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Commercial Motor Vehicles' Safety - A California Perspective

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ABSTRACT

This report presents the findings of an examination of commercial motor vehicle crashes in California. Initially, a review of the basic descriptive statistics associated with truck-involved crashes in California was conducted; it covered the time period between January 1995 and December 2004 based on the Statewide Incident Tracking and Reporting System (SWITRS) data base, which contains information about every single motor vehicle accident in the state reported to a law enforcement agency. In addition to examinations of the entire population of truck-involved crashes in the state over the designated period, truck-involved crashes in Los Angeles County and the San Francisco Bay Area were also investigated. The next part of the report investigated the rates of truck accidents across California to determine the risk factors involved, including exposure to truck crashes, environmental conditions and demographic factors. The investigation involves modeling crashes as a function of these risk factors based on SWITRS data between 1998 and 2004.

Key Words: truck crashes, safety, commercial motor vehicle operations

EXECUTIVE SUMMARY

This report constitutes the third interim deliverable for PATH Project Task Order 6105 under Contract Number 65A0208 – *Compliance & Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions*.

This report presents the findings of an examination of commercial motor vehicle crashes in California. Initially, a review of the basic descriptive statistics associated with truck-involved crashes in California from both temporal and spatial perspectives was conducted; it covered the time period between January 1995 and December 2004 based on the Statewide Incident Tracking and Reporting System (SWITRS) data base, which contains information about every single motor vehicle accident in the state reported to a law enforcement agency. In addition to examinations of the entire population of truck-involved crashes in the state over the designated period, truck-involved crashes in Los Angeles County and the San Francisco Bay Area were also investigated.

During the period between January 1995 and December 2004, CHP investigated, or received reports from local agencies about, 344,281 unique truck-involved crashes. These involved 697,110 parties, including 366,229 trucks, and resulted in 4,176 deaths and 126,392 injuries. Most truck crashes (71.9%) involved two parties, consisting of a collision between two vehicles. The next-leading category (15.1%) was single-vehicle accidents.

In general, the likelihood of a crash generating at least one fatality increased with the number of parties involved. The vast majority of truck-involved crashes during the study period resulted in property damage only. Only one percent of incidents resulted in fatalities. In 50.9% of truck-involved collisions, a truck was determined to be at fault. In the 84.9% of collisions where multiple vehicles were involved, a truck was at fault 45.7% of the time. In those, the incidence of all injuries except the least severe fell significantly. In fatal accidents statewide that involved a truck and at least one other party, a truck was at fault only 23.9% of the time.

During the study period, the number of truck-involved crashes in a given year ranged from 32,522 (1996) to 37,049 (2000). The peak in traffic during 2000 reflects that year's status as the final year of an economic boom. Fatal collisions fell throughout the second half of the 1990s before sharply rising in 2000, but dropped off thereafter.

The fewest crashes occur in January, February, and April, while the most take place in August, September, and October. That crashes peak in those months is not surprising given that the bulk of shipping for holiday retail occurs in them. Fatal truck-involved crashes peak in the summer as well.

In accordance with the predictions of travel behavior theory, truck crashes are minimal during the late night and in the early morning, rise throughout the morning, reach a peak in the early afternoon, and fall off dramatically after 6:00 PM. However, fatal crashes are vastly more likely to occur in the late night and early morning hours. Explanations for

this include driver fatigue and the higher speeds possible during uncongested night traffic.

Unsurprisingly, the fewest truck crashes occur on Sunday and Saturday. The busiest days for truck crashes are Tuesday and Friday. Fatal truck crashes occurred with disproportionate frequency on weekends; this is likely due to the fact that the lower levels of congestion — and thus higher speeds — prevail on weekends.

The majority of crashes occurred on roads designated within the California State Highway System, including U.S. and Interstate highways and numbered state routes. Fatal crashes occurred less often on local roads, probably due to the lower speeds prevalent on them in many rural areas and in virtually all urbanized areas.

The vast majority (77.8%) of truck crashes during the period occurred in clear conditions. Rain was present in 3.2 % of crashes. Winds high enough to be notable were present less than 1% of the time, while fog occurred in 1.1% of crashes. Snow was present in only 0.3% of crashes, reflecting the relatively small number of truck trips occurring within regions of California susceptible to snowfall. Fatal crashes were significantly more likely in conditions of fog and high winds.

Approximately 91% of truck crashes occurred on dry pavement; further, about 94% of crashes happened on roads with no significant damage or obstructions.

The majority of truck-involved collisions occurred away from a control device such as a stop sign or traffic signal. Investigators only rarely deemed the control device obscured or nonfunctional.

Trucks involved in crashes statewide during the study period had median and mean ages of 6 and 7.9 years, respectively. For those involved in fatal accidents, the respective figures were 7 and 8.5 years.

Use of alcohol by truck drivers is vanishingly rare. During the study period, investigating authorities found that drivers of trucks deemed at fault in their respective accidents had consumed alcohol in only 0.5% of cases; this figure rose only to 2.4% in fatal accidents. Drug usage played little or no role in most accidents, although 6.6% of truckers deemed at fault in fatal accidents were under the influence of controlled substances. Fatigued truckers were at fault in only 0.7% of accidents statewide (and only 0.2% in heavily urbanized Los Angeles County), and only 2.9% of the time in fatal crashes.

Twenty six percent of truckers involved in crashes did not have any proof of insurance. Among truck drivers determined to be at fault in an accident, this figure rose to 30.6%. Uninsured truckers were at fault in 50.2% of the 79,204 multi-vehicle accidents in which they were involved.

Defective equipment and 33 non-compliance violations were surprisingly rare among truckers involved in accidents: only 0.6% of trucks involved in accidents were issued

citations for such violations, and investigators noted minor (i.e. non-prosecutable) violations for 1.0% of trucks. For trucks deemed at fault in accidents, these figures rose to 0.91% and 2.57%, respectively.

In accidents where trucks were deemed at fault, the overwhelming majority of accidents occurred due to improper driving — especially unsafe speed, unsafe lane changes, and improper turning.

For trucks towing a load, the most common loads involved in accidents were semi-trailers (65.3%), two trailers (11.7%), pull trailers with dollies (8.0%), and utility trailers (3.5%). Container chassis accounted for only 1.3% of the trucks involved in accidents.

Among trucks declared at fault in multi-vehicle collisions, only 704 — 0.5% — towed container chassis. Trucks towing container chassis involved in multi-vehicle collisions were at fault only 39.6% of the time, significantly less than the 45.7% for trucks in general. In the only 25 fatal multi-vehicle collisions involving a truck towing container chassis, the container hauler was at fault in just eight (32%) of them.

The next part of the report investigated the rates of truck accidents across California to determine the risk factors involved. Such factors include *exposure to truck crashes*, for example, trips, vehicle-miles-traveled, and population density; *environmental conditions* such as traffic conditions, weather, roadway conditions, and geometry; and *driver-specific* factors such as demographics. The investigation involves modeling crashes as a function of these risk factors based on SWITRS data between 1998 and 2004. The results point to a high likelihood that the heavily urbanized counties of the San Francisco Bay Area and greater Los Angeles are actually less dangerous for trucks than the state's rural counties, especially in the state's northern half.

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1.0 INTRODUCTION

This report constitutes the third interim deliverable for PATH Project Task Order 6105 under Contract Number 65A0208 – *Compliance & Commercial Vehicle Operators: A Systems Evaluation of the Problem & Virtual Solutions*.

The focus of this report is on the safety aspects of commercial motor vehicles in California and follows up from a previous project report (California PATH Program et al, 2008), which included a discussion of truck crash causation and the role of non-compliance in truck crashes. For truck crash causation, the following topics were discussed on a national basis:

- General trends in truck crashes
- General characteristics of truck crashes
- Causal factors in truck crashes

In summary from this previous report, the Motor Carrier Safety Improvement Act of 1999 mandated the study of commercial vehicle crash causation resulting in the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA) launching the Large Truck Crash Causation Study (2001-2003). This and other studies have shown that commercial trucking vehicle miles traveled (VMT) have increased at a greater rate than passenger car VMT following 1980 deregulation of the trucking industry. While accidents have fallen per VMT, trucks are still more likely than passenger vehicles to become involved in accidents. Most crashes occur on weekdays, either in daytime between rush hours (0900-1400) or late night/early morning (0000-0700). Rural areas account for majority of fatalities and single-unit trucks crash primarily on less-than 50-mile trips. In terms of causal factors, two-lane undivided roads, roads away from traffic control devices, roads away from junctions account for majority of truck crash fatalities; urban freeway truck crashes disproportionately involve lane changes/merges; truck drivers safer than passenger car drivers except for tendency to speed; and training by trucking school, military, family, etc. is safer than training by trucking company.

In the role of non-compliance, trucking safety is largely a driver issue in that truck driver error is responsible in approximately 40% of truck-on-passenger-car crashes; approximately 25% of roadside truck inspections results in out-of-service, versus about 6% each for driver and hazmat inspections; drivers cited for size/weight violations are approximately 20% more likely to crash; noncompliance in driver-related issues (falsified or missing logbook, excessive hours of service, disqualified driver) results in about 50% greater likelihood of crashing; and brake failure is the most common vehicle issue for about 30% of truck crashes during 2001-2003 study period involving the vehicle. Thus the usefulness of weighing and compliance stations is clear as it is important to find and remove non-compliant trucks off the road as quickly as possible. Increasing the inspectors' ability to identify trucks with defective brakes can save lives and money because bad brakes by far outweigh any other vehicle-related defect in terms of relative importance to truck safety (LTCCS 2005). The significant impact of excessive weight on the likelihood of rollover (Moonesinghe *et al* 2003) also makes a case for faster and more efficient weighing practices.

Chapter 2 examines the basic descriptive statistics associated with truck-involved crashes in California during the period beginning 01 January 1995 and ending 31 December 2004. It uses the Statewide Incident Tracking and Reporting System (SWITRS) maintained by the California Highway Patrol, a database containing pertinent information about every single motor vehicle accident in the state reported to a law enforcement agency. In addition to examinations of the entire population of truck-involved crashes in the state over the designated period, this chapter also looks at truck-involved crashes resulting in at least one fatality; truck crashes in Los Angeles County and the San Francisco Bay Area; and truck crashes involving container drayage vehicles.

Chapter 3 investigates the rates of truck accidents across California to determine the risk factors involved. Such factors include *exposure to truck crashes*, for example, trips, vehicle-miles-traveled, and population density; *environmental conditions* such as traffic conditions, weather, roadway conditions, and geometry; and *driver-specific* factors such as demographics. The investigation involves modeling crashes as a function of these risk factors based on SWITRS data between 1998 and 2004.

2.0 TRUCK-INVOLVED CRASHES IN CALIFORNIA, 1995-2004: A STATISTICAL SNAPSHOT

This chapter first examines the temporal and spatial characteristics of truck-involved crashes during the study period. It then looks at the characteristics of the vehicles and drivers involved. Finally, it discusses the implications of its findings for the policy context at hand.

2.1 Crashes

2.1.1 General Characteristics

2.1.1.1 Crashes and Involved Parties

During the period 01 January 1995 – 31 December 2004, CHP investigated, or received reports from local agencies about, 344,281 unique truck-involved crashes. These involved 697,110 parties, including 366,229 trucks, and resulted in 4,176 deaths and 126,392 injuries.

Most truck crashes (71.9%) involved two parties, consisting of a collision between two vehicles. The next-leading category (15.1%) was single-vehicle accidents. There were a few spectacular multiple-car pileups during the period, including one 58-vehicle collision on Route 99 in Fresno on a foggy morning in February 2002. Results are shown in Figure 2-1 where “LAX” represents results for Los Angeles County and “SFBA” represents the San Francisco Bay Area, which includes the nine counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma.

In general, the likelihood of a crash generating at least one fatality increased with the number of parties involved.

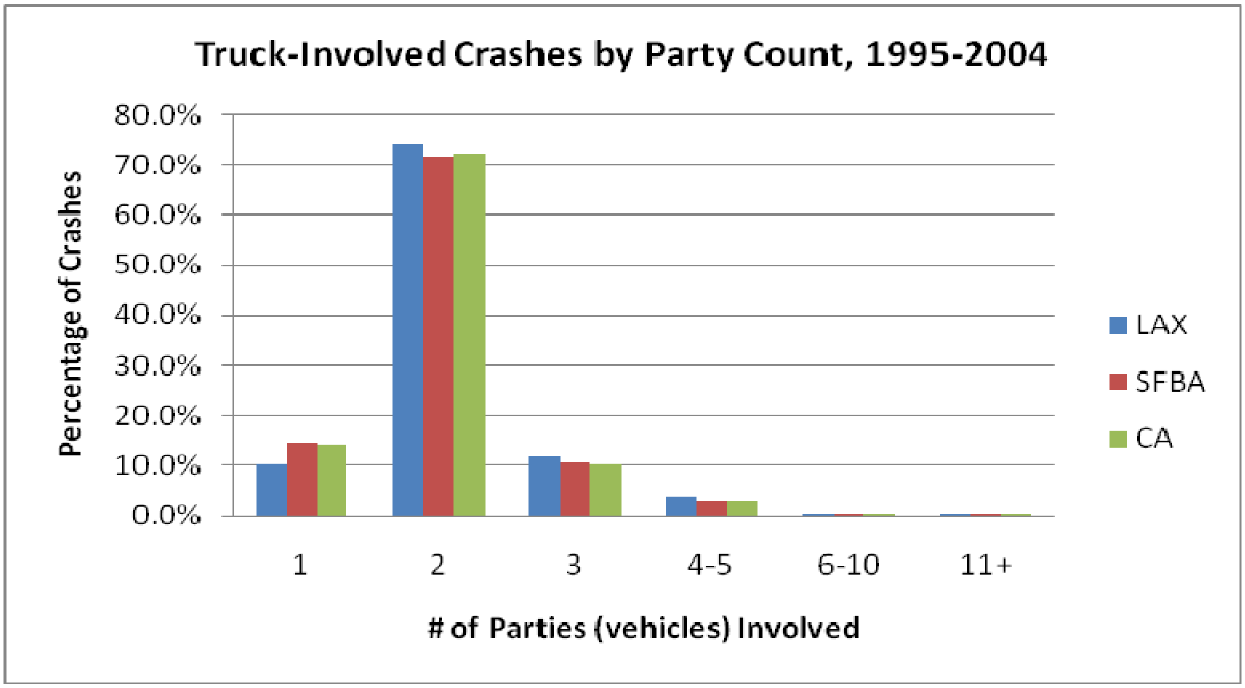

Figure 2-1 Truck-Involved Crashes by Party Count, 1995-2004

2.1.1.2 Crash Severity and Fault

The vast majority of truck-involved crashes during the study period resulted in property damage only. Only one percent of incidents resulted in fatalities.

In 50.9% of truck-involved collisions, a truck was determined to be at fault. In the 84.9% of collisions where multiple vehicles were involved, a truck was at fault 45.7% of the time. In those, the incidence of all injuries except the least severe ("complaint of pain") fell significantly. In fatal accidents statewide that involved a truck and at least one other party, a truck was at fault only 23.9% of the time.

Table 2-1 Truck-Involved Crashes by Severity, 1995-2004

Type	LAX	SFBA	CA-All
Property damage only	77.2%	77.2%	74.6%
Fatal	0.6%	0.7%	1.1%
Injury (Severe)	1.4%	1.4%	1.8%
Injury (Other Visible)	7.5%	6.7%	9.0%
Injury (Complaint of Pain)	13.3%	14.1%	13.5%

Table 2-2 Severity of Truck-Involved Crashes When a Truck Is at Fault (2+ parties), 1995-2004

Type	LAX	SFBA	CA-All
Property damage only	56.7%	52.8%	52.5%
Fatal	1.1%	1.4%	2.0%
Injury (Severe)	2.5%	2.7%	3.3%
Injury (Other Visible)	13.6%	13.5%	15.2%
Injury (Complaint of Pain)	26.1%	29.6%	27.1%

2.1.2 Temporal Characteristics

2.1.2.1 Year

During the study period, the number of truck-involved crashes in a given year ranged from 32,522 (1996) to 37,049 (2000). The peak in traffic during 2000 reflects that year's status as the final year of an economic boom. Fatal collisions fell throughout the second half of the 1990s before sharply rising in 2000, but dropped off thereafter.

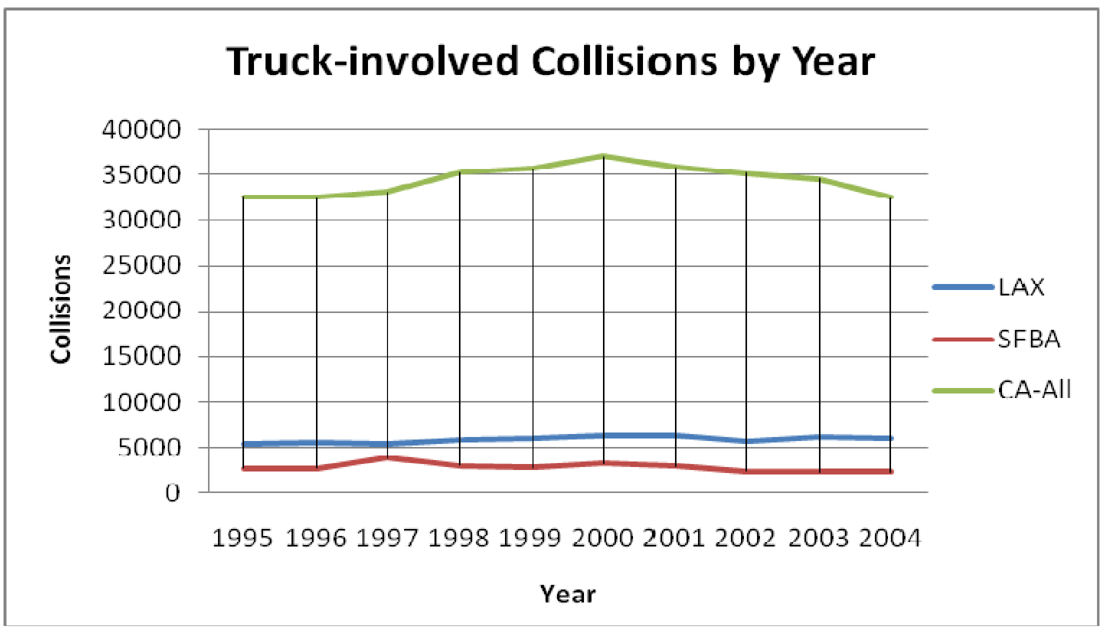

Figure 2-2 Truck-Involved Crashes by Year, 1995-2004, California, San Francisco Bay Area and Los Angeles County

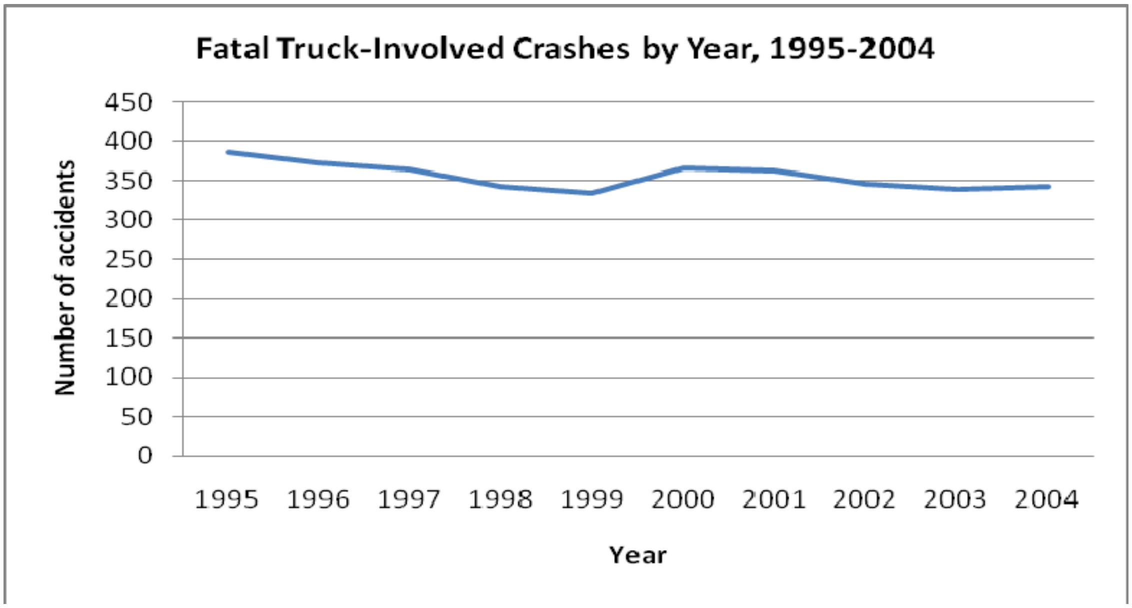

Figure 2-3 Fatal Truck-Involved Crashes by Year in California, 1995-2004

2.1.2.2 Month

The fewest crashes occur in February, January, and April (7.4%, 7.9%, and 8.0% of the total, respectively), while the most take place in August, October, and September (9.2%, 9.1%, and 8.8% respectively). That crashes peak in those months is not surprising given that the bulk of shipping for holiday retail occurs in them. Fatal truck-involved crashes peak in the summer as well.

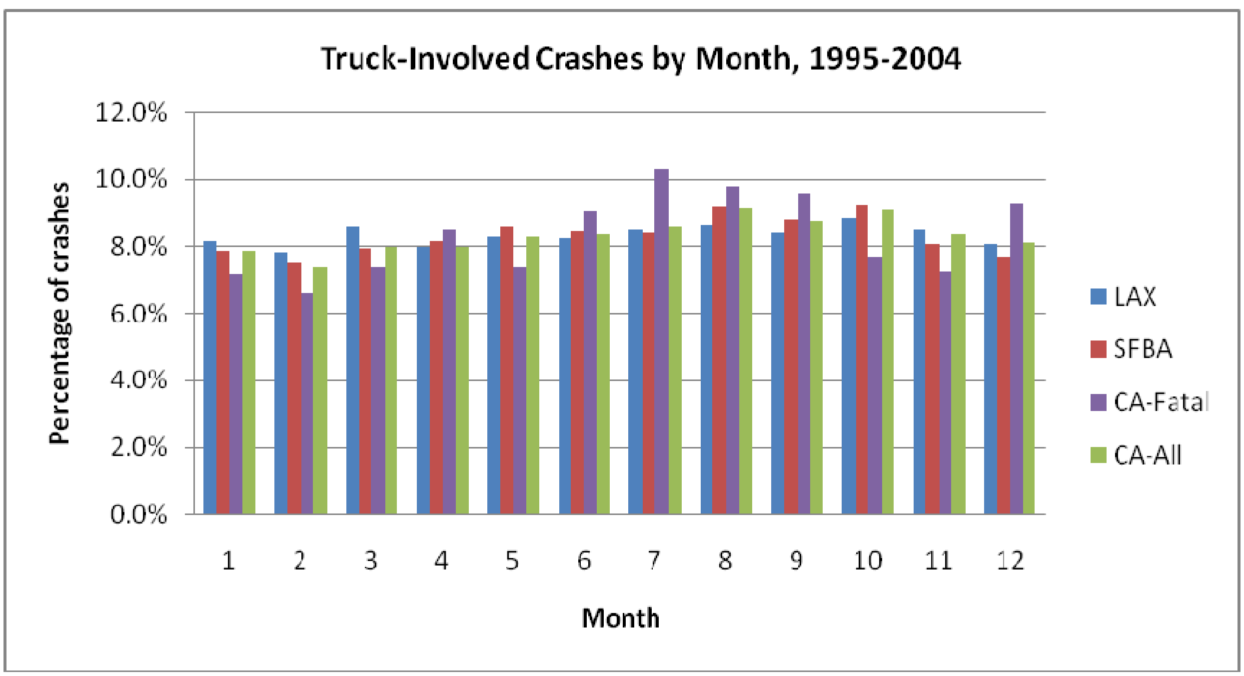

Figure 2-4 Truck-Involved Crashes by Month, 1995-2004

2.1.2.3 Time of Day

In accordance with the predictions of travel behavior theory, truck crashes are minimal at night and in the early morning (12:00 AM – 6:00 AM), rise throughout the morning (6:00 AM – 12:00 PM), peak in the early afternoon (12:00 PM – 3:00 PM), and fall off dramatically after 6:00 PM. This pattern holds for Los Angeles County as well as for the state as a whole. However, fatal crashes are vastly more likely to occur in the late night (9:00 PM – 3:00 AM) and early morning (3:00 AM – 6:00 AM) hours. Explanations for this include driver fatigue and the higher speeds possible during uncongested night traffic.

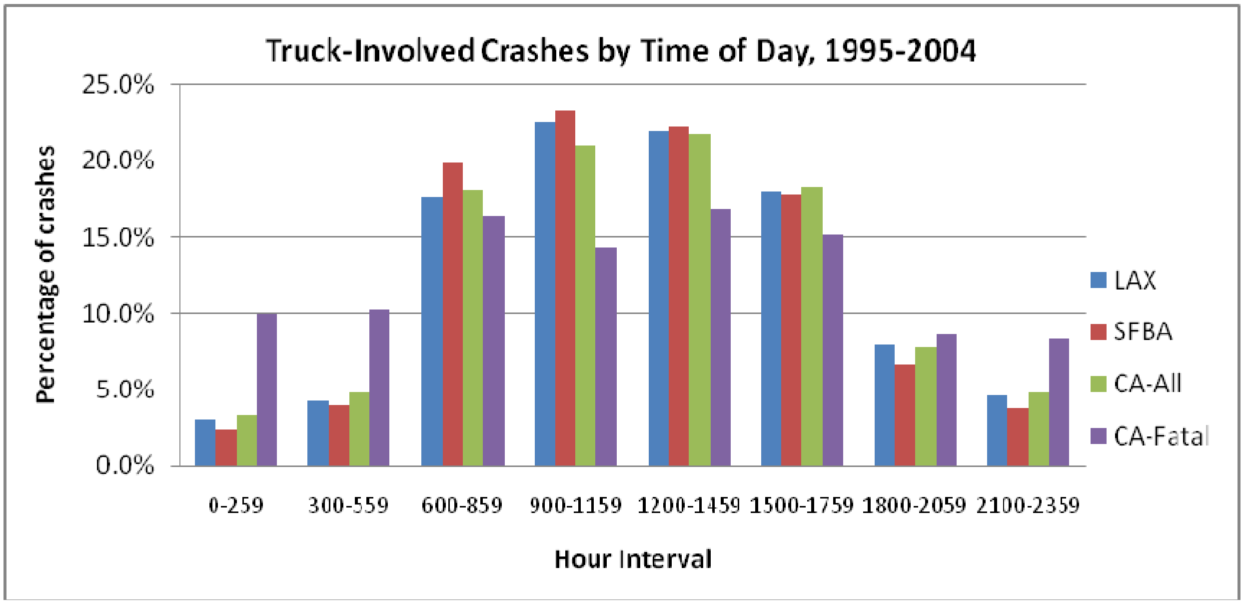

Figure 2-5 Truck-Involved Crashes by Time of Day, 1995-2004

2.1.2.4 Day of the Week

Unsurprisingly, the fewest truck crashes occur on Sunday and Saturday, respectively comprising 4.2% and 6.9% of the total. The busiest days for truck crashes are Tuesday and Friday, with 18.3% and 18.1% respectively. Fatal truck crashes occurred with disproportionate frequency on weekends; this likely owes to the lower levels of congestion—and thus higher speeds—that prevail on weekends.

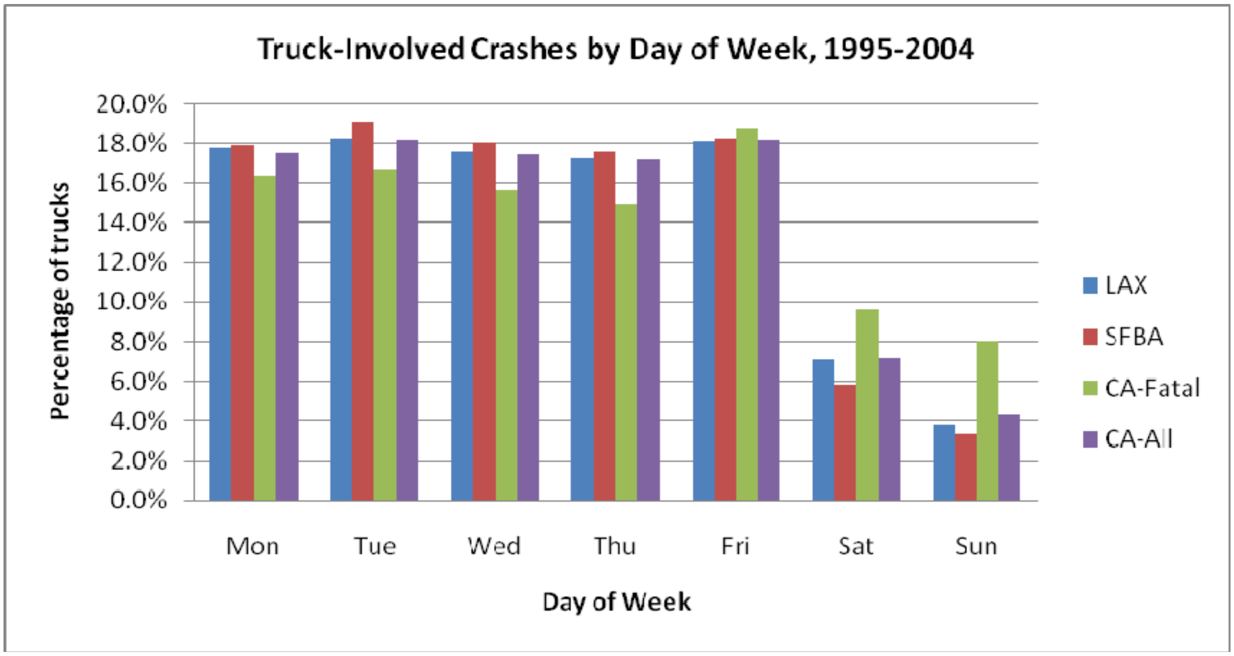

Figure 2-6 Truck-Involved Crashes by Day of Week, 1995-2004

2.1.3 Location Characteristics

2.1.3.1 Counties

Reflecting the heavily local orientation of truck traffic, the distribution of truck crashes across California's counties over the study period reasonably matches the distribution of population. Los Angeles County led with 30.6% of crashes, roughly in line with its 27.4% share of the population.[1] San Bernardino County accounted for a disproportionately high share of crashes (8.2%, vs. 5.4% of the state's population) due to its heavily industrialized economy and sheer geographic size. Alameda County hosted 5.9% of crashes despite having only 4.0% of state population, reflecting traffic generated by the Port of Oakland and by its extensive industrial base. Other leading counties included Orange (6.3%), Riverside (5.6%), San Diego (4.0%), and Santa Clara (2.9%).

[1] 2006 American Community Survey, United States Bureau of the Census.

Table 2-3 Truck-Involved Crashes by County, 1995-2004

County	Crashes	Percent	County	Crashes	Percent	County	Crashes	Percent
(Unlisted)	16	0.01%	Madera	684	0.49%	San Diego	5,598	4.03%
Alameda	8,259	5.94%	Mendocino	407	0.29%	San Francisco	1,498	1.08%
Alpine	21	0.02%	Merced	1,516	1.09%	Shasta	720	0.52%
Amador	178	0.13%	Mono	115	0.08%	Sierra	18	0.01%
Butte	442	0.32%	Monterey	1,963	1.41%	Siskiyou	336	0.24%
Calaveras	139	0.10%	Modoc	61	0.04%	San Joaquin	4,023	2.89%
Contra Costa	2,575	1.85%	Marin	981	0.71%	San Luis Obispo	972	0.70%
Colusa	233	0.17%	Mariposa	52	0.04%	San Mateo	2,235	1.61%
Del Norte	98	0.07%	Napa	544	0.39%	Solano	1,834	1.32%
El Dorado	416	0.30%	Nevada	563	0.41%	Sonoma	1,450	1.04%
Fresno	2,940	2.12%	Orange	8,782	6.32%	Stanislaus	2,447	1.76%
Glenn	175	0.13%	Placer	1,407	1.01%	Sutter	299	0.22%
Humboldt	400	0.29%	Plumas	117	0.08%	Tehama	358	0.26%
Imperial	666	0.48%	Riverside	7,820	5.63%	Trinity	81	0.06%
Inyo	93	0.07%	Sacramento	4,734	3.41%	Tulare	1,756	1.26%
Kern	3,679	2.65%	Santa Barbara	1,205	0.87%	Tuolumne	199	0.14%
Kings	594	0.43%	San Benito	270	0.19%	Ventura	2,764	1.99%
Lake	174	0.13%	San Bernardino	11,368	8.18%	Yolo	895	0.64%
Lassen	186	0.13%	Santa Clara	3,997	2.88%	Yuba	281	0.20%
Los Angeles	42,525	30.60%	Santa Cruz	817	0.59%	**Total**	**138,986**	100.00%

2.1.3.2 Rural/Urban

Using the CHP's eight-part scale (seven population levels for urban areas and a rural zone), fully 31.3% of truck crashes occur in rural areas. This percentage accords with national data, which show a disproportionately high number of accidents occurring on two-lane undivided roads of the sort predominantly found in rural areas. Unsurprisingly, the vast majority of fatal truck-involved crashes occur in rural areas, where truckers may be more likely to travel at an unsafe speed.

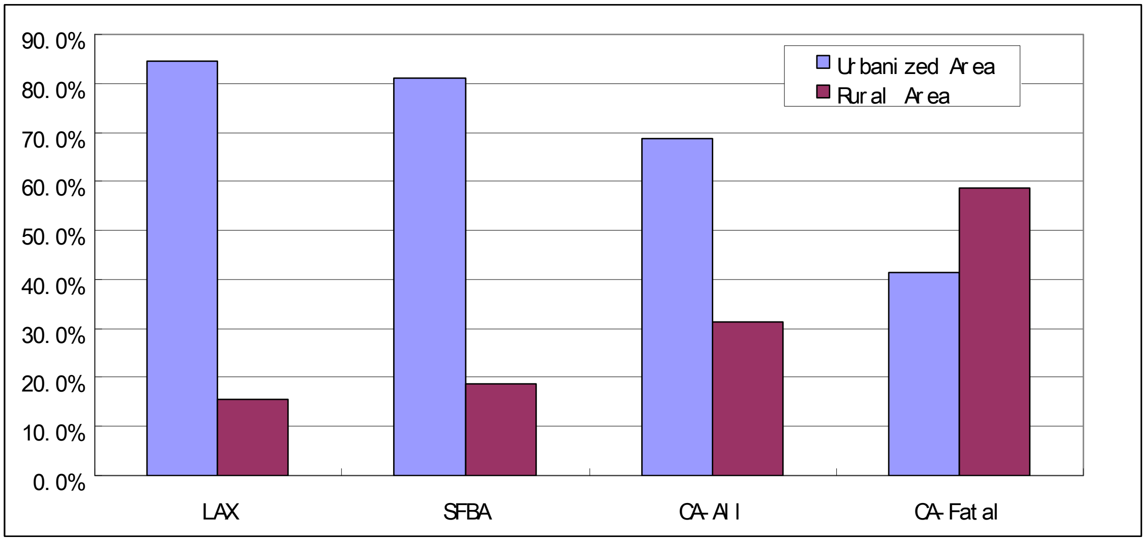

Figure 2-7 Truck-Involved Crashes by Urbanized Category of Location, 1995-2004

2.1.3.3 Road Type

The majority of crashes (59%) occurred on roads designated within the California State Highway System, including U.S. and Interstate highways and numbered state routes. Fatal crashes occurred less often on local roads, probably due to the lower speeds prevalent on them in many rural areas and in virtually all urbanized areas. Due to unclear coding by Caltrans and CHP, we could not determine the lane and barrier configurations of roads in accidents. As noted above, we can presume that a disproportionate number of incidents occurred on two-lane undivided roads.

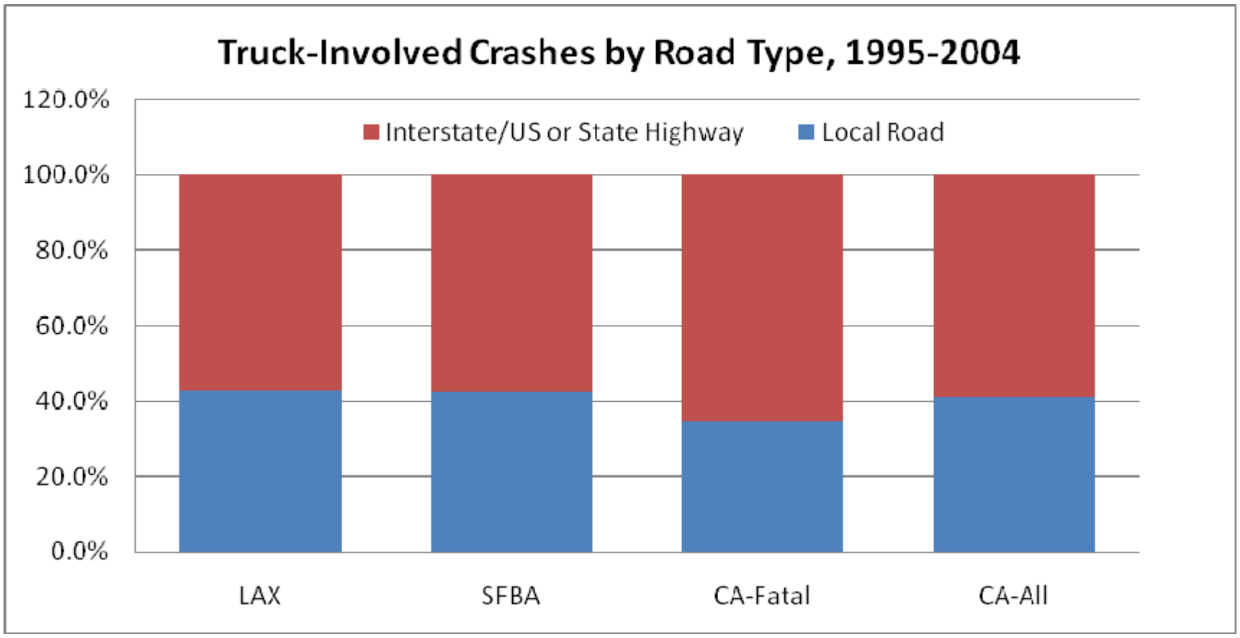

Figure 2-8 Truck-Involved Crashes by Road Type, 1995-2004

2.1.3.4 Weather

The vast majority (77.8%) of truck crashes during the period occurred in clear conditions. Rain was present in 3.2 % of crashes. Winds high enough to be notable were present less than 1% of the time, while fog occurred in 1.1% of crashes. Snow was present in only 0.3% of crashes, reflecting the relatively small number of truck trips occurring within regions of California susceptible to snowfall. Fatal crashes were significantly more likely in conditions of fog and high winds.

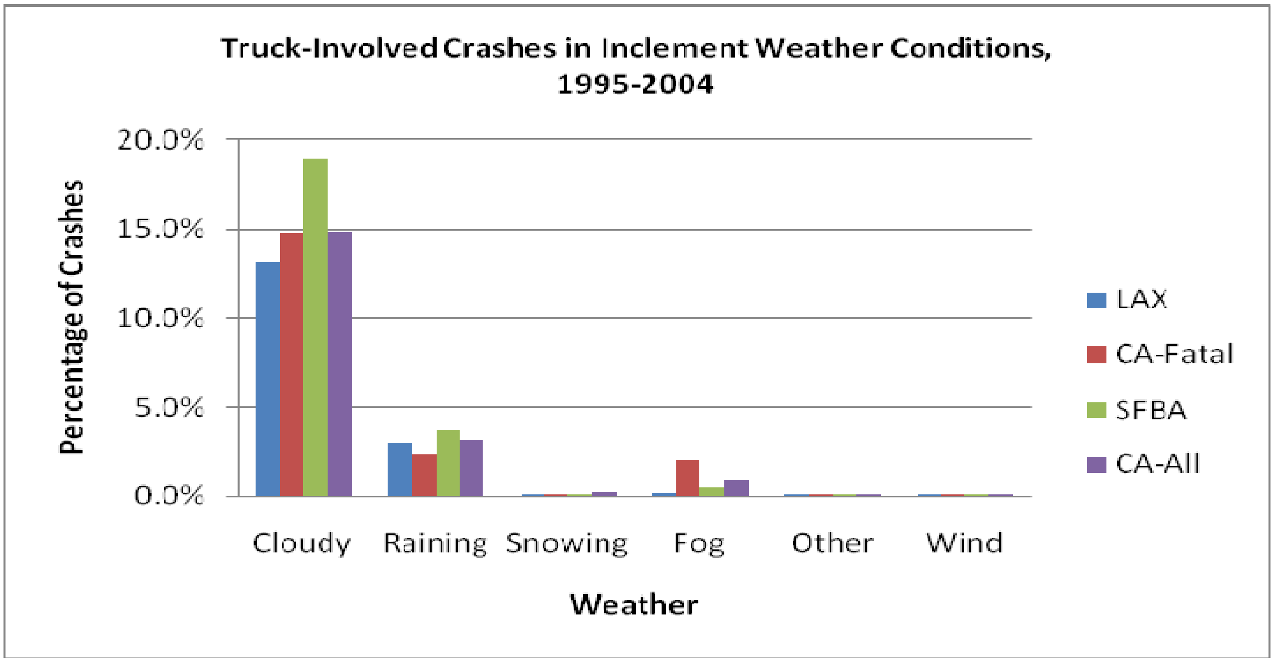

Figure 2-9 Truck-Involved Crashes in Inclement Weather Conditions, 1995-2004

2.1.3.5 Road Surface/Conditions

The overwhelming majority (90.8 %) of truck crashes occurred on dry pavement. A further 94.2 % of crashes happened on roads with no significant damage or obstructions; the only unusual condition of note was construction zones, which were present in just under four percent of recorded truck accidents. Fatal crashes were only slightly more likely to occur on wet pavement than dry.

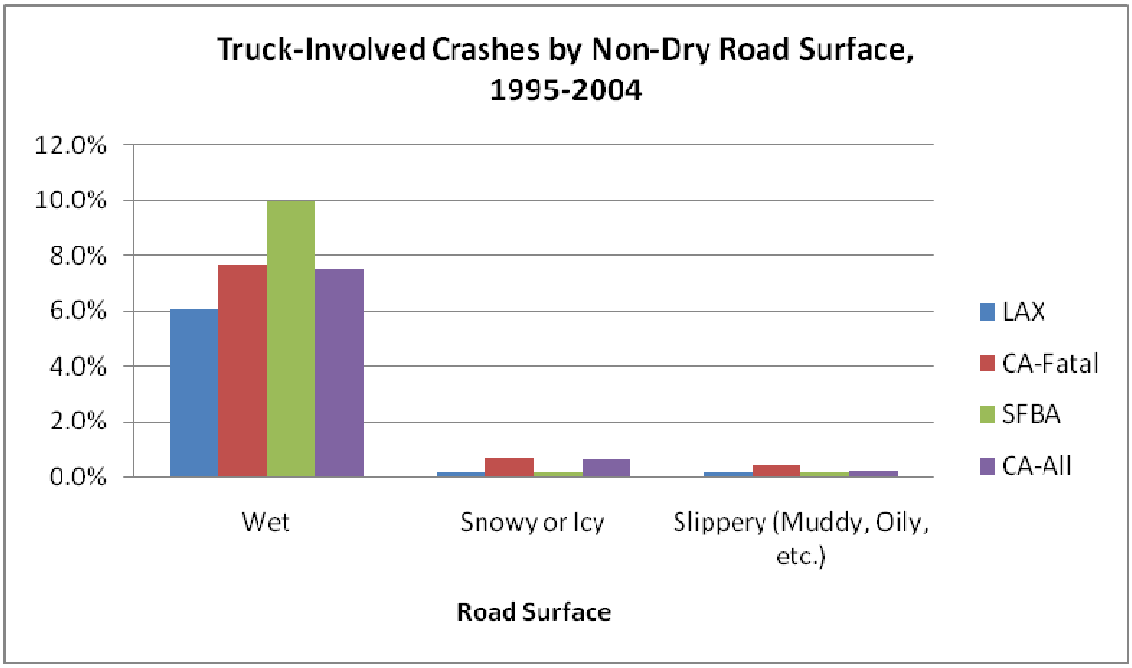

Figure 2-10 Truck-Involved Crashes by Non-Dry Road Surface, 1995-2004

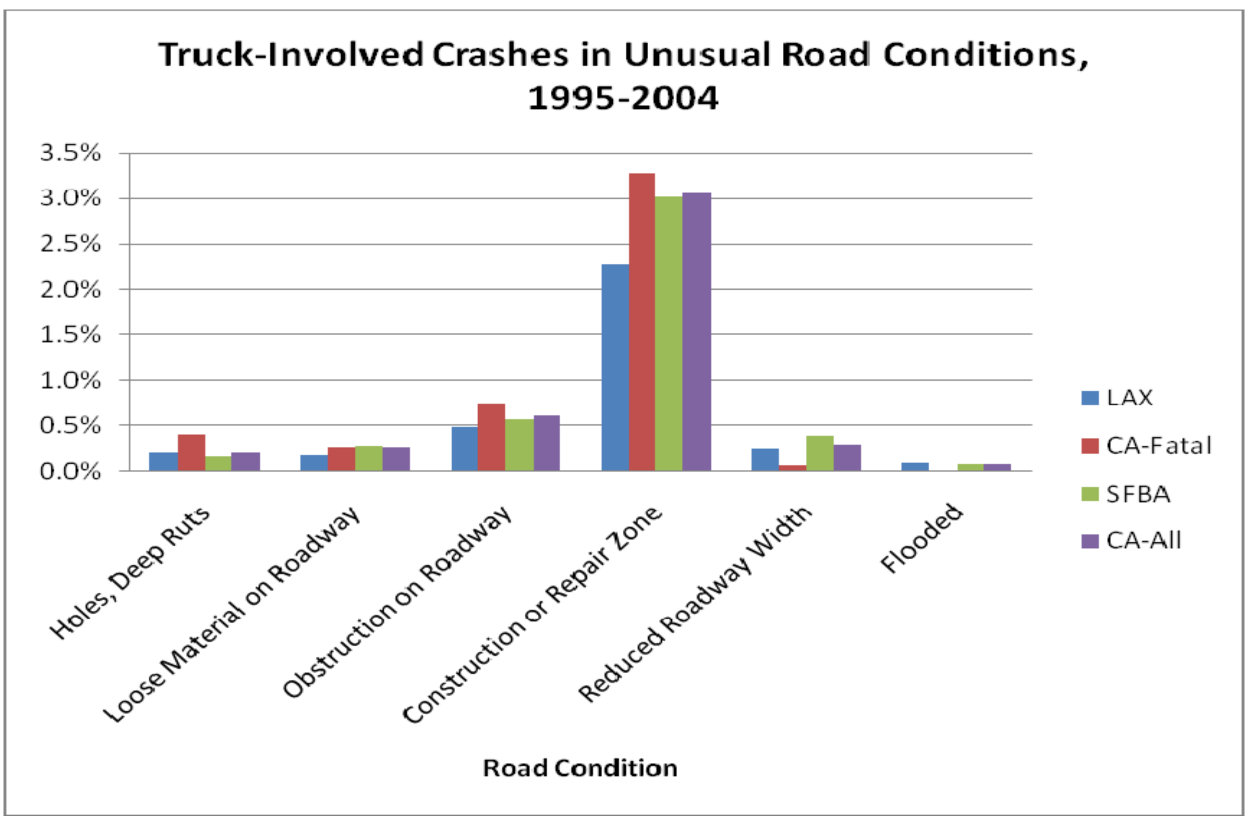

Figure 2-11 Truck-Involved Crashes in Unusual Road Conditions, 1995-2004

2.1.3.6 Lighting
In accordance with the time-of-day statistics discussed above, 78.6 % of truck accidents occurred in daylight. Only 3.1 % occurred at dusk or dawn. 9.9 % occurred on lighted streets at night, while 7.8 % took place on unlighted streets. Streetlights were malfunctioning in less than one-tenth of one percent of crashes.

Fatal accidents occurred with significantly greater frequency in non-daylight conditions. They occurred with particular frequency on dark roads without streetlights—principally, rural highways.

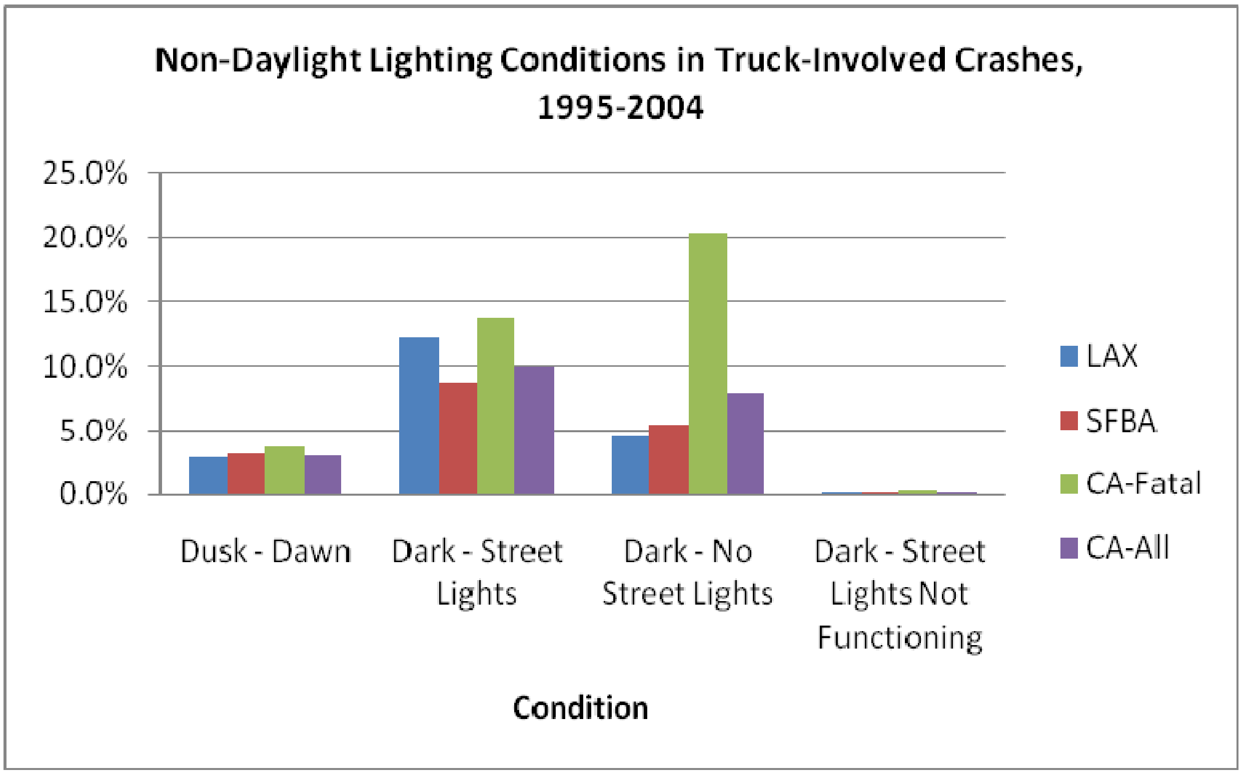

Figure 2-12 Non-Daylight Lighting Conditions in Truck-Involved Crashes, 1995-2004

2.1.3.7 Control Devices
The majority of truck-involved collisions occurred away from a control device such as a stop sign or traffic signal. Investigators only rarely deemed the control device obscured or nonfunctional.

Table 2-4: Control Devices in Truck-Involved Crashes, 1995-2004

Control Device Characteristics	LAX	SFBA	CA	CA-Fatal
Functioning	21.0%	24.8%	25.0%	29.2%
Not Functioning	0.2%	0.1%	0.2%	0.1%
Obscured	0.0%	0.1%	0.1%	0.1%
None present	78.2%	74.4%	74.2%	70.0%
Not Stated	0.5%	0.6%	0.5%	0.6%

2.2 Trucks and Drivers Involved

2.2.1 Vehicle Age

Trucks involved in crashes statewide during the study period had median and mean ages of 6 and 7.93 years, respectively. For those involved in fatal accidents, the respective figures were 7 and 8.50 years.

The age distribution of trucks involved in crashes in Los Angeles County closely matched that for the state as a whole, with respective median and mean ages of 6 and 7.91 years. Container drayage trucks skewed considerably older, with median and mean ages of 10 and 10.34 years respectively.

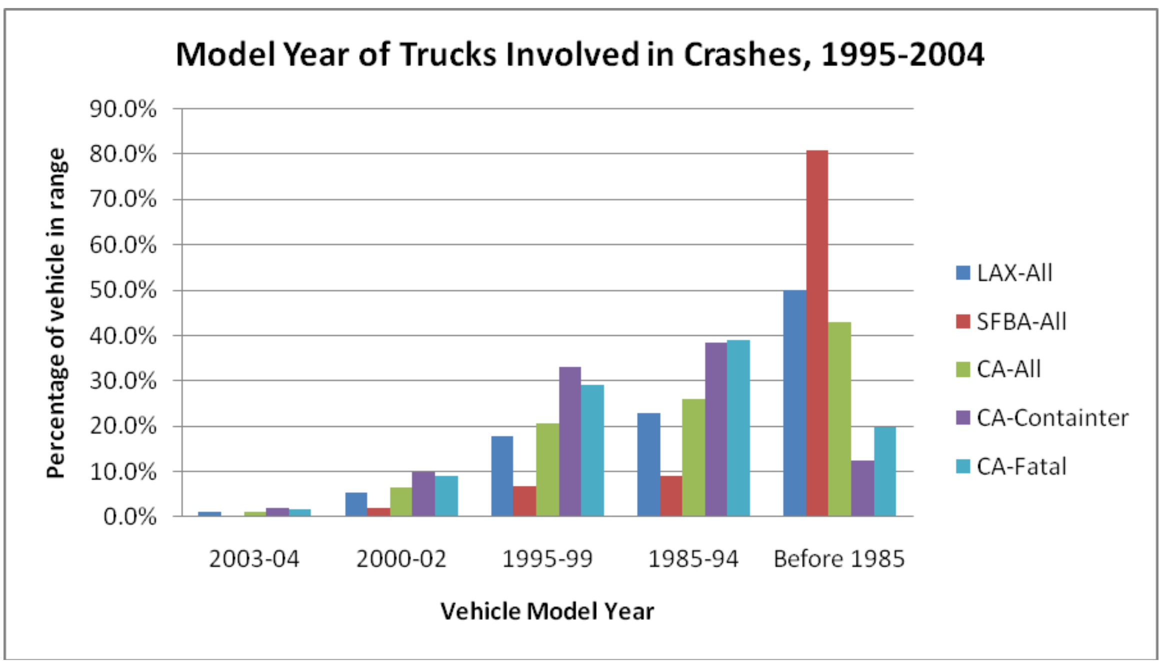

Figure 2-13 Model Year of Trucks Involved in Crashes, 1995-2004

2.2.2 Alcohol, Drugs, and Fatigue

Use of alcohol by truck drivers is vanishingly rare. During the study period, investigating authorities found that drivers of trucks deemed at fault in their respective accidents had consumed alcohol in only 0.5% of cases; this figure rose only to 2.4% in fatal accidents. Drug usage played little or no role in most accidents, although 6.6% of truckers deemed at fault in fatal accidents were under the influence of controlled substances. Fatigued truckers were at fault in only 0.7% of accidents statewide (and only 0.2% in heavily urbanized Los Angeles County), and only 2.9% of the time in fatal crashes.

Table 2-5: Sobriety of Truck Drivers at Fault in Truck-Involved Crashes, 1995-2004

Category	LAX	SFBA	CA-All	CA-Fatal
Had Not Been Drinking	83.3%	81.7%	84.4%	75.6%
Had Been Drinking, Under Influence	0.4%	0.3%	0.5%	2.4%
Had Been Drinking, Not Under Influence	0.2%	0.2%	0.2%	1.0%
Had Been Drinking, Impairment Unknown	0.3%	0.4%	0.3%	0.8%
Impairment Unknown	9.2%	8.5%	8.2%	12.6%
Not Applicable	1.4%	1.5%	1.3%	0.9%
Not Stated	5.2%	7.4%	5.2%	6.7%

2.2.3 Financial Responsibility

26.4% of truckers involved in crashes did not have any proof of insurance. Among truck drivers determined to be at fault in an accident, this figure rose to 30.6%. Uninsured truckers were at fault in 50.2% of the 79,204 multi-vehicle accidents in which they were involved.

2.2.4 Equipment and Compliance Violations

Defective equipment and 33 non-compliance violations were surprisingly rare among truckers involved in accidents: only 0.6% of trucks involved in accidents were issued citations for such violations,[2] and investigators noted minor (i.e. non-prosecutable) violations for 1.0% of trucks.[3] For trucks deemed at fault in accidents, these figures rose to 0.91% and 2.57%, respectively.

In accidents where trucks were deemed at fault, the overwhelming majority of accidents occurred due to improper driving—especially unsafe speed, unsafe lane changes, and improper turning.

[2] CHP lists these as Lights; Brakes; Other Equipment; Improper Registration; Other Non-Moving Violation; Excessive Smoke; Excessive Noise; Overweight; Oversize; and Seat Belt (Equipment).

[3] CHP lists these as Vision Obscurements and Defective Vehicle Equipment.

Table 2-6 Primary Violation in Accidents with Truck at Fault, 1995-2004

Violation Type	LAX	SFBA	CA
Driving Under the Influence of Alcohol or Drug	0.9%	0.8%	1.0%
Impeding Traffic	0.1%	0.0%	0.1%
Unsafe Speed	28.3%	26.3%	27.6%
Following Too Closely	3.4%	3.6%	2.5%
Wrong Side of Road	0.7%	1.9%	2.2%
Improper Passing	1.0%	0.8%	0.9%
Unsafe Lane Change	26.3%	19.2%	20.9%
Improper Turning	16.4%	20.6%	18.8%
Automobile Right of Way	3.8%	3.4%	5.1%
Pedestrian Right of Way	0.3%	0.3%	0.2%
Pedestrian Violation	0.0%	0.0%	0.0%
Traffic Signals and Signs	1.5%	1.8%	1.9%
Hazardous Parking	0.3%	0.5%	0.4%
Lights	0.0%	0.0%	0.0%
Brakes	0.2%	0.3%	0.3%
Other Equipment	0.8%	1.1%	1.1%
Other Hazardous Violation	2.5%	4.6%	4.2%
Other Than Driver (or Pedestrian)	0.1%	0.0%	0.0%
Unsafe Starting or Backing	9.6%	11.6%	10.1%
Other Improper Driving	2.6%	1.8%	1.6%
Fell Asleep	0.0%	0.1%	0.2%
Unknown	0.6%	0.6%	0.4%
Not Stated	0.7%	0.5%	0.5%
Total	**100.0%**	**100.0%**	**100.0%**

2.2.5 Vehicle Types

Investigators reported the detailed CHP classification of vehicle type for 64.4% of trucks involved in accidents. The trucks most commonly involved in accidents were truck tractors (combination trucks) and two-axle unit trucks.

For trucks towing a load, the most common loads involved in accidents were semi-trailers (65.3%), two trailers (11.7%), pull trailers with dollies (8.0%), and utility trailers (3.5%). Container chassis accounted for only 1.3% of the trucks involved in accidents.

Among trucks declared at fault in multi-vehicle collisions, only 704—0.5%—towed container chassis. Trucks towing container chassis involved in multi-vehicle collisions were at fault only 39.6% of the time, significantly less than the 45.7% for trucks in general. In the only 25 fatal multi-vehicle collisions involving a truck towing container chassis, the container hauler was at fault in just eight (32%) of them.

Table 2-7 Truck Types Involved in Crashes, 1995-2004

Vehicle type	Frequency	Percent
Tank truck, two-axle	1684	0.7%
Tank truck, three-axle	2400	1.0%
Truck tractor	133682	56.7%
Two-axle truck	56976	24.2%
Three-axle truck	32446	13.8%
Tow truck, two-axle	7198	3.1%
Tow truck, three-axle	473	0.2%
Truck tractor, hazmat	309	0.1%
Two-axle truck, hazmat	199	0.1%
3+ axle truck, hazmat	157	0.1%
Tank truck, two-axle, hazmat	106	0.0%
Tank truck, three-axle, hazmat	219	0.1%
Truck tractor, hazardous waste	17	0.0%
Two-axle truck, hazardous waste	15	0.0%
3+ axle truck, hazardous waste	14	0.0%
Tank truck, two-axle, hazardous waste	6	0.0%
Tank truck, three-axle, hazardous waste	17	0.0%
Total	**235918**	**100.0%**

2.2.6 Inattention

During the study period, CHP steadily sharpened definitions for various forms of inattention data collected during crash investigations. As such, the best data exist for July 1, 2003 and later. Fully 99.3% of truck drivers involved in crashes in the final 18 months of the study period did not receive any citation for distraction; among the few who did, reading (25 cases) and eating (31 cases) were more common than mobile phone usage (21 cases).

2.3 Summary and Conclusions

In California, total numbers of truck collisions and truck-involved fatal collisions per year are rather stable between the years of 1995 and 2004. In that time period, the numbers of truck collisions per year are all within a range of $35{,}000 \pm 2{,}500$ and while the numbers of truck-involved fatal collisions per year are all within a range of 350 ± 50. Each year, fatal collisions account for about 1% of all truck collisions. This could indicate that predominant factors contribute to truck collisions and truck-involved collisions in California had remained quite constant in the time period.

In the same time period, we found that the primary violations in truck-involved accidents with trucks at fault in California are the following:

- Unsafe speed
- Unsafe lane change
- Improper turning

While these three violations account for two-thirds of all such accidents, they do not appear to be directly related to problems that Virtual Weigh Stations (VWSs) can address, such as overweight or oversize trucks or trucks with faulty brakes. On the other hand, the portion of truck-involved crashes clearly and primarily attributable to factors that VWSs can address such as malfunctioning equipment, e.g., faulty brakes, is very small, i.e., 1.5%. This could give the impression that implementing VWS systems may not appear to be worth the investment. This would, however, be based on an incomplete and only partial assessment of the situation because the nature of the analyzed data was restricted to crash-related data. A substantively more useful data base, had it been available and linked to the original data base of truck-related accidents on a vehicle-by-vehicle basis, would have been one that included information on inspections and associated violations, especially ones that VWSs can address.

Unsurprisingly, disadvantaged global factors such as foggy weather and wet road surface do not play a big role in explaining the total number of truck collisions in California, which has a Mediterranean climate. However, these factors plus personal violations such as unsafe speed, unsafe lane change, and improper turning often contribute to fatal truck collisions. In California, most fatal collisions are associated with disadvantaged global factors and the above violations.

Truck collisions in Los Angeles County and the San Francisco Bay Area, two population and activity centers of the State, share many similar attributes. These attributes include percentage of truck collisions by party count, percentage of truck collisions on highways, percentage of truck collision by severity, rise and decline trends of truck collisions over time, percentage of sobriety of truck drivers, etc. But there is also one significant difference between the truck collisions in two areas. In the San Francisco Bay Area, a significant higher percentage of trucks of model year 1985 or earlier are involved in truck collisions while in Los Angeles County, the opposite is true.

3.0 GEOGRAPHIC DETERMINENTS OF TRUCK ACCIDENTS IN CALIFORNIA, 1998-2004

While truck safety has improved considerably in the past two decades, the perception remains that truck-involved crashes are a serious problem[4]. This is particularly the case in California, which during the period 1996-2000 ranked behind only Delaware, Florida, and Maryland in the number of fatal truck crashes per mile of public road (Moonesinghe *et al* 2003). The explosive growth of international trade during the 1990s and 2000s has made California, and inland southern California in particular, the nation's premier logistics center; truck traffic in the state has increased correspondingly. In southern California, an influential and widely reported study of unsafe working conditions for owner-operator truckers in the port drayage sector (Grobar, Monaco 2004) has led to concern over the potential danger that these trucks might pose to other motorists.[5] The hotly debated prospect of allowing Mexican trucks onto American highways, in order to comply with the North American Free Trade Agreement, has also raised concerns about safety.[6]

An examination of the rates of truck accidents across the whole state, to determine the risk factors involved, is in order. This is especially important given the highly disparate impacts of truck crashes in urban and rural areas: while urban truck crashes result in congestion, rural ones often result in fatalities (Moonesinghe *et al* 2003, Spainhour *et al* 2005). Determining risk factors that vary systematically across counties seems to be the best way of addressing this problem. However, the ranking of which counties are "most dangerous" for truck crashes changes substantially depending on the variable used as a measure of exposure.

3.1 Prior Knowledge

3.1.1 Crash Causation

A typical crash causation analysis focuses on one or a few roads or corridors (e.g., Golob and Regan 2004, Qin *et al* 2004). The investigators either conduct physical traffic counts or use electronic detectors (pressure pads and magnetic loops) to obtain traffic volumes, which they use as a measure of exposure. They quantify and classify crashes by examining law enforcement records that include information about drivers and pre-crash behavior. Using a Poisson, probit, or logit process, they then estimate a model to determine the likelihood (and, when using an ordered probit or multinomial logit, the severity and/or geometry) of a vehicle crash on the road(s) in question.

Prior to the 1980s, investigators usually used simple OLS to estimate crash counts. However, the discovery of heteroskedasticity in the 1970s led to the embrace of other estimation methods. Chief among these were the Poisson and negative-binomial methods, but more exotic methods have also been used (Xie *et al* 2007, Joshua and Garber 1992).

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[4] Throughout the document, the term "truck" refers to commercial vehicles of the sort classified by USDOT and its various agencies as "large trucks"—generally vehicles with empty weights in excess of three tons. Light trucks such as pickups and sport-utility vehicles do not fall into this category even when their empty weights exceed 6000 pounds.

[5] E.g. "A Heavy Load," *L.A. Weekly*, 25 July 2007.

[6] E.g. "Senate votes to ban Mexican Trucks," Associated Press, 11 September 2007.

3.1.2 Truck Safety

Prior to the early 2000s, there existed a serious dearth of scholarly knowledge about truck crash causation. What research did exist primarily focused on driver safety issues, a subject of considerable political contention in the wake of the 1980 deregulation of the trucking industry (Krass 1993), and again in the 1990s as the Department of Transportation weighed changes in commercial driver work rules (Mitler 1997). The Motor Carrier Safety Improvement Act of 1999 mandated a study of commercial vehicle crash causation. In response to this mandate, the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Transportation Safety Administration (NHTSA) jointly launched the Large Truck Crash Causation Study (LTCCS), a research effort that successfully obtained comprehensive data on the characteristics and causes of truck crashes in the United States between 2001 and 2003. Much of the research conducted since has been under the auspices of the LTCCS (LTCCS 2005).

3.2 Analytical Framework

The number of vehicle crashes at any given level of analysis, from a single segment of highway to an entire nation, is a function of both systematically variable and random/stochastic factors. The majority of crash causation literature attempts to identify systematically variable predictors of crashes. These include measures of exposure such as trips, vehicle-miles traveled, and population or activity density; environmental factors, such as traffic conditions, weather, roadway conditions and geometry; and driver-specific factors, such as demographic information, prior actions, and fatigue. This can be summed up in the following meta-model, for which each "predictor" represents an entire category of associated factors:

$$\text{Crashes} = f\,(\text{exposure, environmental conditions, driver behavior, stochastics})$$

3.2.1 Exposure

3.2.1.1 Ideal

The best measure of exposure for truck crashes is truck VMT. However, while annual estimates for this exist at both the micro (road/corridor) and macro (state and federal) levels, even the transportation agencies of the most heavily urbanized regions do not publish truck VMT counts on a county or metropolitan level more than once per regional transportation planning cycle—in California, every four years.[7]

3.2.1.2 Proxies

The first place to look would be at all-vehicle VMT, with which truck VMT should be fairly highly correlated. Indeed, in the data under analysis, all-vehicle VMT has a Pearson correlation coefficient of 0.968 with truck crashes. However, VMT is known to be highly heteroskedastic (Jovanis and Chang 1986). Additionally, a casual examination of the state's goods movement infrastructure shows fairly heavy concentrations in a few counties—most notably Riverside, San Bernardino, San Diego, Alameda, and above all Los Angeles.

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[7] With some effort, the author could probably obtain these data for the Southern California Association of Governments (SCAG) region, consisting of the five-county greater Los Angeles region and Imperial County. Getting them for the other 52 counties in the state, though—and particularly the portions of those counties falling outside of a Census Bureau-declared urban region—would require considerably more legwork, and might well be impossible.

One common response is to use road-mileage or lane-mileage as the measure of exposure. It too is highly correlated with crash counts, with a Pearson coefficient of 0.906 in the data under analysis. However, using road-mileage or lane-mileage as a basis for calculating crash exposure has struck more than a few researchers as unsatisfactory (e.g., Abdel-Aty and Pande 2007, Ivan 2004). To adapt a common saying to the task at hand, *roads* don't crash cars and trucks, *people* do. A dangerous segment of highway is such because of the way that vehicles and their drivers respond while traveling over it.

Another possible measure of exposure is county population. However, per-capita data tend to display spectacular heteroskedasticity when population varies significantly; in California, where the most populous county (Los Angeles) has more than 900 times the population of the least populous (Alpine), this is most definitely the case. Additionally, population appears in the denominator in many of the demographic variables under consideration for use in the present analysis, making it unsuitable for use in either weighted least squares or Poisson estimation procedures.

A novel proxy for truck trips is the size of the trucking industry in a county, including the earnings of independent trucking firms and private haulers alike. While tiny counties in the Sierra and sparsely populated ones in the Sacramento Valley see many times more truck trips (on I-80 and I-5, respectively) in a given day than there are transportation employees in the county, the overwhelming majority of truck trips—both in California and nationally—have a length of 50 or fewer miles (LTCCS 2005). For counties in California, this usually means that they terminate either in their county of origin or at most two counties distant (e.g., trucks hauling containers from the Los Angeles/Long Beach port complex to rail yards near downtown Los Angeles or distribution centers in San Bernardino, Riverside, and Kern Counties). This heavily local orientation is reflected in the 0.976 Pearson coefficient for correlation between the number of truck crashes in the county and the income paid to trucking/warehousing workers there. Income paid to trucking/warehousing workers also has the benefit of high sensitivity to macroeconomic conditions (Leinbach 2004), meaning that including it in a model eliminates a potential source of serial correlation in the residuals. The models presented in the chapter will therefore use the income paid to trucking/warehousing workers, using data provided by the Bureau of Economic Analysis' Regional Accounts, as the measure of exposure for each county-year.

3.2.2 Environmental Factors

3.2.2.1 Traffic Conditions

Increasing density of traffic has both positive and negative effects on the frequency of crashes. Denser levels of traffic mean many more vehicles with which a given car or truck can collide. However, heavier traffic also means slower travel speeds, reducing both the frequency and severity of crashes—particularly for trucks, which tend to receive less aggressive treatment from urban car users than rural ones (Ward 2007).

The generally accepted measure for the intensity of road usage in a given area is VMT per lane-mile of road (e.g., TTI 2007). Unfortunately, as with truck VMT data, publicly available, annually updated lane-mile data generally only exist for metropolitan areas, not counties.[8] For the purposes of this analysis, VMT per road-mile (sometimes referred to as "centerline mileage") will have to do. Future research will use lane-mileage in the denominator of this figure.

3.2.2.2 Road Geometry and Control Devices

The California Highway Patrol's SWITRS crash report data set includes reporting on the physical condition of the pavement; physical proximity to intersections, ramps, and driveways; and functionality and visibility of control devices. However, detailed county-level data on the overall condition of road networks, the prevalence of dangerous intersections, and the like do not appear to exist. The model must therefore exclude these factors from consideration.

3.2.2.3 Weather

While truckers show much more care in inclement weather than motorists in general (Golob and Regan 2004), precipitation and snowfall still cause many truck crashes each year (LTCCS 2005). Since these vary fairly significantly across counties within California, they are good candidates for inclusion in the model.

Assigning single values for precipitation and snowfall to each county in California presents pitfalls, however. Most of California's counties display considerable variation in relief throughout their land area, with resulting impacts on climate: for example, snowcapped Mount San Gorgonio and Mount San Antonio loom over the hot, dry, palm-studded Coachella and San Gabriel Valleys, respectively, yet lie within the same counties (Riverside and Los Angeles respectively). These disparities particularly impact snowfall data: even though counties from Siskiyou in the north to San Diego in the south deploy snowplows every winter, often on heavily traveled state highways and Interstates, only seven county seats in thinly populated mountain counties regularly receive snow. Mountainous regions of counties west of the Sierra also tend to receive considerably more rainfall than the flats.[9] While the majority of vehicle travel (including by trucks) in these counties occurs within the dry, snow-free flats, a number of heavily traveled roads in them cross rain- and snow-prone mountain passes. Notable examples include I-15 through the Cajon Pass in San Bernardino County, CA/SR-58 through the Tehachapi Pass in Kern County, and I-5 over the Grapevine in Los Angeles County. These factors will produce a strong downward bias in the estimated coefficients for precipitation and snowfall in any model predicting crash rates; compensation for these would likely require an elaborate weighting procedure that would significantly complicate the structure of the error terms. An earlier version of this chapter included both precipitation and snowfall in the models estimated, but this version includes only precipitation.

3.2.3 Demographics

3.2.3.1 Age

Certain demographic factors display strong correlation with vehicle crash rates. An automobile insurer, which has a decidedly strong interest in knowing the likelihood of a policyholder experiencing a crash, uses a driver's age, sex, and marital status in addition to driver record,

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[8] Once again, the foolish dichotomy between "urban" and "rural" rears its ugly head.

[9] For example, the Mount Wilson weather station—located only six miles from the downtown Pasadena station but at nearly a mile higher in elevation—routinely receives twice the rainfall of its lowland counterpart.

location of vehicle use, and (only coarsely) annual mileage (the latter two to determine crash exposure rates) to determine the premium it will charge him or her (Edlin 2003). The role of age in this regard is particularly interesting: premiums plummet when a driver turns 25, do not vary significantly with age for four decades thereafter, and then begin to rise again at 65.[10] Actuarial calculations accord with reality: young drivers routinely display unsafe driving habits (driving while distracted, excessive speed, etc.), while older drivers' poorer vision and slower reflexes reduce their ability to anticipate and react to road hazards. On the other hand, older drivers also tend to be more cautious, granting particularly wide berth to trucks (Burkhardt and Mcgavock 1999). The prevalence of young and old drivers in a county will therefore have an impact on its frequency of vehicle crashes of all types, and thus on truck crashes.

3.2.3.2 Language/National Origin

Reflecting its role both as an entrepôt and a destination for immigrants from Latin America, East Asia, and the Middle East, California has higher percentages of foreign-born residents (26.2%) and residents who do not speak English at home (42.5%) than any other state. While this does not necessarily imply limited English proficiency, studies in Australia of drivers originally from non-Anglophone countries indicate that non-native speakers and non-speakers of English display more dangerous driving behavior than Anglophones (Haworth *et al* 2000). Many immigrants do not learn how to drive until they arrive in the United States — and if they are undocumented, they likely will not receive any formal driver education. Additionally, text-based road signs and pavement markings can befuddle drivers with limited English proficiency, causing potentially dangerous situations.

The high correlation ($P = 0.947$) between the percentage of residents of foreign birth and the percentage not speaking English at home dictates that only one should enter the model, in order to eliminate a source of multicollinearity. Anecdotal evidence suggests that many individuals who do not speak English at home are actually fluent speakers of the language, as they have been born and raised in this country and educated in American schools. As such, this chapter will use the percentage of residents of foreign birth as its representative of the effects of language and national origin.

3.2.4 The Model

In keeping with customary practice, and in order to compensate for the heteroskedasticity that plagues vehicle accident analysis, the model was estimated using a log-linear Poisson process. It takes the following form:

$$\ln(\text{Crashes}) = \ln(\text{TruckInc}) + \alpha + \beta_1(\text{VMTRM}) + \beta_2(\text{Precip}) + \beta_3(\text{PctYoung}) + \beta_4(\text{PctOld}) + \beta_5(\text{PctForeign}) + \mu$$

[10] The author has some first-hand experience with this, as he recently turned 25 and his father recently turned 65.

Table 2-8 Definitions of Model Variables

Name	Variable (values by county-year unless otherwise noted)
Crashes	Total number of truck crashes
TruckInc	Total income (x1000) paid to workers in trucking and warehousing
VMTRM	Daily vehicle-miles traveled per centerline mile of road
Precip	Total rainfall at designated county weather station
PctYoung	Portion of county population ages 15-24
PctOld	Portion of county population ages 65+
PctForeign	Portion of county population born outside United States (2000 Census)

Since random phenomena at a level as large as a county might display a normal, rather than Poisson, distribution, a weighted least squares model was also estimated. It takes the following form:

$$Crashes/TruckInc = \alpha + z_1(VMTRM/TruckInc) + z_2(Precip/TruckInc) + z_3(PctYoung/TruckInc) + z_4(PctOld/TruckInc) + z_5(PctForeign/TruckInc) + \mu$$

3.3 Data

3.3.1 Observations and Period of Analysis

The analysis spans the years 1998-2004. Each observation contains data for one county in one year. Before data cleaning and filtering, there were thus 406 observations (58 counties x 7 years).

3.3.2 Sources

3.3.2.1 Crash Files

The crash files themselves come from the Statewide Integrated Traffic Records System (SWITRS) compiled by the California Highway Patrol, which is a record of every traffic accident occurring in the state of California that is reported to a law enforcement agency. SWITRS records pertinent information about crashes themselves (temporal characteristics, location, road conditions, road and crash geometry, party types involved), the parties involved (participant type, occupancy, vehicle characteristics, violations incurred, etc.), and—where applicable—individuals suffering injury or death as a result of the crash.

3.3.2.2 Trucking Industry Income

The trucking industry income figures come from the Regional Accounts of the United States Bureau of Economic Analysis. In 2001, the BEA switched from the Standard Industrial Classification (SIC) system to the North American Industry Classification System (NAICS); as a result, the SIC's old Trucking and Warehousing category was split into separate Trucking and Warehousing categories. The sum of the two NAICS values equals the old SIC value, eliminating any possible kinks in the data. In order for the log-log Poisson estimator to work properly, county-years in which no trucking/warehousing income was reported or data for this category were missing were eliminated from consideration; this probably biased the estimator somewhat.

3.3.2.3 Road Network and Vehicle Travel
Data on the extent and classification of the road network for each county come from the Highway Performance Monitoring System (HPMS) reports issued annually by Caltrans. HPMS also collects estimates of average daily vehicle travel, both urban and rural, within each county.

3.3.2.4 Weather
Precipitation data come from weather station records compiled by the National Climatic Data Center, a unit of the National Oceanic and Atmospheric Administration. Selection of the weather station used operated principally under the criterion of proximity to the county seat. Where possible, the same location was used for all seven years of the analysis; in only one case did the author find it necessary to change locations over the period, and this was to a station only a few miles distant and at virtually the same elevation.[11] A number of stations had no data to report in some years; county-years with no precipitation data were thus eliminated from consideration.

3.3.2.5 Demographics
The age cohort data come from the annual estimates of city, county, and state population (by age and ethnicity) published by the Demographic Research Unit of the California Department of Finance. Data on the percentage of individuals born outside the United States came from the 2000 Census; due to internal and external migration, they may not be completely accurate for any year but 2000.

3.3.3. Descriptive Statistics
3.3.3.1 Basic Descriptives
This section provides the descriptive statistics for the model variables, including minimum, maximum, mean, and standard deviation.

Table 2-9 Descriptive Statistics

Variable	N	Min	Max	Mean	StdDev
Crashes	349	7	11443	673.97	1584.636
TruckInc	349	159.995	2311355.533	143805.332	335592.123
VMTRM	349	0.25	11.34	3.7017	2.9142
Precip	349	0.36	102.49	24.2580	16.1937
PctYoung	349	0.083	0.227	0.142	0.0240
PctOld	349	0.070	0.225	0.128	0.0358
PctForeign	349	0.016	0.368	0.264	0.0979

[11] The stations in question are in Stanislaus County, at downtown Modesto and the Modesto City-County Airport. Heterogeneity of terrain between observation stations explains why, for example, the author used the downtown Pasadena station for Los Angeles County rather than the downtown Los Angeles station, which moved during the period from the Civic Center to the USC campus, a decline of elevation of 100 feet.

3.3.3.2 Correlations
This section provides the correlations between each pair of variables.

Table 2-10 Variable Correlations

	Crashes	TruckInc	VMTRM	Precip	PctYoung	PctOld	PctForeign
Crashes	1	0.976**	0.551**	-0.149**	0.055	-0.282**	0.447**
TruckInc	0.976**	1	0.552**	-0.171**	0.100	-0.309**	0.450**
VMTRM	0.551**	0.5525**	1	-0.189**	-0.057	-0.445**	0.714**
Precip	-0.149**	-0.171**	-0.189**	1	-0.366**	0.375**	-0.462**
PctYoung	0.055	0.100	-0.057	-0.366**	1	-0.485**	0.260**
PctOld	-0.282**	-0.309**	-0.445**	0.375**	-0.485**	1	-0.669**
PctForeign	0.447**	0.450**	0.714**	-0.462**	0.260**	-0.669**	1

** Indicates significance at the 0.01 level (2-tailed).

3.4 Results
3.4.1 Estimated Model 1: Log-Linear Poisson
The following model was estimated by a log-linear Poisson process.

$$Ln(Crashes) = \ln(TruckInc) + \alpha + \beta_1(VMTRM) + \beta_2(Precip) + \beta_3(Snow) + \beta_4(PctYoung) + \beta_5(PctOld) + \beta_6(PctESL) + \mu$$

The results are as follows:

3.4.2 Regression Results (Poisson)
Table 2-11 provides the parameter results for the Poisson Model.

Table 2-11 Model (Poisson) Parameter Estimates

Parameter	B	S	P
Intercept	-10.957	0.0399	0.000
VMTRM	-0.049	0.0014	0.000
Precip	0.0035	0.0002	0.000
PctYoung	-10.679	0.1734	0.000
PctOld	2.676	0.1462	0.000
PctForeign	1.038	0.0447	0.000

($n = 349$, $\Lambda = 8135.289$, Deviance/df = 78.824, Pearson chi-square = 91.782)

3.4.3 Estimated Model 2: WLS
The following weighted model was estimated by least-squares linear regression:

$$Crashes/TruckInc = \alpha + z_1(VMTRM/TruckInc) + z_2(Precip/TruckInc) + z_3(PctYoung/TruckInc) + z_4(PctOld/TruckInc) + z_5(PctForeign/TruckInc) + \mu$$

The results are as follows:

3.4.4 Regression Results (WLS)

Table 2-12 provides the parameter results for the WLS Model.

Table 2-12 Model (WLS) Parameter Estimates

Parameter	B	S	P
Intercept	-22295.654	2750.154	0.000
VMTRM	354.306	99.075	0.000
Precip	34.860	15.692	0.027
PctYoung	78176.037	11802.313	0.000
PctOld	24437.948	10722.984	0.023
PctForeign	35251.119	3128.501	0.000

(n = 349, R^2 = 0.643, R^2 adjusted = 0.638, F = 123.528)

3.4.5 Summary and Conclusions

As expected, the coefficients on precipitation, the percentage of elderly residents, and the percentage of foreign-born residents were strongly and significantly positive for both models. However, intensity of road usage and the percentage of young residents each predict fewer crashes in the Poisson-estimated model and more in that estimated by WLS.

The results still point to a high likelihood that the heavily urbanized counties of the Bay Area and greater Los Angeles are actually less dangerous for trucks than the state's rural counties, especially in the state's northern half. California's counties largely fall into one of three categories: young, urban, dry, heavily immigrant urban counties in the state's two large urban regions; rural, dry, heavily immigrant counties in the state's agricultural heartlands; and old, rural, rainy, white counties along the central and northern coasts and in the foothills of the Sierra.

One response to truck safety concerns is to increase the quantity and quality of equipment and compliance inspections by way of implementing commercial motor vehicle VWS systems at/near fixed compliance facilities in California. A key question in evaluating these stations is whether they would prevent enough truck accidents to pay for themselves. Additional studies are thus required, especially in the area of conducting cost-benefit and/or cost effectiveness analyses.

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Appendix 1: County-Years Excluded from Analysis

Alpine: all years
Amador: 1998
El Dorado: 2001
Glenn: 2001, 2004
Inyo: 1998, 2004
Lake: 2001
Lassen: 1998, 2000, 2003, 2004
Madera: 2003
Mono: all years
Modoc: 2003
Marin: 1999, 2003, 2004
Mariposa: 2001-04
Riverside: 2001, 2002
Sacramento: 2003
San Benito: 2003
Sierra: all years
San Luis Obispo: 2003
San Mateo: 1999, 2001
Sonoma: 2000, 2001
Stanislaus: 1999
Sutter: 1998
Tehama: 1998, 1999
Ventura: 2001
Yuba: 1998, 2002

Appendix 2: Locations of Weather Observatories

County	Observatory	County	Observatory	County	Observatory
Alameda	Berkeley	**Mariposa**	Mariposa Ranger Station	**Santa Barbara**	Santa Barbara 1
Alpine	Markleeville	**Mendocino**	Ukiah 4 WSW	**Santa Clara**	San Jose
Amador	Sutter Hill Road	**Merced**	Merced	**Santa Cruz**	Santa Cruz
Butte	Oroville	**Modoc**	Alturas	**Shasta**	Redding Mun. Airport
Calaveras	Big Trees	**Mono**	Bridgeport	**Sierra**	Downieville
Colusa	Colusa 2 SSW	**Monterey**	Salinas 2	**Siskiyou**	Yreka
Contra Costa	Martinez Water Plant	**Napa**	Napa State Hospital	**Solano**	Fairfield
Del Norte	Crescent City 3 NNW	**Nevada**	Nevada City	**Sonoma**	Santa Rosa
El Dorado	Placerville	**Orange**	Santa Ana Fire Station	**Stanislaus**	Modesto (1998-2002), Modesto City-County Arpt. (2003-04)
Fresno	Fresno Yosemite Int'l Airport	**Placer**	Auburn	**Sutter**	Nicolaus 2
Glenn	Willows 6 W	**Plumas**	Portola	**Tehama**	Red Bluff Mun. Arpt.
Humboldt	Eureka WFO Woodley Isl.	**Riverside**	Riverside Fire Station 3	**Trinity**	Weaverville
Imperial	El Centro SSW	**Sacramento**	Sacramento WSO City	**Tulare**	Visalia
Inyo	Independence	**San Benito**	Hollister 2	**Tuolumne**	New Melones Dam HQ
Kern	Bakersfield Arpt.	**San Bernardino**	Redlands	**Ventura**	Ventura
Kings	Hanford 1 S	**San Diego**	Lindbergh Airport	**Yolo**	Woodland 1 WNW
Lake	Clearlake Highlands	**San Francisco**	San Francisco Downtown	**Yuba**	Marysville
Lassen	Susanville Municipal Arpt.	**San Joaquin**	Stockton Metro Airport		
Los Angeles	Pasadena	**San Luis Obispo**	Cal Poly SLO		
Marin	San Rafael Civic Center	**San Mateo**	Redwood City		