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Safety Impacts of Different Speed Limits on Cars and Trucks

Final Report

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
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FOREWORD

This report will be of interest to highway safety engineers and administrators responsible for the setting of speed limits on Interstate highways. There has been some controversy as to the setting of speed limits for heavy vehicles (typically trucks) to be the same or lower than the speed limits set for lighter vehicles (typically cars). This study examined actual speed and accident data for States that had the same speed limits for all vehicles as compared with States that had different speed limits for cars and heavy trucks.

The results of this research indicate that the mean travel speed of heavy trucks are the same for 65-/65-mi/h (105-/105-km/h) (cars/trucks) and 65-/60-mi/h (105-/97- km/h) speed limits, indicating that a 5-mi/h (8-km/h) speed limit differential has no effect on actual truck speeds. The actual mean speed for heavy trucks where the speed limit was 65/55 mi/h (105/88 km/h) was less than 3 mi/h (5 km/h) below the mean speed for all other vehicles. The speed variances were similar for the overall speed distributions for the 65-/65-mi/h and 65-/60-mi/h speed limits. There is more car/truck interaction occurring with the 65-/55-mi/h limits. The 65-/55-mi/h speed limit did result in fewer trucks exceeding 70 mi/h (113 km/h).

Overall, the accident analysis showed no statistical difference in number of accidents or accident severity among the States with respect to the type of speed limit. In the States with differential speed limits, the rear-end collisions were more likely to involve cars striking trucks. In the uniform speed limit States, car-truck accidents were more likely to involve trucks striking cars.

Two copies of this report are being sent to each Region, and six copies are being sent to each Division office. At least four of the copies sent to the Division should be sent to the State highway agency by the Division office.

Lyle Saxton

Lyle Saxton, Director
Office of Safety and Traffic Operations
Research and Development

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16. Abstract

The objectives of this study were to determine whether differential or uniform speed limits are more beneficial to transportation safety and traffic operations on Interstate highways. The approach to achieving this objective was to examine speed and accident data from States employing both types of limits. Speed data were collected in 12 States at rural and urban locations representing all speed limits currently established on the Interstate highway system for cars/trucks, i.e., 55/55 mi/h (89/89 km/h), 65/55 mi/h (105/89 km/h), 65/60 mi/h (105/97 km/h), and 65/65 mi/h (105/105 km/h). Accident data were obtained from nine States which were geographically distributed across the country and representative of all rural Interstate speed limits currently established.

For the speed data collected, a number of measures of effectiveness (MOE's) were examined including mean speed, speed variance, compliance, and speed distribution measures. For the accident data collected, types of crashes were examined (e.g., rear-end) along with vehicle type involvement (e.g., car-into-truck) and crash severity.

This final report summarizes the effects of uniform and differential speed limits on transportation safety and traffic operations as determined by the examination of speed and accident data.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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LIST OF ABBREVIATIONS

AADT	average annual daily traffic
ANOVA	analysis of variance
ATR	automatic traffic recorder
CT	car-into-truck
FHWA	Federal Highway Administration
h	hour
km	kilometer(s)
mi	mile(s)
MOE	measure of effectiveness
NHTSA	National Highway Traffic Safety Administration
TC	truck-into-car
vs.	versus

CHAPTER 1 - INTRODUCTION

BACKGROUND

On April 2, 1987, the Surface Transportation and Uniform Relocation Assistance Act (P.L. 100-17) became effective and granted States the right to raise speed limits on the rural Interstate highway system from the previously imposed maximum limit of 55 mi/h (89 km/h) to 65 mi/h (105 km/h). The segments of the Interstate highway system classified as rural are defined by the Federal Highway Administration (FHWA) as those segments outside areas with populations of 50,000 or more. As a result of this legislation, 40 States raised the speed limit between April 6, 1987 and July 1988, resulting in approximately 90 percent of all eligible rural Interstate mileage being posted at 65 mi/h (105 km/h).

Of the 40 States which have enacted legislation to raise the speed limit, 10 have established differential limits for cars and larger vehicles (primarily trucks). The speed limits for larger vehicles range from 45 mi/h (72 km/h) on some mountainous segments to 60 mi/h (97 km/h) across several States. While large trucks are the principal vehicles governed by the lower limits, a few States have included other vehicle types in the large vehicle class. In California, for example, cars pulling trailers are considered large vehicles and cannot exceed 55 mi/h (89 km/h). The State of Texas has also added to the array of regulations by establishing a differential speed limit of 60 mi/h (97 km/h) for trucks during daylight hours and 55 mi/h (89 km/h) during nighttime hours. In summary, there have been a variety of definitions and restrictions used to establish differential speed limits for trucks and other large vehicles. Shown in figure 1 are the posted rural Interstate speed limits for each of the 48 contiguous States. Note, that *trucks* include all large vehicles governed by the lower speed limit in those States with a differential limit.

The purpose of a properly established speed limit is to inform motorists of the maximum safe speed under prevailing conditions. This speed should be recognized as safe and reasonable by the majority. With such a limit and proper enforcement, the number of vehicles traveling at excessively high speeds will be reduced and thus the frequency and severity of crashes should decrease. While this rationale for speed limits in general is widely accepted among the traffic engineering profession, the arguments for and against differential speed limits are more debatable.

The rationale for a lower maximum limit for trucks is based on the fact that from any given speed, a heavier vehicle, such as a truck, requires longer to decelerate and come to a complete stop than does a lighter vehicle, such as a car. It has been argued that the lower limit for trucks will make stopping sight distances for cars and trucks more comparable and provide for a more orderly traffic flow.[1]

One of the counter arguments against differential speed limits with respect to stopping distance is the increased sight distance of a truck operator over the driver of a passenger car. The truck driver is able to see the vertical feature of an obstruction in the roadway at a greater distance away than can the operator of a passenger vehicle due to the higher position of the seat in the vehicle. This in turn provides the truck driver more time and

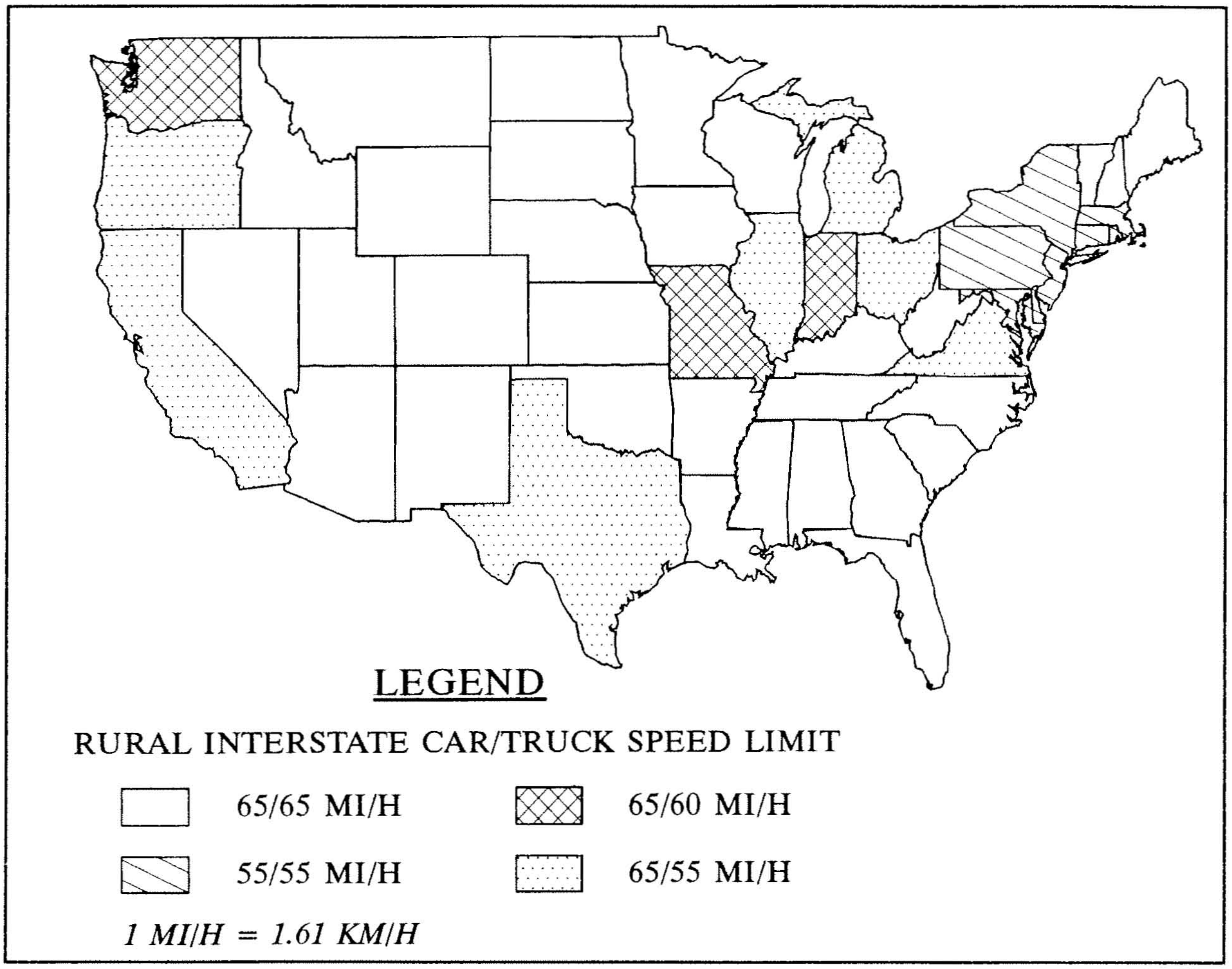


Figure 1. Posted rural Interstate speed limits.

distance to stop. For this reason, the American Association of State Highway and Transportation Officials (AASHTO) design criteria do not include separate design values of stopping sight distance for trucks.[2]

Another argument used by opponents of the differential limit is that a lower limit for trucks may increase the variation in vehicle speeds, resulting in an increase in the number of interactions, and thus, potential conflicts between vehicles.[3] Results from prior research studies do show the increased probability of being involved in an accident as the deviation from the mean speed increases.[4,5,6] However, no research has been conducted to date which examines this issue as it is related to differential versus uniform speed limits.

There are a range of views on differential speed limits as illustrated by the legislation enacted in the States since April 1987. Many of these views are based on dated research or sources of information with no empirical data. Thus, this study was undertaken to assess the practice of using differential speed limits and determine what impact such limits have on traffic operations and safety.

STUDY OBJECTIVE AND SCOPE

The objectives of this study were to determine whether differential or uniform speed limits are more beneficial to transportation safety and traffic operations on Interstate highways. The approach to achieving this objective was to examine speed and accident data from States employing both types of limits. Speed data were collected in 12 States at rural and urban locations representing all speed limits currently established on the Interstate highway system for cars/trucks, i.e., 55/55 mi/h (89/89 km/h), 65/55 mi/h (105/89 km/h), 65/60 mi/h (105/97 km/h), and 65/65 mi/h (105/105 km/h). Accident data were obtained from nine States which were geographically distributed across the country and representative of all rural Interstate speed limits currently established.

For the speed data collected, a number of measures of effectiveness (MOE's) were examined including mean speed, speed variance, compliance, and speed distribution measures. For the accident data collected, types of crashes were examined (e.g., rear-end) along with vehicle type involvement (e.g., car-into-truck) and crash severity.

ORGANIZATION OF THE REPORT

This report summarizes the effects of uniform and differential speed limits on transportation safety and traffic operations as determined by the examination of speed and accident data collected in the performance of this research effort. A review of the literature related to differential speed limits is provided in chapter 2. The research methodology is discussed in chapter 3, while the data collection and reduction efforts are described in chapter 4. Chapter 5 contains the results of the analysis of speed data, and chapter 6 contains the accident analysis results. Finally, a summary of the results and conclusions are provided in chapter 7.

As mentioned in the scope, the four speed limits for cars/trucks included in this study were as follows:

- 55/55 mi/h (89/89 km/h).
- 65/55 mi/h (105/89 km/h).
- 65/60 mi/h (105/97 km/h).
- 65/65 mi/h (105/105 km/h).

These limits are used throughout the report in the discussion of the data collection, data analysis, and presentation of results. In order to make the document clear and concise, the speed limits will simply be referred to hereafter as groups or limits, e.g., 65/55 speed limit group or 65/65 limit.

CHAPTER 2 - LITERATURE REVIEW

Since the Federal legislation was passed in 1987 which allowed States to increase rural Interstate speed limits, there have been several studies conducted which have examined differential speed limits. There were also two studies conducted prior to the imposition of the mandatory 55 mi/h (89 km/h) speed limit in 1974 which specifically addressed differential speed limits. There are a large number of other studies which were not specifically designed to examine differential speed limits, but which do contain results related to issues believed to be impacted by the presence of differential limits. Provided below is a summary of the literature reviewed as it relates to the following topics:

- Travel Speeds.
- Speed Variance.
- Compliance.
- Accident Risk.
- Truck Characteristics.

TRAVEL SPEEDS

A 1991 study was conducted by Garber and Gadiraju in which "test-site/control-site" speed data were examined. The "test" sites were located on rural Interstates while the "control" sites were located either on segments of rural or small urban Interstates or *non-interstate* routes parallel to the test segment. At the test sites, the speed limit was raised to 65 mi/h (105 km/h) for passenger cars while remaining 55 mi/h (89 km/h) for trucks. At the control locations, the speed limit remained 55 mi/h (89 km/h) for all vehicles. Before/after speed data from these locations were used in the analysis. Additional rural Interstate locations were selected in Virginia (65/55 limit) along with corresponding sites across the state line in West Virginia (65/65 limit). These sites were included in the analysis of "after" speed data only since no "before" speed data were available from these locations. The analysis of the speed data yielded the following results:[7]

- At those locations where the speed limit was raised to 65 mi/h (105 km/h), passenger car speeds increased by 1 to 4 mi/h (1.6 to 6.4 km/h) to a range of 62 to 67 mi/h (100 to 108 km/h).

- No statistically significant differences were observed in the before and after mean truck speeds at those locations where the differential speed limit was imposed.

- The speeds at the control sites were unaffected by the increase in the speed limit at the test locations.

A study by Esterlitz et al. examined speed data collected in adjacent States with and without uniform limits. The States with uniform limits of 65 mi/h (105 km/h) for all vehicles were Arizona and Iowa. The States with differential 65/55 limits were California and Illinois. Speed data were collected at three rural Interstate sites in each State and consisted of individual vehicle speeds observed over a 24-hour period. The results of the analysis were as follows:[8]

- Average car speeds were 1.3 mi/h (2.1 km/h) less in States with differential limits and were statistically significantly different.

- Average truck speeds were 2.7 mi/h (4.3 km/h) less in the States with the 10 mi/h (16 km/h) differential limit, and this difference also proved to be statistically significant.

A study was undertaken by Hall and Dickinson in 1972 to determine the effectiveness, desirability, and operational implications associated with differential speed limits on Interstates in Maryland. At the time of the study, 164 mi (264 km) of the Maryland Interstate System were governed by a differential limit for cars/trucks of 70/60 mi/h (113/97 km/h), 12 mi (19 km) by a differential limit of 65/60 mi/h (105/97 km/h), and another 57 mi (92 km) were posted with a uniform limit of 60 mi/h (97 km/h).[3]

An examination of the differences between car and truck speeds at the locations with differential limits showed the difference in mean speeds between the two vehicle types to be $\leq$ 6 mi/h (10 km/h) at over two-thirds of the sites. Likewise, differences in the 85th percentile speeds was $\leq$ 8 mi/h (13 km/h) at more than two-thirds of the locations. In general, the true differential was normally less than the posted 10 mi/h (16 km/h) differential. The only locations where the difference in 85th percentile speeds between cars and trucks exceeded the posted differential were at sites with upgrades of 3.0 percent and greater.

A 1966 study by Ferguson examined car and truck speed data collected using radar in Virginia. At that time the speed limits for cars and trucks on the Interstates were 65 and 50 mi/h (105 and 81 km/h), respectively.[1]

The analysis of Interstate speed data from 27 sites revealed 85th percentile speeds for cars and trucks to average 67 mi/h and 58 mi/h (108 km/h and 93 km/h), respectively. The observed speed differential ranged between 8 and 10 mi/h (13 and 16 km/h) as opposed to the posted differential of 15 mi/h (24 km/h).

Freedman and Williams analyzed speed data from 11 Northeastern States including 6 which retained the 55 mi/h (89 km/h) speed limit, 3 with a uniform 65 mi/h (105 km/h) speed limit, and 2 with a differential limit of 65/55 mi/h (105/89 km/h) for cars/trucks. Speed data were collected at a total of 54 locations during daylight hours only using nondetectable radar.[9]

The results related to the States with differential speed limits showed mean and 85th percentile passenger car speeds [67.7 and 72.2 mi/h (109.0 and 116.2 km/h)] to be very close to the respective speeds for passenger cars [66.7 and 72.1 mi/h (107.4 and 116.1 km/h)] in the States with uniform 65 mi/h limits (105 km/h). The mean and 85th percentile truck speeds in the differential speed limit States [61.4 and 66.3 mi/h (98.9 and 106.7 km/h)] were similar to the respective truck speeds [60.3 and 65.3 mi/h (97.1 and 105.1 km/h)] in the States with uniform 55 mi/h (89 km/h) limits. Similar comparisons were indicated by the data with respect to the percentage of vehicles exceeding the speed limit by varying amounts.

SPEED VARIANCE

One of the principal arguments against differential speed limits is that lower limits for trucks may increase the variation in vehicle speeds, resulting in a greater number of interactions and conflicts between vehicles. As Hauer indicated, traveling at the mean speed of traffic minimizes the number of overtakings, which are high-risk maneuvers.[10] Several research studies have shown that the risk of being involved in an accident increases as a driver's speed deviates from the mean traffic stream speed on that same roadway. The study by Solomon in 1964 was the first effort to illustrate this relationship using data from 2-lane and 4-lane rural roads.[4] A study by Cirillo in 1968 explored this issue with respect to Interstates and produced similar results.[5] In both studies, the relationship between accident involvement and deviation from the mean speed was a u-shape function as shown in figure 2.

A 1988 research effort by Garber and Gadirau explored the issue of speed variance and accidents on both Interstate and non-Interstate roadways in Virginia. The analysis resulted in the following conclusions:[11]

- Accident rates increased as speed variance increased for all roadway types studied.

- Speed variance decreased as average speed increased for mean speeds between 25 and 70 mi/h (40 and 113 km/h).

- Accident rates did not necessarily increase with average speeds.

- Speed variance was at a minimum when the difference between design speed and the posted speed limit was between 5 and 10 mi/h (8 and 16 km/h). This result led to the recommendation that speed limits be posted between 5 and 10 mi/h (8 and 16 km/h) below the design speed of a highway.

A study by Hearne examined relationships between speed variance, mean travel speeds, and accidents in Ireland where the limits for cars and trucks were 55 and 40 mi/h (89 and 64 km/h), respectively. Multiple regression analysis showed speed variance to be a factor on accident occurrence, but not as great a factor as mean truck speed.[12]

No studies have been conducted which directly examine the differences between differential and uniform speed limits with respect to speed variance and its association with accident risk. It should be noted that the study by Cirillo contained Interstate data from 1965 when many of the States imposed differential speed limits. However, the results provided were inclusive of all speed limits, uniform and differential.

With respect to the measure of speed variance and the two types of speed limits, conflicting results have been documented. Esterlitz et al. indicated that speed variance was 5 percent less for the States with differential limits while Hall and Dickinson showed speed variance to be greater on routes with differential limits.[3, 8]

COMPLIANCE

Hall and Dickinson analyzed compliance data at sites with both uniform 60 mi/h (97 km/h) speed limits and differential limits of 70/60 mi/h and 65/60 mi/h (113/97 km/h and 105/97 km/h). Examining the percentages of cars and trucks in compliance with their respective limits revealed that 73 percent of the trucks and 40 percent of the cars were in compliance at the uniform speed locations. The locations with the differential limit showed the opposite effect, i.e., truck compliance fell to 51 percent while car compliance increased to 62 percent.

In the study conducted by Ferguson, the car/truck speed limit on the Interstates was 65/50 mi/h (105/81 km/h). The results showed the compliance of cars

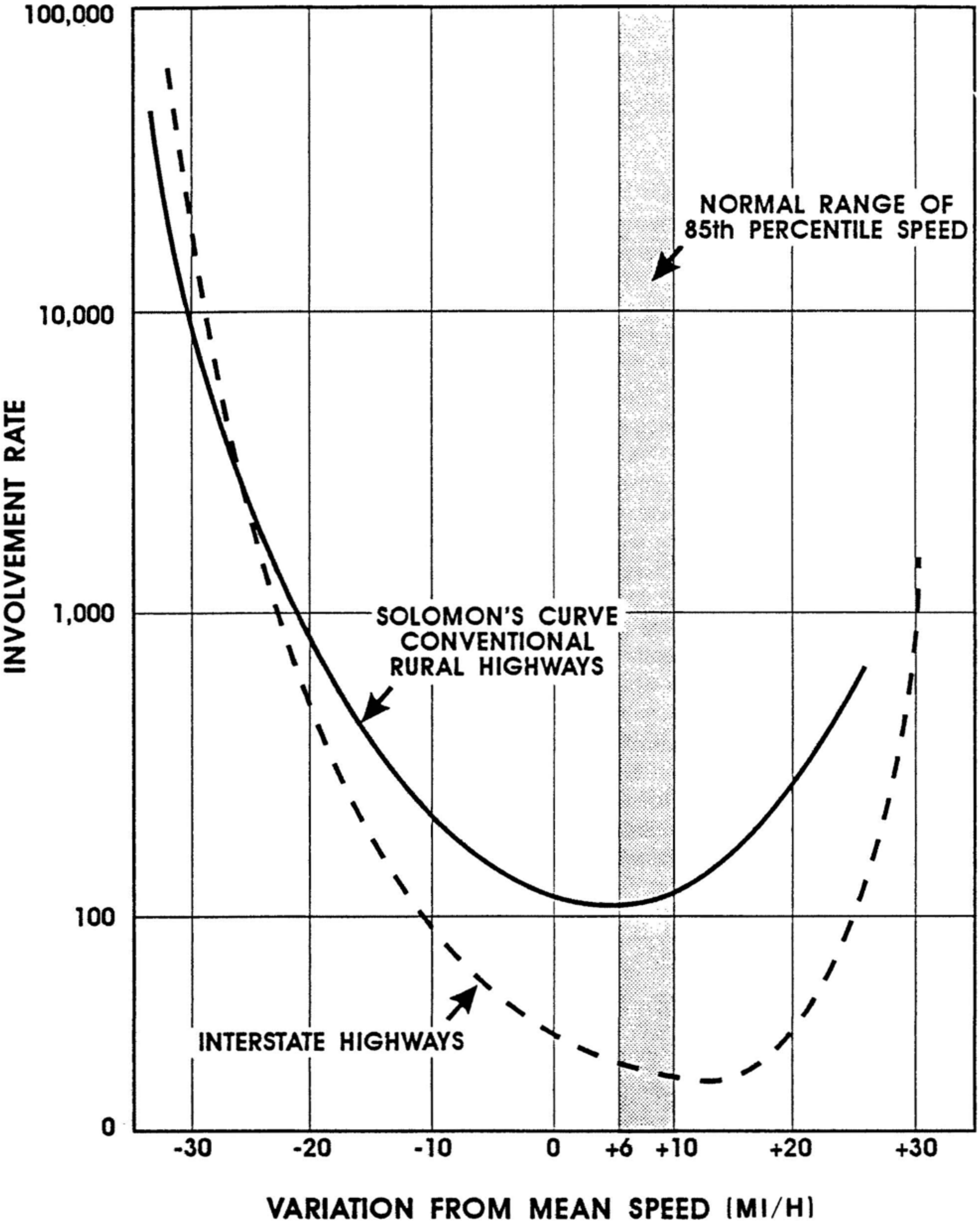


Figure 2. Accident involvement rate curves.

and trucks with their respective speed limits to be very low, but much worse for trucks. As noted by the author, "The overwhelming conclusion with regard to these data was that the posted speed limit for trucks on Interstate routes is consistently disregarded."(1)

One of the variables analyzed by Esterlitz et al. was the was the percentage of vehicles exceeding 70 mi/h (113 km/h). The rationale for choosing this value was related to the fact that 70 mi/h (113 km/h) is the nominal design speed for rural Interstate highways. The results, shown in table 1, indicated that the percentage of trucks exceeding 70 mi/h (113 km/h) was much greater in States with uniform limits compared to States with differential limits. This result was not surprising when considering that trucks in the differential speed limit States must travel 15 mi/h (24 km/h) over their respective speed limit in order to fall into this category. The differences in the percentage of cars exceeding 70 mi/h (113 km/h) by type of speed limit was obviously much smaller since cars are traveling under the same limit in both States. It should also be noted that the percentage of cars is much greater than the percentage of trucks exceeding 70 mi/h (113 km/h).(8)

Table 1. Percent exceeding 70 mi/h.[8]

State	Speed Limit	Trucks	Cars
AZ	Uniform	13.8	26.6
CA	Differential	4.0	20.3
IA	Uniform	9.0	16.6
IL	Differential	3.2	18.5

1 mi/h = 1.61 km/h

ACCIDENT INVOLVEMENT

A recent National Highway Traffic Safety Administration (NHTSA) study examined accident data from four States which raised the speed following the passage of the 1987 Federal legislation. Two of the States (Georgia and Florida) have uniform 65 mi/h (106 km/h) speed limits while the other two (Ohio and Virginia) have differential speed limits of 65/55 mi/h (105/89 km/h) for cars/trucks. The data base consisted only of those accidents which contained police-reported estimated travel speeds of the vehicles involved. As noted by the authors, while under reporting of speed involvement is a perceived problem, the data base does portray relative speeding involvement for different vehicle types since there is no proof that this under reporting is greater for any vehicle type. However, the results presented here should still be interpreted with some degree of caution.(13)

The results of the study show a higher percentage of speeding combination trucks involved in accidents in the States with differential speed limits (*see table 2*). This result may be expected since trucks in these States are more likely to exceed their respective limit of 55 mi/h (89 km/h) when compared to the trucks in the States with the higher limits of 65 mi/h (105 km/h). The values for the "high-speed" accidents (exceeding 65, 70 and 75 mi/h (105, 113, and 121 km/h)), however, indicate very little difference in the percentages of trucks involved between the two types of speed limits. This table also illustrates the fact that the percentage of crash-involved vehicles exceeding the speed limit is generally lower for trucks compared to cars.

Table 2. Percentages of crash-involved vehicles as a function of speed limit compliance for States with differential and uniform limits.

Speed Limit Compliance	Combination Trucks		Passenger Vehicles	
	Uniform	Differential	Uniform	Differential
% not speeding	95.53	94.41	93.78	95.09
% exceeding limit	4.47	5.60	6.23	4.92
% exceeding 65 mi/h	0.51	0.48	0.89	0.69
% exceeding 70 mi/h	0.14	0.18[1]	0.46	0.48
% exceeding 75 mi/h	0.06	0.10	0.30	0.23

[1] Computed with data from Virginia only since Ohio data did not provide this level of detail.

1 mi/h = 1.61 km/h

Data from the Fatal Accident Reporting System were examined in a similar manner to determine the percentages of trucks involved in fatal crashes compared to other types of vehicles. The results showed passenger cars at a much greater risk of being involved in a fatal crash compared to a combination truck. With respect to vehicles in excess of 70 mi/h (113 km/h), only 1 of every 120 crash-involved vehicles was a truck. In addition, only 1 of every 135 fatal crash-involved trucks was in excess of 70 mi/h (113 km/h).

The type of truck accidents of greatest concern on differential speed limit roadways has been the front-to-rear involvement. In 1977, Zaremba and Ginsburg conducted a study to investigate the effects of front-to-rear accidents of both cars and trucks before and after the enactment of the mandatory 55 mi/h (89 km/h) speed limit in 1974. Three of the four States (North Carolina, Maryland, and Pennsylvania) examined in this study had differential speed limits [70/45, 70/60, and 65/55 mi/h (113/64, 11/97, and 105/89 km/h), respectively] before the law was enacted. The fourth State (Texas) had a uniform limit of 70 mi/h (113 km/h). The accidents investigated occurred in the time frame of 2 to 4 years (depending on the State) prior to and within 1 year after the speed limit change during 1974.[14]

The overall reduction in auto-truck front-to-rear accident rates created by moving to a uniform limit was approximately 15 percent on high-speed roadways (Interstate highways, rural U.S. highways and State roads). This accident type was separated into car-struck-in-rear-by-truck (CSRT) and truck-struck-in-rear-by-car (TSRC) accidents, and accident rate reductions of 5 and 34 percent, respectively, were observed. The TSRC accident rate had a overwhelming reduction due to the uniform and lower speed limit.

The report also noted a decrease of 19 percent in car-struck-in-rear-by-car (CSRC) accident rates after the implementation of the 55 mi/h (89 km/h) limit. The explanation of this reduction was not stated. One possible explanation of the reduction of the CSRC accident occurrence on uniform speed limit facilities could have been due to the absence of cars being hampered (slowed) by the lower travel speed of trucks, thus increasing the potential for a car to strike the rear of another car. Under the uniform speed limit, additional reductions in CSRC accidents could possibly have been due to the absence of low speed passing maneuvers previously caused under the differential limit by slower trucks.

The 1991 study conducted by Garber and Gadiraju included an analysis of accident data. The data collected for each segment included a minimum of 3 years of "before" data and 1 year of "after" data. Variables extracted from the data and used in the analysis included accident severity, number of vehicles involved, vehicle types involved, and collision type. The results of the analysis indicated the following:[7]

- There was no statistically significant difference in fatal, injury, or overall accident rates before and after the differential speed limit was imposed at the test sites.

- Accident rates at the control locations were unaffected by the change in speed limit at the test sites.

- Comparisons of accident rates in the adjacent States of Virginia and West Virginia resulted in: a) relatively more rear-end accidents in Virginia, suggesting this may be the result of the differential limit; and b) a lower number of two-vehicle accidents in West Virginia than in Virginia after the changes in speed limits.

The overall conclusions of the authors of this effort are that differential speed limits of 65/55 mi/h (105/89 km/h) for cars/trucks do not provide any safety benefit over uniform limits of 65 mi/h (105 km/h). In fact, one of their results indicated "...that the imposition of the differential speed limit on Interstate highways with average annual daily traffic (AADT) less than 50,000 may result in higher rates for certain types of accidents such as rear-end and sideswipe accidents..."[7]

Accident data from 1970 and 1971 were analyzed by Hall and Dickinson to determine any relationships which may exist between speeds, speed limits, and safety. The results of this analysis resulted in the following conclusions:[3]

- The truck accident rate decreased as truck speeds increased. The authors cautioned, however, against extrapolating these results to truck speeds higher than those observed in the study. It was noted that only 3 percent of all truck speeds measured were in excess of 70 mi/h (113 km/h).

- There was no relationship between truck accidents and the posted differential speed limit, i.e., the reduced limit for trucks did not result in a decrease in truck accidents.

TRUCK CHARACTERISTICS

The operating and dimensional characteristics of combination vehicles, as well as large straight trucks, are often cited as reasons for the appropriateness of lower speed limits for these vehicles. A 1989 study by Garber and Gadiraju, through simulation modelling, examined the issue of lower speed limits for trucks as well as lane restrictions. The results of the effort showed lower speed limits and right-lane only restrictions to result in increased interactions between cars and trucks. The recommendation was for trucks and cars to have the same speed limit, preferably 65 mi/h (105 km/h).[15]

Central to the arguments for lower truck speed limits is the concept of "balanced braking." This concept is based on the premise that a large truck traveling at the same speed as a car will require a longer distance to react and come to a complete stop. In order to make the stopping distances the same for each vehicle type, trucks must travel at a lower speed limit. A 1978 study by Fry et al., conducted in Australia, provided an example of this concept. The recommendation based on this analysis was a continuance of the already existing lower speed limit for trucks.[16] However, the problem with the study by Fry et al. is the lack of recognition of the higher eye sight level of a truck driver compared to a driver of a passenger vehicle. This mistake was noted in a 1985 report by the Federal Office of Road Safety in Australia which recommended that differential speed limits were not justified.[17]

AASHTO, while recognizing braking differences between vehicles, also recognizes the increased height of the truck driver as noted by this statement: "Trucks as a whole, especially the larger and heavier units, require longer stopping distances from a given speed than passenger vehicles do. However, there is one factor that tends to balance the additional braking lengths for trucks for given speeds with those for passenger cars. The truck operator is able to see the vertical features of the obstruction substantially farther because of the higher position of the seat in the vehicle." For this reason, AASHTO does not provide two separate design values for stopping sight distance for cars and trucks.[2]

An evaluation of the stopping sight distances currently recommended by AASHTO was recently conducted by Harwood et al. Stopping sight distances were derived from the AASHTO equations for braking an empty tractor semi-trailer, with good tires, on a poor, wet road. Three scenarios were considered: 1) conventional braking system with a best-performance driver, 2) conventional braking system with a worst-performance driver, and 3) antilock braking system. The results indicated that the distances for the truck with the antilock braking system were equivalent to or better than the AASHTO criteria. The trucks with conventional brake systems, however, did not perform very well. In only 1 case out of 12 was the derived stopping sight distance equivalent to the AASHTO criteria. In the remaining cases, the truck required longer distances, especially for the worst-performance driver. A new set of stopping sight distances for the design of new roadways was recommended unless antilock brakes become universal in the trucking industry.[18]

CHAPTER 3 - RESEARCH METHODOLOGY

The research methodology for meeting the objectives of this study was designed to answer two key questions:

- *What impacts do different types of speed limits have on traffic operations, i.e., what are the effects on travel speeds of cars and trucks?*

- *What impacts do different types of speed limits have on transportation safety, i.e., what are the effects with respect to the types of accidents, the types of vehicles involved, and crash severity?*

Obtaining answers to these questions required the collection and analysis of both speed and accident data. Provided below is a brief summary of the methodology employed in this research effort for each type of data.

SPEED DATA ANALYSIS METHODOLOGY

To assess the impact of speed limits on travel speeds of cars and trucks, speed and vehicle classification data were collected primarily at rural locations with supplemental data collected at urban locations in 11 States. The data collection sites were selected in pairs, such that each pair contained the same general traffic stream traveling under two different speed limits. The criteria used in the selection process, the number of sites selected, and the speed limits of each matched pair of sites are discussed in the next chapter.

The measures of effectiveness (MOE's) used in the analysis of the speed data were selected to assess the impact of speed limits on travel speeds of cars, trucks, and where applicable, the overall traffic stream and included:

- Mean speed.

- Speed variance (standard deviation and coefficient of variation).

- Speed distribution (85th - 15th percentile speeds).

- Noncompliance (percentage of vehicles exceeding the speed limit by various amounts).

In addition to speed limit and vehicle type, other independent variables included in the analysis were time of day (day vs. night vs. dawn/dusk), day of week (weekday vs. weekend), and area (rural vs. urban).

ACCIDENT DATA ANALYSIS METHODOLOGY

Determination of any differences in accidents which may be associated with the various speed limits required large statewide data bases. In addition, adequate volume data were necessary to control for exposure. Thus, accident and volume data were collected from nine States representing the full range of rural Interstate speed limits now in effect. The time period was from the date of the speed limit change in each State through the end of 1990, which resulted in over 3 years of data for all States except one.

The primary MOE selected for the analysis was the proportion of accidents classified by collision type, vehicle type, or accident severity. The primary stratifying variable was traffic volume.

CHAPTER 4 - DATA COLLECTION AND REDUCTION

SITE SELECTION

Selection of States

The country was divided into three regions (east, central, and west) in order to obtain at least three States per region with different types of speed limits (uniform and differential) while acquiring the desired national representation in terms of geographics. The States in each region were selected based on the rural Interstate speed limit, the speed limit of the adjoining State, and the number of Interstate routes crossing State boundaries that would allow for simultaneous collection of speed data in two States with different speed limits.

Based on these criteria, 12 States were selected as shown in table 3. This selection resulted in 4 States with 65/65 uniform speed limits, 4 with 65/55 differential limits, 3 with 65/60 differential limits, 1 with a 55/55 uniform limit. Statewide accident data were acquired from 9 of the 12 States (3 in each region) while speed data were collected in 11 States.

Speed Data Locations

The selection of sites where speed data were collected within the chosen States fell into two categories: 1) rural contiguous locations, and 2) rural/urban locations. Provided below are details on the sites selected and the criteria used in making the selections.

Rural Contiguous Locations

The objective of selecting rural Interstate locations in contiguous States was to collect data simultaneously at matched pairs of sites straddling the border. This type of data collection allowed for the comparison of the same general traffic stream traveling under two different speed limits (e.g., 65/65 vs. 65/55). The criteria used to select these locations were as follows:

Table 3. States included in the study.

Region	State	Type of Data Collected		Car/Truck Speed Limit (mi/h)
		Speed	Accident	
East	NC	√	√	65/65
	VA	√	√	65/55
	PA		√	55/55
Central	IA	√	√	65/65
	MO	√		65/60
	IN	√	√	65/60
	IL	√	√	65/55
West	ID	√	√	65/65
	AZ	√		65/65
	WA	√	√	65/60
	OR	√	√	65/55
	CA	√		65/55

1 mi/h = 1.61 km/h

- Each matched pair of contiguous State rural Interstate sites had to be separated by no more than 100 mi (161 km) and no major urban area or major Interstate interchange could exist between the sites.

- The permanent loop detectors, if available, had to be located such that data could be collected for the same direction of travel for each matched pair.

- The geometric features, including number of travel lanes and type of terrain, for each matched pair had to be similar.

- Each site had to be a minimum of 5 mi (8 km) from the State line to allow time for drivers entering a State to adjust to a new posted speed limit. The sites also had to be located a minimum of 1 mi (1.6 km) downstream from any interchange.

Applying these criteria, 13 matched pairs, or 26 rural contiguous sites, were selected in 11 States as shown in figure 3. These locations allowed for the comparison of speeds between locations with the uniform 65/65 speed limit and those with either type of differential limit.

Rural/Urban Locations

In addition to the rural contiguous locations, pairs of urban and rural sites on the same Interstate were also selected. Simultaneous data collected at these matched pairs of sites allowed for the comparison of speeds of the same general traffic stream traveling under the uniform urban speed limit of 55 mi/h (89 km/h) and the three different rural speed limits included in the study. The criteria used to select these locations were the same as those used for the selection of the rural contiguous locations with respect to separation distance, location of loop detectors, geometric features, and distance downstream of an interchange. Using these criteria, three matched pairs (six sites) were selected; one pair for each type of rural speed limit included in the study (*see figure 3*). The rural sites included in these rural/urban pairs also served as rural contiguous locations.

DATA COLLECTION

Speed Data

The speed data collected for this study consisted of 24-hour continuous data obtained with automatic traffic recorders (ATR's). The raw data collected for each vehicle passing the site during the data collection period consisted of speed, number of axles, axle spacings, lane of travel, and time of passing as shown in figure 4. This type of data were collected simultaneously during a weekday at each of the 13 rural contiguous site pairs and the 3 rural/urban site pairs selected for the study. In addition, weekend data were collected at three rural contiguous site pairs. Provided below is a discussion of the field procedures employed during the data collection effort.

During the selection of sites, proper authorities within each State were contacted to determine the location of all speed and count stations where permanent loops were located and to learn of any special requirements for the field data collection efforts to be undertaken in this study. This step was followed by the acquisition of permits and the completion of other requisite paperwork in each State. Upon arriving in a State where data were to be collected, the two-person field team met with proper State officials to further discuss specific deployment guidelines and schedules of work.

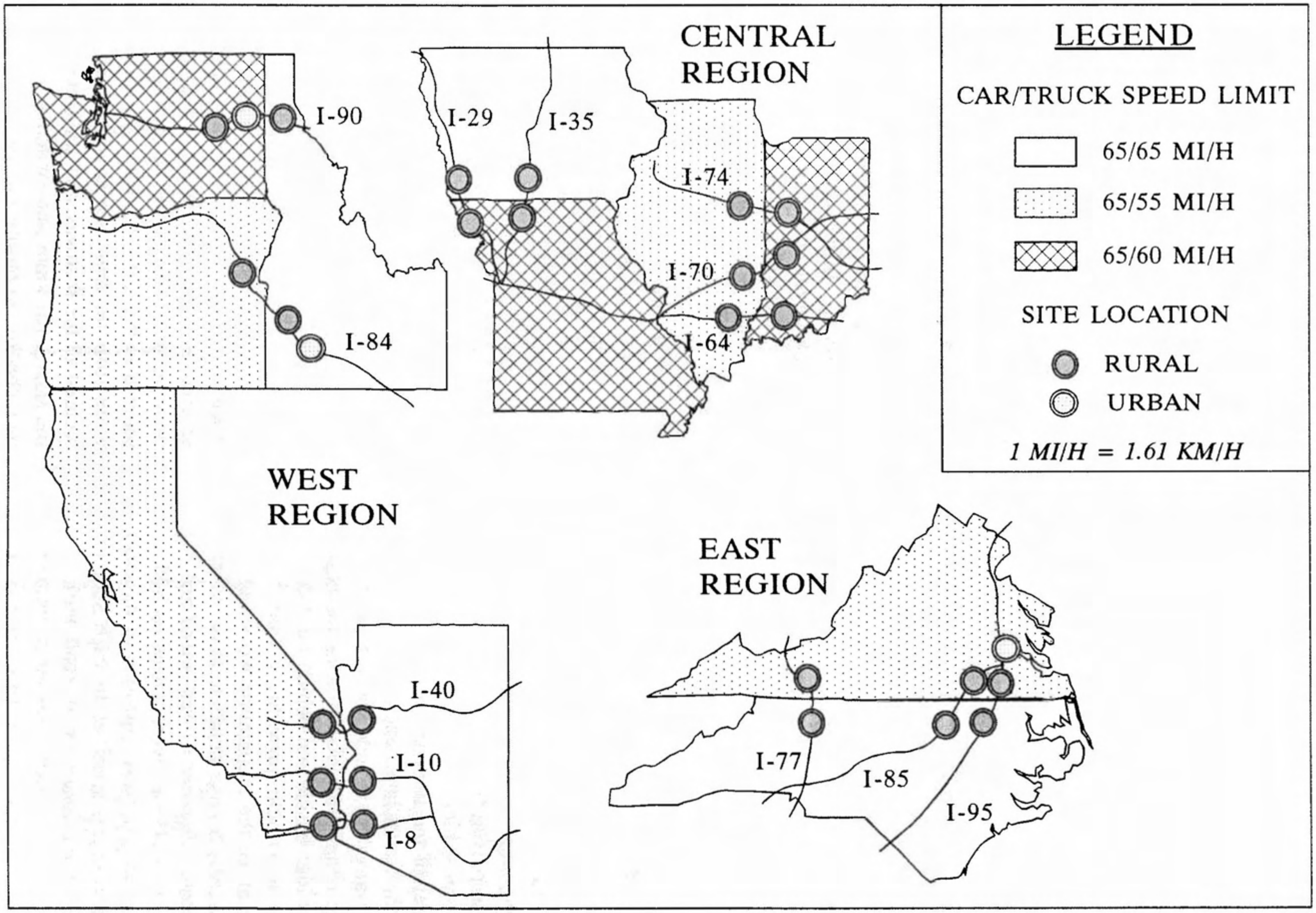


Figure 3. Speed data collection sites.

```
File OPENED at 11/20/90 16:48
STORAGE: Raw
SITE  : I77MP63.5
INFO#1 : RURAL NC
INFO#2 : WITH RURAL VA I77MP19.3
2 Active Lanes. Date Format = MM/DD/YY. Unit Type = 1

3: LANE USED   TRIG=LOOP   AXLE=TPSW   PRES=LOOP
   Sensor Spacing=16.0'     Loop2 Length= 6.0'
   INFO: ______________     1 Record Interval:
   INTERVAL#1 Start=00:00  Length=00:15

4: LANE USED   TRIG=LOOP   AXLE=TPSW   PRES=LOOP
   Sensor Spacing=16.0'     Loop2 Length= 6.0'
   INFO: ______________     1 Record Interval:
   INTERVAL#1 Start=00:00  Length=00:15

3: 16:48:22  54MI/H,  2 Axles,  9.7'
3: 16:48:24  57MI/H,  7 Axles, 14.9'  4.5' 28.5'  4.2'  8.6' 20.6'
3: 16:48:26  56MI/H,  7 Axles, 16.7'  4.3' 26.5'  3.9'  8.0' 19.6'
3: 16:48:28  61MI/H,  2 Axles,  9.3'
4: 16:48:46  64MI/H,  2 Axles,  8.9'
4: 16:48:47  61MI/H,  2 Axles,  8.5'
4: 16:48:51  59MI/H,  2 Axles,  8.5'
3: 16:48:51  59MI/H,  5 Axles, 16.6'  4.3' 31.4'  3.9'
3: 16:49:24  59MI/H,  2 Axles, 11.1'
4: 16:50:19  55MI/H,  2 Axles, 10.5'
3: 16:50:25  59MI/H,  2 Axles,  9.0'
```

Figure 4. Beginning of speed data collection file.

Once the field team arrived at a deployment site, several safety measures were employed (*see figure 5*). The data collection vehicle was pulled onto the right shoulder of the Interstate at a safe distance from the travel lanes and a flashing yellow beacon atop the vehicle was activated. Traffic cones were placed along the edge of shoulder beside and behind the data collection vehicle, providing a work area where all of the preparation work was conducted. Signs, including those which read *Right Shoulder Closed Ahead* and *Road Work Ahead*, were placed on both sides of the roadway upstream of the work site at distances specified by each State to ensure driver awareness of road work ahead. Finally, each member of the field team wore proper safety attire, including a reflectorized safety vest.

With the safety measures in place, the deployment of the equipment proceeded. Depending on the availability and working order of permanent loops at the site, the required number and configuration of tape switches and permanent or portable loops was first determined. There were two types of sites encountered. The first type was a speed monitoring station in which two permanent loops were located in each travel lane. The second type was a count station in which only one permanent loop was available in each travel lane. For the first scenario (two permanent loops per lane), a tape switch was placed between each set of loops as shown in figure 6 - scenario A. In this configuration the tape switch serves as an axle sensor while the loops detect vehicle presence and crossing times for computing speeds. For the sites with one permanent loop, tape switches were located upstream and downstream of the loop as shown in figure 6 - scenario B. In this configuration, the loop detects vehicle presence while the tape switches detect axles and crossing times for determining vehicle speeds. For those sites where no permanent loops existed or where the loops were damaged, portable temporary loops were used in place of the permanent loops.

Once the determination was made regarding the equipment to be placed on the roadway, all preparation work was conducted on the shoulder of the Interstate. The portable loops used (if any) were then placed in the center of each travel lane and secured using industrial tapes. The tape switches were then placed in each lane and secured in the same manner. All lead wires from the deployed equipment were secured to the roadway and connected to the ATR. All loops and switches were then checked to ensure that each was working properly. The final step in equipment deployment was to check the

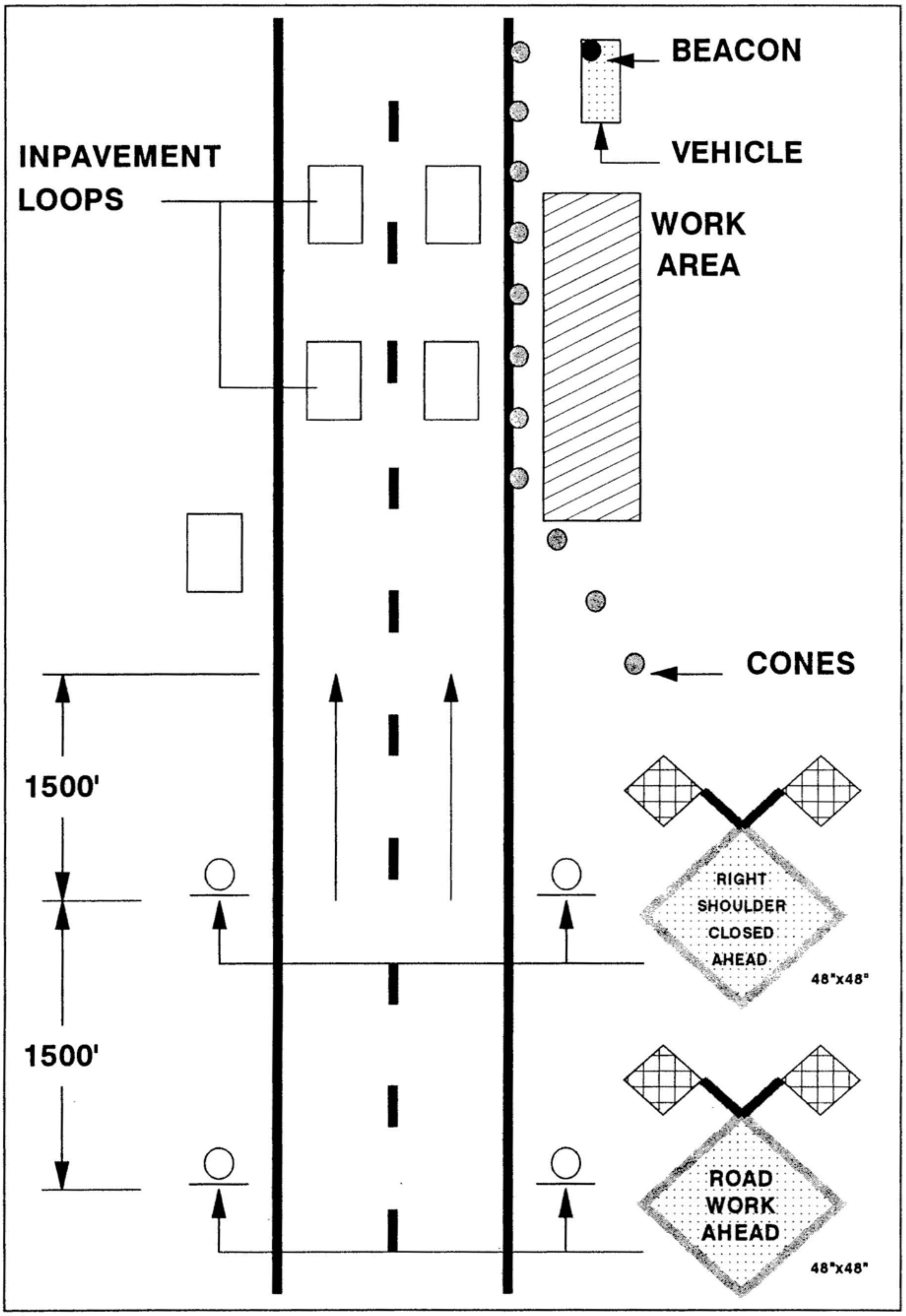


Figure 5. Location of signs and other safety devices at data collection sites.

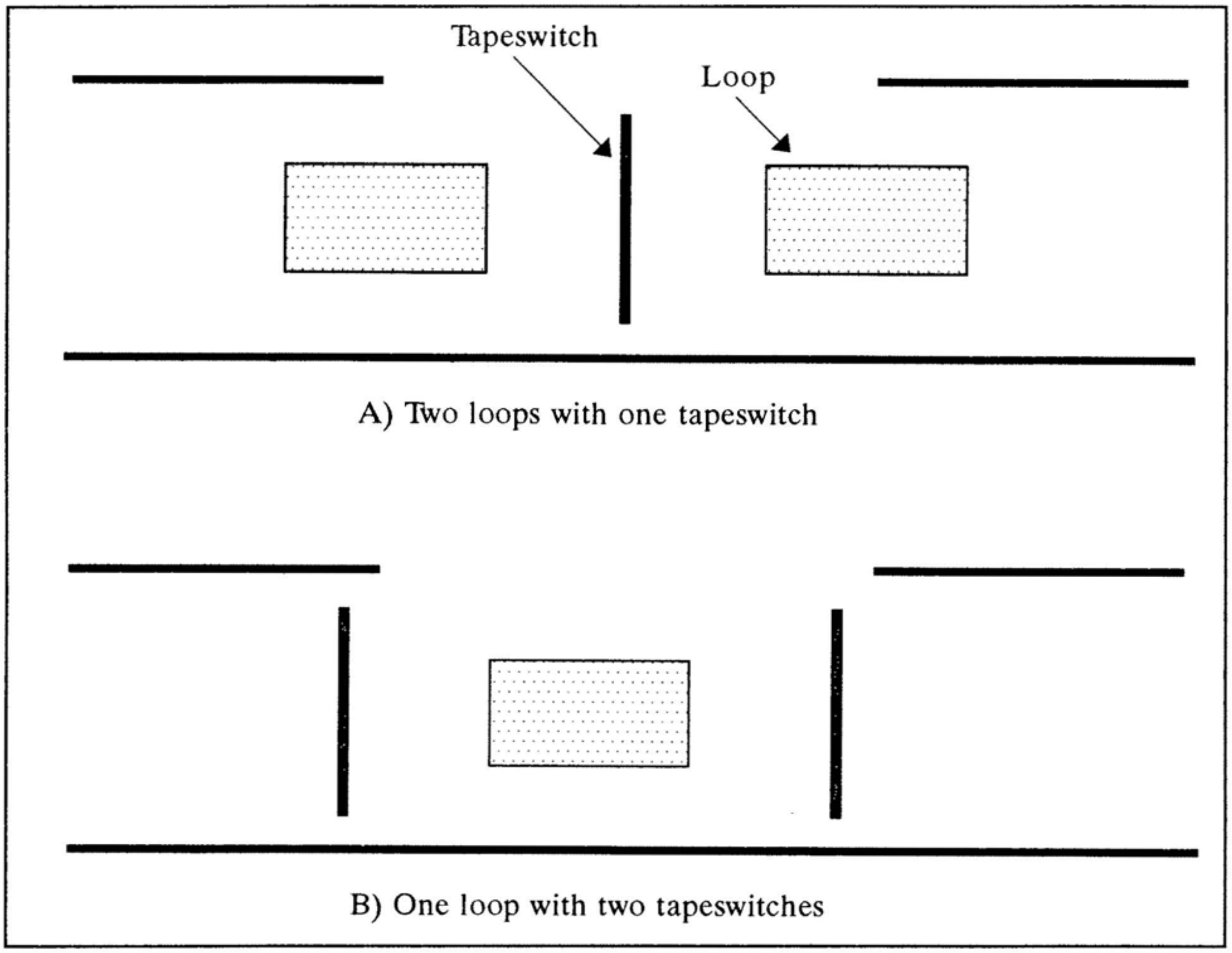


Figure 6. Configuration of loops and tape switches for speed data collection.

accuracy of the traffic stream data being collected by the ATR. A calibrated radar gun was used to acquire vehicle speeds which in turn were compared to the speeds being monitored by the ATR. The allowable tolerance between the two devices was ± 1 mi/h. (1.61 km/h). The other items checked with respect to equipment operations were the number of axles and axle spacings of various vehicle configurations. With all equipment properly deployed and calibrated, the ATR was programmed to collect raw vehicle data for a 24-h period.

At the conclusion of the data collection period, the data recorded by the ATR were checked for accuracy by computing the percentage of usable vehicles, i.e., those with a recorded speed and axle spacing(s). Valid data for a minimum of 75 percent of the vehicles traversing the site during the period must have been obtained for the site to have been accepted as a success. Otherwise, the equipment problems were determined and corrected, and the ATR was reset to collect an additional 24 h of data. If the threshold was met or exceeded, the data were downloaded to a laptop computer. The signs, traffic cones, and other safety devices were then put in place, and the equipment was removed from the roadway.

Accident Data

Statewide Interstate accident data were acquired from 9 of the 12 States as previously shown in table 3. The nine States were Pennsylvania, Virginia, North Carolina, Indiana, Illinois, Iowa, Idaho, Oregon, and Washington. This selection resulted in three States (each with a different rural Interstate speed limit) in each region of the country previously established. The time period for which the data were obtained was from the time the speed limit was increased in 1987 through the end of 1990, resulting in more than 3 years of accident data. The one exception was Virginia, whose speed limit changed in July 1988. The variables acquired included all those available on the complete accident record maintained by each State.

To supplement the accident data, other pieces of information were also acquired. This included information regarding the exact mileposts where the speed limits changed from rural to urban and the dates on which those changes became effective, and traffic volume counts for the Interstates for the same years as the accident data provided. This information was used for separating rural and urban accidents and for stratifying the accident data during the analysis.

DATA REDUCTION

Speed Data

Summary statistics for the raw vehicle speed and traffic stream data collected at each location were produced using a simple analysis program and included:

- Mean speed.
- Percentile speeds.
- Standard deviation.
- Compliance statistics.
- Pace statistics.

These statistics were produced for all free-flow vehicles (those with headways $\geq$ 4 seconds) at a given location and for three separate classes of free-flow vehicles - cars, trucks, and other. The *cars* classification encompassed vehicles such as passenger cars, pickup trucks, and vans. The *trucks* classification included all combination trucks (semis, doubles, and triples). And finally, the *others* classification included single unit trucks, dump trucks, buses, recreational vehicles, and other vehicles which did not fall into either of the other two classifications. The analyses discussed in the next chapter primarily examined the *car* and *truck* data. The *other* data were not included due to the inconsistencies between States with respect to the vehicle types governed by the lower rural Interstate speed limits. In some States, single unit trucks exceeding weight thresholds were included while in others cars pulling trailers were included. These inconsistencies, combined with the fact that fewer than 5 percent of the traffic generally fell into this classification, resulted in the decision to examine only those vehicle classes which were consistently governed by rural Interstate speed limits in all States, i.e., passenger vehicles and combination trucks.

The summary statistics were produced for the full 24-h data collection period at each location as well as daytime, nighttime, and dawn/dusk time periods. The daytime period was defined as beginning at 8 am and ending at 5 pm while the nighttime period was from 9 pm until 6 am. The dawn/dusk time period included the remaining hours.

Accident Data

The accident data received from each State were downloaded to a personal computer and prepared for data analysis. The variables desired from each file were extracted and all variable codes were converted to a common format. Shown in table 4 are the variables that were retrieved from the final accident files for each State. However, it should be noted that all States do not include all of the desired variables in their files. Thus, some of the analyses conducted were limited to fewer than nine States.

Table 4. Variables retrieved from the State accident files.

Route	Collision type
Milepost	Vehicle type
Estimated travel speed	Date
Time of day	Weather conditions
Day of week	Surface conditions
Speed limit	Light conditions
Number of vehicles	Number of injuries
Number of fatalities	Accident severity
Driver condition	Violations
Age	Sex
Pre-crash maneuver	Injury severity
Contributing circumstances	Seatbelt use
Direction of travel	Vehicle condition

CHAPTER 5 - SPEED DATA ANALYSIS

As discussed in chapter 3, the objective of the speed data analysis was to assess the impact that different types of speed limits have on travel speeds of cars and trucks. Provided in this chapter are discussions of the evaluation methods employed and the results obtained in the statistical analyses. The primary analysis focused on the 13 rural contiguous site pairs discussed in chapter 4, and the results are presented in three sections: 1) analysis of mean speeds, 2) analysis of speed variance, and 3) analysis of other speed distribution characteristics. Additional sections at the end of the chapter discuss the analysis of weekday versus weekend data and rural versus urban data.

The sampling unit in the following analyses is the site. Thus, the dependent variables for a given site represent estimated values of the population, produced through the measurement of speeds of thousands of vehicles over a 24-h period. However, the large number of measurements acquired during the data collection period allows for the assumption that the sampling values are very accurate measurements of the population under the conditions the data were collected. The dependent and independent variables used in the analyses, along with the variable names used in many of the subsequent tables are shown in table 5.

ANALYSIS OF MEAN SPEEDS

Time of the Day and Vehicle Type

Shown in table 6 are the mean speeds by time of the day and vehicle type for each pair of rural contiguous locations. The highest mean speeds for cars typically occurred during the dawn/dusk time period while the lowest mean speeds occurred at night. For each site the standard deviation of the mean speeds for the three time periods was calculated to further assess the influence of time of day and is also shown in the table. While these standard deviations were, for most of the rows, less than 1.0, the consistency with which nighttime mean speeds were the lowest values suggest a general trend. Thus, a potential significant difference in mean speeds by time of day may exist.

The pattern for trucks is not as clear. At most of the sites, the dawn/dusk time period contained the highest mean speeds of the three time periods, similar to the data for car speeds. At many of the sites, however, the nighttime mean speeds were greater than the daytime mean speeds. Thus, the tendency to reduce speeds at night was very clear for cars but was not as conclusive for trucks. This indicates that possible interactions between the variables vehicle type and time of day may exist.

Although the differences in mean speeds for the three time periods were very small, they may still be statistically significant, given the consistency presented by the data. Further evidence of the consistency in mean speeds by time of day is shown in table 7 in which the data are grouped by type of speed limit and State. Again, the highest mean speeds for both cars and trucks occurred during the dawn/dusk time period while the lowest mean speeds for cars occurred at night, and the lowest speeds for trucks were mixed between day and night periods.

Examining the group means in table 7, the magnitudes of the differences in the

Table 5. Dependent and independent variables included in the speed data analysis.

Variable	Variable Name	Description
Dependent		
Mean Speed	**MEAN**	Mean speed of 24-h sample
Standard Deviation	**SDEV**	Standard deviation of 24-h sample
Mean Speed Difference	**DIFF**	Difference in mean speeds of contiguous site pairs
Coefficient of Variation	**CVAR**	Standard deviation divided by the mean (expressed as a percentage)
Noncompliance	**NCXX**	Percentage of vehicles in sample exceeding speed limit by various amounts, e.g., NC10 represents the percentage of vehicles exceeding limit by 10 mi/h.
Percentile Speed	**PXX**	Percentile speed of 24-h sample; e.g, P85 represents the 85th percentile speed.
Independent		
Vehicle Type	**VEHTYPE**	Two levels: car vs. truck
Time of Day	**TIMEDAY**	Three levels: day vs. night vs. dawn/dusk
Day of Week	**DAYWEEK**	Two levels: weekday vs. weekend
Speed Limit (mi/h)	**SPEEDLIM**	Three levels (car/truck): 65/65 vs. 65/60 vs. 65/55
Area	**AREA**	Two levels: rural vs. urban
Pair Type	**PAIRTYPE**	Six levels: created through the combination of vehicle type and speed limit.

1 mi/h = 1.61 km/h

mean speeds by time of day were very similar for all three speed limits. This fact indicates that speed limit alone did not affect the speeds of drivers during different times of the day. In other words, there was no interaction between time of day and type of speed limit. This point is illustrated in figure 7 which shows a plot of the mean speeds by time of day and vehicle type. The three lines for each type of vehicle (cars and trucks) are reasonably parallel, indicating no interaction between time of day and type of speed limit. However, the two groups of lines, i.e., cars versus trucks, are not parallel. This fact confirms previous statements that interactions may exist between the variables time of day and vehicle type.

To determine if mean speed is significantly affected by time of day, a randomized complete block design was selected, with the sites (**SITE**) serving as the blocking variable. Since interactions

Table 6. Mean speeds of cars and trucks by site by time of day.

Pair/ Route	State	Mean Car Speeds (mi/h)					Mean Truck Speeds (mi/h)				
		All Day	Day	Night	Dawn/ Dusk	Std. Dev.	All Day	Day	Night	Dawn/ Dusk	Std. Dev.
1	NC	68.8	68.8	67.7	69.3	0.8	65.1	65.3	64.3	65.7	0.7
77	VA	69.7	69.9	68.7	70.1	0.8	64.3	64.7	63.1	65.1	1.1
2	NC	65.6	65.5	65.1	66.1	0.5	58.7	58.7	58.0	59.4	0.7
85	VA	66.9	66.7	65.9	67.8	1.0	59.3	59.6	58.6	59.8	0.6
3	NC	69.3	69.2	69.0	69.8	0.4	65.3	64.7	65.4	65.9	0.6
95	VA	68.8	68.7	68.2	69.5	0.7	59.1	58.8	59.1	59.5	0.4
4	IN	67.4	66.9	67.3	68.4	0.8	63.6	62.4	64.6	64.0	1.1
64	IL	66.3	66.3	65.2	67.1	1.0	61.6	61.5	61.7	61.9	0.2
5	IN	70.9	70.9	70.1	71.4	0.7	68.0	67.8	68.1	68.4	0.3
70	IL	66.7	66.8	65.5	67.3	0.9	62.4	62.3	62.6	62.3	0.2
6	IN	68.4	68.5	67.4	68.5	0.6	63.3	64.2	61.8	63.5	1.2
74	IL	66.6	65.9	65.7	67.4	0.9	59.0	59.0	57.9	59.9	1.0
7	IA	68.5	68.3	67.6	69.4	0.9	66.3	65.8	66.1	67.0	0.6
29	MO	67.5	67.6	67.0	67.8	0.4	64.5	64.9	63.8	65.1	0.7
8	IA	68.1	68.0	67.0	68.9	1.0	64.3	64.0	63.9	64.9	0.6
35	MO	65.5	65.5	64.7	65.9	0.6	59.8	59.5	60.2	59.7	0.4
9	ID	66.6	66.4	66.0	67.2	0.6	62.3	62.2	62.0	62.5	0.3
84	OR	66.6	66.5	66.7	67.0	0.3	60.2	60.5	60.0	60.3	0.3
10	ID	63.9	64.1	61.9	63.7	1.2	61.0	61.4	59.0	61.1	1.3
90	WA	67.2	67.2	67.8	67.2	0.3	62.3	62.2	62.5	62.7	0.3
11	AZ	69.2	69.2	68.9	69.2	0.2	67.2	66.9	67.8	66.9	0.5
8	CA	67.1	67.0	67.1	66.9	0.1	61.0	60.7	61.2	61.2	0.3
12	AZ	68.5	68.2	68.3	69.4	0.7	64.9	65.1	64.5	65.3	0.4
10	CA	68.0	68.6	66.7	67.4	1.0	60.4	61.7	59.8	60.0	1.0
13	AZ	67.8	68.5	65.6	67.1	1.5	62.5	62.1	62.8	62.2	0.4
40	CA	67.1	67.0	66.8	67.6	0.4	63.3	63.2	63.2	63.4	0.1

1 mi/h = 1.61 km/h

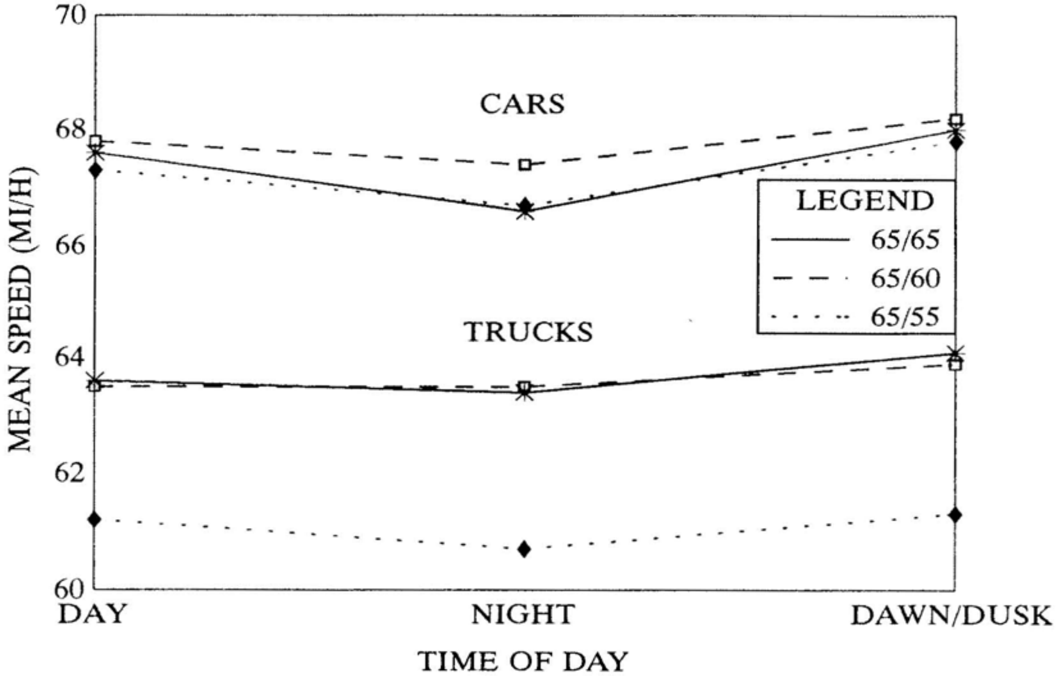
Table 7. Mean speeds of cars and trucks by speed limit by time of day.

Car/Truck Speed Limit (mi/h)	State	Mean Car Speeds (mi/h)				Mean Truck Speeds (mi/h)			
		All Day	Day	Night	Dawn/ Dusk	All Day	Day	Night	Dawn/ Dusk
65/55	VA	68.5	68.4	67.6	69.1	60.9	61.0	60.3	61.5
	IL	66.5	66.3	65.5	67.3	61.0	60.9	60.7	61.4
	CA	67.4	67.5	66.9	67.3	61.6	61.9	61.4	61.5
	OR	66.6	66.5	66.7	67.0	60.2	60.5	60.0	60.3
	Group Mean	67.4	67.3	66.7	67.8	61.1	61.2	60.7	61.3
65/60	IN	68.9	68.8	68.3	69.4	65.0	64.8	64.8	65.3
	MO	66.5	66.5	65.8	66.8	62.1	62.2	62.0	62.4
	WA	67.2	67.2	67.8	67.2	62.3	62.2	62.5	62.7
	Group Mean	67.8	67.8	67.4	68.2	63.6	63.5	63.5	63.9
65/65	NC	67.9	67.8	67.3	68.4	63.0	62.9	62.6	63.7
	IA	68.3	68.2	67.3	69.2	65.3	64.9	65.0	66.0
	AZ	68.5	68.6	67.6	68.6	64.9	64.7	65.0	64.8
	ID	65.2	65.2	64.0	65.5	61.6	61.8	60.5	61.8
	Group Mean	67.6	67.6	66.7	68.0	63.8	63.6	63.4	64.1

1 mi/h = 1.61 km/h

between time of day and vehicle type are suspected, two separate analyses of variance (ANOVA's) were conducted, one for cars and the other for trucks. Prior to performing the analysis, the assumptions of equality of variances within the blocks for the dependent variable mean speed were verified using Bartlett's test for homogeneity of variance. The test produced chi-square statistics for cars and trucks of 18.03 and 27.61, respectively. Both values are smaller than the critical value of 35.17 at the 95 percent confidence level, and thus, the variances within each vehicle class are equal.

The results from the ANOVA for car mean speeds are provided in table 8 and indicate that time of day did significantly affect car mean speeds ($P = 0.0001$). Comparisons between the three time of day periods were then made using the Bonferroni multiple comparison test. The results, also shown in table 8 showed significant differences, at the 95-percent confidence level, in mean speeds between the daytime and dawn/dusk periods, daytime and nighttime periods, and dawn/dusk and nighttime periods.



1 MI/H = 1.61 KM/H

Figure 7. Mean speeds of cars and trucks by time of day and speed limit.

Table 8. ANOVA and Bonferroni comparison test results for car mean speeds (MEAN) with class variable time of day (TIMEDAY) and blocking variable SITE.

ANOVA Results					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
TIMEDAY	2	17.06	8.53	33.11	0.0001
SITE	25	179.35	7.17	27.85	0.0001

Bonferroni Multiple Comparison Test Results		
Means by Factor Levels		Results
TIMEDAY	MEAN (mi/h)	$0.364 \leq \beta_D - \beta_N \leq 1.044$[1]
Day	67.55	$-0.771 \leq \beta_D - \beta_K \leq -0.091$[1]
Night	66.84	$-1.475 \leq \beta_N - \beta_K \leq -0.795$[1]
Dawn/Dusk	67.98	D = Day, N = Night, K = Dawn/Dusk

[1] Significant at the 95-percent confidence level
1 mi/h = 1.61 km/h

The results for the ANOVA for truck mean speeds are provided in table 9. With a P-value of 0.004, truck mean speeds were also significantly affected by time of day. Further analysis using the Bonferroni multiple comparison test indicated that mean speeds during the dawn/dusk time period are significantly greater than those during the nighttime period. However, the difference in mean speeds for daytime versus nighttime and dawn/dusk versus daytime were not significantly different.

Speed Limit

Shown in figure 8 are the average car and truck mean speeds for all sites grouped by type of speed limit. The speeds for cars were very similar. This is no surprise since cars were governed by the 65 mi/h (105 km/h) speed limit at all locations. Truck speeds, however, do differ, although not by the amounts reflected in the different speed limits. Trucks governed by the 55 mi/h (89 km/h) speed limit were only 2.5 and 2.7 mi/h (4.0 and 4.3 km/h) slower than trucks governed by the 60 and 65 mi/h (97 and 89 km/h) speed limits, respectively. Mean speeds of trucks governed by the 65 and 60 mi/h (105 and 97 km/h) speed limits were separated by only 0.2 mi/h (0.3 km/h).

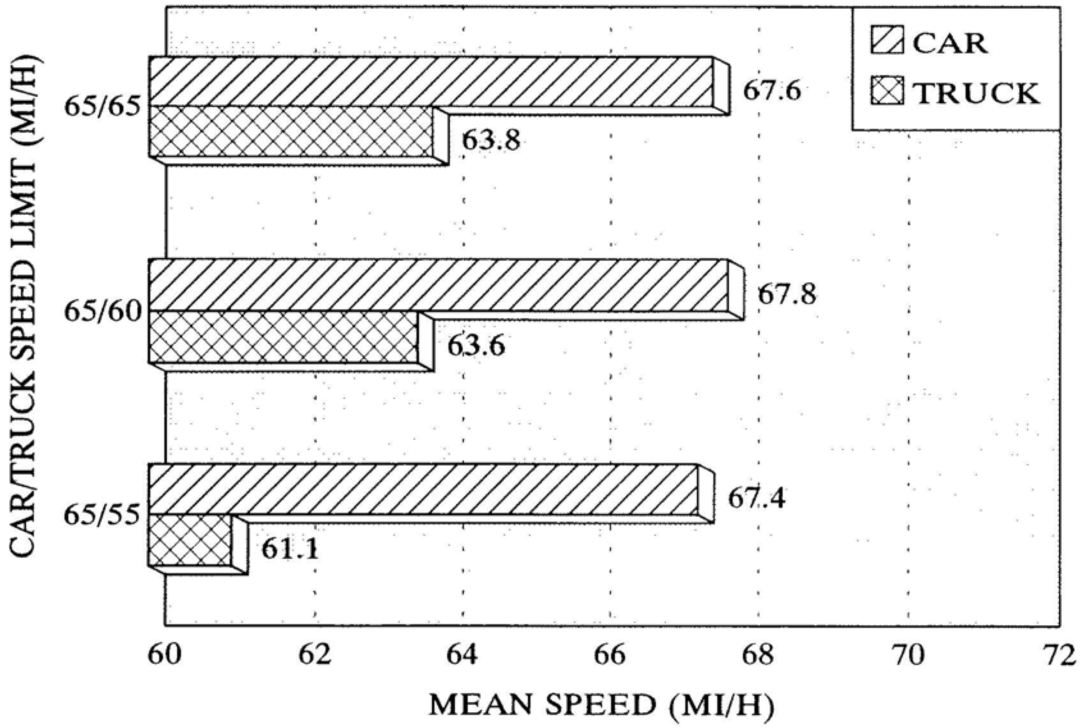
Several ANOVA's were run to assess how the three different speed limits (**SPEEDLIM**) affect the differences in the mean speeds of both cars and trucks. Other variables included in the analysis were time of day (**TIMEDAY**) and vehicle type (**VEHTYPE**). The first ANOVA

Table 9. ANOVA and Bonferroni comparison test results for truck mean speeds (MEAN) with class variable time of day (TIMEDAY) and blocking variable SITE.

ANOVA Results					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
TIMEDAY	2	4.75	2.38	6.17	0.0040
SITE	25	518.38	20.74	53.88	0.0001

Bonferroni Multiple Comparison Test Results		
Means by Factor Levels		Results
TIMEDAY	MEAN (mi/h)	$-0.139 \leq \beta_D - \beta_N \leq 0.693$
Day	62.66	$-0.743 \leq \beta_D - \beta_K \leq 0.089$
Night	62.39	$-1.019 \leq \beta_N - \beta_K \leq -0.188$[1]
Dawn/Dusk	62.99	D = Day, N = Night, K = Dawn/Dusk

[1] Significant at the 95-percent confidence level
1 mi/h = 1.61 km/h



1 MI/H = 1.61 KM/H

Figure 8. Mean speeds of cars and trucks by speed limit.

conducted included all variables and all interaction terms. The results are shown in table 10 and indicate the significant effect of speed limit and vehicle type on mean speeds with P-values of 0.0002 and 0.0001, respectively. The interaction between these variables also proved to be significant (P = 0.0039), indicating that the mean speeds for the two vehicle types are not consistently different across the three speed limit classes. The other variable, time of day, proved not to be significant in this model, and there was also no interaction between time of day and speed limit.

A second ANOVA was executed after eliminating the interaction term for time of day and speed limit. Time of day remained in the model since earlier analyses did find significant effects when analyzing each vehicle type separately. The results from this analysis reconfirmed the significance of speed limit and vehicle type on mean speeds, each with a P-value of 0.0001. The interaction between these two variables was also reconfirmed with a P-value of 0.0032. Time of day proved not to be a significant factor once again.

Due to the strong interaction between vehicle type and speed limit, two separate ANOVA's (one for cars and one for trucks) were performed to further analyze the impact of speed limit on mean speeds. The results, shown in table 11, indicate that speed limit was not a significant factor (P = 0.5794) on car mean speeds but was a significant factor (P = 0.0001) on truck mean speeds. Car speeds were also significantly affected (P = 0.0504) by time of day, confirming the results of earlier tests. However, truck speeds were not significantly affected by time of day (P = 0.6742).

Table 10. ANOVA results for car and truck mean speeds (MEAN) with class variables speed limit (SPEEDLIM), vehicle type (VEHTYPE), and time of day (TIMEDAY).

ANOVA Results					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
SPEEDLIM	2	77.65	38.82	9.15	0.0002
VEHTYPE	1	889.94	889.94	209.78	0.0001
TIMEDAY	2	19.75	9.88	2.33	0.1012
VEHTYPE x SPEEDLIM	2	48.88	24.44	5.76	0.0039
VEHTYPE x TIMEDAY	2	2.06	1.03	0.24	0.7850
SPEEDLIM x TIMEDAY	4	0.92	0.23	0.05	0.9944

Means by Factor Levels					
SPEEDLIM (Car/Truck)	MEAN (mi/h)	TIMEDAY	MEAN (mi/h)	VEHTYPE	MEAN (mi/h)
65/65	64.17	Day	65.15	Car	67.50
65/60	65.72	Night	64.73	Truck	62.80
65/55	63.13	Dawn/Dusk	65.50		

1 mi/h = 1.61 km/h

Since time of day did not impact truck speeds and there was no interaction between time of day and speed limit, a final ANOVA was performed for truck speeds with the single variable speed limit. The results produced a P-value of 0.0001, reconfirming the significant impact of speed limit on truck mean speeds. Comparisons between speed limit classes were then made using Tukey's multiple comparisons test. The results shown in table 12, indicate that the differences in mean speeds between the States with the 55 mi/h (89 km/h) truck speed limit and either of the other two truck speed limits was significant at the 95 percent confidence level. However, the difference between the States with the 65 and 60 mi/h (105 and 97 km/h) truck speed limits is not significant.

Contiguous Site Pairs

A final approach in assessing the effect of the speed limit regulations on car and truck mean speeds was an analysis of the 13 rural contiguous site pairs by type of speed limits governing each pair. Shown in table 13 are the six pair types included in the analysis and the number of

Table 11. Results of separate ANOVA's for car and truck mean speeds (MEAN) with class variables speed limit (SPEEDLIM) and time of day (TIMEDAY).

ANOVA Results for Car Mean Speeds					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
SPEEDLIM	2	3.01	1.50	0.55	0.5794
TIMEDAY	2	17.06	8.53	3.12	0.0504
SPEEDLIM x TIMEDAY	4	0.65	0.16	0.06	0.9932
ANOVA Results for Truck Mean Speeds					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
SPEEDLIM	2	123.53	61.76	10.31	0.0001
TIMEDAY	2	4.75	2.38	0.40	0.6742
SPEEDLIM x TIMEDAY	4	0.61	0.15	0.03	0.9987

1 mi/h = 1.61 km/h

Table 12. Tukey's multiple comparison test results for truck mean speed (MEAN) by speed limit (SPEEDLIM).

SPEEDLIM (Car/Truck)	MEAN (mi/h)	Tukey Grouping[1]	
65/65	63.70	A	
65/60	63.63	A	
65/55	61.09		B

[1] Means with the same letter are not significantly different at the 95-percent confidence level

1 mi/h = 1.61 km/h

Table 13. Description of variables and number of pairs associated with each pair type.

Pair Type	Vehicle Type	Car/Truck Speed Limits (mi/h)	Number of Pairs
1	Car	65/65 - 65/55	7
2	Car	65/60 - 65/55	3
3	Car	65/65 - 65/60	3
4	Truck	65/65 - 65/55	7
5	Truck	65/60 - 65/55	3
6	Truck	65/65 - 65/60	3

1 mi/h = 1.61 km/h

pairs in each group. The pair types were developed based on the car/truck speed limits at contiguous locations and vehicle type.

Shown in table 14 are the differences in mean speeds for each contiguous site pair by vehicle type, pair type, and time of day. Two separate ANOVA's (one for cars and one for trucks) were performed with the class variables pair type and time of day. The results showed time of day not to be a significant variable in either model. Thus, a second set of models was run with only the variable pair type. For cars, the variable proved to be significant ($P = 0.0074$) as shown in table 15, which indicates that the differences in mean speeds are not consistent in each of the three pair types for cars. Bonferroni confidence intervals were computed to determine if the difference in each pair type was significantly different from zero. Examination of the intervals revealed that the mean differences of 0.2 and 0.1 mi/h (0.3 and 0.2 km/h) for pair types 1 and 3, respectively were not significantly greater than zero (*see table 15*). However, for pair type 2, the mean difference of 2.4 mi/h (3.9 km/h) was significantly greater.

For trucks, the variable pair type proved not to be significant ($P = 0.1456$) as shown in table 16, indicating some degree of consistency in the mean differences across the three pair types for trucks. In examining the Bonferroni confidence intervals, the difference of 1.4 mi/h (2.3 km/h) for pair type 6 proved not to be significantly greater than zero. For pair types 4 and 5, however, the differences of 2.6 and 4.0 mi/h (4.2 and 6.4 km/h), respectively were significantly greater.

Summary of Analysis of Mean Speeds

The results from the statistical analyses conducted for the variable mean speed can be summarized as follows:

- Car mean speeds are significantly different with respect to all time-of-day periods (day vs. night, day vs. dawn/dusk, and night vs. dawn/dusk). Truck speeds, however, were only significantly different for night vs. dawn/dusk. For both vehicle types, these differences were very small (0.4 to 1.1 mi/h (0.6 to 1.8 km/h)) and cannot be considered practical differences.

- An analysis of mean speeds by speed limit for all 26 rural locations showed car mean speeds not to be significantly affected by the type of car/truck speed limit. Truck mean speeds, however, were impacted by the type of speed limit. Speeds for trucks traveling under the

Table 14. Differences in mean speeds between rural contiguous site pairs.

Car/Truck Speed Limits (mi/h)	Pair Number	Car Mean Speed Differences (mi/h)				Truck Mean Speed Differences (mi/h)			
		All Day	Day	Night	Dawn/ Dusk	All Day	Day	Night	Dawn/ Dusk
65/65 - 65/55	1	-0.9	-1.1	-1.0	-0.8	0.8	0.6	1.2	0.6
	2	-1.3	-1.2	-0.8	-1.7	-0.6	-0.9	-0.6	-0.4
	3	0.5	0.5	0.8	0.3	6.2	5.9	6.3	6.4
	9	0.0	-0.1	-0.7	0.2	2.1	1.7	2.0	2.2
	11	2.1	2.2	1.8	2.3	6.2	6.2	6.6	5.7
	12	0.5	-0.4	1.6	2.0	4.5	3.4	4.7	5.3
	13	0.7	1.5	-1.2	-0.5	-0.8	-1.1	-0.4	-1.2
	Group Mean	0.2	0.2	0.1	0.3	2.6	2.3	2.8	2.7
65/60 - 65/55	4	1.1	0.6	2.1	1.3	2.0	0.9	2.9	2.1
	5	4.2	4.1	4.6	4.1	5.6	5.5	5.5	6.1
	6	1.8	2.6	1.7	1.1	4.3	5.2	3.9	3.6
	Group Mean	2.4	2.4	2.8	2.2	4.0	3.9	4.1	3.9
65/65 - 65/60	7	1.0	0.7	0.6	1.6	1.8	0.9	2.3	1.9
	8	2.6	2.5	2.3	3.0	4.5	4.5	3.7	5.2
	10	-3.3	-3.1	-5.9	-3.5	-1.3	-0.8	-3.5	-1.6
	Group Mean	0.1	0.0	-1.0	0.4	1.7	1.5	0.8	1.8

1 mi/h = 1.61 km/h

65/55 limit are significantly less than speeds for trucks travelling under the 65/60 65/65 limits. However, the differences between truck mean speeds under the upper two limits were not significantly different.

- An analysis of the 13 rural contiguous site pairs proved significant differences in car speeds existed only for pairs governed by 65/60 and 65/55 speed limits. The mean difference for the three pairs included in this group was 2.4 mi/h (3.9 km/h). For truck mean speeds, the differences of 2.6 and 4.0 mi/h (4.2 and 6.4 km/h) for the pairs governed by 65/65 - 65/55 and 65/60 - 65/55, respectively, proved to be significant.

ANALYSIS OF SPEED VARIANCE

The dependent variables used in the subsequent analyses of speed variance were standard deviation (**SDEV**) and coefficient of variation (**CVAR**). Since the number of vehicles collected at each

Table 15. ANOVA results and Bonferroni confidence intervals for car mean speed differences (DIFF) with class variable PAIRTYPE.

ANOVA Results					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
PAIRTYPE	2	40.88	20.44	5.65	0.0074

Bonferroni Confidence Intervals			
		Confidence Limits	
PAIRTYPE	DIFF (mi/h)	Lower	Upper
1	0.2	-0.866	1.219
2	2.4[1]	0.874	4.059
3	0.1	-1.793	1.393

[1] Significant at the 95-percent confidence level
1 mi/h = 1.61 km/h

Table 16. ANOVA results and Bonferroni confidence intervals for truck mean speed differences (DIFF) with class variable PAIRTYPE.

ANOVA Results					
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P-value
PAIRTYPE	2	29.75	14.87	2.03	0.1456

Bonferroni Confidence Intervals			
		Confidence Limits	
PAIRTYPE	DIFF (mi/h)	Lower	Upper
4	2.6[1]	1.099	4.063
5	4.0[1]	1.703	6.230
6	1.7	-0.864	3.664

[1] Significant at the 95-percent confidence level
1 mi/h = 1.61 km/h

location is very large (typically in the 1000's), statistical significance testing of the differences in standard deviations or coefficients of variation proved meaningless in most cases. Thus, much of the analysis presented below was qualitative in nature. However, where statistical significance testing was deemed appropriate, proper tests were used and the results are provided.

Time of day and Vehicle Type

Shown in table 17 are the standard deviations for each site by speed limit, time of day, and vehicle type. In table 18 are the coefficients of variation are presented in the same format. Examining the data, it is clear that nighttime speeds exhibited the greatest variance for cars. In fact, the largest standard deviation and coefficient of variation for 22 and 23 of the 26 sites, respectively, occurred during the nighttime period. Trucks, on the other hand, have mixed results. Of the 26 sites, only 12 contained the largest standard deviation during the nighttime period. However, in examining the coefficients of variation, 18 of the 26 sites exhibit the largest values during the nighttime period.

With respect to vehicle type, the standard deviations for cars are consistently higher than for trucks. For the all-day time period, 22 of the 26 sites had higher standard deviations for cars. This pattern is present for the other time periods as well. Since, truck mean speeds were less than cars, it was no surprise that the larger standard deviations occurred for cars. However, the coefficient of variation, which corrects for the magnitude of the mean speed, also produced patterns showing cars to consistently exhibit greater variance than trucks for all time periods.

Speed Limit

Shown in table 19 are the coefficients of variation by State and speed limit. Examining the group means for each speed limit group, the coefficients of variation for cars had a range of 8.0 percent for the 65/60 group to 8.5 percent for the 65/55 group. For trucks, the lowest value was 7.5 percent in the 65/55 group while the other speed limit groups were relatively close at 7.9 and 8.1 percent. For all vehicles, the highest value was 9.6 percent in the 65/55 group while the other speed limits had values of 9.0 and 9.1 percent. Overall, it appears that the car speed variance is not impacted by the type of speed limit. However, the speed variance for trucks may be significantly lower for the 65/55 group compared to the other groups, and the variance for all vehicles may be significantly greater for the 65/55 group compared to the other groups. Further analyses of the site pairs provided more definitive results.

Contiguous Site Pairs

The final analysis of speed variance was an examination of the 13 contiguous site pairs and the differences in coefficients of variation between each pair. Shown in table 20 are these coefficients and differences for the all-day time period. The difference was computed by subtracting the lower truck speed limit value (e.g., 65/55) from the higher truck speed limit value (e.g., 65/65).

For cars, only 6 of the 13 pairs exhibited greater variance at the sites with the higher truck speed limit, while the variance for trucks was almost always greatest at the locations with the higher truck limit (10 of 13 pairs). Observing the variance for all vehicles, however, it was shown that the greatest variance occurs

Table 17. Speed standard deviations by speed limit by vehicle type and time of day.

Car/Truck Speed Limit (mi/h)	State	Pair	Car Speed Standard Deviation (mi/h)				Truck Speed Standard Deviation (mi/h)			
			All Day	Day	Night	Dawn/ Dusk	All Day	Day	Night	Dawn/ Dusk
65/55	VA	1	5.1	5.1	4.9	5.3	4.6	4.7	4.1	4.6
		2	5.4	5.2	5.8	5.4	3.9	3.8	4.1	3.9
		3	5.3	5.0	5.9	5.5	3.7	3.4	4.1	3.5
	IL	4	5.4	5.3	6.0	5.3	4.9	4.7	5.2	4.9
		5	5.7	5.5	6.8	5.5	4.9	4.7	5.2	4.7
		6	6.0	5.8	6.2	6.0	5.4	5.2	5.4	5.4
	CA	11	6.1	5.8	8.3	6.1	4.1	3.9	4.7	4.2
		12	6.2	5.9	6.7	6.3	4.1	4.1	4.0	3.9
		13	6.3	6.3	6.2	6.2	5.0	4.9	5.3	4.6
	OR	9	5.3	5.3	5.9	5.1	4.4	4.3	4.4	4.6
	Group Mean		5.7	5.5	6.3	5.7	4.5	4.4	4.7	4.4
65/60	IN	4	5.4	5.2	5.6	5.4	5.2	5.2	5.0	5.1
		5	5.3	5.0	6.7	5.0	5.4	4.9	6.1	5.4
		6	6.0	6.0	6.9	5.8	4.9	5.1	4.9	4.5
	MO	7	5.7	5.2	6.5	5.8	4.7	4.5	4.5	5.1
		8	5.8	5.7	6.1	5.7	6.7	6.8	6.4	6.8
	WA	10	4.4	4.4	5.6	4.0	3.8	3.8	3.9	3.3
	Group Mean		5.4	5.3	6.2	5.3	5.1	5.1	5.1	5.0
65/65	NC	1	5.2	5.1	5.3	5.3	5.0	5.0	4.9	5.2
		2	5.4	5.2	5.7	5.4	5.5	5.2	5.4	5.8
		3	5.6	5.1	5.9	6.4	4.7	4.5	4.6	5.0
	IA	7	5.0	4.9	5.5	4.8	5.1	5.5	4.8	4.9
		8	5.0	4.9	5.0	5.2	4.4	4.3	4.3	4.7
	AZ	11	6.3	6.1	7.0	6.6	5.1	4.5	5.5	5.6
		12	6.8	6.4	7.6	7.1	4.9	5.0	5.0	4.5
		13	6.5	5.9	7.5	7.1	5.1	5.3	5.1	5.0
	ID	9	5.3	5.3	6.2	4.9	4.6	4.3	4.9	4.7
		10	5.4	5.4	6.1	5.4	5.0	4.6	5.4	5.5
	Group Mean		5.7	5.4	6.2	5.8	4.9	4.8	5.0	5.1

1 mi/h = 1.61 km/h

Table 18. Coefficients of variation by speed limit by vehicle type and time of day.

Car/Truck Speed Limit (mi/h)	State	Pair	Car Coefficients of Variation (%)				Truck Coefficients of Variation (%)			
			All Day	Day	Night	Dawn/ Dusk	All Day	Day	Night	Dawn/ Dusk
65/55	VA	1	7.3	7.3	7.1	7.6	7.2	7.3	6.5	7.1
		2	8.1	7.8	8.8	8.0	6.6	6.4	7.0	6.5
		3	7.7	7.3	8.7	7.9	6.3	5.8	6.9	5.9
	IL	4	8.1	8.0	9.2	7.9	8.0	7.6	8.4	7.9
		5	8.5	8.2	10.4	8.2	7.9	7.5	8.3	7.5
		6	9.0	8.8	9.4	8.9	9.2	8.8	9.3	9.0
	CA	11	9.1	8.7	12.4	9.1	6.7	6.4	7.7	6.9
		12	9.1	8.6	10.0	9.3	6.8	6.6	6.7	6.5
		13	9.4	9.4	9.3	9.2	7.9	7.8	8.4	7.3
	OR	9	8.0	8.0	8.8	7.6	7.3	7.1	7.3	7.6
	Group Mean		8.4	8.2	9.4	8.4	7.4	7.1	7.7	7.2
65/60	IN	4	8.0	7.8	8.3	7.9	8.2	8.3	7.7	8.0
		5	7.5	7.1	9.6	7.0	7.9	7.2	9.0	7.9
		6	8.8	8.8	10.2	8.5	7.7	7.9	7.9	7.1
	MO	7	8.4	7.7	9.7	8.6	7.3	6.9	7.1	7.8
		8	8.9	8.7	9.4	8.6	11.2	11.4	10.6	11.4
	WA	10	6.5	6.5	8.3	6.0	6.1	6.1	6.2	5.3
	Group Mean		8.0	7.8	9.3	7.8	8.1	8.0	8.1	7.9
65/65	NC	1	7.6	7.4	7.8	7.6	7.7	7.7	7.6	7.9
		2	8.2	7.9	8.8	8.2	9.4	8.9	9.3	9.8
		3	8.1	7.4	8.6	9.2	7.2	7.0	7.0	7.6
	IA	7	7.3	7.2	8.1	6.9	7.7	8.4	7.3	7.3
		8	7.3	7.2	7.5	7.5	6.8	6.7	6.7	7.2
	AZ	11	9.1	8.8	10.2	9.5	7.6	6.7	8.1	8.4
		12	9.9	9.4	11.1	10.2	7.6	7.7	7.8	6.9
		13	9.6	8.6	11.4	10.6	8.2	8.5	8.1	8.0
	ID	9	8.0	8.0	9.4	7.3	7.4	6.9	7.9	7.5
		10	8.5	8.4	9.9	8.5	8.2	7.5	9.2	9.0
	Group Mean		8.4	8.0	9.3	8.6	7.8	7.6	7.9	8.0

1 mi/h = 1.61 km/h

Table 19. Coefficients of variation for cars, trucks, and all vehicles by speed limit and State.

Car/Truck Speed Limit (mi/h)	State	Number of Sites	Coefficient of Variation (%)		
			Car	Truck	All
65/55	VA	3	7.7	6.7	9.2
	IL	3	8.6	8.5	9.7
	CA	3	9.2	7.3	9.9
	OR	1	8.0	7.3	9.3
	Group Mean		8.5	7.5	9.6
65/60	IN	3	8.1	8.0	8.9
	MO	2	8.6	9.2	9.7
	WA	1	6.5	6.1	7.8
	Group Mean		8.0	8.1	9.0
65/65	NC	3	7.9	8.3	9.2
	IA	2	7.3	7.3	8.0
	AZ	3	9.5	7.9	9.9
	ID	2	8.2	7.8	9.0
	Group Mean		8.3	7.9	9.1

1 mi/h = 1.61 km/h

predominately at the locations with the lower truck speed limits (10 of 13 pairs).

Statistical significance testing using the nonparametric sign-test, showed the differences in the coefficients of variation for the 13 matched pairs not to be significantly different for cars (P = 0.5). However, the differences for trucks and all vehicles were significantly different, with P-values of 0.019 and 0.046, respectively.

Summary of Analysis of Speed Variance

The results for the analysis of speed variance can be summarized as follows:

- Cars consistently exhibited greater variance than trucks across all speed limit groups. However, the differences in the coefficient of variation between the two vehicle types was typically less than 1 percent and thus, cannot be considered practical differences.

Table 20. Differences in coefficients of variation for the 13 pairs of rural contiguous locations.

Pair	State	Cars		Trucks		All Vehicles	
		Coefficient (%)	Difference	Coefficient (%)	Difference	Coefficient (%)	Difference
1	NC	7.6	0.3	7.7	0.5	8.6	-0.1
	VA	7.3		7.2		8.7	
2	NC	8.2	0.1	9.4	2.8	10.1	0.7
	VA	8.1		6.6		9.4	
3	NC	8.1	0.4	7.2	0.9	8.8	-0.7
	VA	7.7		6.3		9.5	
4	IN	8.0	-0.1	8.2	0.2	9.0	-0.3
	IL	8.1		8.0		9.3	
5	IN	7.5	-1.0	7.9	0.0	8.2	-1.1
	IL	8.5		7.9		9.3	
6	IN	8.8	-0.2	7.7	-2.5	9.4	-1.2
	IL	9.0		9.2		10.6	
7	IA	7.3	-1.1	7.7	0.4	7.8	-0.8
	MO	8.4		7.3		8.6	
8	IA	7.3	-1.6	6.8	-4.4	8.1	-2.6
	MO	8.9		11.2		10.7	
9	ID	8.0	0.0	7.4	0.1	8.7	-0.6
	OR	8.0		7.3		9.3	
10	ID	8.5	2.0	8.2	2.1	9.2	1.4
	WA	6.5		6.1		7.8	
11	AZ	9.1	0.0	7.6	0.9	9.3	-0.5
	CA	9.1		6.7		9.8	
12	AZ	9.9	0.8	7.6	0.8	9.9	-0.2
	CA	9.1		6.8		10.1	
13	AZ	9.6	0.2	8.2	0.3	10.4	0.7
	CA	9.4		7.9		9.7	

- The speed variance for cars and trucks was typically greatest during the night time period. However, these differences were typically small and could not be considered practical differences.

- Examination of the coefficients of variation by type of speed limit showed no distinct patterns for cars. However, for trucks, the variance was lowest for the 65/55 speed limit group and relatively different from the variances of the other speed limit groups. For all vehicles, the variance was greatest for the 65/55 group and was also relatively different from the other groups.

- An analysis of the 13 contiguous site pairs revealed no significant differences in speed variance for cars. For trucks and all vehicles, the differences were significantly different, with trucks consistently exhibiting the greatest variance at locations with the higher truck speed limits while all vehicles exhibited the greatest variance at locations with lower truck speed limits.

ANALYSIS OF OTHER SPEED CHARACTERISTICS

Speed Distribution

Another way of examining the impact of speed limits on travel speeds is an analysis of the overall speed distribution, i.e., an examination of the differences in the upper and lower percentile speeds. Such differences provide information on how the distribution is spread, which in turn, serves as a measure of vehicle interaction. For this analysis, the difference between the 85th and 15th percentile speeds was selected as the dependent variable. Shown in table 21 are these differences for cars, trucks, and all vehicles by State and speed limit.

Examining the group means, the largest difference for cars occurred in the 65/55 speed limit group [10.6 mi/h (17.1 km/h)] while the differences for the 65/60 and 65/65 speed limit groups were 9.8 and 10.0 mi/h (15.8 and 16.1 km/h), respectively. For trucks, the differences for the 65/60 and 65/65 speed limit groups were almost equal at 10.0 and 10.1 mi/h (16.1 and 16.3 km/h), respectively. However, the difference for the 65/55 speed limit group was much smaller at only 8.7 mi/h (14.0 km/h). Finally, for all vehicles, the differences followed a similar pattern to that described for cars.

When the differences were examined by vehicle type within each speed limit group, an obvious pattern emerged. For the 65/60 and 65/65 groups, the differences between cars and trucks was only 0.2 and 0.1 mi/h (0.3 and 0.2 km/h), respectively. For the 65/55 group, however, the difference in values for these two vehicle groups was 2.9 mi/h (3.1 mi/h). When comparing all vehicles to trucks, similar patterns were found with the 65/55 speed limit group again resulting in a value much larger when compared to the other speed limit groups.

Overall, these results indicate that the differential speed limit of 65/60 has very little impact upon the distribution of vehicle speeds when compared to the 65/65 uniform speed limit. However, the differential 65/55 speed limit does appear to affect the distribution of vehicle speeds in two ways. First, for trucks, the differences in the 85th and 15th percentile speeds were much smaller than the other groups, indicating less variance for truck speeds. Second, the variance for cars and all vehicles appears to be greater when compared to the other groups since the differences in percentile speeds were larger.

Table 21. Difference between 85th and 15th percentile speeds by vehicle type, State, and speed limit.

Car/Truck Speed Limit (mi/h)	State	Number of Sites	85th - 15th Percentile Speed (mi/h)		
			Cars	Trucks	All Vehicles
65/55	VA	3	9.7	8.0	11.7
	IL	3	11.0	9.7	11.7
	CA	3	11.3	8.3	13.0
	OR	1	10.0	9.0	12.0
	Group Mean		10.6	8.7	12.1
65/60	IN	3	9.7	10.0	11.3
	MO	2	10.5	11.5	12.0
	WA	1	9.0	7.0	9.0
	Group Mean		9.8	10.0	11.2
65/65	NC	3	9.3	9.7	11.3
	IA	2	9.5	10.0	10.5
	AZ	3	11.3	10.3	12.0
	ID	2	9.5	10.5	11.5
	Group Mean		10.0	10.1	11.4

1 mi/h = 1.61 mi/h

Finally, it is also apparent that cars and trucks generally follow the same distribution pattern for the 65/65 and 65/60 speed limit groups since the differences across vehicle types and across groups are approximately equal. However, cars and trucks in the 65/55 speed limit group do not appear to follow similar distributions due to the differences between the two vehicle types. These results lead to the conclusion that more car/truck interaction occurs in the 65/55 speed limit group as compared to the other speed limit groups.

Compliance

The final task conducted to determine the impact of different speed limit regulations on vehicle travel speeds was a qualitative analysis of compliance with the respective speed limits. The dependent variables used in the analysis were the percentage of vehicles traveling above the speed limit by various amounts, i.e., those vehicles in noncompliance by various amounts. The levels of noncompliance included were above the speed limit, above the speed limit by 5 mi/h (8 km/h), by

10 mi/h (16 km/h), and by 15 mi/h (24 km/h); variables **NCSL, NC05, NC10,** and **NC15**.

Shown in table 22 are the various levels of noncompliance for cars and trucks by State and speed limit. Comparing the group means for cars, the lowest values for exceeding the speed limit and exceeding the limit by 5 mi/h (8 km/h) occurred in the 65/55 speed limit group, indicating that lower truck speeds may play a role in reducing the number of cars in noncompliance. However, for the highest level of noncompliance, the percentage of cars in violation was very similar. For trucks, the lower limits of 65/55 and 65/60 resulted in much higher rates of noncompliance across all levels when compared to the 65/65 speed limit group. This fact indicates that compliance will not be achieved with speed limits deemed to be unreasonable by drivers. However, it should be noted that the differential 65/55 speed limit group did result in fewer trucks traveling at excessively high speeds. For example, the percentage of vehicles in excess of 70 mi/h (113 km/h) for the 65/65, 65/60, and 65/55 speed limit groups were 9.2, 9.8, and 3.1 percent, respectively.

Table 22. Percentage of vehicles in noncompliance by State and speed limit.

Car/Truck Speed Limit	State	Number of Sites	Car Noncompliance (%)				Truck Noncompliance (%)			
			NCSL	NC05	NC10	NC15	NCSL	NC05	NC10	NC15
65/55	VA	3	71.7	31.0	8.0	1.7	89.3	51.7	14.3	2.7
	IL	3	57.3	21.7	5.0	1.0	86.3	54.3	16.3	4.3
	CA	3	63.7	25.3	7.3	1.7	93.3	57.7	17.0	3.0
	OR	1	60.0	19.0	4.0	1.0	87.0	43.0	12.0	1.0
	Group Mean		63.8	25.3	6.5	1.4	89.4	53.4	15.5	3.1
65/60	IN	3	73.7	36.0	10.0	2.0	81.7	40.3	15.3	5.0
	MO	2	61.5	20.0	3.5	0.5	70.5	25.0	5.5	1.5
	WA	1	68.0	16.0	2.0	1.0	73.0	17.0	2.0	0.0
	Group Mean		68.7	27.3	6.5	1.3	76.5	31.3	9.8	3.0
65/65	NC	3	68.3	29.0	7.7	1.0	31.7	8.7	1.7	0.3
	IA	2	75.0	27.0	6.0	1.0	47.5	10.5	2.0	0.0
	AZ	3	71.7	35.3	11.0	3.0	43.7	13.3	2.3	0.3
	ID	2	48.0	13.5	3.0	0.5	17.5	2.5	0.0	0.0
	Group Mean		66.6	27.4	7.4	1.5	35.6	9.2	1.6	0.2

1 mi/h = 1.61 km/h

WEEKDAY VERSUS WEEKEND SPEEDS

As previously noted in chapter 4, weekend speed data were collected at 4 of the 13 rural contiguous site pairs. The weekend and weekday speed data collected at these locations are shown in table 23. For cars, 3 of the 8 sites exhibit differences greater than 1 mi/h (1.6 km/h) while for trucks, 4 of the 8 sites exhibit differences greater than 1 mi/h (1.6 km/h). However, the 11.4 mi/h (18.4 km/h) difference for trucks at the North Carolina site is an obvious outlier. Within each of the four pairs of sites, the differences are consistent, either positive or negative across both locations and both vehicle types.

The overall differences in weekday versus weekend mean speeds, after combining data from all sites, were -0.1 and 1.1 mi/h (-0.2 and 1.8 km/h) for cars and trucks, respectively. Significance testing on the overall means for the two vehicle types showed no significant differences in the mean speeds with respect to day of week.

Table 23. Weekday and weekend mean speeds collected at rural contiguous site pairs.

Pair	State	Day of Week	Car Speed (mi/h)	Truck Speed (mi/h)	Pair	State	Day of Week	Car Speed (mi/h)	Truck Speed (mi/h)
1	NC	Weekday	68.8	65.1	8	IA	Weekday	68.1	64.3
		Weekend	65.8	53.7			Weekend	67.7	63.3
		Difference	3.0	11.4			Difference	0.4	1.0
	VA	Weekday	69.7	64.3		MO	Weekday	65.5	59.8
		Weekend	69.3	63.5			Weekend	65.0	59.2
		Difference	0.4	0.8			Difference	0.5	0.6
4	IN	Weekday	67.4	63.6	9	ID	Weekday	66.6	62.3
		Weekend	68.9	64.3			Weekend	67.2	63.4
		Difference	-1.5	-0.7			Difference	-0.6	-1.1
	IL	Weekday	66.3	61.6		OR	Weekday	66.6	60.2
		Weekend	68.8	63.5			Weekend	67.0	61.5
		Difference	-2.5	-1.9			Difference	-0.4	-1.3
Overall Mean		Weekday	67.4	62.6					
		Weekend	67.5	61.5					
		Difference	-0.1	1.1					

1 mi/h =1.61 km/h

RURAL VERSUS URBAN SPEEDS

The speed data collected at the contiguous rural/urban site pairs are shown in table 24. The urban speed limit at all three locations was 55 mi/h (89 km/h) for all vehicles. The collection and analysis of these data were intended to determine how the various rural speed limits and subsequent travel speeds impact upon the travel speeds in the urban areas. However, it should be noted that these data represent only six sites, and that any conclusions represent only those sites and cannot be extrapolated to all locations in general.

For car mean speeds, the data showed cars traveling under the 65/55 limit to exhibit the same mean speed of 68.5 mi/h (110.3 km/h) in both the rural and urban areas, thus exceeding the urban speed limit by 13.5 mi/h (21.7 km/h). For cars traveling under the speed limits of 65/60 and 65/65, the urban speeds were approximately 6 mi/h (9.7 km/h) less than the rural speeds. For both speed limits, the mean speed exceeded the urban speed limit by approximately 6 mi/h (9.7 km/h).

For trucks traveling under the 65/55 limit, the rural and urban mean speeds differed by only 1.2 mi/h (1.9 km/h), resulting in both means exceeding the rural and urban speed limit of 55 mi/h (89 km/h) by approximately 5 mi/h (8.1 km/h). For the 65/60 speed limit, trucks at the rural site exceeded the speed limit while in the urban area, the mean speeds were more than 7 mi/h (11 km/h) below the speed limit. Finally, for the 65/65 speed limit group, mean rural speeds were below the limit by 2.8 mi/h (4.5 km/h) while mean urban speeds exceeded the limit by the same amount.

In general, trucks exceeded the urban speed limit of 55 mi/h (89 km/h) by smaller amounts than cars. However, no definitive conclusions were drawn

Table 24. Mean speeds for the rural/urban site pairs.

State	Rural Car/Truck Speed Limit (mi/h)	Area	Car Mean Speed (mi/h)	Mean - Speed Limit	Truck Mean Speed (mi/h)	Mean - Speed Limit
VA	65/55	Rural	68.5	3.5	59.6	4.6
		Urban	68.5	13.5	60.8	5.8
WA	65/60	Rural	67.2	2.2	62.4	2.4
		Urban	61.1	6.1	47.6	-7.4
ID	65/65	Rural	66.6	1.6	62.2	-2.8
		Urban	60.9	5.9	57.8	2.8

1 mi/h = 1.61 km/h

regarding the impact of the various rural speed limits on urban travel speeds of either cars or trucks, due to the extremely small sample of sites.

CHAPTER 6 - ACCIDENT DATA ANALYSIS

The analysis of accident data was intended to assess how the various speed limits employed on the rural Interstates has impacted the safety of such highways. Provided in this chapter are discussions of the evaluation methods employed and the results obtained in the statistical analyses. The analysis included mainline rural Interstate accident data from nine States, as previously shown in table 3 (*see chapter 4*), and the results are presented in the following sections: 1) general accident characteristics, 2) analysis of collision type, and 3) analysis of accident severity.

The dependent variable used in the analyses was the proportion of accidents classified by specific vehicle type, collision type, or severity categories, e.g., car-into-truck rear-end accidents. The primary stratifying variable used for controlling exposure was traffic volume.

During the conduct of the analysis, a limited examination of the proportions of accidents with and without alcohol involvement and work-zone activity was undertaken. The results showed virtually no differences in the proportions of accidents associated with overall accidents, collision type, vehicle type, or severity. Thus, the results provided below include all accidents.

GENERAL ACCIDENT CHARACTERISTICS

The principal stratifying variable used in the analyses was traffic volume, or more specifically AADT. Thus, a first step in the analysis was an examination of the overall distribution of accidents by traffic volume for each State as shown in table 25. The data were stratified by eight volume groups in order to assess how the proportions of accidents vary from State to State. Examining the data, it was apparent that there were no explicit patterns revealed with respect to either traffic volume or type of speed limit. For each AADT group, there were a wide range of accident proportions. For example, in the 0 to 8,000 group, four States experienced fewer than 3 percent of the accidents in this group while one State showed a proportion of almost 65 percent. In the 16,000 to 24,000 AADT group, the proportions were much more balanced between States, but there remained a large range from 6.95 to 41.16 percent.

Within the various speed limit groups, there were large differences in the proportions by State with respect to the AADT groups. Consider Oregon and Virginia as an example, both with speed limits of 65/55. In Oregon, 26.23 percent of the accidents occurred on segments with volumes of less than 8,000 vehicles per day, while in Virginia only 1.16 percent of the accidents occurred in this AADT group. The percentages were reversed for these two States when examining volumes in excess of 70,000 vehicles per day. Similar comparisons can be made in the other speed limit groups.

However, further examination of the number of miles of rural Interstate stratified by traffic volume (*see table 26*) revealed that the accident proportions for the various volume classifications were similar to the mileage proportions. For example, Idaho experienced 37.22 percent of its accidents on segments with volumes of less than 8,000 vehicles per day. This corresponds very closely to the almost 42 percent of mileage that exists in the State

Table 25. Accident proportions by State and traffic volume.

Car/Truck Speed Limit (mi/h)	State	Traffic Volume (1000's)								
		0-8	8-16	16-24	24-32	32-40	40-50	50-70	>70	Total
55/55	PA	2.89 (268)[1]	5.12 (475)	27.18 (2522)	31.15 (2891)	16.75 (1555)	10.10 (937)	4.80 (446)	2.01 (188)	100.00 (9282)
65/55	IL	7.04 (1062)	60.83 (9181)	28.5 (4302)	1.97 (298)	0.71 (107)	0.37 (56)	0.23 (34)	0.35 (53)	100.00 (15093)
	OR	26.23 (725)	16.35 (452)	16.57 (458)	21.31 (589)	1.70 (47)	7.27 (201)	9.48 (262)	1.09 (30)	100.00 (2764)
	VA	1.16 (94)	4.30 (349)	16.36 (1327)	27.44 (2226)	17.95 (1456)	0.83 (67)	1.34 (109)	30.63 (2485)	100.00 (8113)
65/60	IN	1.36 (184)	22.99 (3105)	41.16 (5559)	25.89 (3497)	5.20 (703)	1.72 (232)	1.36 (184)	0.32 (43)	100.00 (13507)
	WA	6.39 (57)	25.34 (226)	21.64 (193)	18.83 (168)	13.23 (118)	9.64 (86)	3.48 (31)	1.46 (13)	100.00 (892)
65/65	IA	64.78 (1135)	20.66 (362)	11.42 (200)	0.91 (16)	1.08 (19)	0.68 (12)	0.46 (8)	0.00 (0)	100.00 (1752)
	ID	37.22 (1258)	44.76 (1513)	6.95 (235)	9.02 (305)	0.65 (22)	1.39 (47)	0.00 (0)	0.00 (0)	100.00 (3380)
	NC	0.98 (73)	2.88 (214)	34.66 (2574)	25.50 (1894)	12.85 (954)	6.52 (484)	14.69 (1091)	1.91 (142)	100.00 (7426)

[1] Accident frequencies are shown in parentheses.
1 mi/h = 1.61 km/h

with volumes of less than 6,000 vehicles per day. On the other hand, North Carolina has almost 71 percent of its rural Interstate mileage in the > 20,000 vehicles per day classification. Examining the accident data for volume groups > 24,000 vehicles per day, the percentage of accidents was 61.47 percent. Thus, the differences in accident proportions for the various volume groups were simply reflective of the differences in mileage proportions among the States.

ANALYSIS OF COLLISION TYPE

The examination of the data by collision type was based on the premise that higher proportions of certain collision types involving specific vehicle types are expected to occur in States with differential versus uniform speed limits. For example, more car-into-truck rear-end accidents were hypothesized to have occurred in States with differential speed limits. Shown in table 27 are the proportions of accidents for the following collision types:

- Single - included all single vehicle accidents, e.g., run-off-road or fixed object.
- Rear-end - included all multiple vehicle rear-end accidents.

Table 26. Rural Interstate mileage by traffic volume and total vehicle-miles of travel.[19]

Car/Truck Speed Limit (mi/h)	State	Average Annual Daily Traffic Volume (1000's)					Annual Vehicle Miles of Travel (millions)
		0-6	6-10	10-20	> 20	Total	
55/55	PA	0 (0.00)[1]	25 (2.14)	758 (65.01)	383 (32.85)	1166	8027
65/55	IL	15 (1.06)	242 (17.10)	938 (66.29)	220 (15.55)	1415	7723
	OR	56 (9.41)	196 (32.94)	183 (30.76)	160 (26.89)	595	3698
	VA	0 (0.00)	46 (5.92)	244 (31.40)	487 (62.68)	777	7300
65/60	IN	0 (0.00)	51 (5.91)	326 (37.78)	486 (56.32)	863	6943
	WA	10 (1.92)	152 (29.23)	192 (36.92)	166 (31.92)	520	3755
65/65	IA	18	191	277	158	644	3307
	ID	223 (41.84)	156 (29.27)	148 (27.77)	6 (1.13)	533	1543
	NC	0 (0.00)	40 (5.69)	165 (23.47)	498 (70.84)	703	6801

[1] Mileage percentages are shown in parentheses.
1 mi/h = 1.61 km/h

- Multiple - included all other types of multiple vehicle accidents, e.g., sideswipe.
- Other - included all remaining accidents.

In general, the patterns were very consistent for all States except Indiana. Single vehicle accidents are the major component, followed in order by rear-end accidents, other multiple vehicle accidents, and finally all other types of accidents. However, when the variable traffic volume was introduced, different patterns emerged. Shown in table 28 are the collision type data for Illinois and Idaho stratified by AADT. Within the low traffic volume classifications, the pattern was the same as previously described with single vehicle accidents being the major contributor. However, as the traffic volume increased, the rear-end and other multiple vehicle accidents became the major components. While this was no surprise, the results do illustrate that increased traffic volumes result in increased vehicle interaction which, in turn, results in a higher proportion of multiple vehicle accidents.

Provided in table 29 are the accident proportions by collision type and State for the traffic volumes of 0 to 8000 and 16,000 to 24,000 vehicles per day. An examination of these data and data for the other volume groups did not reveal any

Table 27. Accident proportions by State and collision type.

Car/Truck Speed Limit (mi/h)	State	Collision Type			
		Single	Rear-End	Multiple	Other
55/55	PA	73.50	16.06	10.44	0.00
65/55	IL	68.85	13.57	13.34	4.24
	OR	54.78	19.36	17.91	7.96
	VA	67.71	16.48	13.46	2.35
65/60	IN	15.02	14.05	43.73	27.19
	WA	66.59	10.43	10.65	12.33
65/65	IA	70.72	14.38	5.42	9.47
	ID	76.63	11.11	7.80	4.46
	NC	55.94	19.12	19.61	5.33

1 mi/h = 1.61 km/h

Table 28. Accident proportions by collision type and traffic volume for Idaho and Illinois.

Illinois								
Accident Type	Average Annual Daily Traffic Volume (1000's)							
	0-8	8-16	16-24	24-32	32-40	40-50	50-70	> 70
Single	81.73	72.65	61.23	48.32	44.86	12.5	35.29	15.09
Rear-End	7.44	11.04	18.36	26.17	28.97	35.71	32.35	47.17
Multiple	7.63	11.95	16.39	19.80	21.50	35.71	26.47	37.74
Other	3.20	4.36	4.02	5.70	4.67	16.07	5.88	0.00

Idaho						
Accident Type	Average Annual Daily Traffic Volume (1000's)					
	0-8	8-16	16-24	24-32	32-40	> 40
Single	80.21	80.04	63.83	64.92	36.36	29.79
Rear-End	8.51	9.98	14.04	18.36	40.91	40.43
Multiple	5.80	6.41	16.17	14.75	13.64	17.02
Other	5.48	3.57	5.96	1.97	9.09	12.77

obvious patterns pertaining to collision type with respect to the various States and type of speed limit. After eliminating the outlier Indiana, a chi-square analysis was performed on the remaining eight States. The results showed no association between the distribution of accidents by collision type and type of speed limit for any of the

Table 29. Accident proportions by State and collision type for AADT classifications 0 to 8000 and 16,000 to 24,000.

Average Annual Daily Traffic Volume = 0 - 8,000					
Car/Truck Speed Limit (mi/h)	State	Collision Type			
		Single	Rear-End	Multiple	Other
55/55	PA	53.44	31.81	14.75	0.00
65/55	IL	81.73	7.44	7.63	3.20
	OR	64.83	12.69	12.00	10.48
	VA	68.09	20.21	9.57	2.13
65/60	WA	87.72	3.51	1.75	7.02
65/65	IA	72.95	13.13	5.20	8.72
	ID	80.21	8.51	5.80	5.48
	NC	68.49	16.44	9.59	5.48
Average Annual Daily Traffic Volume = 16,000 - 24,000					
Car/Truck Speed Limit (mi/h)	State	Collision Type			
		Single	Rear-End	Multiple	Other
55/55	PA	36.66	47.18	16.16	0.00
65/55	IL	61.23	18.36	16.39	4.02
	OR	58.08	18.78	16.59	6.55
	VA	72.80	14.17	10.78	2.26
65/60	WA	60.62	13.99	7.25	18.13
65/65	IA	66.00	21.00	4.50	8.50
	ID	63.83	14.04	16.17	5.96
	NC	55.52	19.81	19.46	5.21

1 mi/h = 1.61 km/h

eight volume groups, confirming earlier observations.

As another means of examining collision type with respect to speed limit, the mean accident proportions for the States within the car/truck speed limit groups of 65/65 and 65/55 are shown in table 30. The accident proportions within the various volume classifications were similar for the two speed limit groups in most cases. Statistical tests of the data confirmed the lack of any differences between the two speed limit groups with respect to collision type.

The next step in the analysis was an examination of the vehicle types involved. For this analysis, the vehicle types selected included:

- Cars - includes all passenger vehicles (cars, vans, and pickups).
- Trucks - includes all combination trucks (singles, doubles, and triples).
- Other - includes all other vehicle types (e.g., single unit trucks, buses, and recreational vehicles).

Shown in table 31 are the accident proportions for each State as a function of the vehicle type(s) involved. Since the majority of accidents were single vehicle accidents (*see table 27*), it is no surprise that the majority of vehicle types involved fall into the single vehicle categories.

Table 30. Accident proportions by collision type and traffic volume for States with 65/65 and 65/55 mi/h speed limits for cars/trucks.

65/65 Car/Truck Speed Limit (mi/h)								
Accident Type	Average Annual Daily Traffic Volume (1000's)							
	0-8	8-16	16-24	24-32	32-40	40-50	50-70	> 70
Single	73.8	69.4	61.8	61.1	54.7	51.7	66.2	56.7
Rear-End	12.7	14.0	18.4	15.0	25.0	23.4	14.7	17.7
Multiple	6.9	9.8	13.5	15.4	17.3	19.7	16.8	17.7
Other	6.6	6.7	6.3	8.6	8.8	11.8	4.6	7.8
65/55 Car/Truck Speed Limit (mi/h)								
Accident Type	Average Annual Daily Traffic Volume (1000's)							
	0-8	8-16	16-24	24-32	32-40	> 40	50-70	> 70
Single	71.5	67.1	63.9	55.6	52.4	35.6	39.7	30.9
Rear-End	13.5	15.0	17.1	21.7	26.3	32.4	26.5	38.4
Multiple	9.7	13.3	14.7	17.2	15.6	24.6	28.6	28.6
Other	5.3	4.6	4.3	5.4	5.6	11.1	5.2	3.2

1 mi/h = 1.61 km/h

Table 31. Accident proportions by State and vehicle types involved.

Car/Truck Speed Limit (mi/h)	State	Vehicle Types Involved					
		Single Car	Single Truck	Multiple Car	Multiple Truck	Car/Truck	Other
55/55	PA	55.14	12.42	12.36	3.24	12.22	4.62
65/55	IL	58.90	10.56	14.09	1.45	9.33	5.66
	OR	50.58	4.98	25.93	1.20	11.82	5.49
	VA	59.11	3.67	21.03	0.84	9.68	5.66
65/60	IN	58.49	7.75	14.48	1.42	9.65	8.21
	WA	59.46	6.53	21.73	0.34	9.46	2.48
65/65	IA	58.39	9.91	16.95	0.81	7.26	6.69
	ID	66.57	8.52	13.80	0.87	6.04	4.21
	NC	38.74	4.30	17.67	1.56	12.53	25.20

1 mi/h = 1.61 km/h

Car-involved accidents made up the three highest proportions with single car accidents having the largest percentage followed by multiple car accidents and car/truck accidents. Single truck accidents were typically less common than car/truck accidents and multiple truck accidents were always the least of the vehicle type involvements. As with collision type above, an examination of the data by type of speed limit revealed no patterns to indicate that vehicle type involvement is influenced by speed limit. This result was confirmed through a chi-square analysis.

The final analysis of collision type was a more detailed examination of multiple vehicle accidents, or more specifically those accidents involving both a car and a truck. The vehicle types involved were combined with the type of collision to produce the following categories:

- Rear-End: car-into-truck and truck-into-car.
- Sideswipe: car-into-truck and truck-into-car.
- Other: car-into-truck and truck-into-car.

Shown in table 32 are the accident proportions for these categories of vehicle type and collision type by State. The largest percentage of car-into-truck (CT) and truck-into-car (TC) type accidents were sideswipe accidents in all but one case. With respect to the different speed limit groups, the greatest percentages of CT type accidents for both rear-end and sideswipe accidents occurred in the 55/55 speed limit group which only includes Pennsylvania, followed by the 65/60 group. The lowest percentage of CT type accidents for all collision types occurred in the 65/65 speed limit group. For TC type accidents, the greatest percentage of accidents for all collision types occurred in the two uniform speed limit groups, while the

Table 32. Accident proportions by State and vehicle type/collision type categories.

Car/Truck Speed Limit (mi/h)	State	Rear-End		Sideswipe		Other	
		CT[1]	TC[2]	CT[1]	TC[2]	CT[1]	TC[2]
55/55	PA	18.35	12.35	28.52	27.77	3.34	1.75
65/55	IL	12.94	9.26	24.65	14.72	1.15	0.86
	OR	12.22	9.40	14.86	18.92	2.03	1.35
	VA	9.38	6.61	24.17	15.11	2.08	0.81
	Group Mean	11.51	8.42	21.23	16.25	1.75	1.01
65/60	IN	15.47	6.84	19.17	8.07	2.11	1.07
	WA	18.48	2.17	24.72	17.98	2.97	0.85
	Group Mean	16.98	4.51	21.95	13.03	2.54	0.96
65/65	IA	6.43	11.65	15.07	24.66	1.70	1.98
	ID	10.40	12.53	22.27	11.79	0.80	0.58
	NC	8.47	6.57	22.64	20.06	4.42	3.70
	Group Mean	8.43	10.25	19.99	18.84	2.31	2.09
Uniform (65/65 and 55/55)		10.91	10.78	22.12	21.07	2.57	2.01
Differential (65/55 and 65/60)		13.70	6.86	21.52	14.96	2.07	0.99

[1] Car-into-Truck
[2] Truck-into-Car
1 mi/h = 1.61 km/h

lowest percentage occurred in the 65/60 group.

At the bottom of table 32 are the accident proportions based on the type of speed limit, i.e., uniform vs. differential. These results show that CT type accidents for the collision types of sideswipe and other are relatively equal for the two types of speed limits. However, for rear-end accidents, CT type collisions are 26 percent greater in the States with differential speed limits. For TC type accidents, however, the results indicate that the uniform speed limit States experience much greater proportions for all collision types. In fact, for rear-end, sideswipe, and other collision types, the uniform speed limit States had accident proportions which were 57, 41, and 103 percent greater, respectively, than those experienced in the differential speed limit States. However, statistical analyses showed none of the differences in collision type/vehicle type with respect to uniform vs. differential speed limits to be significantly different at the 95-percent confidence level.

ANALYSIS OF ACCIDENT SEVERITY

The final analysis of the accident data was an examination of accident severity with the following classifications:

- Fatal.
- Injury.
- Property Damage Only (PDO).

Shown in table 33 are the accident proportions for the three levels of severity for each State. The range of fatal accident proportions were from 0.01 for three States to 0.03 in one State. The range of injury accident proportions was much greater, from 0.23 to 0.45. With respect to type of speed limit, the 65/65 speed limit group had an average combined fatal/injury accident proportion of 0.42. This compares to 0.34, 0.37, and 0.24 for the 55/55, 65/55, and 65/60 groups, respectively. Fatal and injury accident proportions for the two types of speed limits (uniform vs. differential) are shown at the bottom of table 33. While there are no differences in the fatal accident proportions, the injury accident proportions for the uniform speed limit States are 18

Table 33. Accident proportions by State and accident severity.

Car/Truck Speed Limit (mi/h)	State	Accident Proportions			Fatalities/ Fatal Accident	Injuries/ Injury Accident
		Fatal	Injury	PDO[1]		
55/55	PA	0.01	0.33	0.66	1.21	1.70
65/55	IL	0.02	0.30	0.68	1.44	1.75
	VA	0.02	0.39	0.59	1.20	1.68
65/60	IN	0.01	0.23	0.76	1.27	1.66
	WA	0.01	0.38	0.61	1.29	1.56
65/65	IA	0.01	0.33	0.66	1.21	1.70
	ID	0.03	0.45	0.52	1.12	1.71
	NC	0.02	0.43	0.55	1.24	1.77
Uniform (65/65 and 55/55)		0.02	0.39	0.59		
Differential (65/55 and 65/60)		0.02	0.33	0.65		

[1] PDO = Property Damage Only
1 mi/h = 1.61 km/h

percent greater for the States with uniform speed limits compared to the differential speed limit States. However, this difference is not statistically significant.

CHAPTER 7 - SUMMARY AND CONCLUSIONS

SUMMARY OF RESULTS

The objectives of this study were to determine whether differential or uniform speed limits are more beneficial to transportation safety and traffic operations on rural Interstate highways. To achieve these objectives, speed and accident data from 12 States representing all speed limit combinations presently existing on Interstate highways were collected and analyzed. A summary of the results from the analysis of these data is provided below.

Speed Data

The analysis of the speed data was designed to answer the following question:

What impacts do different types of speed limits have on traffic operations, i.e., what are the effects on travel speeds of cars and trucks?

The mean speeds for cars under the three speed limits included in this study (65/65, 65/60, and 65/55) were 67.6, 67.8, and 67.4 mi/h (108.8, 109.2, and 108.5 km/h), respectively, and were not significantly different. However, an analysis of the contiguous site pairs did show the difference of 2.4 mi/h (3.9 km/h) between sites governed by the 65/60 and 65/55 limits to be significantly different.

Truck mean speeds were significantly less in States governed by the 65/55 limit when compared to the 65/60 and 65/65 limits. However, the differences in speeds between the States with 60 and 65 mi/h (97 and 105 km/h) truck limits were not significantly different. The speeds for the three limits of 65/65, 65/60, and 65/55 were 63.8, 63.6, and 61.1 mi/h (102.7, 102.4, and 98.4 km/h), respectively.

The mean speeds were also analyzed with respect to time of day (day vs. night vs. dawn/dusk). For cars, the differences in speeds between all three time periods were significant. For trucks, however, the only significant difference was between the time periods night and dawn/dusk. For both vehicle types, these differences were very small (0.4 to 1.1 mi/h (0.6 to 1.8 km/h)) and cannot be considered practical differences. In addition, no significant or practical differences were for found for time of day with respect to type of speed limit.

Other analyses of mean speeds included weekday vs. weekend data and rural vs. urban data. For the weekday vs. weekend mean speeds, no significant differences were found with respect to day of week or type of speed limit. For the rural vs. urban mean speeds, cars exceeded the urban limits by greater amounts than trucks. However, no conclusions could be drawn with respect to urban speeds and type of speed limit due to the small number of sites in the sample.

The analysis of speed variance showed cars to exhibit greater variance than trucks across all speed limit groups, although the differences between the two vehicle types was relatively small in most cases. The results also showed both vehicle types to exhibit the greatest variance during the night, although, the differences in variance between the three time of day periods was typically very small.

With respect to type of speed limit, no significant differences in the speed variance of cars was found. For trucks, however, the variance was significantly greater at the locations with higher truck speed limits (10 of 13 site pairs). For all vehicles in the traffic stream, the variance was significantly greater at sites with the lower truck speed limits (10 of 13 site pairs).

An analysis of the overall speed distribution was undertaken by examining the differences in the 85th and 15th percentile speeds. The results showed the 65/65 and 65/60 speed limit groups to be very similar with respect to cars, trucks, and all vehicles. The distributions for cars and trucks within each group were also similar. However, the values for cars and trucks in the 65/55 speed limit group were not similar to each other, with cars experiencing a difference of 10.6 mi/h (17.1 km/h) and trucks only 8.7 mi/h (14.0 km/h).

The examination of vehicles not complying with the various speed limits showed cars to generally be consistent across all speed limit groups. However, as a group, the 65/55 limits did produce fewer cars (63.8 percent) exceeding the speed limit by 10 mi/h (16 km/h) or less compared with the 65/60 and 65/65 speed limit groups (68.7 and 66.6 percent, respectively). At the level of exceeding the limit by more than 15 mi/h (24 km/h) however, the differences in noncompliance between the speed limit groups are negligible.

The number of trucks in noncompliance was much greater for the 65/55 and 65/60 speed limit groups (89.4 and 76.5 percent, respectively) compared to the 65/65 group (35.6 percent). However, the lower limit of 65/55 did result in only 3.1 percent of the trucks exceeding 70 mi/h (113 km/h). This compared to 9.8 and 9.2 percent for the 65/60 and 65/65 groups, respectively.

Accident Data

The analysis of the accident data was designed to answer the following question:

- *What impacts do different types of speed limits have on transportation safety, i.e., what are the effects with respect to the types of accidents, the types of vehicles involved, and the crash severity?*

The analysis of accident proportions by collision type (single vs. rear-end vs. other multiple vehicle vs. other) showed no patterns that could be attributed to the type of speed limit. Similarly, no relationships between speed limit and vehicle types involved were shown to exist in the accident data.

However, combining collision type and vehicle type did produce some obvious patterns with respect to the type of speed limit. For States with differential speed limits, either 65/60 or 65/55, the proportion of CT rear-end accidents was 26 percent greater when compared to uniform speed limit States. For sideswipe and other types of CT accidents, there were very small differences in the accident proportions between types of speed limits. For TC accidents, the proportions were greater in the uniform speed limit States for rear-end, sideswipe, and other collision types by 57, 41, and 103 percent, respectively. However, none of the differences just described were significant at the 95-percent confidence level.

An analysis of accident severity showed uniform and differential speed limit States to have the same fatal accident proportion of 0.01. The injury accident proportion, however, was 18 percent greater in the uniform speed limit States (0.39 compared to 0.33). Nevertheless, this difference was not significant.

CONCLUSIONS

With respect to traffic operations and the three rural Interstate speed limits included in this study (65/65, 65/60, and 65/55), the findings resulted in the following conclusions:

- Mean travel speeds of cars are not affected by the type of speed limit. However, the 65/55 speed limit does appear to reduce the number of cars exceeding the speed limit by 10 mi/h (16 km/h) or less.

- Mean travel speeds of trucks are the same for the speed limit groups of 65/65 and 65/60, indicating that the 5 mi/h (8 km/h) differential has no effect on truck speeds. However, the 65/55 speed limit did result in lower truck mean speeds, although the difference from the upper speed limit groups was less than 3 mi/h (5 km/h).

- The 65/60 and 65/55 speed limits groups experienced much greater percentages of trucks in noncompliance with their respective speed limits when compared to the 65/65 speed limit group (by more than 2 to 1). However, the 65/55 group did result in fewer trucks exceeding 70 mi/h (113 km/h), thus limiting the number of high-speed trucks. The 65/65 and 65/60 speed limit groups experienced similar values for the number of trucks exceeding 70 mi/h (113 km/h), reconfirming the lack of effectiveness of the 5 mi/h (8 km/h) differential.

- Speed variance for trucks increased significantly at locations with higher truck limits (e.g., 65/65 compared to 65/60 and 65/55) while car speed variance was unaffected. More importantly, the speed variance for the overall traffic stream increased significantly at locations with differential speed limits, indicating more car/truck interactions.

- From the examination of the overall speed distribution, the 65/65 and 65/60 speed limits were very similar with respect to cars, trucks, and all vehicles. Within each group, the distributions for cars and trucks were also similar. For the 65/55 speed limit group, however, the differences in the car and truck distributions reconfirms the above result, i.e., that more car/truck interactions occurred under this speed limit.

Overall, the 65/65 and 65/60 speed limits exhibited very few differences with respect to mean travel speeds, speed variance, and compliance for cars, trucks, and all vehicles, providing evidence that the 5 mi/h (8 km/h) differential speed limit is not effective. The 65/55 speed limit, however, does affect the travel speeds of trucks by reducing the number of trucks in excess of 70 mi/h (113 km/h) and consequently, reducing the speed variance for trucks. On the other hand, the 65/55 speed limit also results in a larger speed variance for all vehicles and a greater difference in the distributions of car and truck speeds, which, in turn, results in a higher number of car/truck interactions when compared to 65/60 and 65/65 speed limit groups.

With respect to transportation safety, the findings resulted in the following conclusions:

- The uniform speed limit States experienced higher proportions of TC accidents for all collision types, including rear-end and sideswipe accidents. Although these proportions were not significantly greater at the 95-percent confidence level than those in the differential speed limit States, they were significantly greater at the 90-percent confidence level for rear-end accidents and at the 85-percent confidence level for sideswipe accidents.

- The differential speed limit States experienced higher proportions of CT accidents for rear-end collisions. However, this difference was not statistically significant.

- There were no differences in fatal accident proportions between the differential and uniform speed limit States, but the uniform speed limit States did experience a higher proportion of injury accidents. This difference, however, was not statistically significant.

Overall, the accident analysis showed very little difference in overall accidents or accident severity between the States with respect to the type of speed limit. However, the findings do suggest that the types of collisions and the roles of the vehicles involved may be impacted by the type of speed limit. In the differential speed limit States, the car-truck rear-end collisions were more likely to involve cars striking trucks. In the uniform speed limit States, all car-truck accidents were more likely to involve trucks striking cars.

FURTHER RESEARCH

While the speed data analysis conducted in this effort resulted in definitive conclusions, the accident data analysis was limited. However, certain trends in the data with respect to collision type/vehicle type involvement were identified. Further research is needed on the accident data to more clearly define the parameters affecting the affecting collision type and vehicle type involvement. Additional work is also needed to determine the levels of exposure at which any differences may be significant.

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