	2.56
7	7	1.75	1.21	0.94	0.85	1.03	1.49	2.17	3.21	4.63	6.31	7.55	7.63	7.32	7.08	7.00	6.90	6.70	6.19	5.39	4.81	4.16	3.54	2.93	2.24
8	1	1.27	1.08	0.71	0.57	0.64	0.75	1.40	1.98	3.12	5.38	6.37	7.51	7.93	7.78	8.15	8.59	8.30	8.38	7.06	6.28	5.11	3.39	2.75	1.88
8	2	1.15	1.03	0.81	0.99	1.40	2.53	4.45	5.11	5.25	6.03	6.19	6.30	6.42	6.44	6.80	7.30	7.35	7.11	5.08	4.38	3.50	2.69	2.41	1.74
8	3	1.21	1.19	1.01	1.19	1.58	2.72	4.58	5.26	5.31	5.71	5.84	5.45	5.67	5.04	5.85	6.84	6.35	6.73	5.05	4.67	3.94	2.96	3.07	2.30
8	4	1.62	2.14	1.88	1.75	2.83	3.32	4.74	4.94	5.12	5.70	5.22	5.51	5.95	5.32	6.21	7.14	6.67	7.27	5.50	5.22	4.18	3.23	3.12	2.46
8	5	1.74	2.38	1.98	1.82	3.04	3.34	4.82	5.03	5.27	5.80	5.35	6.01	6.83	6.92	7.48	8.27	8.08	7.98	5.90	5.10	4.37	3.26	2.90	2.09
8	6	1.48	1.38	1.21	1.36	1.72	2.77	4.55	5.24	5.72	6.89	7.19	7.73	8.37	8.40	9.14	10.0	9.73	10.1	8.13	6.81	5.64	4.19	3.60	2.60
8	7	1.64	1.42	1.08	1.01	1.19	1.59	2.69	3.54	5.08	7.22	7.78	7.99	7.43	7.12	7.11	6.98	6.75	6.25	5.04	4.65	3.97	3.04	2.77	2.07
9	1	1.13	0.93	0.60	0.51	0.60	0.72	1.32	1.86	2.82	4.84	5.85	6.93	7.20	7.12	7.43	7.93	7.78	7.82	6.67	5.92	4.64	2.91	2.34	1.52
9	2	0.98	0.90	0.71	0.84	1.17	2.12	3.68	4.31	4.49	5.15	5.42	5.40	5.40	4.63	5.37	6.29	5.44	6.13	5.12	4.80	4.05	3.06	3.33	2.54
9	3	1.96	2.73	2.21	1.99	3.25	3.35	4.38	4.58	4.55	4.69	4.09	4.32	4.57	3.96	4.60	5.56	4.90	5.62	4.62	4.38	3.95	3.05	3.31	2.72
9	4	2.34	3.48	2.88	2.72	3.90	3.77	4.46	4.58	4.43	4.53	3.86	4.29	5.16	4.92	5.51	6.48	6.06	6.18	4.74	4.09	3.50	2.85	2.87	2.31
9	5	1.65	2.06	1.84	1.78	2.59	3.21	4.51	5.04	5.03	5.36	5.17	5.29	6.13	6.12	6.92	7.71	7.64	7.40	5.42	4.74	3.89	2.89	2.60	1.82
9	6	1.30	1.26	1.07	1.28	1.67	2.71	4.31	4.93	5.15	5.90	6.18	6.63	7.48	7.65	8.48	9.47	9.18	9.27	7.39	6.16	4.81	3.55	3.15	2.23
9	7	1.34	1.18	0.94	0.97	1.18	1.61	2.65	3.50	4.75	6.20	6.67	6.86	6.53	6.38	6.40	6.32	6.17	5.77	4.84	4.45	3.60	2.81	2.48	1.75
10	1	1.26	0.91	0.64	0.57	0.58	0.77	1.13	1.74	2.80	4.30	5.83	6.96	7.46	7.68	7.96	8.27	8.46	8.50	7.63	6.23	4.75	3.50	2.38	1.72
10	2	1.23	0.95	0.85	0.88	1.27	2.41	3.71	4.64	4.82	5.34	5.64	5.83	5.93	6.15	6.37	6.68	6.98	6.70	5.20	4.01	3.29	2.78	2.27	1.72

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
10	3	1.31	1.10	1.07	1.11	1.50	2.57	3.78	4.80	4.89	5.21	5.41	5.38	5.58	5.94	6.28	6.80	7.10	6.75	5.41	4.13	3.44	2.90	2.39	1.78
10	4	1.39	1.18	1.07	1.18	1.57	2.65	3.94	4.90	5.03	5.46	5.68	5.66	5.74	6.08	6.50	7.04	7.28	6.88	5.49	4.31	3.49	3.04	2.46	1.90
10	5	1.42	1.21	1.14	1.20	1.62	2.73	3.97	4.95	5.20	5.58	5.77	5.93	6.14	6.54	6.98	7.59	7.85	7.42	6.23	4.93	3.91	3.32	2.75	2.04
10	6	1.57	1.26	1.16	1.25	1.65	2.68	3.79	4.79	5.11	5.78	6.44	6.78	7.28	7.89	8.43	9.07	9.45	9.20	7.94	6.17	4.80	3.96	3.18	2.33
10	7	1.57	1.20	0.99	0.97	1.16	1.66	2.20	3.15	4.41	5.79	6.70	7.06	6.87	6.61	6.55	6.52	6.31	5.92	5.26	4.43	3.95	3.35	2.59	1.91
11	1	1.20	0.95	0.67	0.56	0.61	0.78	1.08	1.56	2.44	3.54	4.87	5.92	6.64	6.94	7.10	7.52	7.69	7.37	6.35	5.33	4.07	3.01	2.11	1.52
11	2	1.09	0.90	0.80	0.82	1.17	2.14	3.42	4.44	4.67	4.83	5.12	5.15	5.30	5.45	5.71	6.02	6.41	6.30	5.20	3.93	3.07	2.61	2.16	1.68
11	3	1.28	1.10	1.02	1.07	1.44	2.37	3.63	4.64	4.99	5.10	5.19	5.18	5.42	5.73	6.11	6.56	6.93	6.76	5.56	4.28	3.43	2.97	2.43	1.92
11	4	1.48	1.20	1.09	1.18	1.53	2.45	3.79	4.86	5.17	5.47	5.80	6.00	6.24	6.57	7.01	7.54	7.87	7.71	6.51	5.07	4.07	3.35	2.62	2.02
11	5	1.53	1.22	1.10	1.13	1.42	2.15	3.16	4.15	4.65	5.44	5.95	6.36	6.18	5.93	5.87	6.22	6.76	6.51	5.44	4.48	3.69	3.09	2.45	1.84
11	6	1.37	1.09	1.00	1.01	1.33	2.14	3.22	4.12	4.61	5.21	5.67	6.16	6.65	7.13	7.69	8.15	8.41	8.35	7.26	5.69	4.49	3.60	2.86	2.26
11	7	1.40	1.06	0.87	0.87	1.07	1.54	2.01	2.79	3.93	5.13	6.22	6.68	6.74	6.60	6.51	6.47	6.45	6.12	5.37	4.40	3.70	3.05	2.38	1.74
12	1	1.24	0.90	0.69	0.61	0.64	0.81	1.18	1.59	2.42	3.72	5.15	6.15	6.59	6.71	6.92	7.02	6.98	6.83	6.10	4.92	3.93	3.04	2.16	1.54
12	2	1.17	0.94	0.82	0.85	1.18	2.10	3.37	4.24	4.53	4.93	5.32	5.63	5.80	6.04	6.20	6.51	6.76	6.44	5.28	4.04	3.28	2.85	2.34	1.82
12	3	1.38	1.20	1.09	1.10	1.41	2.30	3.51	4.40	4.67	4.99	5.29	5.72	5.89	6.08	6.36	6.77	7.07	6.71	5.63	4.39	3.51	3.02	2.50	1.89
12	4	1.43	1.17	1.06	1.10	1.35	2.10	3.10	3.96	4.16	4.64	5.12	5.51	5.71	6.09	6.39	6.56	6.62	6.07	5.02	3.87	3.06	2.60	2.10	1.63
12	5	1.32	1.04	0.95	0.95	1.20	1.96	2.94	3.68	4.09	4.44	4.97	5.30	5.47	5.68	5.87	6.23	6.43	6.16	5.22	4.18	3.44	3.00	2.35	1.82
12	6	1.33	1.10	1.03	1.04	1.31	2.15	3.18	3.99	4.46	5.18	5.90	6.44	6.77	7.13	7.58	7.91	8.14	7.86	6.83	5.30	4.29	3.57	2.86	2.15
12	7	1.49	1.15	0.96	0.91	1.05	1.49	1.98	2.64	3.65	5.04	6.28	7.01	6.94	6.76	6.65	6.66	6.49	6.12	5.23	4.27	3.58	3.12	2.48	1.75

Table E.2 AADT Hourly Volume Adjustment Factors for Urban Freeways in Indiana

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
1	1	1.00	0.64	0.49	0.45	0.47	0.69	1.09	1.30	1.76	2.50	3.36	3.89	4.63	4.75	4.89	4.89	4.83	4.60	4.11	3.28	2.58	2.03	1.54	1.07
1	2	0.69	0.50	0.47	0.59	1.06	2.47	4.89	6.84	5.47	4.63	4.53	4.67	4.82	5.04	5.65	6.68	7.70	7.82	5.20	3.61	2.94	2.32	1.79	1.36
1	3	0.91	0.66	0.60	0.69	1.13	2.37	4.59	6.34	5.23	4.39	4.21	4.20	4.42	4.59	5.27	6.29	7.40	7.52	5.03	3.47	2.79	2.35	1.79	1.32
1	4	0.97	0.77	0.65	0.69	1.04	2.08	3.91	5.40	4.56	4.00	4.09	4.37	4.64	4.83	5.39	6.15	6.93	6.89	4.90	3.49	2.85	2.33	1.75	1.31
1	5	0.94	0.68	0.63	0.74	1.23	2.52	4.73	6.39	5.21	4.19	4.19	4.24	4.55	4.78	5.33	6.45	7.30	7.18	5.04	3.58	2.85	2.38	1.92	1.43
1	6	1.01	0.76	0.72	0.82	1.26	2.51	4.59	6.29	5.29	4.65	4.76	5.01	5.25	5.58	6.23	7.33	8.24	8.05	6.04	4.29	3.34	2.95	2.30	1.73
1	7	1.20	0.86	0.69	0.69	0.83	1.26	1.85	2.33	2.97	3.58	4.38	4.95	5.21	5.25	5.30	5.38	5.10	4.83	4.13	3.25	2.78	2.61	2.11	1.58
2	1	1.02	0.68	0.51	0.45	0.46	0.68	1.03	1.28	1.79	2.52	3.43	4.04	4.73	4.92	5.05	5.16	5.12	4.78	4.01	3.14	2.53	2.03	1.66	1.07
2	2	0.70	0.51	0.47	0.59	1.11	2.50	4.70	6.76	5.58	4.54	4.50	4.64	4.82	4.89	5.49	6.29	7.13	7.20	4.88	3.43	2.74	2.25	1.74	1.33
2	3	0.91	0.68	0.61	0.76	1.24	2.64	4.99	7.14	5.89	4.83	4.56	4.73	4.96	5.18	5.75	6.75	7.43	7.12	4.87	3.44	2.72	2.34	1.75	1.29
2	4	0.87	0.64	0.58	0.71	1.15	2.43	4.55	6.40	5.31	4.43	4.26	4.40	4.56	4.78	5.46	6.42	7.35	7.48	5.27	3.78	3.06	2.58	1.94	1.43
2	5	0.98	0.72	0.66	0.77	1.26	2.61	5.00	7.08	5.89	4.85	4.63	4.79	5.00	5.16	5.79	6.82	7.89	7.81	5.53	4.11	3.28	2.72	2.08	1.55
2	6	1.07	0.80	0.73	0.84	1.29	2.58	4.84	6.83	5.68	4.96	4.90	5.17	5.35	5.71	6.34	7.25	7.94	8.04	6.28	4.63	3.58	3.14	2.58	1.92
2	7	1.26	0.86	0.69	0.66	0.79	1.21	1.81	2.45	3.16	3.78	4.48	4.95	5.19	5.12	5.24	5.29	5.29	5.06	4.49	3.55	2.88	2.59	2.06	1.52
3	1	1.22	0.83	0.64	0.58	0.63	0.94	1.45	1.99	2.48	3.20	4.08	4.77	5.42	5.64	5.71	5.77	5.78	5.52	4.76	3.85	3.16	2.39	1.76	1.20
3	2	0.83	0.60	0.54	0.66	1.25	2.74	5.01	6.83	5.71	4.73	4.61	4.77	4.98	5.21	5.78	6.78	7.77	7.84	5.48	3.90	3.13	2.62	2.06	1.51
3	3	1.01	0.74	0.67	0.79	1.34	2.83	5.22	7.33	6.12	4.99	4.75	4.80	5.11	5.30	4.31	4.77	5.46	5.59	4.12	3.51	4.08	4.57	4.10	2.95
3	4	2.31	2.09	2.18	2.36	2.86	4.20	6.16	7.21	5.62	4.09	3.70	3.66	3.63	3.66	4.08	4.84	5.75	5.74	4.29	3.69	4.18	4.69	4.17	3.42
3	5	2.92	2.81	2.78	2.81	3.09	4.40	6.07	7.10	5.72	4.50	4.22	4.10	4.07	4.07	5.66	7.18	8.44	8.32	6.15	4.64	3.99	3.45	2.86	2.44
3	6	2.01	1.83	1.76	1.64	1.85	2.94	4.92	6.52	5.41	5.37	5.52	5.95	6.23	6.56	7.24	8.35	9.13	8.95	7.03	5.31	4.29	3.67	2.88	2.14
3	7	1.56	1.16	0.94	0.90	1.02	1.54	2.22	2.96	3.81	4.67	5.39	5.86	6.13	6.12	6.14	6.19	6.10	5.91	5.17	4.18	3.48	3.09	2.55	1.88
4	1	1.29	0.88	0.70	0.61	0.63	0.94	1.57	2.20	2.73	3.65	4.64	5.30	5.99	6.07	6.11	6.36	6.68	6.55	5.66	4.65	3.76	2.87	2.03	1.35
4	2	0.87	0.63	0.56	0.71	1.31	2.89	5.40	7.39	6.04	5.03	5.03	5.14	5.31	5.44	5.95	6.89	7.84	7.82	5.33	3.85	3.17	2.62	2.04	1.56
4	3	1.06	0.81	0.77	0.93	1.51	3.02	5.40	7.30	5.99	4.95	4.84	4.90	4.40	4.46	4.96	5.97	6.93	7.32	5.62	4.70	3.94	3.29	2.70	2.30
4	4	2.01	1.86	1.97	2.37	3.08	4.18	5.72	6.76	5.55	4.61	4.39	4.09	4.11	4.22	4.80	5.83	6.91	7.38	6.26	5.40	4.38	3.65	3.08	2.69
4	5	2.32	2.29	2.40	2.65	3.09	3.99	5.46	6.60	5.54	4.64	4.43	4.44	5.02	5.22	5.90	7.07	8.01	8.42	6.71	5.40	4.39	3.53	2.83	2.35
4	6	1.97	1.76	1.77	1.83	2.16	3.07	4.73	6.23	5.49	5.19	5.40	6.20	6.50	6.82	7.44	8.36	9.09	8.82	7.01	5.33	4.32	3.64	2.90	2.21
4	7	1.51	1.04	0.82	0.83	0.99	1.56	2.36	3.28	4.16	4.97	5.64	5.95	6.06	6.02	6.10	6.25	6.11	5.94	5.34	4.36	3.72	3.31	2.80	2.08
5	1	1.28	0.83	0.61	0.54	0.56	0.85	1.46	2.04	2.71	3.64	4.65	5.31	5.87	5.90	5.94	6.08	6.24	6.16	5.49	4.54	3.70	2.79	2.04	1.41
5	2	0.93	0.66	0.54	0.63	1.08	2.35	4.49	6.03	5.11	4.68	4.96	4.99	4.59	4.63	5.08	5.77	6.59	6.82	5.49	4.79	4.00	3.38	2.81	2.42
5	3	2.16	2.07	2.08	2.33	2.85	3.91	5.22	6.34	5.42	4.03	3.76	3.42	3.17	3.34	3.61	4.21	5.50	5.70	5.52	5.08	4.63	4.61	4.25	4.03
5	4	4.12	4.52	4.68	4.78	5.00	4.92	5.39	5.70	4.81	3.84	3.47	3.33	3.34	3.49	3.91	4.62	5.63	5.96	5.53	5.08	4.91	4.66	4.10	3.88

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
5	5	3.94	3.77	4.26	4.31	4.35	4.84	5.50	6.01	4.91	4.35	3.99	4.25	4.90	4.99	5.81	7.59	8.41	8.49	6.35	4.93	4.08	3.46	2.67	2.04
5	6	1.50	1.15	1.09	1.25	1.76	2.98	5.18	6.93	5.98	5.42	5.58	5.97	6.32	6.61	7.30	8.25	8.99	8.85	7.13	5.51	4.45	3.75	3.02	2.30
5	7	1.55	1.05	0.81	0.78	0.94	1.47	2.29	3.16	4.10	4.88	5.50	5.82	5.96	5.92	6.01	6.04	5.85	5.61	5.05	4.31	3.76	3.39	2.74	1.99
6	1	1.47	0.98	0.69	0.58	0.61	0.88	1.34	1.85	2.60	3.58	4.69	5.35	6.00	6.15	6.14	6.22	6.22	6.10	5.52	4.72	3.92	3.13	2.29	1.58
6	2	1.01	0.70	0.59	0.69	1.33	2.83	5.08	6.79	6.28	5.08	5.06	5.13	4.86	5.02	5.24	5.28	5.96	6.22	5.03	4.14	3.81	3.87	4.06	3.35
6	3	2.82	2.62	2.58	2.67	3.06	4.12	5.54	6.84	6.16	4.13	3.76	3.16	2.45	2.42	2.46	2.97	3.96	4.53	4.98	5.26	5.02	5.06	5.26	4.98
6	4	4.70	4.85	5.24	5.41	5.67	5.82	5.55	5.75	4.93	3.83	3.23	2.82	2.57	2.44	2.55	3.20	4.29	4.94	5.36	5.47	5.27	4.96	4.95	4.73
6	5	4.76	4.86	5.12	5.43	6.05	5.94	5.85	5.99	5.07	4.38	3.80	3.59	4.55	4.38	5.26	7.27	8.21	8.21	6.34	4.91	4.27	3.74	3.13	2.38
6	6	1.92	1.54	1.66	1.60	2.24	3.36	5.22	6.53	6.12	5.58	5.71	6.22	6.46	6.84	7.55	8.39	9.04	8.89	7.28	5.62	4.50	3.91	3.25	2.47
6	7	1.66	1.13	0.89	0.88	1.10	1.64	2.46	3.33	4.15	4.98	5.59	5.93	6.05	6.02	6.05	6.16	5.93	5.71	5.08	4.41	3.78	3.40	2.85	2.15
7	1	1.57	1.05	0.76	0.64	0.67	0.93	1.37	1.92	2.72	3.79	5.01	5.86	6.58	6.92	6.95	6.85	6.86	6.83	6.16	5.27	4.38	3.47	2.58	1.78
7	2	1.14	0.78	0.68	0.78	1.46	2.94	4.86	6.29	6.06	5.01	5.00	4.60	4.27	4.36	4.67	5.32	6.18	6.58	5.66	4.73	4.07	3.63	3.35	3.13
7	3	3.15	3.05	3.02	3.14	3.62	4.23	5.23	5.98	5.48	4.36	4.02	3.42	3.04	3.08	3.48	4.17	4.91	5.85	5.97	5.17	4.74	4.47	4.37	4.31
7	4	4.36	4.29	4.46	4.43	4.60	4.79	5.08	5.35	4.85	4.25	3.88	3.69	3.60	3.55	3.94	4.71	5.41	6.33	6.37	5.35	4.85	4.66	4.60	4.30
7	5	3.76	3.74	3.99	4.22	4.40	4.72	5.18	5.52	5.03	4.62	4.30	4.78	5.22	5.30	6.02	7.00	7.73	7.99	6.77	5.36	4.48	4.02	3.43	2.75
7	6	1.75	1.34	1.24	1.33	1.87	2.98	4.42	5.60	5.70	5.56	5.88	6.26	6.64	6.88	7.29	7.78	8.17	8.06	6.82	5.35	4.26	3.63	3.12	2.54
7	7	1.71	1.11	0.85	0.80	1.00	1.53	2.20	2.98	3.86	4.85	5.51	6.04	6.18	6.26	6.20	6.21	6.08	5.85	5.27	4.57	3.95	3.45	2.90	2.25
8	1	1.31	1.00	0.71	0.64	0.63	0.93	1.49	1.79	2.60	4.15	4.95	5.53	6.19	6.46	6.46	6.49	6.60	6.34	5.37	5.00	4.14	2.94	2.47	1.67
8	2	0.90	0.72	0.61	1.13	1.46	3.19	5.97	6.64	6.03	4.95	4.59	4.18	4.97	3.74	4.67	6.81	5.54	6.95	5.36	4.98	4.01	2.86	3.76	2.95
8	3	1.58	3.31	2.69	1.90	3.95	4.00	5.96	5.70	5.28	4.60	3.54	3.80	4.13	2.96	4.00	5.64	4.46	6.01	5.20	5.26	4.50	3.71	4.52	3.61
8	4	2.64	4.17	3.71	3.15	5.26	4.79	6.05	5.70	5.38	4.38	3.38	3.57	4.12	2.94	4.17	5.96	5.12	6.71	5.47	5.48	4.65	3.93	4.63	3.58
8	5	2.67	4.22	3.72	3.17	5.12	4.65	5.93	5.47	5.40	4.62	3.60	3.93	5.01	3.80	5.18	7.67	6.89	8.07	5.98	5.40	4.41	3.39	3.97	3.01
8	6	1.77	3.35	2.55	1.89	3.89	3.67	5.82	5.57	5.62	5.59	4.78	6.12	6.57	6.77	7.40	8.60	8.88	9.12	6.78	5.89	4.67	3.67	3.29	2.52
8	7	1.48	1.15	0.91	0.98	1.08	1.65	2.69	3.21	4.10	5.30	5.87	6.14	6.15	6.23	6.04	6.05	6.18	5.81	4.86	4.57	3.80	3.21	2.99	2.27
9	1	1.14	0.87	0.60	0.54	0.55	0.85	1.37	1.62	2.35	3.73	4.45	5.10	5.70	5.90	5.91	6.05	6.26	5.96	4.96	4.57	3.60	2.33	1.88	1.29
9	2	0.79	0.63	0.54	0.95	1.24	2.74	5.35	6.03	5.62	4.53	4.41	4.63	4.70	4.10	5.00	6.32	5.88	6.56	5.14	4.55	3.84	2.95	3.38	2.57
9	3	1.80	2.90	2.11	2.15	3.47	4.02	6.08	6.20	5.88	4.53	3.94	3.99	4.02	3.26	3.93	5.65	4.38	5.72	5.06	4.39	4.45	3.55	4.56	3.38
9	4	2.63	4.04	3.28	3.08	4.62	4.99	6.18	6.55	5.66	4.52	3.86	3.24	4.11	2.63	3.65	6.18	4.60	6.78	5.58	5.09	4.54	3.46	4.72	3.44
9	5	2.13	3.95	3.74	2.77	5.20	4.59	6.01	5.95	5.32	4.78	3.57	3.63	4.90	3.11	4.81	7.50	6.38	8.39	6.09	5.84	4.21	2.93	3.47	2.65
9	6	1.32	3.04	2.83	1.81	4.50	3.64	5.94	5.47	5.38	5.20	3.95	5.73	6.24	6.55	7.26	8.65	8.95	8.87	6.61	5.63	4.32	3.35	3.01	2.17
9	7	1.24	0.98	0.79	0.90	0.99	1.62	2.67	3.15	3.96	4.87	5.29	5.58	5.71	5.77	5.77	5.75	5.76	5.44	4.58	4.33	3.58	2.85	2.65	2.01
10	1	1.35	0.89	0.64	0.56	0.60	0.89	1.25	1.69	2.47	3.55	4.69	5.44	5.95	6.21	6.37	6.46	6.67	6.41	5.72	4.74	3.68	2.66	1.95	1.35
10	2	0.89	0.63	0.57	0.75	1.49	3.04	5.09	6.46	6.08	5.12	5.05	5.10	5.21	5.36	5.84	6.64	7.48	7.57	5.95	4.29	3.38	2.75	2.20	1.73
10	3	1.30	1.05	1.06	1.26	1.93	3.26	5.17	6.33	6.02	4.74	4.48	4.35	4.38	4.58	5.15	6.11	7.15	7.42	6.32	4.86	3.91	3.26	2.73	2.34

M	D	H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23
10	4	4.44	3.74	4.76	5.30	4.83	6.00	5.53	6.13	4.94	3.85	3.62	2.88	3.27	3.23	3.80	4.99	6.15	6.64	6.24	5.24	4.54	4.14	3.92	3.40
10	5	3.29	3.34	3.63	3.71	4.22	4.83	5.55	5.90	5.28	4.44	3.98	3.98	4.37	4.55	5.28	6.61	7.66	7.95	6.84	5.19	4.17	3.66	3.09	2.66
10	6	2.36	2.30	2.40	2.50	2.88	3.57	4.87	5.82	5.43	5.00	5.01	5.92	6.35	6.77	7.46	8.28	9.03	8.94	7.35	5.53	4.28	3.58	2.99	2.17
10	7	1.52	1.01	0.81	0.80	1.04	1.62	2.32	3.11	3.99	4.83	5.48	5.90	5.99	5.92	5.98	6.05	5.98	5.73	5.21	4.55	3.87	3.31	2.76	2.02
11	1	1.38	1.01	0.68	0.59	0.65	0.94	1.28	1.67	2.36	3.32	4.44	5.21	5.83	6.13	6.26	6.28	6.41	6.04	5.18	4.14	3.24	2.45	1.87	1.34
11	2	0.86	0.60	0.56	0.73	1.42	2.98	5.21	6.83	6.28	5.10	4.86	4.93	5.11	5.32	5.93	6.88	7.76	7.85	5.89	3.93	3.04	2.48	1.99	1.50
11	3	1.10	0.80	0.74	0.91	1.56	3.00	5.13	6.68	6.30	5.32	5.06	5.13	5.33	5.59	6.20	7.24	8.04	8.01	6.27	4.46	3.47	2.85	2.27	1.71
11	4	1.17	0.88	0.78	0.95	1.56	2.98	5.27	7.08	6.65	5.49	5.35	5.11	5.22	5.51	6.07	6.92	7.82	8.08	6.80	4.95	3.88	3.20	2.68	2.20
11	5	1.68	1.41	1.38	1.64	2.10	2.99	4.35	5.49	5.30	4.61	4.62	4.95	5.07	4.99	5.36	6.12	6.79	7.01	6.19	4.87	3.97	3.32	2.75	2.19
11	6	1.70	1.42	1.43	1.67	2.14	3.14	4.63	5.83	5.58	4.90	4.98	5.61	6.07	6.49	7.06	7.99	8.47	8.36	7.07	5.18	4.03	3.37	2.86	2.11
11	7	1.40	0.95	0.76	0.76	1.00	1.52	2.15	2.86	3.68	4.49	5.29	5.77	5.91	5.85	5.96	6.02	6.05	5.84	5.20	4.27	3.47	3.00	2.48	1.82
12	1	1.64	1.10	0.81	0.66	0.66	0.88	1.16	1.53	2.16	3.00	4.08	4.91	5.59	5.90	6.00	6.08	6.11	5.80	5.20	4.44	3.60	2.84	2.19	1.58
12	2	1.11	0.79	0.65	0.74	1.27	2.44	4.19	5.79	6.07	5.40	5.30	5.33	5.52	5.81	6.30	7.08	7.76	7.77	6.39	4.74	3.65	2.98	2.37	1.84
12	3	1.33	0.99	0.85	0.95	1.47	2.62	4.31	5.72	5.73	5.25	5.31	5.44	5.62	5.96	6.42	7.29	7.91	7.77	6.39	4.87	3.83	3.11	2.50	1.92
12	4	1.42	1.04	0.86	0.92	1.33	2.31	3.83	5.30	5.55	5.11	5.11	5.28	5.61	5.91	6.30	6.90	7.34	7.23	5.99	4.55	3.62	3.02	2.41	1.85
12	5	1.39	1.00	0.81	0.85	1.24	2.16	3.66	4.99	5.32	4.86	4.78	4.93	5.20	5.45	5.91	6.64	7.12	7.22	6.16	4.82	3.90	3.21	2.60	1.98
12	6	1.41	1.01	0.83	0.88	1.31	2.27	3.75	5.18	5.64	5.42	5.68	5.96	6.33	6.69	7.16	7.87	8.31	8.23	7.01	5.55	4.39	3.69	3.11	2.46
12	7	1.77	1.25	0.94	0.85	0.98	1.36	1.86	2.53	3.29	4.17	5.10	5.79	6.16	6.35	6.30	6.32	6.26	6.03	5.44	4.60	3.82	3.33	2.84	2.22

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at https://docs.lib.purdue.edu/jtrp/.

Further information about JTRP and its current research program is available at https://engineering.purdue.edu/JTRP.

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