The 100-Car Naturalistic Driving Study: A Descriptive Analysis of Light Vehicle-Heavy Vehicle Interactions from the Light Vehicle Driver's Perspective

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U.S. Department of Transportation
Federal Motor Carrier Safety Administration

Foreword

The 100-Car Naturalistic Driving Study was undertaken with the goal of obtaining data on driver performance and behavior in the moments leading up to a crash. This type of data is not available from either of the traditional methods of studying driver behavior in regards to crashes and traffic safety, such as empirical studies and crash databases (e.g., General Estimates System and the Fatality Analysis Reporting System). Crash databases are derived from police accidents reports (PARs) and contain a wealth of data describing the non-controversial facts of the crash such as location, number of vehicles involved, type of crash, and time of day. For a variety of reasons, however, these databases do not provide good insight into the driver behavior and performance leading up to the crash. The empirical method provides a different approach to investigating driver behavior by studying how people drive under various conditions. These studies are usually conducted as highly controlled experiments using instrumented vehicles to obtain a variety of vehicle and driver performance data. Typically, these studies involve drivers operating study test vehicles for a short period of time (i.e., a few hours) in a contrived environment (i.e., either simulator or closed test track).

Naturalistic studies can be used to understand crash causation and driver behavior and supplement information learned through epidemiological and empirical approaches. Naturalistic studies include driver/subjects operating vehicles in their daily lives (e.g., commuting to work) for an extended period of time (e.g., one year). In order to collect such a dataset, the National Highway Traffic Safety Administration, the ITS Joint Program Office of the Federal Highway Administration, the Federal Motor Carrier Safety Administration, the Virginia Department of Transportation, and Virginia Tech contracted with the Virginia Tech Transportation Institute to conduct the "100-Car Naturalistic Driving Study." This large-scale naturalistic driving study was conducted using 100 instrumented vehicles (80 privately-owned and 20 leased vehicles). This data collection effort was conducted in the Washington, DC metropolitan area on a variety of urban, suburban, and rural roadways over a span of 13 months.

This publication is considered a final report and does not supersede another publication.

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Robert J. Carroll was the FMCSA COTR for this project.

16. Abstract
There have been several studies that have investigated interactions between light and heavy vehicles. These have primarily consisted of crash database analyses where Police Accident Reports have been studied. These approaches are generally reliable, but they do have limitations. Hanowski, Keisler, and Wierwille (2004) addressed these limitations using a naturalistic approach to investigate light vehicle-heavy vehicle (LV-HV) interactions. In their study, HVs were instrumented with a variety of data collection equipment including video cameras. However, one of the limitations in their study was the lack on instrumentation in LVs.

These limitations were addressed in the 100-Car Study by installing video cameras and other data collection equipment on LVs (Dingus et al., 2004). All identified LV-HV interactions from the 100-Car data set were included in the current report. Data analysts reviewed each LV-HV interaction event and coded the Incident Type, Primary Maneuver, Contributing Factor(s), Accident Type, and Critical Reason(s). This project's primary goals were to: (1) gain a better understanding of LV-HV interactions, (2) continue to develop a classification scheme for LV-HV interactions, (3) compare the current data to the data obtained in the Hanowski, Keisler, and Wierwille (2004) study for a more complete picture of the LV-HV interaction problem, and (4) provide background information that would serve as a necessary prerequisite to the development of countermeasures for LV-HV interactions.

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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
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m2	cd/m2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force 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	megagrams	1.103	short tons (2000 lbs)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	Lux	0.0929	foot-candles	fc
cd/m2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

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

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EXECUTIVE SUMMARY
THE LIGHT VEHICLE – HEAVY VEHICLE INTERACTION PROBLEM

In 2002, 434,000 large trucks (gross weight $\geq$ 10,000 lbs) were involved in vehicle crashes; 4,542 of these crashes resulted in fatalities. In these crashes, 4,897 people died and an additional 210,000 were injured. Though accounting for 4% of all registered vehicles in 2002, large trucks represented 8% of all vehicles involved in fatal crashes (National Highway Traffic Safety Administration, NHTSA, 2003). However, truck drivers have lower non-fatal crash rates per million vehicle miles traveled than light vehicles (NHTSA, 2003). Nonetheless, light vehicles are extremely vulnerable when they interact with trucks because trucks often weigh 20-30 times as much as light vehicles (Insurance Institute for Highway Safety, 2002), and trucks take 20-40% farther to stop than light vehicles (NHTSA, 1987). A better understanding of LV-HV interactions is needed to develop future interventions and countermeasures directed at mitigating the problem. The data from the 100-Car Study (Dingus et al., 2004) were used in the current project to assess the LV-HV interaction problem from the LV drivers' perspective.

PROJECT GOALS

There were four primary goals in the current effort:

1. Gain a better understanding of LV-HV interactions on the nation's roadways.
2. Continue to develop the classification scheme and corresponding Contributing Factors list for LV-HV interactions used in Hanowski, Keisler, and Wierwille (2004) and use the terminology and methodology described in the LTCCS (Thieriez, Radja, and Toth, 2002).
3. Compare the current data to the data obtained in the Hanowski, Keisler, and Wierwille (2004) study for a more complete picture of the LV-HV interaction problem.
4. Provide background information that would serve as a necessary prerequisite to the development of countermeasures for LV-HV interactions.

METHOD

One hundred and nine participants who commute to and from the Washington, DC metro area were recruited as drivers in the 100-Car Study. The 109 participants ranged in age from 18 to over 55 years (43 female, 66 male). One hundred LVs were instrumented for this study; 80 vehicles were owned by the participants, while 20 were leased vehicles from VTTI.

The data used in the current effort consisted of video recordings of critical incidents. Five video cameras were used in the video recording system: (1) a forward-looking camera that captured the forward roadway scene, traffic situation, and possible incidents; (2) a driver's face camera that was used to record facial expressions, eyelid closure, glance position, and head turns; (3) a right-side camera that was mounted on the A-pillar of the passenger side and faced outward; (4) a dome camera that was mounted from inside the vehicle and faced over the drivers shoulder towards the steering wheel, hands, and feet; and (5) a rear camera that was intended to capture the situation behind the vehicle. Infrared lighting was used to illuminate the vehicle cab so that the driver's face as well as their hands could still be viewed by the camera during nighttime driving.

The video continuously recorded while the ignition was on, thereby allowing laboratory review and selection of the video without losses of any kind. The videotaped episodes/incidents were selected and keyed to digitally-recorded data.

Of interest in the data set were “critical incidents” defined as unexpected events resulting in a close call or requiring fast action (evasive maneuver) on the part of a driver to avoid a crash. Critical incidents were detected by one of three methods. The first method involved flagging events where the car sensors exceeded a specified value (e.g., brake response of >0.6 g). The second incident flagging method occurred when the driver pressed an incident pushbutton located on the dashboard (i.e., drivers were instructed to depress a button on the dashboard if they witnessed an incident or were involved in an incident). The third method of detecting incidents was through analysts’ judgments when reviewing the video. Only those events that involved a LV-HV interaction are described in the current analyses.

RESULT HIGHLIGHTS

Light Vehicle-Heavy Vehicle Interaction Data Set

The 100-Car Study captured 9,125 incidents, which were divided into four categories: (1) LV-LV Interactions; (2) LV-HV Interactions; (3) Single Vehicle Conflicts; and (4) Other. Of the 9,125 events, 246 (2.7%) involved a LV-HV interaction.

Incident Types

With the 246 LV-HV interactions recorded in the data set, the next step in the analysis was to determine the vehicles’ actions for each incident. To this end, the video and relevant data for each incident were carefully reviewed and then classified according to “Incident Type.” Twenty-seven different Incident Types were identified in the data set.

The most frequent Incident Type involving a LV-HV interaction was Late Braking for Stopped/Stopping Traffic. Across all 246 incidents, this particular Incident Type occurred 66 times and accounted for 26.8% of the incidents captured. The majority of the incidents (48.8%) involved one of two different Incident Types: Late Braking for Stopped/Stopping Traffic, and Lane Change Without Sufficient Gap.

Descriptive statistics for the Incident Types were also calculated for incidents as a function of the at-fault driver. The at-fault driver is the driver that was assessed, by the analyst, to have been responsible for causing the event. Of the 246 LV-HV interaction incidents recorded, 138 (56%) were judged to have been the fault of the LV driver, while 79 (32%) were attributed to the HV driver. For the remaining 29 incidents (12%), it was unclear which vehicle driver was at-fault. By removing the “unknown” cases from the LV-HV driver at-fault analyses, it was found that the LV driver was at-fault in 64% (138/217) of the LV-HV interaction incidents, while the HV driver was at fault in 36% (79/217) of the incidents.

The most frequent Incident Type for HV driver at-fault incidents was Lane Change Without Sufficient Gap (26.6%), followed by Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%). The most frequent Incident Type for LV driver at-fault incidents was Late Braking for Stopped/Stopping Traffic (41.3%), followed by Lane Change Without Sufficient Gap (21.7%), and Aborted Lane Change (8%). The most frequent Incident Type for Unknown at-fault incidents was Late Braking for Stopped/Stopping Traffic (27.6%), followed by Conflict With Oncoming Traffic (13.8%), Lane Change Without Sufficient Gap (10.3%), and Unable to Determine (10.3%).

Primary Maneuvers, Secondary Maneuvers, and Conflict Types

After each of the 246 incidents was classified by Incident Type, the next step in the analysis was to identify the "Primary Maneuvers" and "Secondary Maneuvers" involved in each incident. The Primary Maneuver refers to the maneuver of the driver who initiated the incident (not necessarily at-fault). Across the 246 interaction incidents, 19 different Primary Maneuvers were identified. The most frequent Primary Maneuvers were Braking (22.7%), Changing Lanes (21.1%), and Stopped (15%). These three Primary Maneuvers represented 58.9% of the recorded incidents.

In addition to identifying the Primary Maneuver for each incident, the Secondary Maneuver, or the maneuver of the responding driver (i.e., driver of the second vehicle involved in the interaction), was also classified. Considering the maneuvers of both vehicles involved in the incident, a clear picture of the conflict, or Conflict Type, could be determined. A total of 66 different Conflict Types (i.e., Primary Maneuver and Secondary Maneuver combinations) were identified.

Contributing Factors

Just as the Incident Types describe the action or what happened during an incident, Contributing Factors provide likely reasons *why* an incident occurred. For each incident that was analyzed, a number of Contributing Factors were identified. It should be noted that the Contributing Factor categories were taken from Wierwille, Kieliszewski, Hanowski, Keisler, and Olsen (2000) and from the GES Physical Impairments screen (USDOT/NHTSA, 2003, p. 434). Due to the methodology used, where the data collection equipment was only instrumented in the LV, the Contributing Factor was based solely on the behaviors of the LV driver. Without cameras inside the HV there was no way to determine, with any degree of certainty, the behavior(s) of the HV driver. Even when the HV driver was judged to have been at-fault, the behaviors of the LV driver were identified. Put another way, for the events that were caused by the LV driver, the analyses considered the LV driver's behaviors that may have contributed to the event. For events where the HV-driver was at-fault, the analysis also considered the LV driver's behaviors. However, the consideration is for the LV driver behaviors that occurred as the driver reacted to the HV driver's actions.

Note that multiple factors could be assessed for each individual event (as such, the percentages for the factors total more than 100%). Across all 246 incidents, the most frequent Contributing Factor was Driving Techniques (49.5%), followed by Unknown (24%) and Distracted (18.7%).

The most frequent Contributing Factor for HV driver at-fault incidents was Unknown (68.4%), followed by Driving Techniques (15.2%), and Distracted (11.4%). The most frequent Contributing Factor for LV driver at-fault incidents was Driving Techniques (70.3%), followed by Distracted (22.5%) and Aggressive Driving (22.5%). The most frequent Contributing Factor for Unknown driver at-fault incidents was Driving Techniques (48.3%), followed by Distracted (20.7%), Roadway Alignment (10.3%), and Unknown (10.3%).

Driver Distraction

A substantial number of the LV-HV incidents had Distraction listed as a Contributing Factor. Again, as indicated above, the incidents where Driver Distraction was mentioned refer to the behavior of the LV driver. The Distraction Contributing Factor was sub-divided into more distinct categories. See Table 22 for a listing of the frequency, percentage, and rank ordering for each sub-category in the Distraction Contributing Factor. The most frequent sub-category for the Distraction Contributing Factor was Talking/Listening on Cell Phone (21.7%), followed by Passenger in Adjacent Seat (13%), and Dialing Hand-Held Phone (8.7%).

CLASSIFICATION STRATEGY USED IN THE LTCCS

Accident Type

Each of the 246 LV-HV interactions were grouped by Accident Type based on the methodology used in the LTCCS (Thieriez, Radja, and Toth, 2002). Note that there was only one LV-HV crash recorded in the 100-Car Study. Therefore, using the Accident Types from the LTCCS does not reflect an absolute match, but rather a relative match. However, to facilitate future data comparisons with the near-crash data collected in the current study with other studies using the LTCCS, each of the 246 LV-HV interactions were coded using the LTCCS classification scheme. Because only one crash occurred, the closest match with respect to Accident Types was recorded for each incident.

Overall, the most frequent Accident Types were Scenarios 38/39[1]: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (19.9%); 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle (16.3%); and 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle (13%). These three Accident Types represented 49.2% of the Accident Types for all LV-HV incidents.

The Accident Types for HV and LV driver at-fault incidents differed. The most prevalent Accident Types for HV driver at-fault incidents were Scenarios 44/45: Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot (27.8%), 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (15.2%), and 25/25: Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed Vehicle (8.9%). These three Accident Types accounted for 51.9% of the HV driver at-fault incidents. The most prevalent Accident Types for LV driver at-fault incidents were Scenarios 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle (26.8%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (22.5%); and 28/29: Same Trafficway/Same

[1] Scenario classification taken from Thieriez, Radja, & Toth, 2002.

Direction: Rear-End: Approaches Decelerating Vehicle (17.4%). These three Accident Types accounted for 66.7% at the LV driver at-fault incidents.

The most prevalent Accident Type for HV driver at-fault incidents involved a Sideswipe Angle. By summing all the HV driver at-fault Accident Types that involved a Sideswipe Angle, it was found that 41.8% of the HV driver at-fault incidents were coded with this Accident Type. Conversely, the most prevalent Accident Type for LV driver at-fault incidents involved a Rear-End Approach. By summing all LV driver at-fault Accident Types that involved a Rear-End approach, it was found that 55.1% of the LV driver at-fault incidents were coded with this Accident Type.

Critical Reason for the Critical Event

To be consistent with the LTCCS (Thieriez, Radja, and Toth, 2002), the LV driver at-fault incidents were coded with a Critical Reason for the incident. The Critical Reason for the incident was considered the primary reason for *why* the incident occurred. More than one Critical Reason could be coded for each incident (10 of the recorded incidents were coded with two Critical Reasons). Only the LV driver at-fault incidents were coded with a Critical Reason because those vehicles were equipped with video of the driver. For the HV driver at-fault incidents, it was not possible to determine with any certainty what the driver was doing that contributed to the event; therefore, all HV driver at-fault incidents were coded as “Unknown reason for the critical event.”

Overall, the most frequent Critical Reasons for LV driver at-fault incidents were Aggressive Driving Behavior (24.6%), Too Fast for Conditions (15.2%), and Misjudgment of Gap (13.8%). There were other interesting trends. Sixty-four of the 138 LV at-fault incidents (46.4%) were coded with at least one Critical Reason that was a risky driving behavior (i.e., Aggressive Driving Behavior, Too Fast for Conditions, Following too Closely, and Illegal Maneuver), while 22.5% of the LV driver at-fault incidents involved some type of awareness variable (i.e., Internal Distraction, Inattention, External Distraction).

COMPARISONS USING THE 100-CAR DATA, THE LOCAL SHORT HAUL DATA, AND THE SLEEPER BERTH DATA

The current study builds on a previous project that classified critical incidents (crashes and near-crashes) recorded in two fatigue study with Local/Short Haul (L/SH) drivers and Sleeper Berth (SB) drivers (Hanowski, Keisler, and Wierwille, 2004). The two truck studies involved instrumentation in the truck and recorded events from the HV driver’s perspective. In contrast, the current study recorded events as they unfolded from the LV driver’s perspective. The events from the three studies were combined and the classifications were compared.

A total of 142 LV-HV interactions were identified in the L/SH study. Of these, 117 (82.4%) incidents were judged to be the fault of the LV driver, while the remaining 25 (17.6%) incidents were the fault of the HV driver. In the SB study, a total of 68 LV-HV interactions were identified. Of these, 47 (69.1%) were assessed to have been the fault of the LV driver, while the remaining 21 (38.9%) were the fault of the HV driver. Of the 246 LV-HV interaction incidents recorded in the current study, 138 (56%) were judged to have been the fault of the LV driver, while 79 (32%) were attributed to the HV driver. For the remaining 29 incidents (12%), it was unclear which vehicle driver was at-fault. Considering the combined data, these three studies consistently show that LV drivers were judged to be responsible for the majority of LV-HV interactions. Of the 427 LV-HV incidents identified across the three studies (excluding the 29 Unknown at-fault incidents in the current study), 302 (70.7%) were judged to have been the fault of the LV driver, while the remaining 125 (29.3%) were the fault of the HV driver (a 2.4:1 ratio).

There were a number of interesting findings from the comparisons between the 100-Car, SB, and L/SH studies. Comparisons were conducted with respect to the Incident Type, Primary Maneuver, and Contributing Factor. The Incident Type comparison indicated that Lane Change Without Sufficient Gap was the most frequent Incident Type across all three studies. A breakdown of incidents as a function of the at-fault driver showed that Lane Change Without Sufficient Gap incidents were primarily attributed to LV drivers. Critical incidents that involved a LV driver changing lanes in front of an HV, leaving the HV driver with very little headway between vehicles, were a common Incident Type that was captured in all three studies.

While the Incident Types for the LV driver at-fault incidents shared some similarities across the three studies, the Incident Types for the HV driver at-fault incident were more varied across the studies. In the 100-Car Study, 48.1% of the HV driver at-fault Incident Types included Lane Change Without Sufficient Gap or Lateral Deviation of Through Traffic. In the SB study, 71.4% of the HV driver at-fault incidents included Late Braking for Stopped/Stopping Traffic and Following Too Closely. In the L/SH study, 48% of HV at-fault incidents included Roadway Entrance Without Clearance, Wide Turn Into Adjacent Lane, or Late Braking for Stopped/Stopping Traffic.

One possible explanation for these differences was the predominant Road Type traveled in each study as well as the predominant trucking operations in the SB and L/SH studies. However, it could be argued that the HVs in the 100-Car Study represent a more diverse population of HVs since they were not limited to L/SH and SB trucks. In fact, 25 different HV types were identified as being involved in LV-HV interactions in the 100-Car Study. Thus, it is likely the results for at-fault HV drivers in the 100-Car Study might be more representative of HV drivers in general, while the results for HV drivers in the SB and L/SH studies may provide greater insight for these specific operations.

Recall that the Contributing Factors category describes why the incident occurred. The most frequent Contributing Factor across the three studies was Driving Techniques. A breakdown of incidents as a function of the at-fault driver showed that Driving Techniques were primarily attributed to HV drivers. Thus, when the Contributing Factor was known, Driving Techniques was the most frequent Contributing Factor for HV driver at-fault incidents in each of the studies. Similarly, the most frequent Contributing Factors for LV driver at-fault incidents across the three studies were Driving Techniques and Aggressive Driving. These two Contributing Factors accounted for 69.7% of the LV driver at-fault incidents across the three studies. However, a large proportion of the LV driver at-fault incidents in the 100-Car Study involved the Distracted

Contributing Factor. In fact, the only time a LV driver at-fault incident was coded with the Distracted Contributing Factors was in the 100-Car Study. This is due to the methodological approach used in that only the LVs in the 100-Car Study were instrumented (thereby allowing analysis of the LV drivers' behaviors while driving) while the LVs in both the SB and L/SH studies were not instrumented.

CONCLUSIONS

The analyses that were conducted with the LV-HV interactions captured in the 100-Car Study provide convincing evidence to support the contention that LV-HV interactions are a serious problem. While the 100-Car Study captured 9,125 critical incidents, only 246 LV-HV interactions (2.7%) were identified. While 2.7% may appear to represent a small proportion of the overall critical incident picture, it should be noted that LV-HV interactions have the potential to become serious, and even fatal due to the tremendous difference in weight between an HV and LV.

There are six key findings that stem from the analyses conducted on the interactions between HVs and LVs. First, of the 246 interactions that were analyzed, 138 (56.1%) were assessed to have been the fault of the LV driver. HV drivers were at-fault in 79 (32.1%) of the incidents, while in the remaining 29 (11.8%) incidents, it was unknown if the HV or LV driver was at-fault. Excluding the incidents where it was unknown if the HV or LV driver was at-fault, 63.6% and 36.4% of the incidents were the fault of the LV and HV drivers, respectively. Thus, LV drivers were judged to have been responsible for a substantial proportion of the LV-HV interactions. These findings support what the drivers in the Hanowski et al. (1998) focus groups reported about LVs being their most important safety concern. Further, the results are similar to prior published studies that used a crash database approach to assess LV-HV interactions (cf. Blower, 1998; Stuster, 1999; Wang, Knipling, and Blincoe, 1999). Based on these findings, it is suggested that focusing on the LV driver, and their errors, may provide the largest area of opportunity for reducing such events.

The second important finding from these analyses was in regard to the different Incident Types that were frequent among HV and LV drivers. For LV driver at-fault incidents, the most frequent Incident Types were: Late Braking for Stopped/Stopping Traffic (41.3%), Lane Change Without Sufficient Gap (21.7%), and Aborted Lane Change (8%). These particular Incident Types are indicative of at-risk driving behaviors. Once again, the objective data support the sentiment of the L/SH drivers in the Hanowski et al. (1998) focus group who indicated that during their daily travel, they were often "cut-off" by LV drivers. In addition, the data supports the results from the L/SH on-road study (Hanowski, Keisler, and Wierwille, 2004) where the most prevalent Incident Type for LV driver at-fault incident was Lane Change Without Sufficient Gap (accounting for 24.8% of the LV driver at-fault incidents in the L/SH study). In contrast, the most frequent Incident Types for HV at-fault drivers were: Lane Change Without Sufficient Gap (26.6%), Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%).

The third finding is the difference in the Primary Maneuvers for HV and LV drivers. The most frequent Primary Maneuvers for LV driver at-fault incidents were: Braking (32.6%), Stopped

(21.7%), and Changing Lanes (16.7%). The two most frequent Primary Maneuvers for LV driver at-fault incidents involved assumed difficulties on the part of the LV driver decelerating or stopping. In contrast, the most frequent Primary Maneuvers for HV driver at-fault incidents were: Changing Lanes (32.9%), Crosses Over Lane Line (20.3%), and Left Turn (15.2%). The two most frequent Primary Maneuvers for HV driver at-fault incidents involved difficulties changing or crossing over the lane line while the vehicle was in motion. These results make intuitive sense because HV drivers have limited visibility and deal with blind spots thereby making lane changes difficult in traffic.

The fourth important finding is related to the Contributing Factors that were most frequent with LV and HV drivers. For LV drivers, the most frequent Contributing Factors for at-fault incidents were: Driving Techniques (70.3%), Distracted (22.5%), and Aggressive Driving (22.5%). The most frequent Contributing Factors for HV driver at-fault incidents were: Unknown (68.4%), Driving Techniques (15.2%), and Distracted (11.4%). The large number of Unknown Contributing Factors for HV driver at-fault incidents is indicative of the methodology used to code these events. Because the HV did not have any video cameras, the Contributing Factor was coded with respect to the behaviors of the LV driver. As the LV driver was not responsible for the incident, it was unlikely they would be coded with a Contributing Factor, thus the high frequency of Unknown Contributing Factors. Further, the methodology used to code the Contributing Factors also explains the similarities between LVs and HVs (i.e., they were all coded with respect to the LV driver, and therefore, they should be similar).

The fifth noteworthy finding from the current research involves the Accident Types (using the LTCCS approach and terminology) that were most prevalent for LV and HV drivers. The most prevalent Accident Types for LV driver at-fault incidents were: Scenarios 20/21: Same Trafficway/Same Direction: Rear End: Approaches Stopped Vehicle (26.8%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (22.5%); and 28/29: Same Trafficway/Same Direction: Rear End: Approaches Decelerating Vehicle (17.4%). Approximately 55% of the LV driver at-fault incidents involved a Rear End approach. These Accident Types also support the findings from the analysis of the most prevalent Primary Maneuvers for LV driver at-fault incidents: decelerating or stopped. Conversely, the most prevalent Accident Types for HV driver at-fault incidents were: Scenarios 44/45: Same Trafficway/Same Direction: Forward Impact: Sideswipe Angle: In Blind Spot (27.7%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (15.2%); and 25/25: Same Trafficway/Same Direction: Rear End: Approaches Constant Speed Vehicle (8.9%). Approximately 42% of the HV driver at-fault incidents involved a Sideswipe Angle. These Accident Types also support the findings from the most prevalent Primary Maneuvers for HV driver at-fault incidents: changing lanes and crossing the lane line.

The sixth noteworthy finding from the current research reflects some of the similarities and differences found between the current study and prior studies using a crash database approach in analyzing LV-HV interactions. While both approaches found that LV drivers were responsible for the majority of LV-HV interactions, the reasons *why* these interactions occurred differed with respect to the methodologies used to assess these interactions. For example, the current research found that 22.5% of the LV driver at-fault incidents were cited with the Contributing Factors of Aggressive Driving. In Stuster's (1999) analysis, only 4.3% of the LVs were cited with the driver-related factor “Erratic/Reckless Driving” (it should be noted that Stuster assessed only fatal crashes). Moreover, Hankey et al. (1999) found that 31.1% of the fatal crashes in the FARS database were cited with Aggressive Driving. The results from the current study (22.5%) are within the range reported by Stuster (4.3%) and Hankey (31.1%).

The current research also found that 41.8% of the HV driver at-fault incidents involved a Sideswipe Angle, while 55.1% of the LV driver at-fault incidents involved a Rear End approach. These results differed from Blower’s (1998) review of fatal LV-HV crashes. He found that 9.4% of fatal LV-HV interactions, where only the HV driver was cited with a driver related factor, involved a sideswipe angle. Further, Blower’s (1998) analysis found that 13.9% of the fatal LV-HV interactions, where only the LV driver was cited with a driver-related factor, involved a rear-end strike. When Council et al. (2003) reviewed all types of LV-HV crashes in North Carolina, they found that 23.2% of the HV driver at-fault crashes involved a sideswipe and 28.5% of the LV driver at-fault crashes involved a rear-end approach. These discrepancies might highlight the differences between analyzing crashes and near crashes and/or the methodologies used analyze the data (i.e., a crash database approach versus a naturalistic or *in situ* data collection approach).

The results of the current study in conjunction with Hanowski, Keisler, and Wierwille (2004) indicated that LV-HV interactions represent a serious problem. While there were several differences across the three studies, the results consistently showed that LV drivers are more likely to be responsible for the LV-HV interaction than HV drivers. It is believed that the results from the 100-Car, SB, and L/SH studies provide a more complete description of the LV-HV interaction picture. Furthermore, the comparisons among these three studies address the limitations of not having both an instrumented LV and HV.

CHAPTER 1: LIGHT VEHICLE – HEAVY VEHICLE INTERACTIONS COLLECTED IN THE 100-CAR STUDY

INTRODUCTION

Overview of the Light Vehicle–Heavy Vehicle Problem

Truck crashes represent a significant problem on our highways. In 2002, 434,000 large trucks (gross weight ≥ 10,000 lbs) were involved in vehicle crashes; 4,542 of these crashes resulted in a fatality. A total of 4,897 people died and an additional 210,000 were injured. Large trucks accounted for 4% of all registered vehicles in 2002, yet represented 8% of all vehicles involved in fatal crashes (National Highway Traffic Safety Administration, NHTSA, 2003). Truck crashes and their associated injuries and fatalities cost an estimated 24.4 billion in direct and indirect costs in 2002 (FMCSA, 2002).

The disproportionate number of vehicles to fatalities among large trucks is likely to contribute to the perception that truck drivers are irresponsible. However, these data do not signify that truck drivers are necessarily the problem. In fact, truck drivers have lower non-fatal crash rates per million vehicle miles traveled than light vehicles (NHTSA, 2003). However, light vehicles are extremely vulnerable when they interact with trucks because trucks often weigh 20-30 times as much as light vehicles (Insurance Institute for Highway Safety, 2002), and trucks take 20-40% farther to stop than light vehicles (NHTSA, 1987). This is best illustrated by the fact that over three-fourths of multiple vehicle fatal truck crashes resulted in the occupant(s) of the other vehicle being killed (NHTSA, 2004).

To combat this problem, proposals have been made to separate light and heavy vehicles on high-volume roads. For example, *STAR Solutions* has proposed to separate heavy trucks from passenger traffic on Interstate 81 (http://www.virginiadot.org/infoservice/resources/is-I-81-Star-exec.pdf), thereby reducing the likelihood of light vehicle-heavy vehicle (LV-HV) interactions. However, the enormous cost and logistical difficulties associated with new and modified road construction suggest that, in most cases, these vehicles will have to share the road for the foreseeable future. Thus, a better understanding of LV-HV interactions is needed to develop alternative interventions and countermeasures directed at reducing and/or eliminating the problem.

Prior Research on Light Vehicle-Heavy Vehicle Interactions

When Hanowski, Wiewille, Gellatly, Early, and Dingus (1998) conducted focus groups with local/short-haul truck drivers, they found that participants ranked "problems with light vehicles" as the most important safety issue. In fact, this was the only safety issue that was consistently cited in all 11 focus groups that were conducted. Similarly, Neale et al. (1998) found that LV-HV interactions were a significant safety concern among a sample of long-haul truck drivers. Only recently has empirical evidence supported truck drivers' claims.

Blower (1998) analyzed the University of Michigan Transportation Research Institute's "Trucks Involved in Fatal Accidents" database for all two-vehicle, truck-passenger vehicle fatal crashes in 1994 and 1995 (n = 5,453). He found that truck drivers were cited with a driver-related factor in 26.5% of the fatal crashes, while passenger vehicle drivers were cited in over 80% of the fatal crashes. The passenger vehicle driver was the only driver cited in 70.3% of the fatal crashes, while truck drivers were the only driver cited in 16.2% of the fatal crashes.

Stuster (1999) found similar results when he reviewed the U.S. Department of Transportation's *Fatality Analysis Reporting System*. He found that truck driver-related factors were cited in 29% of fatal truck crashes involving a passenger vehicle, while 67% of these same interactions were cited as passenger vehicle-related. Moreover, Wang, Knipling, and Blincoe (1999) found that LVs were the initiators in LV-HV fatal crashes by a ratio of approximately 3:1. Thus, it appears the actions of LVs are responsible for a substantial amount of the fatal LV-HV interactions.

Council, Harkey, Nabors, Khattack, and Mohamedshah (2003) took a different approach when they analyzed 16,264 LV-HV interactions from the North Carolina Highway Safety Information System. Rather than examining the police reports from fatal LV-HV interactions, they examined the police reports of both crashes and fatal crashes. While the prior studies assessed the most severe crashes, the Council et al. (2003) study assessed the overall LV-HV crash picture. Contrary to the other studies, however, Council et al. (2003) found that the truck driver was assigned fault in 48% of the crashes, while the passenger vehicle driver was assigned fault in 40.2% of the crashes (8.9% of the crashes were assigned fault to both drivers, while 2.9% were assigned fault to neither driver). The Council et al. (2003) data suggests that HV drivers were responsible for the majority of the LV-HV interactions (for all types of crashes). Thus, there appears to be some inconsistencies in the literature regarding assigned culpability in LV-HV interactions.

These prior studies assessed LV-HV interactions by examining vehicle crash databases that rely on police reports and crash reconstruction. These approaches are generally reliable, but they do have limitations, including witnesses and crash participants can be biased and report conflicting stories; police officers, while often experienced, generally do not receive extensive training in crash reconstruction; and witnesses or crash participants that were severely injured or killed in the crash are unlikely or are unable to effectively persuade the police officer about their side of the crash (also referred to as the "surviving driver" hypothesis).

Blower (1998) acknowledged the surviving driver limitation in his discussion and compared fatal LV-HV interactions with respect to driver survivability. When only the truck driver survived the fatal LV-HV interaction, the LV driver was cited with at least one driver-related factor in 81.9% of the fatal crashes, while the HV driver was cited in only 24.1% of the fatal LV-HV crashes. Conversely, when only the LV driver survived the fatal LV-HV interactions, the LV drivers were cited with at least one driver-related factor in 46.7% of the crashes, while HV drivers were cited in 57.7% of the crashes.

It would appear that driver survivability does affect which driver is cited in fatal LV-HV crashes. This makes intuitive sense because the surviving driver is able to report their biased account of the event. However, when both LV and HV drivers survive the crash, the LV driver was cited in 74.1% of the crashes while the HV driver was cited in only 35.5% of the crashes (Blower, 1998).

The crash database approach does not necessarily shed light on the full variety of LV-HV interactions because they rely solely on crashes and fatal crashes. While LV drivers have been shown to be culpable in a significant proportion of LV-HV interactions (Wang, Knipling, and Blincoe, 1999), we do not know why. An alternative approach, and the method used in the current study, is to study the pre-event behaviors of all LV-HV interaction critical incidents, including crashes, near-crashes, and crash-relevant conflicts.

Because the focus of this research is on analyzing critical incidents, it is important to define the three categories that are of most interest: crashes, near-crashes, and crash-relevant conflicts. In the 100-Car Study, Dingus et al. (2004) defined crashes, near-crashes, and crash relevant conflicts as follows:

> <u>Crash:</u> Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated, and includes other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, cyclists, or animals.
>
> <u>Near-Crash:</u> Any circumstance that requires a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities. As a guide: Subject vehicle braking >0.5 g or steering input that results in a lateral acceleration >0.4 g to avoid a crash constitutes a rapid maneuver.
>
> <u>Crash-Relevant Conflict (Incident):</u> Any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or animal that is less severe than a rapid evasive maneuver (as defined above), but greater in severity than a "normal maneuver" to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A "crash avoidance response" for the subject vehicle is defined as a control input that falls outside of the 99% confidence limit for control input as measured for the same subject.

Hanowski, Keisler, and Wierwille (2004) assessed two on-road *in situ* data collection efforts, one involving local/short-haul (L/SH) trucking and the other long-haul trucking with drivers who used sleeper berths, to examine critical incidents that occurred between LVs and HVs. In this study, critical incidents were defined as crashes and near-crashes. Near-crashes were events resulting in a close call or requiring rapid action by a driver to avoid a crash. Video and non-video data collected during the two studies were used to characterize 210 critical incidents involving LV-HV interactions. Of the 210 critical incidents analyzed in the Hanowski, Keisler, and Wierwille (2004) study, 78% were assessed to have been initiated by the LV driver, while the remaining 22% were initiated by the HV driver. It should be noted that in Hanowski, Keisler, and Wierwille (2004), "initiate" is synonymous with "at-fault." Thus, a vehicle that initiated an incident is meant to reflect the vehicle that was at-fault or responsible for the incident.

The benefits of the naturalistic data collection approach used in Hanowski, Keisler, and Wierwille (2004) are three-fold: (1) video and other supporting data are collected before, during, and after the event occurs, thereby providing a complete picture of the incident as it unfolds; (2) various types of non-crash LV-HV interactions can be analyzed; and (3) the use of video and non-video data allowed one to make objective assessments on the critical reason(s) for the incident (rather than incomplete, subjective police reports).

However, one limitation of this approach was that the video cameras were only installed in the HVs and not the LVs. Therefore, Hanowski, Keisler, and Wierwille (2004) were only able to assess LV-HV interactions from the HV driver's perspective. Thus, it is possible they missed critical incidents that were only apparent from the LV driver's perspective. Furthermore, the lack of instrumentation in LVs limits the understanding of the LV driver's behavior during the incident.

These limitations were addressed in the 100-Car Study by installing video cameras on LVs (Dingus et al., 2004). All identified LV-HV interactions from the 100-Car data set were included in the current analyses. Together, results from the current study and the Hanowski, Keisler, and Wierwille (2004) study may provide a more complete picture of the LV-HV interaction problem.

The current study used two classification methodologies to assess all LV-HV interactions: the classification methodology used in Hanowski, Keisler, and Wierwille (2004) (originally developed by Wierwille et al., 2001), and the methodology and terminology from the Large Truck Crash Causation Study (LTCCS) (Thieriez, Radja, and Toth, 2002). Thus, all LV-HV interactions in the current data set were coded with two similar, yet distinct, classification approaches. The primary advantage of this method is that reliable and valid comparisons can be made with both prior and future research studies using either approach.

Research Goals

The data from the 100-Car Study (Dingus et al., 2004) were used in the current project to assess the LV-HV interaction problem from the LV drivers' perspective. There were four primary aims in the current effort:

- Gain a better understanding of LV-HV interactions on our nation's roadways.
- Continue to develop the classification scheme and corresponding Contributing Factors list for LV-HV interactions used in Hanowski, Keisler, and Wierwille (2004) and use the terminology and methodology described in the LTCCS (Thieriez, Radja, and Toth, 2002).
- Compare the current data to the data obtained in the Hanowski, Keisler, and Wierwille (2004) study for a more complete picture of the LV-HV interaction problem.
- Provide background information that would serve as a necessary prerequisite to the development of countermeasures for LV-HV interactions.

METHOD

Participants and Setting

One hundred participants who commute to and from the Washington, DC metro area were initially recruited as drivers in the 100-Car Study (Dingus et al., 2004). As some participants had to be replaced for various reasons (e.g., dropped out of the study because they moved from the area), the final number of participants was 109. Age and number of miles driven annually were used to select a subject population that would increase the probability that rear-end collisions would occur in 13 months of data collection. High mileage drivers were selected to increase the number of vehicle miles traveled per year (increase exposure). Greater number of younger drivers (ages 18 through 25) were recruited as they are overly represented in rear-end collisions as compared to other age groups. Also, more males than females were recruited since males are overly represented in rear-end crashes (Knipling, Wang, and Yin, 1993). It should be noted that participants were recruited from all age groups and that the target average annual mileage per year was approximately 27,000 miles/year. However, the actual mileage driven by participants in the 100-Car Study did not match their self-reported annual mileage prior to the study. The actual mileage of participants in the 100-Car Study can be found in Dingus et al. (2004). Table 1, shown below, displays the age and gender distribution of participants.

Table 1. Participant Age and Gender Distributions.

Age	Gender (N and % of Total)		Total
	Female	Male	
18-20	9 8.3%	7 6.4%	16 14.7%
21-24	11 10.1%	10 9.2%	21 19.3%
25-34	7 6.4%	12 11.0%	19 17.4%
35-44	4 3.7%	16 14.7%	20 18.4%
45-54	7 6.4%	13 11.9%	20 18.3%
55+	5 4.6%	8 7.3%	13 11.9%
Total N Total Percentage	43 39.4%	66 60.6%	109 100.0%

Light Vehicle Types

The data that were collected in the 100-Car Study came from six makes/models/years of LVs, including Toyota Camry (1997-2001), Toyota Corolla (1993-2002), Ford Explorer (1995-2000), Ford Taurus (2000-2002), Chevrolet Malibu (2002), and Chevrolet Cavalier (2002). The Toyota and Ford models were chosen based on recent sales figures and on the number of vehicles available in the Washington, DC area. Figures 1 and 2 show examples of the LVs used in the 100-Car Study.

Figure 1. Toyota Camry and Toyota Corolla Used in 100-Car Study.

Figure 2. Ford Explorer and Ford Taurus Used in 100-Car Study.

A total of 20 Chevrolet vehicles (10 Malibus and 10 Cavaliers) were leased from the Virginia Tech Motor Pool and were instrumented with data collection equipment. Twenty participants were given leased vehicles to drive for one year. The additional 80 vehicles (comprised of the aforementioned Toyota and Ford models) were the participants' personal vehicles. These vehicles were instrumented with the identical data collection systems as the leased vehicles.

Data Collection Methodology for the 100-Car Study

A full description of the research methodology used in the on-road portion of the 100-Car Study can be found in Dingus et al. (2004). Because the data used in the current effort consisted of the video recordings of critical incidents, the primary methodological considerations to be described in this report are those related to the video systems.

Video Camera Systems

As shown in Figure 3, five video cameras were used in the video recording system: (1) a forward-looking camera that captured the forward roadway scene, traffic situation, and possible incidents; (2) a driver's face camera that was used to record facial expressions, eyelid closure, glance position, and head turns; (3) a right-side camera was mounted on the A-pillar of the passenger side and faced outward; (4) a dome camera was mounted from inside the vehicle and faced over the driver's shoulder towards the steering wheel, hands, and feet; and (5) a rear camera that was intended to capture the situation behind the vehicle. Infrared lighting was used to illuminate the vehicle cab so that the driver's face as well as their hands could be viewed by the camera during nighttime driving.

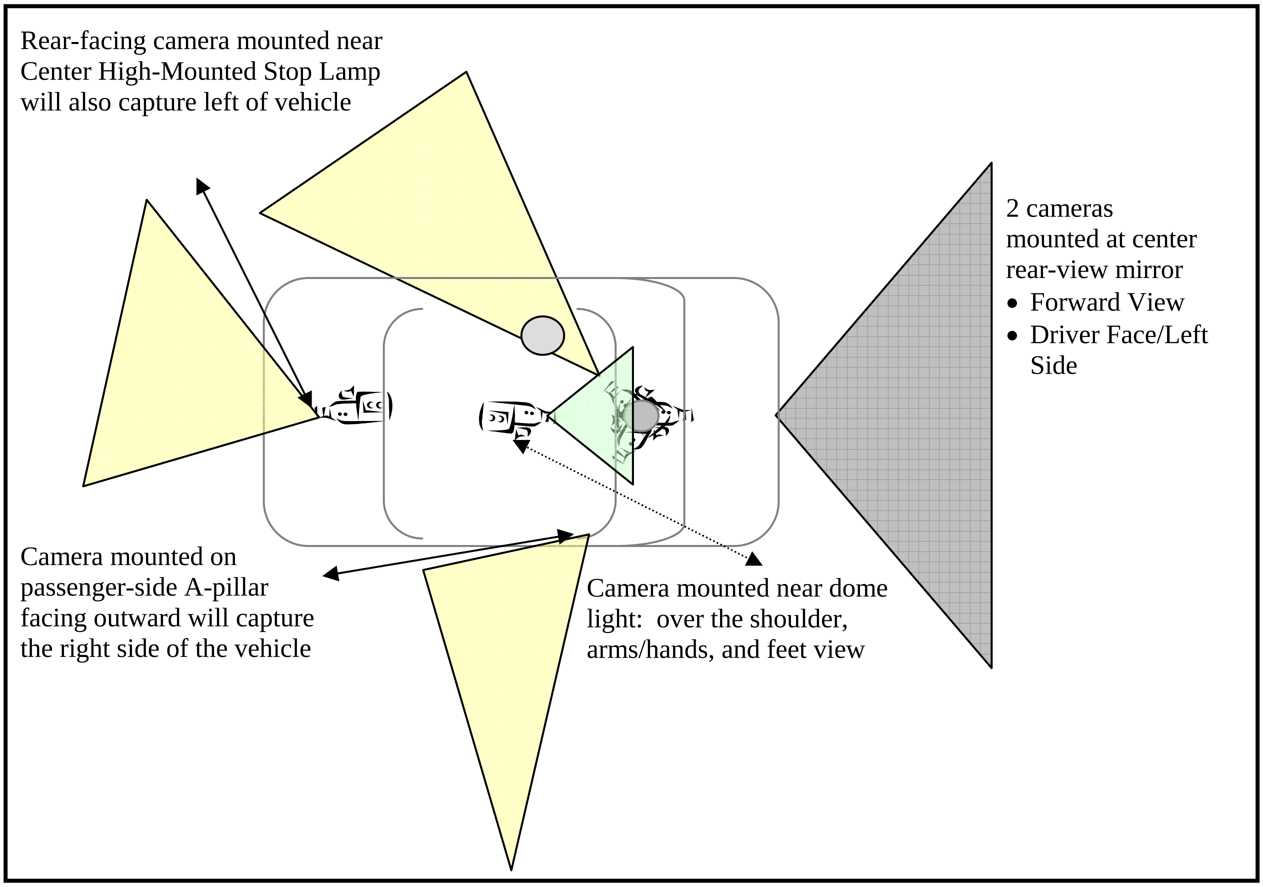


Figure 3. The Five Camera Views Recorded in the Instrumented Vehicle.

The video camera arrangement shown in Figure 3 had several advantages. First, it provided good coverage around the vehicle so that incidents could be captured as they developed. Second, the driver's facial expression, approximate glance direction, and approximate level of eye closure were also captured. Third, the arrangement provided appropriate views, whether moving forward or backward.

The five camera images were multiplexed into a single image as shown in Figures 4 and 5. Note that the right side camera and the rear camera were presented in the lower left quadrant in a split arrangement.

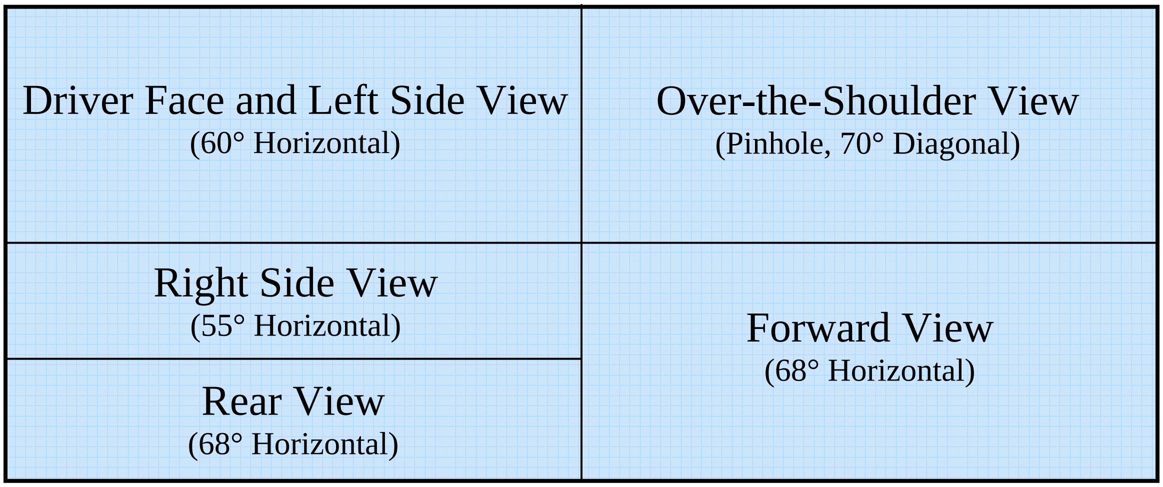


Figure 4. Diagram of the Multiplexed Camera Views.

Figure 5. Split-Screen Presentation of the Five Camera Views.

Video Recording Operation

Video recording was tied to the booting/powering system and it began to operate 2 minutes after the ignition was on. It also shut down in an orderly manner when the ignition was turned off. It was desired for the recording system to record for as long as possible without requiring technician/researcher attention. Therefore, multiple recorders designed to operate in sequence were used. The video continuously recorded while the ignition was on, thereby allowing laboratory review and selection of the video without losses of any kind.

The videotaped episodes/incidents were selected and keyed to digitally recorded data. In some cases, the videotape timestamp was used to access the corresponding digital data. In other cases, the incident flags (described later) in the digital data were used to access the corresponding video. Therefore, there was a straightforward keying procedure that allowed both kinds of access to take place efficiently.

Data Collection and Storage

"Chase" vehicles drove to pre-determined locations (e.g., parking lots) and downloaded the data from the experimental vehicles via a data transfer cable that connected to an outlet located near the rear license plate. Each chase vehicle had a laptop computer with a large hard drive to store all vehicle data. After each download from the experimental vehicles, the success of the duplication procedure was verified. Once 2.3 GB of data were downloaded from experimental vehicles, the data were copied to a DVD and verified. This DVD was duplicated; one copy was sent to VTTI and the other copy was kept in Northern Virginia.

As the data arrived at VTTI, they were downloaded to VTTI's network attached storage (NAS) and saved. Once the data was safely copied to the networked attached storage at VTTI and quality checks were performed, the data were then remotely deleted from the experimental vehicle hard drive.

Incident Flag

A critical incident involves an unexpected event resulting in a close call or requiring rapid action (evasive maneuver) on the part of a driver to avoid a crash. Critical incidents were detected by one of three methods. The first method involved flagging events where the car sensors exceeded a specified value. An example of this is a braking response of >0.6 g would be recorded as a potential incident where the driver may have braked in a panic.

Table 2 lists all of the triggers and levels that were used in this first method. The second incident flagging method occurred when the driver pressed an incident pushbutton located on the dashboard. Drivers were instructed to depress a button on the dashboard (after the event, not during the event) if they witnessed an incident or were involved in an incident. The third method of detecting incidents was through analysts' judgments when reviewing the video. Note that the video systems were operational as long as the ignition was turned on. In identifying incidents, analysts looked through epochs flagged from either of the first two methods and could flag additional events within the epoch (termed "user triggered") if an incident was detected visually. Only those events that involved a LV-HV interaction are described in the current analyses. The results of other project analyses can be found in Dingus et al. (2004).

Table 2. Triggers and Their Levels Used to Identify Critical Incidents in the 100-Car Study Database.

Trigger Type	Description
Lateral Acceleration	Lateral motion equal or greater than 0.7 g.
Longitudinal Acceleration	Acceleration or deceleration equal or greater than 0.6 g. Acceleration or deceleration equal or greater than 0.5 coupled with a forward TTC of 4 s or less. All longitudinal decelerations between 0.4 g and 0.5 g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
Critical Incident Button	Activated by the driver upon pressing a button located on the dashboard when an incident occurred that he/she deemed critical.
Forward time-to-collision	Acceleration or deceleration equal or greater than 0.5 coupled with a forward TTC of 4 s or less. All longitudinal decelerations between 0.4 g and 0.5 g coupled with a forward TTC value of ≤ 4 s and that the corresponding forward range value at the minimum TTC is not greater than 100 ft.
Rear time-to-collision	Any rear TTC trigger value of 2 s or less that also has a corresponding rear range distance of ≤ 50 ft AND any rear TTC trigger value where the absolute acceleration of the following vehicle is greater than 0.3 g
Yaw rate	Any value greater than or equal to a plus AND minus 4 degree change in heading (i.e., vehicle must return to the same general direction of travel) within a 3 s window of time.

The incident flags (associated with the first and second triggering methods) were computed and detected on-line (as well as stored) with the flag appearing in the video. Since the entire video recording was reviewed, the presence of flags served as an indicator to the analyst of the high likelihood, but not certainty, of an incident occurrence. However, the analyst was also mindful of the possibility of incidents without flags and reviewed the tapes accordingly. The data analysts watched 90 s epochs (1 min prior and 30 s post incident) of each driving incident and recorded the information shown in Table 3.

Table 3. Information Recorded During 90 s Epoch Analysis.

Event severity	Surface condition
Event nature	Traffic flow
Event time begin and end	Travel lanes
Subject number	Traffic density
Pre-incident maneuver	Traffic control
Maneuver judgment	Relation to junction
Precipitating event	Alignment
Driver reaction	Locality
Driver behavior	Lighting
Driver Impairments	Weather
Alcohol use	Wipers
Willful behavior	Driver's seat belt
Driver proficiency	Surrounding vehicle position
Roadway infrastructure	Surrounding vehicle type
Driver distraction	Surrounding vehicle maneuver
Hands on wheel	Surrounding vehicle reaction
Vehicle contributing factors	Fault
Visual obstructions	Narrative

Data Reduction Reliability

Given that data analysts were asked to perform subjective judgments on the video and driving data, training procedures were implemented to improve both inter- and intra-rater reliability. Reliability testing was then conducted to measure the resultant inter- and intra-rater reliability. First, data analyst managers performed spot checks of the data analysts' work, monitoring both event validity judgments as well as recording all database variables. All data analysts also performed 30 mins of spot-checking of their own or other data analysts' work per week.

To determine how successful these techniques were, an inter- and intra-rater reliability test was conducted during the last three months of data reduction. Three reliability tests were developed (each containing 20 events) for which the data analyst was required to make validity judgments. In each of the three reliability tests, three of the 20 events were also fully reduced by the data analysts. Three of the test events on Test 1 were repeated on Test 2 and three other events were duplicated between Tests 2 and 3, to obtain a measure of intra-rater reliability.

The Kappa statistic was also used to calculate inter-rater reliability (Cicchetti and Feinstein, 1990). The Kappa coefficient ($K = 0.65$, $p < 0.0001$) indicated that the association among raters was significant. The average of the pair-wise correlation coefficients for the inter-rater analysis was 0.86. The coefficients for the intra-rater analysis were extremely high with nine raters achieving a correlation of 1.0 among the three reliability tests and five raters achieving a correlation of 0.99. Given these three methods of calculating inter-rater reliability, it appears that the data analysts training coupled with spot-checking and weekly meetings proved to be an effective method for achieving high inter-rater and intra-rater reliability.

Strengths and Limitations of the Methodology Used

All research approaches have strengths and limitations. Listed below are the strengths and limitations of the approach used in the current study.

Strengths

The primary strength of the approach used in this study was that all driver behaviors, visible by way of the video camera, were recorded whenever the vehicle was on and in motion. This information is vital in developing an understanding of the incident, the events leading up to the incident, and the aftermath of the incident from the LV driver's viewpoint. The video camera arrangement described allowed researchers to watch the critical incidents unfold from multiple camera views. The video camera system that was used not only afforded an opportunity to understand what happened, but in many cases why it happened. A second advantage of this approach was that multiple cameras views helped ensure that any critical incidents involving the LV driver were captured and available for analysis.

Possible Limitations

There were two possible limitations of the approach used in the current research. First, because the video cameras were installed in the LVs and not the HVs, critical incidents could only be captured from the LV driver's perspective. It was possible that LV-HV interactions, which may have only been apparent from the HV driver's viewpoint, were not recorded. However, because there was fairly complete video recording coverage around the entire LV, it was likely that most LV-HV interactions that occurred were recorded.

Second, because there were no cameras mounted in any HV, it is difficult to have a complete understanding of the HV driver's behavior during the incident. The video camera that was directed at the LV driver's face, along with the verbal utterances of the driver, provided the researchers with a fairly complete understanding of the LV driver's behavior before, during, and after each incident. However, this was not the case regarding the behavior of the HV driver. The absence of video footage of the HV driver's face meant that the HV driver's behavior had to be surmised based on the video of the HV collected from the LVs and the comments and facial expressions made by the LV driver.

These limitations were also raised in Hanowski, Keisler, and Wierwille (2004) for the LV-HV analyses that were conducted with both L/SH and sleeper berth (SB) trucks. Considering the previous Hanowski, Keisler, and Wierwille (2004) work in conjunction with the current research, a more complete assessment of LV-HV interactions from both the HV and LV driver's perspective was expected. Assumptions regarding driver behavior were required for each of these research efforts, particularly for the driver of the non-instrumented vehicle.

RESULTS

Light Vehicle-Heavy Vehicle Interaction Data Set

The 100-Car Study (Dingus et al., 2004) captured 9,125 incidents. These 9,125 incidents were divided into four categories: LV-LV Interactions, LV-HV Interactions; Single Vehicle Conflicts, and Other. Table 4 provides a description of the different vehicle types in each category.

Table 4. Vehicle Types Captured in the 100-Car Study.

Vehicle Category	Vehicles Considered in Each Vehicle Category	
Light Vehicle	Automobile	
	Minivan/Standard Van	
	Motorcycle/Moped	
	Pick-up Truck	
	Sport Utility Vehicle	
Heavy Vehicle	Bus	Conversion Bus
		Greyhound Bus
		School Bus
		Transit Bus
	Emergency Vehicle	Ambulance
		Fire Truck
	Straight Truck	Straight Truck: Beverage
		Straight Truck: Box
		Straight Truck: Concrete Mixer
		Straight Truck: Dump
		Straight Truck: Flatbed
		Straight Truck: Garbage
		Straight Truck: Multistop/Step Van
		Straight Truck: Other
		Straight Truck: Tow Truck
		Straight Truck: Trailer
		Straight Truck: Unknown
	Tractor-Trailer	Tractor Only
		Tractor-Trailer: Car Carrier
		Tractor-Trailer: Dump Trailer
		Tractor-Trailer: Enclosed Box
		Tractor-Trailer: Flatbed
		Tractor-Trailer: Other
		Tractor-Trailer: Tank
	Construction Equipment	

The data set used in the current effort was comprised of a subset of incidents from the 9,125 incidents described above. The 9,125 incidents were reviewed and only those that involved a LV-HV interaction were included in the present analysis.

Figure 6 shows a pie chart of the 9,125 events as a function of the vehicles involved and whether or not the incident was an interaction between vehicles. As can be seen, of the 9,125 events, 246 (2.7%) involved a LV-HV interaction. In 2003, there were a total of 6,328,000 crashes in the U.S. (NHTSA, 2004). Of these crashes, 313,663 (5%) were classified as a LV-HV interaction. Thus, the present data set has fewer LV-HV interactions than the national crash statistics.

Of the 246 LV-HV recorded incidents, 219 (89%) were crash-relevant conflicts, 25 (10.2%) were near crashes, 1 (.4%) was a crash, and 1 (.4%) was undetermined.[2] For the 79 incidents where the HV driver was judged to have been at-fault, 66 (83.5%) were crash-relevant conflicts and 13 (16.5%) were near crashes. For the 138 incidents where the LV driver was judged to have been at-fault, 128 (92.8%) were crash-relevant conflicts, 8 (5.8%) were near crashes, 1 (.7%) was a crash, and 1 (.7%) was undetermined. For the 29 incidents where it was unknown if the LV or HV driver was at-fault, 29 (100%) were crash-relevant conflicts.

[2] This was a unique event that was not identified from any of the triggering methods. This event involved the driver reporting that he had received a ticket for illegally passing a stopped school bus. This self-report was then confirmed by reviewing the video.

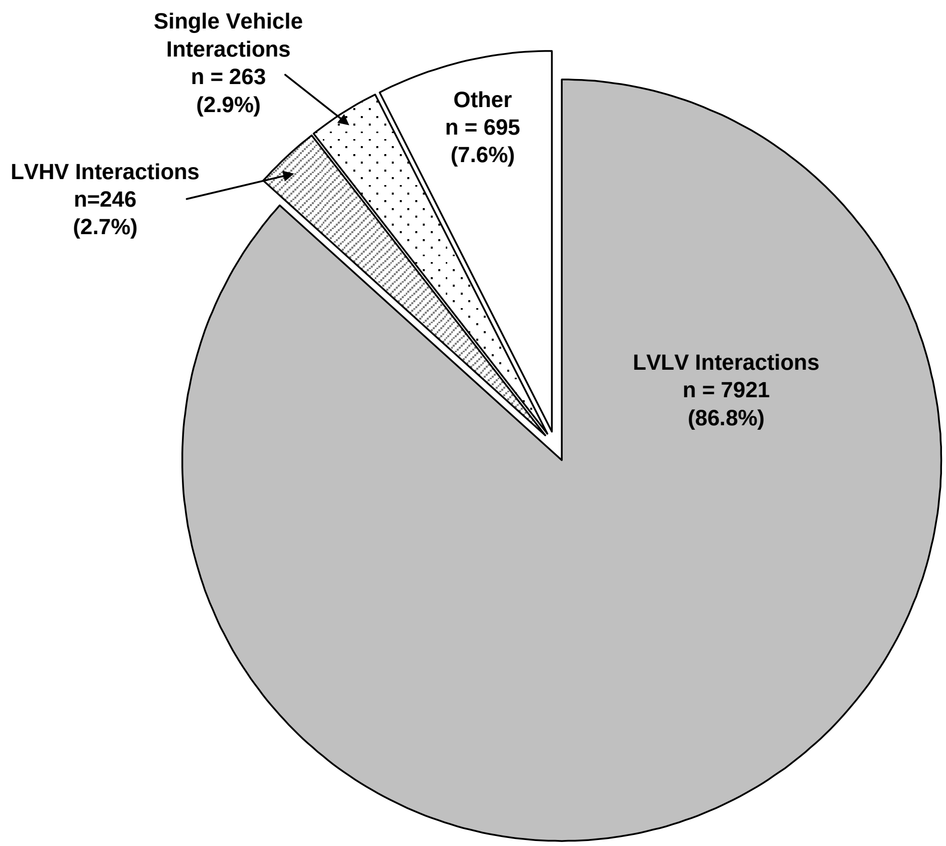
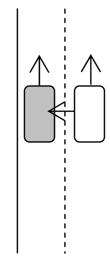
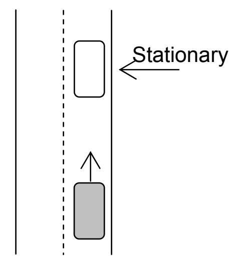
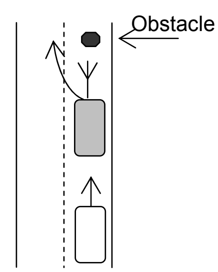
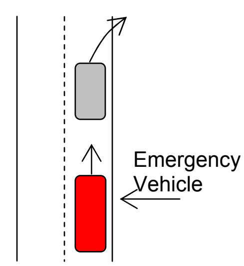
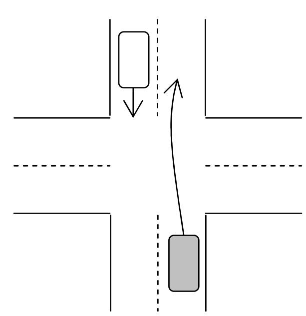


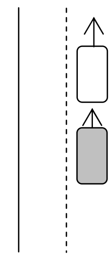
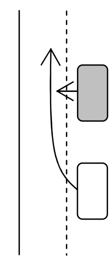
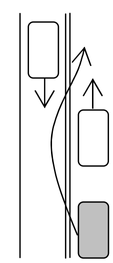
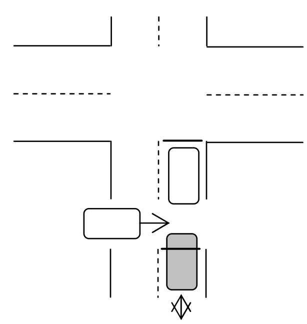
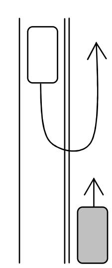
Figure 6. Distribution of the 9,125 Incidents Captured in 100-Car Study.

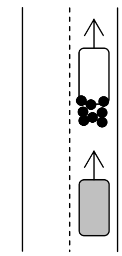
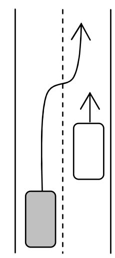
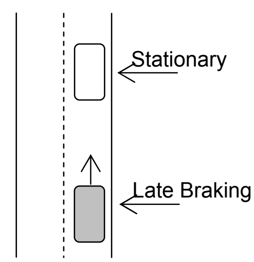
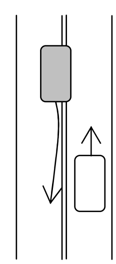
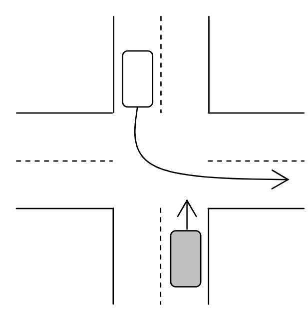
Incident Types

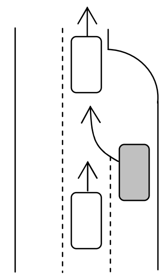
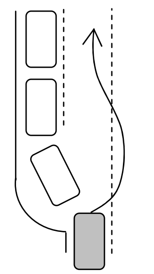
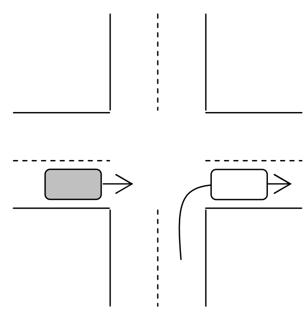
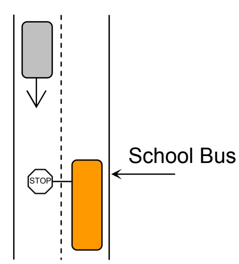
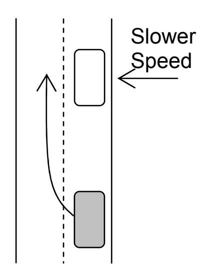
Given that the 100-Car data set was comprised of 246 LV-HV interactions, the next step in the analysis was to determine the vehicles' actions for each incident. To this end, the video and relevant data for each incident were carefully reviewed and then classified as an "Incident Type." Twenty-seven different Incident Types were identified (a detailed description of each is presented in Table 5). It should be noted that the 27 Incident Types listed do not necessarily comprise the entire universe of all types of LV-HV interaction incidents. Rather, the 27 Incident Types listed comprise those that were identified in this data set (N = 246). The Incident Types are written in such a way as to be interchangeable regarding LVs and HVs. Note that this is the same classification strategy outlined in the Hanowski, Keisler, and Wierwille (2004) study. However, in the Hanowski, Keisler, and Wierwille (2004) study, only 20 Incident Types were identified in their data set.

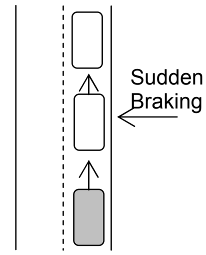
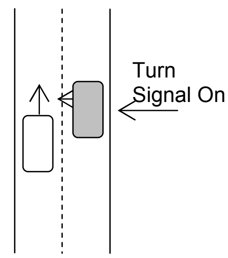
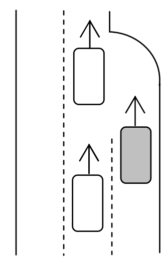
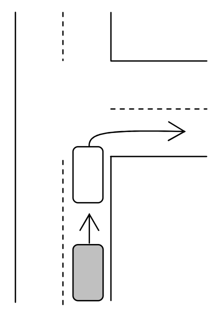
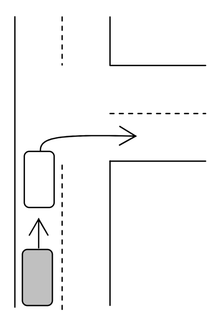
Table 5. Description of the Incident Types that were Identified in the Current Research.

Incident Type	Description	Illustration
Aborted Lane Change	A driver tries to make a lane change into a lane where there is already a vehicle (driver does not see vehicle). The driver has to brake and move back into the original lane.	
Approaches Traffic Quickly	A driver approaches stopped/slowing traffic too quickly and has to brake hard/suddenly to avoid hitting the lead vehicle.	
Backing in Roadway	A driver backs the vehicle while on a roadway in order to maneuver around an obstacle ahead on the roadway.	
Clear Path for Emergency Vehicle	A driver is traveling ahead of an emergency vehicle (e.g., ambulance, fire truck) and has to move to the side of the road to let the emergency vehicle pass.	
Conflict With Oncoming Traffic	A driver is approaching oncoming traffic (e.g., through an intersection) and has to maneuver back into the correct lane to avoid an oncoming vehicle.	

Incident Type	Description	Illustration
Following Too Closely	A driver does not allow adequate spacing between their vehicle and the lead vehicle (e.g., tailgating).	
Improper Lane Change	A driver makes an improper lane change with regard to another vehicle (e.g., does not use signal, changes lanes behind another vehicle then does not let vehicle change lanes, changes lanes across multiple lanes, etc.)	
Improper Passing	A driver passes another vehicle when it is illegal or unsafe (e.g., passing across a double yellow line or without clearance from oncoming traffic).	
Improper Stopping at an Intersection	A driver does not stop appropriately at the white stop line at an intersection.	
Improper U-Turn	A driver makes a U-turn in the middle of the road (over the double yellow line) and blocks traffic in the opposite direction.	

Incident Type	Description	Illustration
Improperly Covered Debris From Lead Vehicle	Debris is blown from the lead vehicle and obstructs driver's view in the following vehicle.	
Lane Change Without Sufficient Gap	A driver enters an adjacent lane without allowing adequate space between the driver's vehicle and the vehicle ahead/behind it.	
Late Braking for Stopped/ Stopping Traffic	A driver fails to slow in advance for stopped or stopping traffic and must brake abruptly.	
Lateral Deviation of Through Vehicle	A driver has substantial lateral deviation of a through vehicle. Vehicle may or may not deviate from the lane.	
Left Turn Without Clearance	A driver turns left without adequate clearance from either oncoming through traffic or cross traffic from the left. The driver crosses another driver's path while entering an intersecting roadway.	

Incident Type	Description	Illustration
Merge Without Sufficient Gap	A driver merges into traffic without a sufficient gap to either the front or back of one or more vehicles.	
Obstruction in Roadway	A stationary object blocks through traffic, such as traffic that is backed up or an animal in the roadway.	
Roadway Entrance Without Clearance	A driver turns onto a roadway without adequate clearance from through traffic.	
School Bus Passing Violation	A driver fails to stop for a stopped school bus with the stop arm extended.	
Slow Speed	A driver is traveling at a much slower speed than the rest of the traffic, causing following traffic to pass the slow vehicle to avoid a conflict.	

Incident Type	Description	Illustration
Sudden Braking in Roadway	A driver is traveling ahead of another vehicle and brakes suddenly and improperly in the roadway for traffic, a traffic light, etc., causing the following vehicle to come close to their vehicle or to also brake suddenly.	
Through Traffic Does Not Allow Lane Change	A driver is trying to make a lane change (with their turn signal on) but traffic in the adjacent lane will not allow the lane change to be completed.	
Through Traffic Does Not Allow Merge	Through traffic obstructs a driver from entering the roadway.	
Turn Without Sufficient Warning	A driver slows and turns without using a turn signal or without using a turn signal in advance.	
Turn/Exit From Incorrect Lane	A driver turns onto a side road from the incorrect lane (e.g., a driver makes a right turn from the left lane instead of the right lane).	

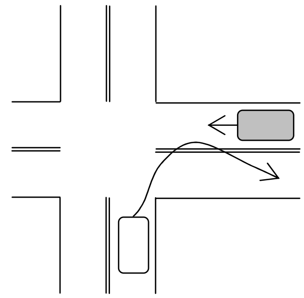
Incident Type	Description	Illustration
Wide Turn Into Adjacent Lane	A vehicle partially enters an adjacent lane when turning. Traffic in the adjacent lane may be moving in the same or opposite direction.	
Unable to Determine	It is not possible to determine which vehicle is at fault, therefore, it is not possible to assign an incident type to the event.	

Table 6 shows the frequency, percentage, and rank ordering for the Incident Types across the entire 100-Car data set. The rank ordering highlights the frequency of Incident Types from most frequently occurring (ranked as a low number, “1”) to least frequently occurring (ranked as a high number, “23.5”). Incident Types that had an equal number of occurrences were ranked as a “tie” and the mean of the rankings was assigned. For example, “Approaches Traffic Quickly,” and “Roadway Entrance Without Clearance” occurred equally with a frequency of “6.” Because their order in the ranking would consist of the ninth and tenth positions, a mean ranking of “9.5” was assigned to both Incident Types.

As can be seen from the data presented in Table 6, the most frequent Incident Type involving a LV-HV interaction was Late Braking for Stopped/Stopping Traffic. Across all 246 incidents, this particular Incident Type occurred 66 times and accounted for 26.8% of the incidents captured. The bar graph shown in Figure 7 illustrates the frequency and percentage of each Incident Type across the entire data set. As can be seen from Figure 7, the majority of the incidents (48.8%) involved one of two different Incident Types: Late Braking for Stopped/Stopping Traffic, and Lane Change Without Sufficient Gap.

Table 6. Frequency, Percentage, and Rank Ordering of the Incident Types Across all LV-HV Incidents (N_{Total} = 246).

Incident Type	Frequency of all LV-HV Incidents (N_{Total} = 246)	Percentage of all LV-HV Incidents (N_{Total} = 246)	Combined Rank of all LV-HV Incidents
Late Braking for Stopped/Stopping Traffic	66	26.8%	1
Lane Change Without Sufficient Gap	54	22.0%	2
Lateral Deviation of Through Vehicle	20	8.1%	3
Aborted Lane Change	15	6.1%	4
Left Turn Without Clearance	13	5.3%	5
Improper Passing	12	4.9%	6
Merge Without Sufficient Gap	9	3.7%	7
Conflict With Oncoming Traffic	8	3.3%	8
Approaches Traffic Quickly	6	2.4%	9.5
Roadway Entrance Without Clearance	6	2.4%	9.5
Following Too Closely	5	2.0%	11.5
Obstruction in Roadway	5	2.0%	11.5
Improper Lane Change	4	1.6%	13
Through Traffic Does Not Allow Lane Change	3	1.2%	14.5
Unable to Determine	3	1.2%	14.5
Clear Path for Emergency Vehicle	2	0.8%	18
Improper Stopping at an Intersection	2	0.8%	18
School Bus Passing Violation	2	0.8%	18
Through Traffic Does Not Allow Merge	2	0.8%	18
Wide Turn Into Adjacent Lane	2	0.8%	18
Backing in Roadway	1	0.4%	24
Improper U-Turn	1	0.4%	24
Improperly Covered Debris from Lead Vehicle	1	0.4%	24
Slow Speed	1	0.4%	24
Sudden Braking in Roadway	1	0.4%	24
Turn Without Sufficient Warning	1	0.4%	24
Turn/Exit From Incorrect Lane	1	0.4%	24

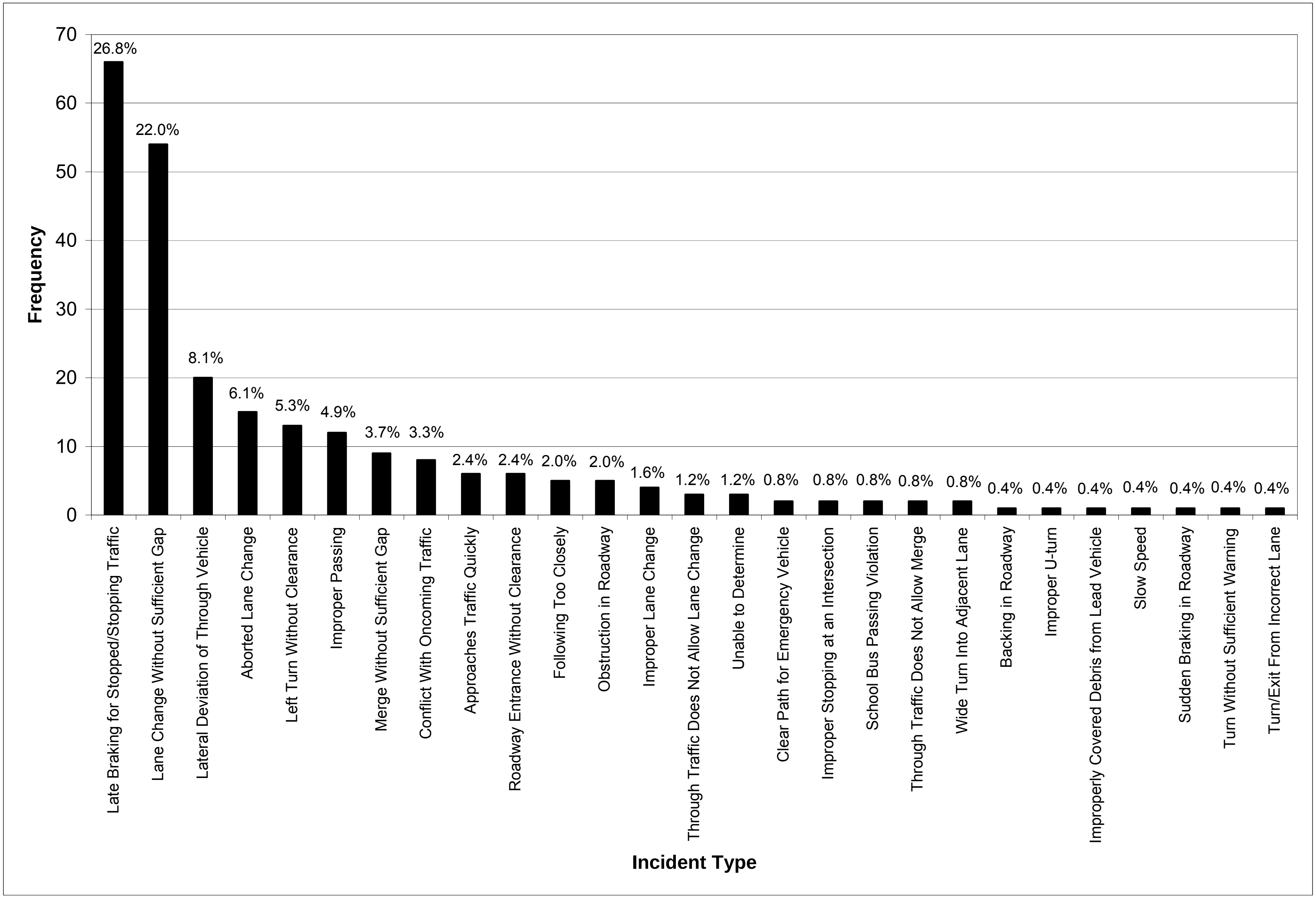


Figure 7. Frequency of Incident Types Across all LV-HV Incidents (N_{Total} = 246).

Descriptive statistics for the Incident Types were also calculated for incidents as a function of the at-fault driver. The at-fault driver is the driver that was assessed, by the analyst, to have been responsible for causing the event. Of the 246 LV-HV interaction incidents recorded, 138 (56%) were judged to have been the fault of the LV driver, while 79 (32%) were attributed to the HV driver. For the remaining 29 incidents (12%), it was unclear which vehicle driver was at-fault. By removing the "unknown" cases from the LV-HV driver at-fault analyses, it was found that the LV driver was at-fault in 64% (138/217) of the LV-HV interaction incidents while the HV driver was at-fault in 36% (79/217) of the incidents.

Table 7 shows the frequency, percentage, and rank ordering for the Incident Types where the HV driver was judged to be at-fault. As can be seen, the most frequent Incident Type for HV driver at-fault incidents was Lane Change Without Sufficient Gap (26.6%), followed by Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%). Figure 8 shows a bar graph of the 79 HV driver at-fault incidents as a function of the Incident Type.

Table 7. Frequency, Percentage, and Rank Ordering of the Incident Types for HV Driver At-Fault Incidents (n_{HV} = 79).

Incident Type	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Combined Rank of HV Driver At-Fault Incidents
Lane Change Without Sufficient Gap	21	26.6%	1
Lateral Deviation of Through Vehicle	17	21.5%	2
Left Turn Without Clearance	11	13.9%	3
Aborted Lane Change	4	5.1%	4.5
Obstruction in Roadway	4	5.1%	4.5
Merge Without Sufficient Gap	3	3.8%	6.5
Through Traffic Does Not Allow Merge	3	3.8%	6.5
Roadway Entrance Without Clearance	2	2.5%	8.5
Wide Turn Into Adjacent Lane	2	2.5%	8.5
Backing in Roadway	1	1.3%	15.5
Clear Path for Emergency Vehicle	1	1.3%	15.5
Conflict With Oncoming Traffic	1	1.3%	15.5
Following Too Closely	1	1.3%	15.5
Improper Lane Change	1	1.3%	15.5
Improper U-Turn	1	1.3%	15.5
Improperly Covered Debris from Lead Vehicle	1	1.3%	15.5
Late Braking for Stopped/Stopping Traffic	1	1.3%	15.5
Slow Speed	1	1.3%	15.5
Sudden Braking in Roadway	1	1.3%	15.5
Turn Without Sufficient Warning	1	1.3%	15.5
Turn/Exit From Incorrect Lane	1	1.3%	15.5

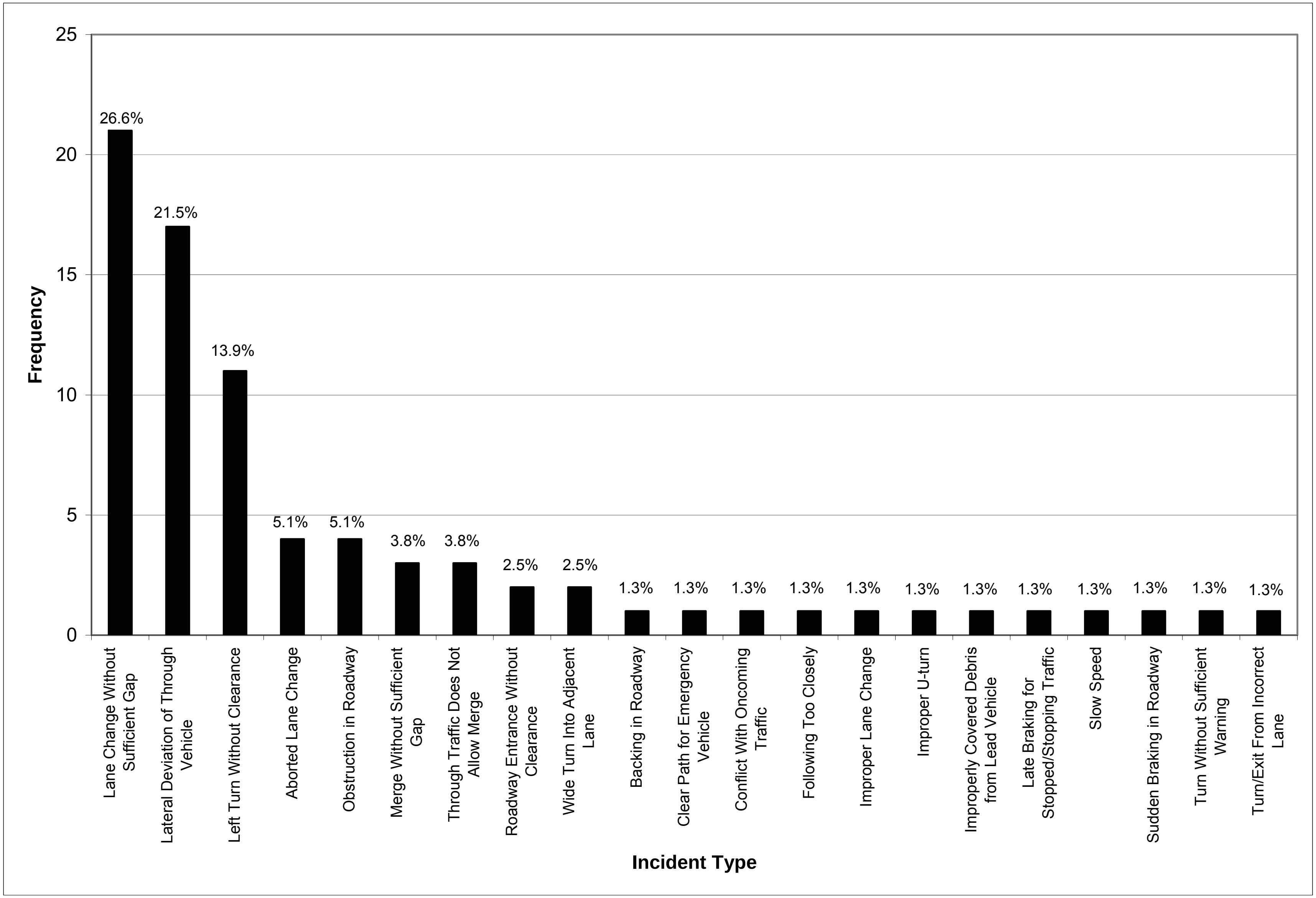


Figure 8. Frequency of Incident Types for HV Driver At-Fault Incidents (n_{HV} = 79).

Table 8 shows the frequency, percentage, and rank ordering for the Incident Types where the LV driver was at-fault. The most frequent Incident Type for LV driver at-fault incidents was Late Braking for Stopped/Stopping Traffic (41.3%) and Lane Change Without Sufficient Gap (21.7%). Figure 9 shows a bar graph of the 138 LV driver at-fault incidents as a function of the Incident Type.

Table 8. Frequency, Percentage, and Rank Ordering of the Incident Types for LV Driver At-Fault Incidents (n_{LV} = 138).

Incident Type	Frequency of LV Driver At-Fault Incidents (n_{LV} = 138)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 138)	Combined Rank of LV Driver At-Fault Incidents
Late Braking for Stopped/Stopping Traffic	57	41.3%	1
Lane Change Without Sufficient Gap	30	21.7%	2
Aborted Lane Change	11	8.0%	3
Improper Passing	10	7.2%	4
Approaches Traffic Quickly	6	4.3%	5
Merge Without Sufficient Gap	5	3.6%	6
Following Too Closely	4	2.9%	7
Conflict With Oncoming Traffic	3	2.2%	9
Improper Lane Change	3	2.2%	9
Lateral Deviation of Through Vehicle	3	2.2%	9
Improper Stopping at an Intersection	2	1.4%	12
Roadway Entrance Without Clearance	2	1.4%	12
School Bus Passing Violation	2	1.4%	12

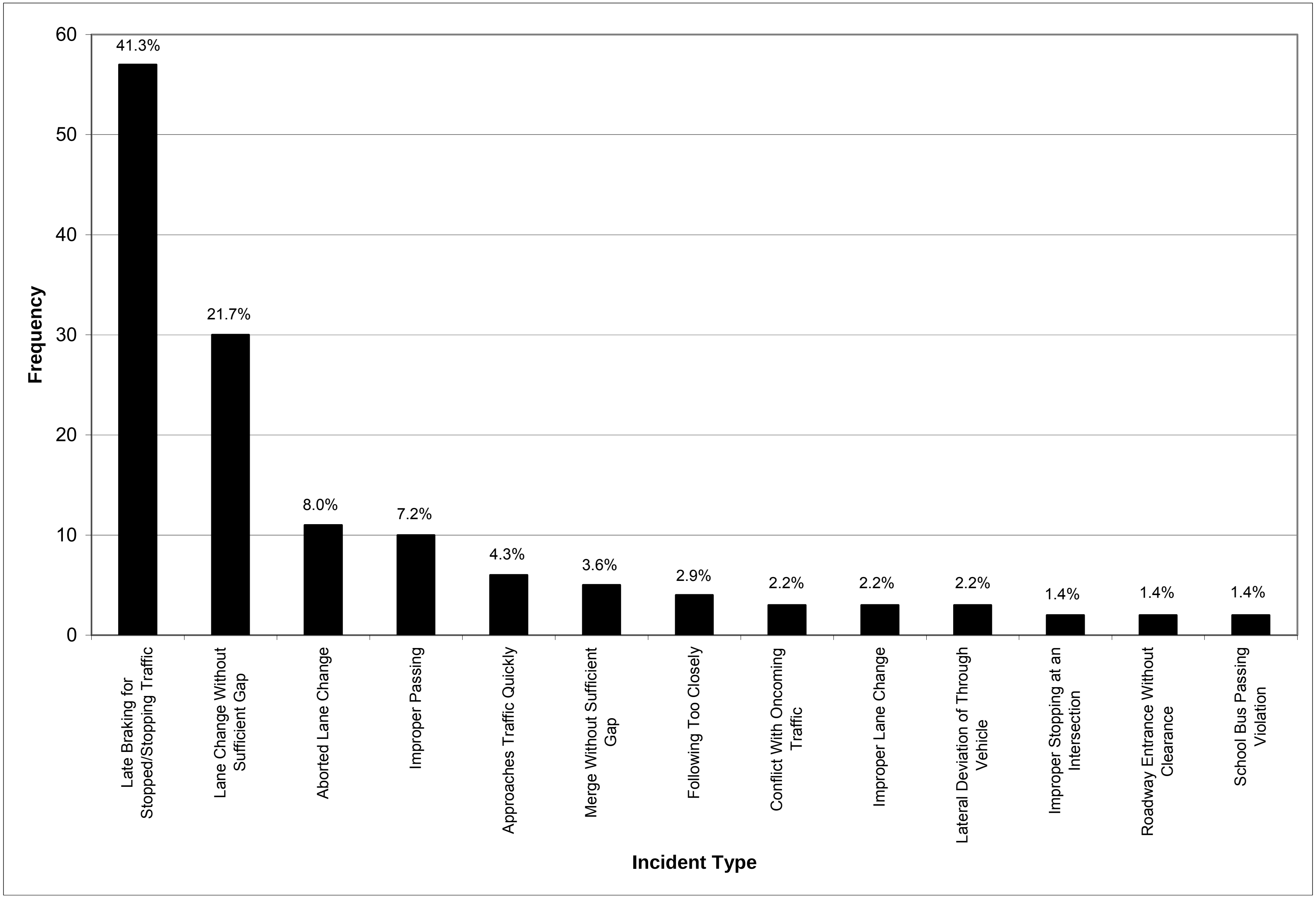


Figure 9. Frequency of Incident Types for LV Driver At-Fault Incidents (n_{LV} = 138).

Table 9 shows the frequency, percentage, and rank ordering for the Incident Types when the at-fault driver was unknown. The most frequent Incident Type for Unknown at-fault incidents was Late Braking for Stopped/Stopping Traffic (27.6%), followed by Conflict With Oncoming Traffic (13.8%), Lane Change Without Sufficient Gap (10.3%), and Unable to Determine (10.3%). Figure 10 shows a bar graph of the 29 Unknown at-fault incidents as a function of the Incident Type.

Figure 10 illustrates the Incident Types, with respect to the driver assessed to be at-fault, by group (HV, LV, and Unknown). The figure shows that the Incident Types differed depending on whether the HV or LV driver was at-fault. Across all at-fault incidents, the most frequent Incident Type were Late Braking for Stopped/Stopping Traffic, Lane Change Without Sufficient Gap, and Lateral Deviation of Through Vehicle.

Table 9. Frequency, Percentage, and Rank Ordering of the Incident Types for Unknown At-Fault Incidents (n_{Un} = 29).

Incident Type	Frequency of Unknown At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown At-Fault Incidents (n_{Un} = 29)	Combined Rank of Unknown At-Fault Incidents
Late Braking for Stopped/Stopping Traffic	8	27.6%	1
Conflict With Oncoming Traffic	4	13.8%	2
Lane Change Without Sufficient Gap	3	10.3%	3.5
Unable to Determine	3	10.3%	3.5
Improper Passing	2	6.9%	6.5
Left Turn Without Clearance	2	6.9%	6.5
Roadway Entrance Without Clearance	2	6.9%	6.5
Through Traffic Does Not Allow Lane Change	2	6.9%	6.5
Clear Path for Emergency Vehicle	1	3.4%	10
Merge Without Sufficient Gap	1	3.4%	10
Obstruction in Roadway	1	3.4%	10

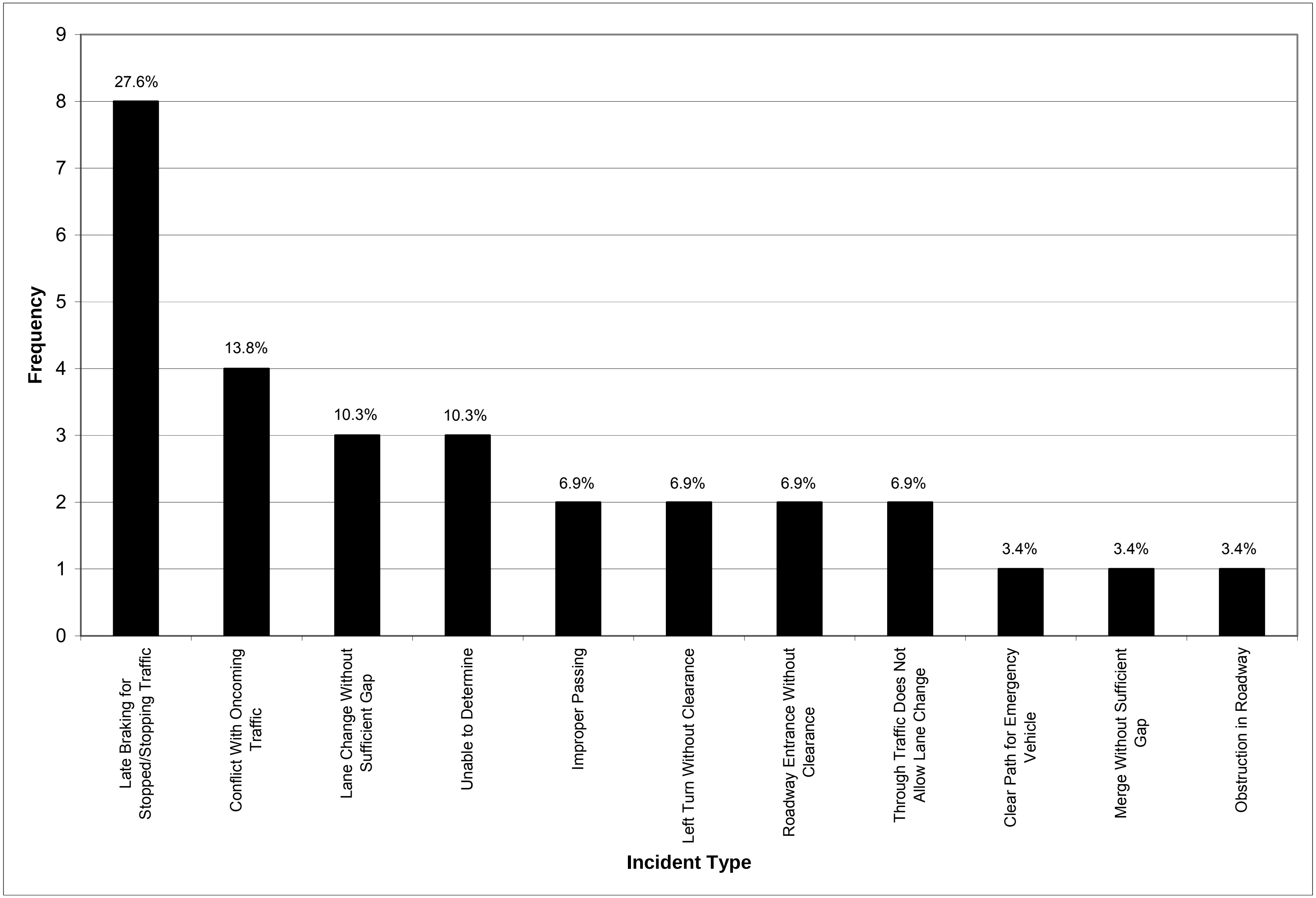


Figure 10. Frequency of Incident Types for Unknown At-Fault Incidents (n_{Un} = 29).

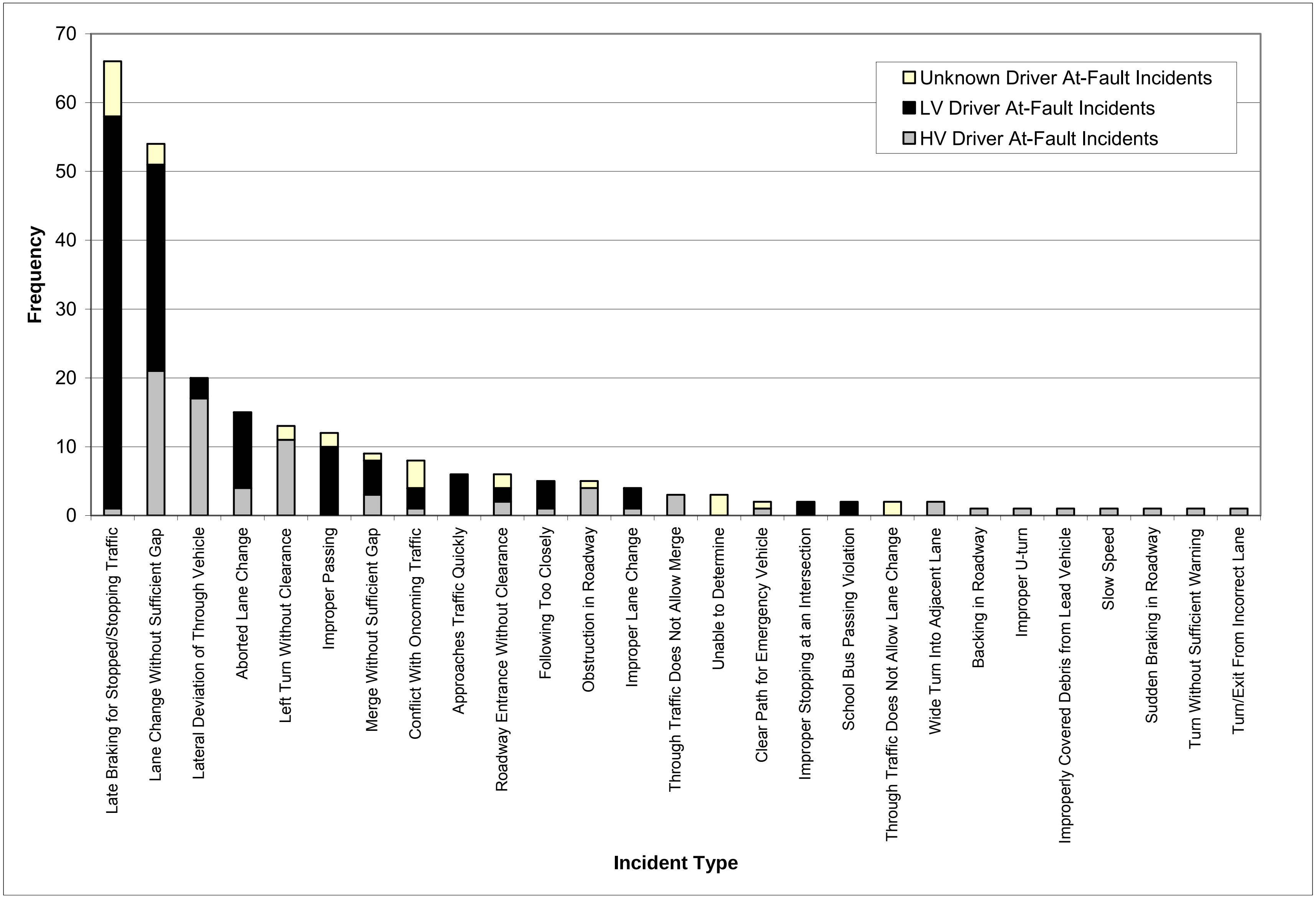


Figure 11. Frequency of Incident Types for HV, LV, and Unknown At-Fault Incidents (n_{HV} = 79, n_{LV} = 138, and n_{Un} = 29).

Summary of Incident Type
Overall, the most common Incident Types were Late Braking for Stopped/Stopping Traffic (26.8%), Lane Change Without Sufficient Gap (22%), and Lateral Deviation of Through Vehicle (8.1%). These three Incident Types represented 56.9% of the LV-HV incidents.

A substantial number of LV-HV interactions were judged to have been the fault of the LV driver. Of the 246 LV-HV interaction incidents, 56.1% (63.6%, excluding the incident where it was unknown if the HV or LV driver was at-fault) of the LV drivers were at-fault, 32.1% (46.4% excluding the Unknown at-fault incidents) of the HV drivers were at-fault, while in the remaining 11.8%, it was unknown if the HV or LV driver was at-fault.

As can be seen in Figure 11, the Incident Types differed depending on whether the HV or LV driver was at-fault. The most prevalent Incident Types for HV driver at-fault incidents were Lane Change Without Sufficient Gap (26.6%), Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%). These three incident types accounted for 51.7% of the HV driver at-fault incidents. The most frequent Incident Types for LV drivers were Late Braking for Stopped/Stopping Traffic (41.3%) and Lane Change Without Sufficient Gap (21.7%). These two incident types accounted for 63.0% of the LV driver at-fault incidents. Note that the most prevalent Incident Type for at-fault LV drivers, Lane Change Without Sufficient Gap, was similar to the truck driver focus groups' reports in Hanowski et al. (1998) who indicated that "being cut-off by LV drivers" was a frequently occurring problem in local/short-haul trucking.

Primary Maneuvers, Secondary Maneuvers and Conflict Types

After each of the 246 incidents was classified by Incident Type, the next step in the analysis was to identify the "Primary Maneuvers" and "Secondary Maneuvers" involved in each incident. The Primary Maneuver refers to the maneuver of the driver who initiated the incident (not necessarily at-fault). Table 10 shows each Primary Maneuver and its corresponding definition. Across the 246 interaction incidents, 19 different Primary Maneuvers were identified.

Table 10. List and Definition of Each Primary Maneuver Types.

Primary Maneuver	Definition
Aborted Lane Change	The initiating vehicle begins to make a lane change, but finds a second vehicle in its blind spot and aborts the lane change.
To the left	The initiating vehicle begins to make a lane change to the left, but finds a second vehicle in its blind spot and aborts the lane change.
To the right	The initiating vehicle begins to make a lane change to the right, but finds a second vehicle in its blind spot and aborts the lane change.
Avoiding Vehicle	The initiating vehicle performs an evasive maneuver in order to avoid a second vehicle.
Swerves to the left	The initiating vehicle swerves to the left in order to avoid a second vehicle.
Swerves to the right	The initiating vehicle swerves to the right in order to avoid a second vehicle.
Backing	The initiating vehicle backs up in the roadway.

Primary Maneuver	Definition
Braking	The initiating vehicle brakes on the roadway.
For a stop sign	The initiating vehicle brakes for a stop sign.
For a stopped vehicle	The initiating vehicle brakes for a stopped vehicle.
For a traffic signal	The initiating vehicle brakes for a traffic signal.
For a yield sign	The initiating vehicle brakes for a yield sign.
For construction	The initiating vehicle brakes for construction.
For traffic	The initiating vehicle brakes for lead traffic.
In a left turn lane	The initiating vehicle brakes in a left turn lane.
In a right turn lane	The initiating vehicle brakes in a right turn lane.
In an exit lane	The initiating vehicle brakes in an exit lane.
Reason Unknown	The initiating vehicle brakes for an unknown reason.
To change lanes	The initiating vehicle brakes to change lanes.
To make a left turn	The initiating vehicle brakes to make a left turn.
To make a right turn	The initiating vehicle brakes to make a right turn.
Changing Lanes	The initiating vehicle changes lanes.
To the left	The initiating vehicle changes lanes to the left.
To the right	The initiating vehicle changes lanes to the right.
Crossing Over Lane Line	The initiating vehicle crosses over the lane line (into another traffic lane).
To the left	The initiating vehicle changes lanes to the left.
To the right	The initiating vehicle changes lanes to the right.
Enters Roadway	The initiating vehicle enters the roadway.
From side of road	The initiating vehicle enters the roadway from the side of the road.
From the shoulder	The initiating vehicle enters the roadway from the shoulder.
Incomplete Lane Change	The initiating vehicle does not complete its lane change (i.e., the vehicle is not completely in the new lane and is obstructing the original lane).
Left Turn	The initiating vehicle makes a left turn.
Across path	The initiating vehicle makes a left turn across the path of other vehicles.
From side road	The initiating vehicle makes a left turn from a side road.
Oncoming traffic	The initiating vehicle makes a left turn across the path of oncoming traffic.
Onto side road	The initiating vehicle makes a left turn onto a side road.
Merging	The initiating vehicle merges into traffic.
From the shoulder	The initiating vehicle merges into traffic from the shoulder.
To the left	The initiating vehicle merges into traffic to the left.
Move to Shoulder	The initiating vehicle moves off of the roadway onto the shoulder.
Parked	The initiating vehicle is parked on the side of the road.
Right turn	The initiating vehicle makes a right turn.
From side road	The initiating vehicle makes a right turn from a side road.
Onto side road	The initiating vehicle makes a right turn onto a side road.
Slower Speed	The initiating vehicle is traveling at a slower speed than following traffic.

Primary Maneuver	Definition
Stopped	The initiating vehicle is stopped.
At a railroad crossing	The initiating vehicle is stopped at a railroad crossing.
At a stop sign	The initiating vehicle is stopped at a stop sign.
At a traffic signal	The initiating vehicle is stopped at a traffic signal.
Delivering mail	The initiating vehicle is stopped delivering mail.
In left turn lane	The initiating vehicle is stopped in a left turn lane.
In roadway	The initiating vehicle is stopped in the roadway.
In traffic	The initiating vehicle is stopped in traffic.
Loading/Unloading	The initiating vehicle is stopped loading/unloading.
On side of road	The initiating vehicle is stopped on the side of the road.
To make a left turn	The initiating vehicle is stopped to make a left turn.
To make a right turn	The initiating vehicle is stopped to make a right turn.
Drifts to the Left	The initiating vehicle drifts to the left.
Through Traffic	The initiating vehicle is traveling straight.
Doesn't allow merge	The initiating vehicle is traveling straight and does not allow traffic to merge.
Oncoming traffic	The initiating vehicle is traveling straight in the opposite direction (i.e., oncoming).
Traveling ahead	The initiating vehicle is traveling ahead of other vehicles.
U-Turn	The initiating vehicle makes a U-turn.

In addition to identifying the Primary Maneuver for each incident, the Secondary Maneuver, or the maneuver of the responding driver (i.e., driver of the second vehicle involved in the interaction), was also classified. Considering the maneuvers of both vehicles involved in the incident, a clear picture of the conflict, or Conflict Type, could be determined. Table 11 shows the Conflict Types that were identified in the 246 interaction incidents that were analyzed. As can be seen, Table 11 consists of 66 different Conflict Types (i.e., Primary Maneuver and Secondary Maneuver combinations).

Table 11. The 66 Different Conflict Types Identified Across all LV-HV Incidents.

Primary Maneuver	Conflict Type	Secondary Maneuver
Aborted Lane Change	1	Brakes and changes lanes
	2	Changes lanes
	3	No reaction
	4	Unknown if action was attempted
Avoiding Vehicle	5	No reaction
	6	Unknown if action was attempted
Backing	7	Backing
Braking	8	Brakes and changes lanes
	9	Braking
	10	Changes lanes

Primary Maneuver	Conflict Type	Secondary Maneuver
Changing Lanes	11	Brakes and changes lanes
	12	Brakes and swerves around in lane
	13	Brakes and swerves to the right/left
	14	Braking
	15	Continues driving
	16	No reaction
	17	Unknown if action was attempted
Crossing Over Lane Line	18	Brakes and changes lanes
	19	Brakes and swerves to the right/left
	20	Braking
	21	Swerves to the right/left
	22	Unknown if action was attempted
Enters Roadway	23	Brakes then passes on left
	24	Braking
Incomplete Lane Change	25	Brakes and swerves right/left
	26	Braking
Left Turn	27	Accelerates and honks horn
	28	Accelerates and swerves right/left
	29	Brakes and swerves right/left
	30	Braking
	31	Changes lanes
	32	Stops on roadway
Merging	33	Braking
	34	No reaction
Move to Shoulder	35	Brakes and swerves right/left
	36	Braking
Parked	37	Brakes and swerves right/left
Right Turn	38	Brakes and changes lanes
	39	Brakes and swerves right/left
	40	Braking
	41	Stops on roadway
Slower Speed	42	Accelerates and changes lanes
	43	Brakes and changes lanes
	44	Brakes and passes vehicle
	45	Braking
	46	Changes lanes
	47	Swerves with intent to change lanes
Stopped	48	Brakes and changes lanes

Primary Maneuver	Conflict Type	Secondary Maneuver
	49	Brakes and passes vehicle
	50	Brakes and swerves right/left
	51	Braking
	52	Changes lanes
	53	No reaction
	54	Passes vehicle
	55	Stops on roadway
	56	Swerves on roadway
	57	Swerves to the right/left
Drifts to the Left	58	Braking
Through Traffic	59	Brakes and changes lanes once other vehicle passes
	60	Brakes and moves to the shoulder
	61	Brakes and swerves to the right/left
	62	Braking
	63	Stops on roadway
	64	Swerves to the right/left
Traveling Ahead	65	Accelerates
U-Turn	66	Braking

Table 12 shows the frequency, percentage, and rank ordering of each Primary Maneuver across the entire LV-HV 100-Car data set. The most frequent Primary Maneuver was Braking (22.8%), followed by Changing Lanes (21.1%) and Stopped (15%). Figure 12 shows a bar graph of the 246 incidents as a function of the Primary Maneuver.

Table 12. Frequency, Percentage, and Rank ordering of the Primary Maneuvers Across all LV-HV Incidents (N_{Total} = 246).

Primary Maneuver	Frequency of all LV-HV Incidents (N_{Total} = 246)	Percentage of all LV-HV Incidents (N_{Total} = 246)	Combined Rank of all LV-HV Incidents
Braking	56	22.8%	1
Changing Lanes	52	21.1%	2
Stopped	37	15.0%	3
Crossing Over Lane Line	19	7.7%	4
Left Turn	16	6.5%	5.5
Through Traffic	16	6.5%	5.5
Slower Speed	15	6.1%	6
Aborted Lane Change	8	3.3%	7
Merging	6	2.4%	9.5
Right Turn	6	2.4%	9.5

Primary Maneuver	Frequency of all LV-HV Incidents (N_{Total} = 246)	Percentage of all LV-HV Incidents (N_{Total} = 246)	Combined Rank of all LV-HV Incidents
Avoiding Vehicle	3	1.2%	11.5
Move to Shoulder	3	1.2%	11.5
Enters Roadway	2	0.8%	13.5
Incomplete Lane Change	2	0.8%	13.5
Backing	1	0.4%	17
Drifts to the Left	1	0.4%	17
Parked	1	0.4%	17
Traveling Ahead	1	0.4%	17
U-Turn	1	0.4%	17

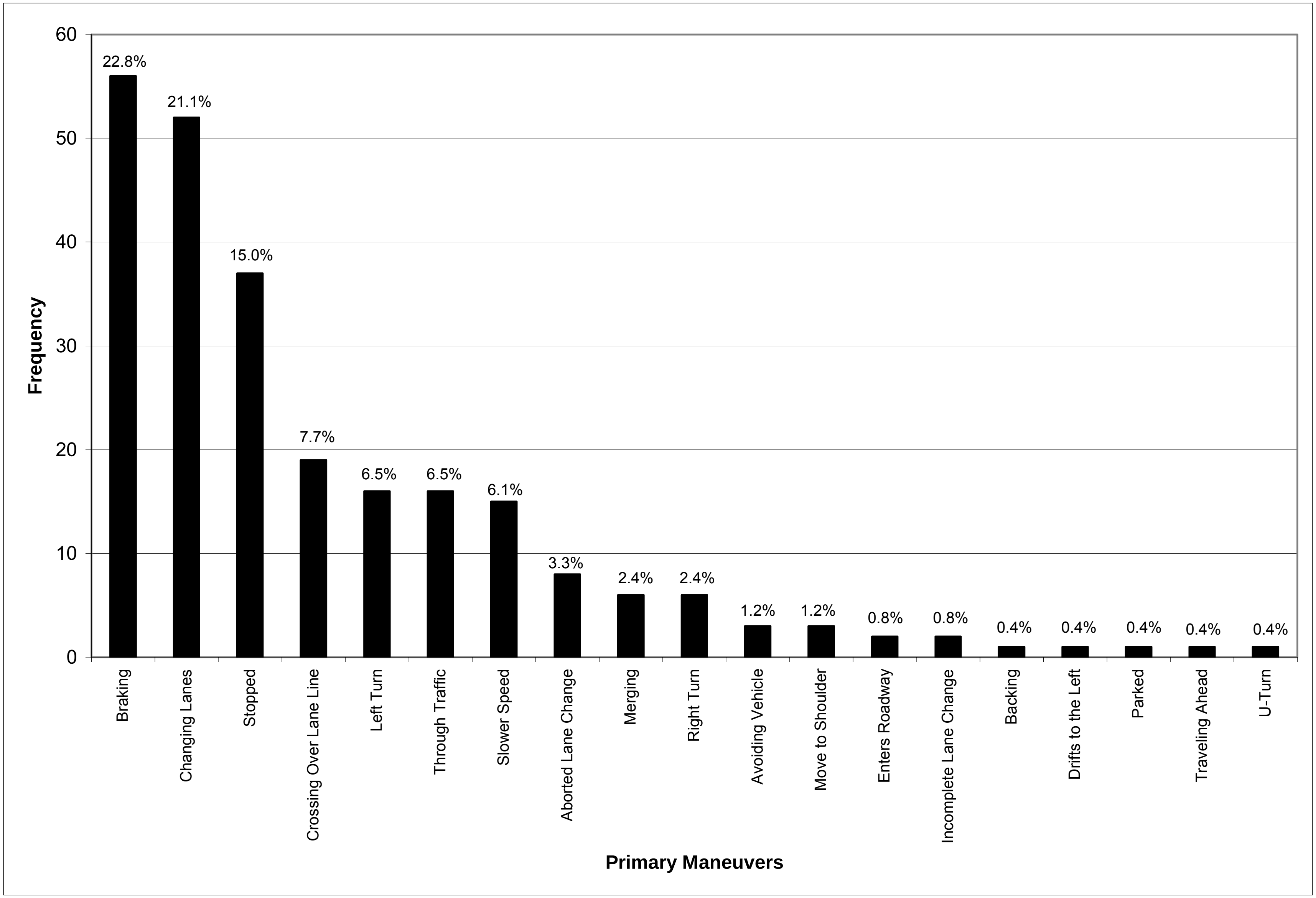


Figure 12. Frequency of Primary Maneuvers Across all LV-HV Incidents (N_{Total} = 246).

Table 13 displays the frequency, percentage, and rank ordering for the Primary Maneuvers where the HV driver was at-fault. As can be seen in Table 13, the most frequent Primary Maneuver for HV driver at-fault incidents was Changing Lanes (32.9%), followed by Crossing Over Lane Line (20.3%) and Left Turn (15.2%). Figure 13 shows a bar graph of the 79 HV driver at-fault incidents as a function of the Primary Maneuver.

Table 13. Frequency, Percentage, and Rank Ordering of the Primary Maneuvers for the HV Driver At-Fault Incidents (n_{HV} = 79).

Primary Maneuver	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Combined Rank of HV Driver At-Fault Incidents
Changing Lanes	26	32.9%	1
Crossing Over Lane Line	16	20.3%	2
Left Turn	12	15.2%	3
Stopped	4	5.1%	4.5
Through Traffic	4	5.1%	4.5
Braking	3	3.8%	6.5
Merging	3	3.8%	6.5
Right Turn	2	2.5%	8
Aborted Lane Change	1	1.3%	13
Backing	1	1.3%	13
Enters Roadway	1	1.3%	13
Incomplete Lane Change	1	1.3%	13
Moved to Shoulder	1	1.3%	13
Parked	1	1.3%	13
Slower Speed	1	1.3%	13
Traveling Ahead	1	1.3%	13
U-Turn	1	1.3%	13

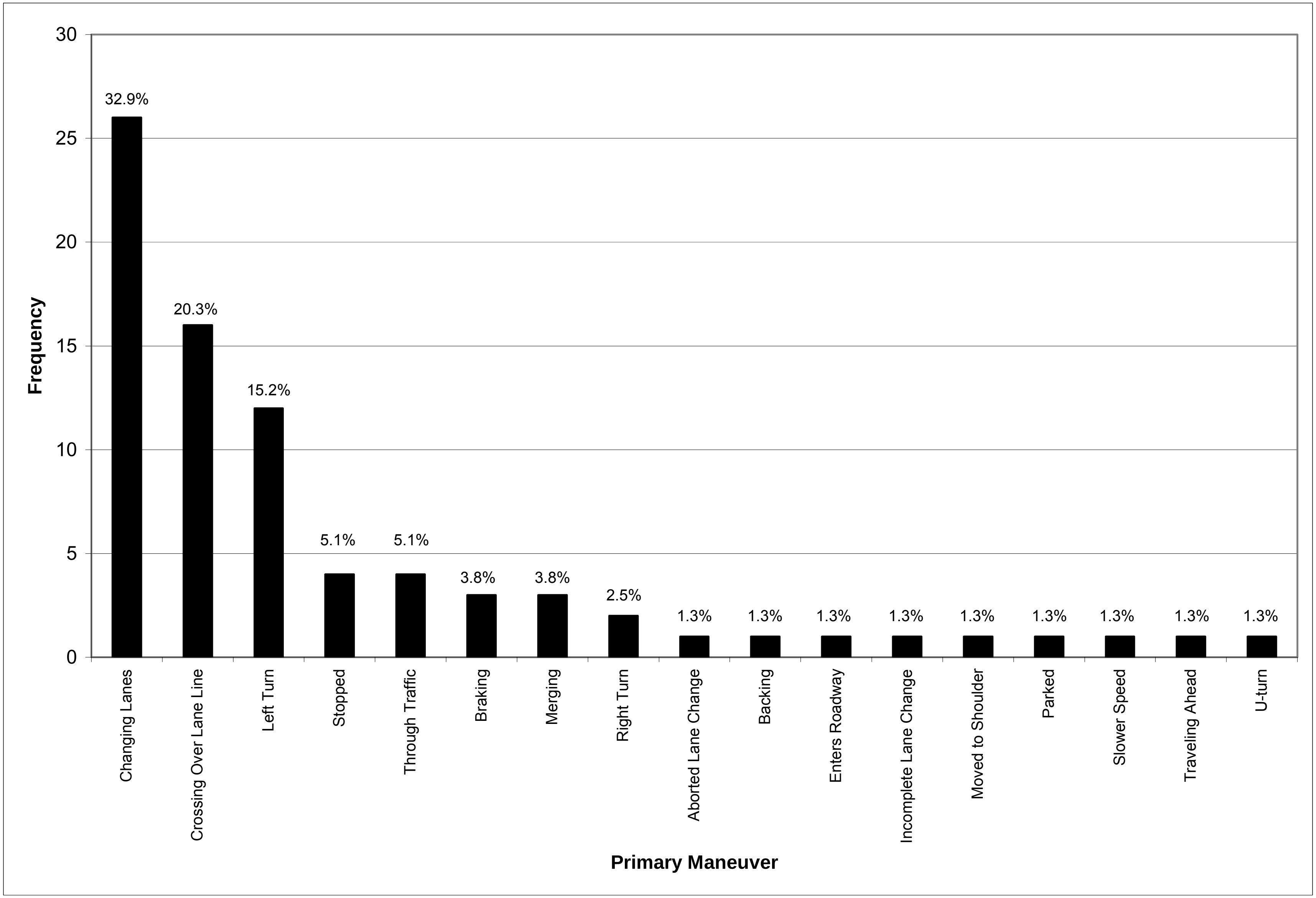


Figure 13. Frequency of Primary Maneuvers for HV Driver At-Fault Incidents (n_{HV} = 79).

Table 14 displays the frequency, percentage, and rank ordering for the Primary Maneuvers where the LV driver was at-fault. As can be seen in Table 14, the most frequent Primary Maneuver for LV driver at-fault incidents was Braking (32.6%), followed by Stopped (21.7%) and Changing Lanes (16.7%). Figure 14 shows a bar graph of the 138 LV driver at-fault incidents as a function of the Primary Maneuver.

Table 14. Frequency, Percentage, and Rank Ordering of the Primary Maneuvers for the LV Driver At-Fault Incidents (n_{LV} = 138).

Primary Maneuver	Frequency of LV Driver At-Fault Incidents (n_{LV} = 138)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 138)	Combined Rank of LV Driver At-Fault Incidents
Braking	45	32.6%	1
Stopped	30	21.7%	2
Changing Lanes	23	16.7%	3
Slower Speed	13	9.4%	4
Aborted Lane Change	7	5.1%	5
Through Traffic	6	4.3%	6
Avoiding Vehicle	3	2.2%	8
Merging	3	2.2%	8
Right Turn	3	2.2%	8
Crossing Over Lane Line	2	1.4%	10
Drifts to the Left	1	0.7%	12
Left Turn	1	0.7%	12
Moved to Shoulder	1	0.7%	12

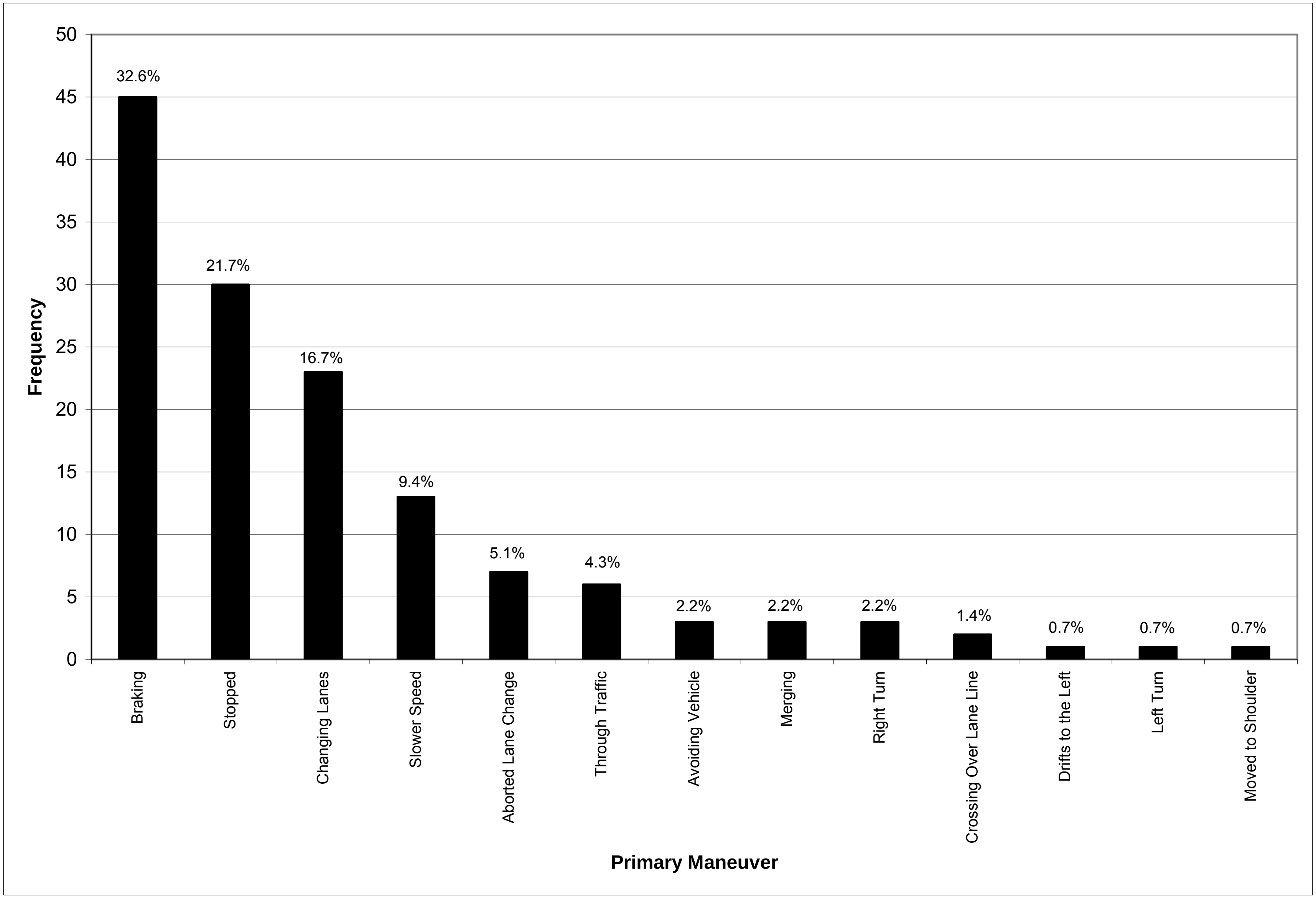


Figure 14. Frequency of Primary Maneuvers for LV Driver At-Fault Incidents (n_{LV} = 138).

Table 15 displays the frequency, percentage, and rank ordering for the Primary Maneuvers where it was unknown if the HV or LV driver was at-fault. As can be seen in Table 15, the most frequent Primary Maneuver for Unknown at-fault incidents was Braking (27.6%), followed by Through Traffic (20.7%), Changing Lanes (10.3%), Left Turn (10.3%), and Stopped (10.3%). Figure 15 shows a bar graph of the 29 Unknown at-fault incidents as a function of the Primary Maneuver.

Figure 16 illustrates the Primary Maneuvers, with respect to the driver assessed to have been at-fault, by group (LV, HV, and Unknown). Figure 16 illustrates that the Primary Maneuvers differ depending on whether the HV or LV driver was at-fault. Across all incidents, the most frequent Primary Maneuvers were Braking, Changing Lanes, and Stopped.

Table 15. Frequency, Percentage, and Rank Ordering of the Primary Maneuvers for the Unknown At-Fault Incidents (n_{Un} = 29).

Primary Maneuver	Frequency of Unknown At-Fault Incidents (N_{Un} = 29)	Percentage of Unknown At-Fault Incidents (N_{Un} = 29)	Combined Rank of Unknown At-Fault Incidents
Braking	8	27.6%	1
Through Traffic	6	20.7%	2
Changing Lanes	3	10.3%	4
Left Turn	3	10.3%	4
Stopped	3	10.3%	4
Crossing Over Lane Line	1	3.4%	8.5
Enters Roadway	1	3.4%	8.5
Incomplete Lane Change	1	3.4%	8.5
Moved to Shoulder	1	3.4%	8.5
Right Turn	1	3.4%	8.5
Slower Speed	1	3.4%	8.5

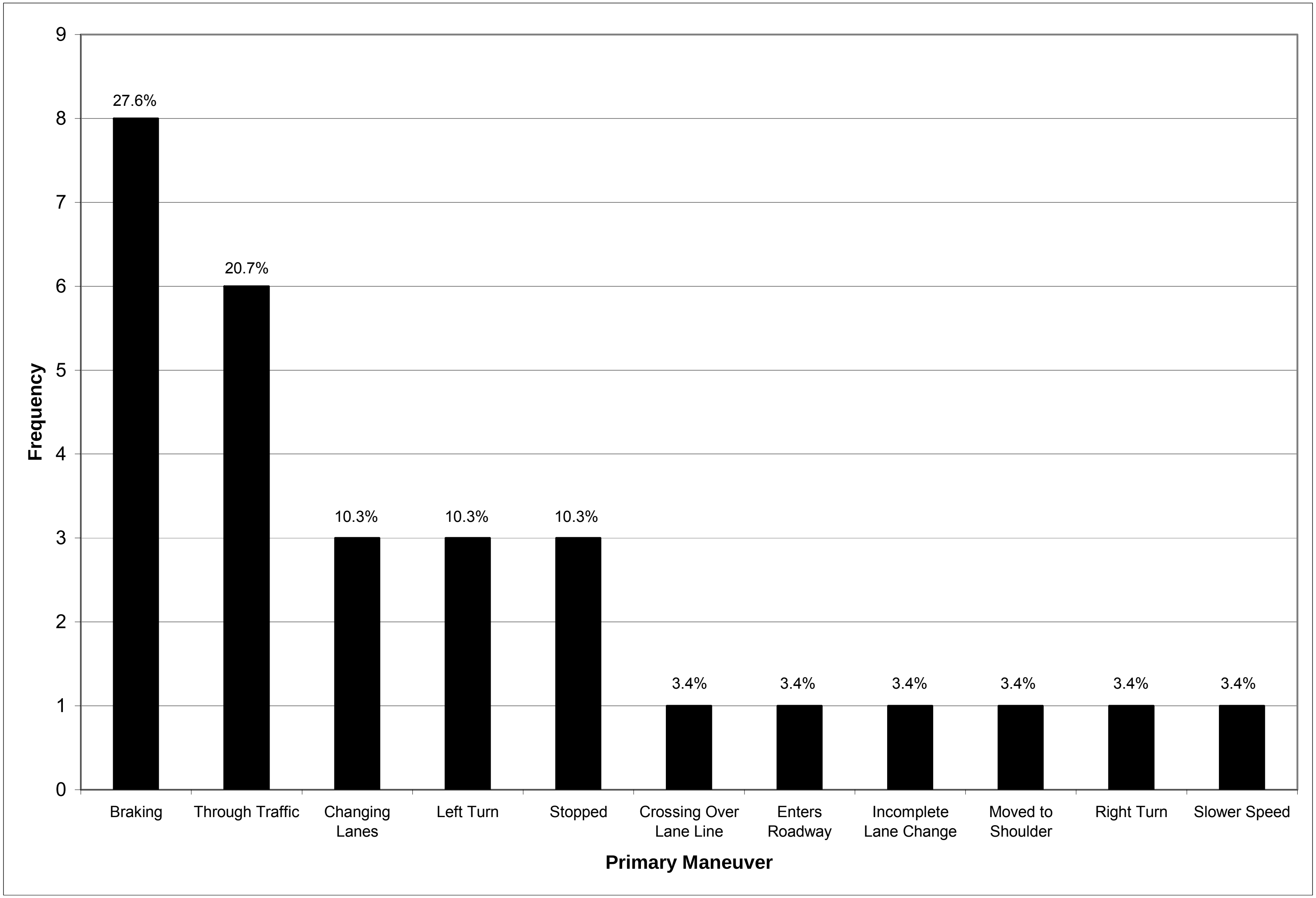


Figure 15. Frequency of Primary Maneuvers for Unknown At-Fault Incidents (n_{Un} = 29).

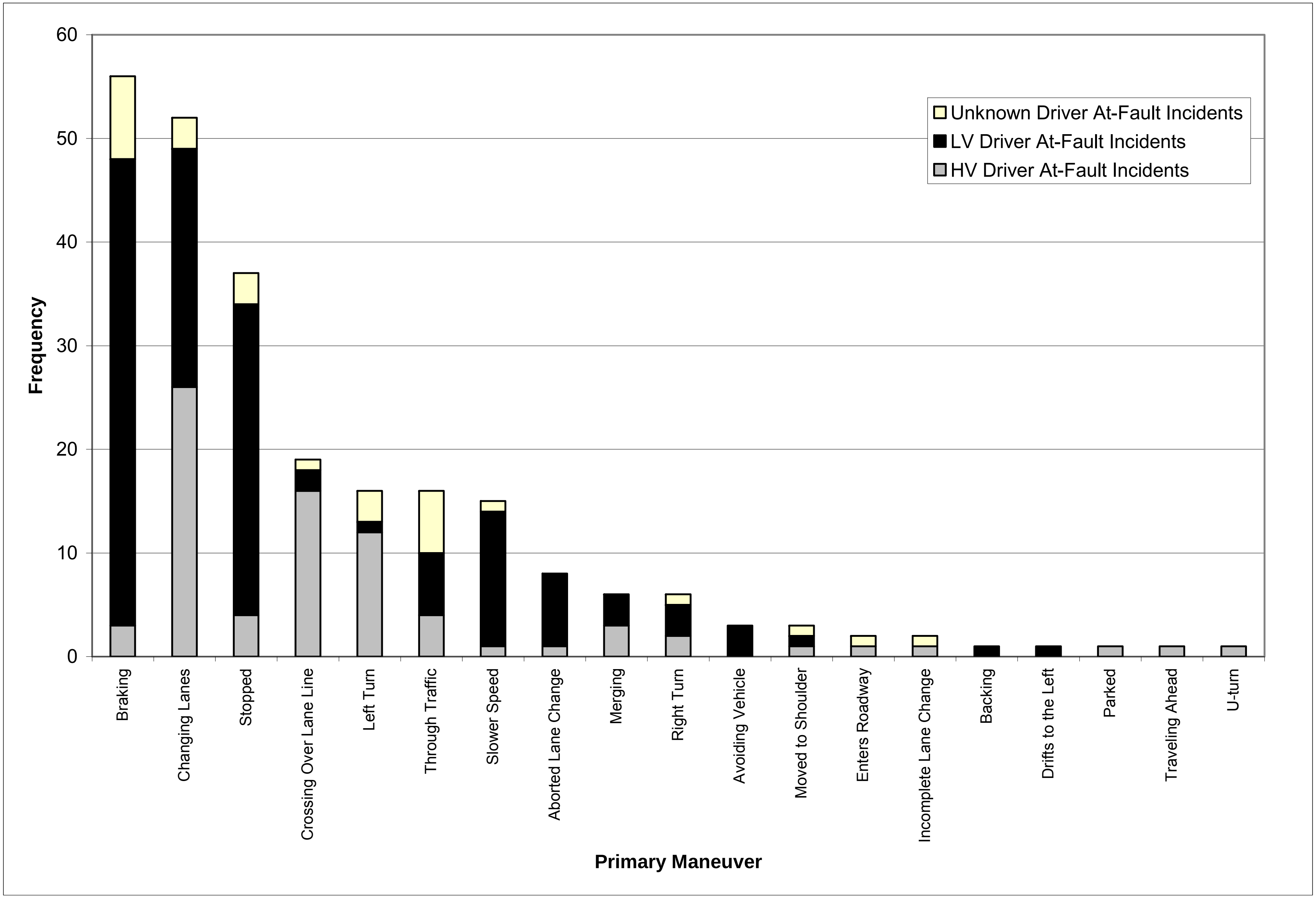


Figure 16. Frequency of Primary Maneuvers for HV, LV, and Unknown At-Fault Incidents (n_{HV} = 79, n_{LV} = 138, and n_{Un} = 29).

Summary of Primary Maneuvers
Overall, the most frequent Primary Maneuvers were Braking (22.7%), Changing Lanes (21.1%), and Stopped (15%). These three Primary Maneuvers represented 58.9% of the recorded incidents. The most frequent Primary Maneuvers, excluding the Unknown at-fault incidents, were Braking (25.8%), Changing Lanes (21.1%), and Stopped (15%). These three maneuver types represented 60.4% of the Primary Maneuvers for both HV and LV driver at-fault incidents.

As can be seen in Figure 16, the Primary Maneuvers differed depending on whether the HV or LV driver was at-fault. The most prevalent Primary Maneuvers for HV driver at-fault incidents were Changing Lanes (32.9%), Crossing Over Lane Line (20.3%), and Left Turn (15.2%). These three Primary Maneuvers accounted for 68.4% of the HV driver at-fault incidents. The most prevalent Primary Maneuvers for LV driver at-fault incidents were Braking (32.6%), Stopped (21.7%), and Changing Lanes (16.7%). These three Primary Maneuvers accounted for 71% of the LV driver at-fault incidents. From this data it appears that most Primary Maneuvers for HV driver at-fault incidents occurred when the HV was in-motion and changing lanes or crossing the lane line. In contrast, a significant proportion of the Primary Maneuvers when the LV driver was at-fault occurred when the LV was decelerating or stopped.

Contributing Factors

Just as the Incident Types describe the action or what happened during an incident, Contributing Factors provide likely reasons *why* an incident occurred. For each incident that was analyzed, a number of Contributing Factors were identified. It should be noted that the Contributing Factor categories were taken from Wierwille, Kieliszewski, Hanowski, Keisler, and Olsen (2000) and from the GES Physical Impairments screen (USDOT/NHTSA, 2003, p. 434). Each Contributing Factor and its corresponding definition are shown in Table 16. It should be noted that an incident could receive multiple Contributing Factors (e.g., both Driver Impairment and Willful Behavior). In addition, the Contributing Factor was based solely on the behaviors of the LV driver. Without cameras inside the HV there was no way to determine, with any degree of certainty, the behavior(s) of the HV driver.

Even when the HV driver was judged to have been at-fault, the behaviors of the LV driver are identified. Put another way, for the events that were caused by the LV driver, the analyses considered the LV driver's behaviors that may have contributed to the event. For events where the HV-driver was at-fault, the analysis also considered the LV driver's behaviors. However, the consideration is for the LV driver behaviors that occurred as the driver reacted to the HV driver's actions. For example, an HV driver at-fault incident that was assigned a Contributing Factors of "Distraction" would refer to the LV driver being distracted (not the HV driver) as he/she reacted to the event. Table 16 shows each of the contributing factors identified in this study. A complete list of contributing factors can be found in Dingus et al. (2004).

Table 16. Contributing Factors Used to Identify the Primary Cause of the Incident.

Contributing Factor	Description
Driver Impairment – The driver's behavior, judgment or driving ability is altered or hindered.	
Drowsy, fatigued	Impairs the driver's attention and/or judgment. Determined through yawning, slow eye closures, heavy eyes, etc.
Angry	Impairs the driver's attention and/or judgment. Determined through facial expressions or verbal comments made by the driver.
Other emotional state	Impairs the driver's attention and/or judgment. Determined through facial expressions or verbal comments made by the driver.
Distracted	Impairs the driver's attention and/or judgment.
Other	Impairs the driver's ability to drive safely.
Unknown	Impairs the driver's ability to drive safely.
Willful Behavior – The driver knowingly and purposefully drives in an unsafe or inappropriate manner	
Aggressive driving	The driver intentionally drives unsafely or inappropriately, usually due to impatience (e.g., quickly passes another vehicle just before a turn, fails to remain a safe distance from another vehicle, excessive speed).
Purposeful violation of traffic laws	The driver knowingly violates a traffic law (e.g., fails to respond to a traffic signal or stop sign).
Driver Proficiency – An individual's driving skills, abilities, or knowledge is inadequate	
Driving techniques	Driver appears unsure or incompetent as to how to safely perform a driving maneuver (e.g., failing to check for traffic before proceeding onto a roadway).
Infrastructure – The driver's physical surroundings hinder his/her ability to drive safely and appropriately or confuse the driver.	
Roadway alignment	It is difficult for the driver to maneuver due to the geometry of a roadway or intersection (e.g., an arrow roadway or sharp turn).
Roadway delineation	Poor visibility (e.g., faded paint) or positioning of roadway or lane borders.

Table 17 shows the frequency, percentage, and rank ordering for each Contributing Factor across all 246 incidents. As can be seen in Table 17, the most frequent Contributing Factor was Driving Techniques (49.5%), followed by Unknown (24%), Distracted (18.7%), and Aggressive Driving (15%)[3]. Figure 17 shows a bar graph of the 246 incidents as a function of the Contributing Factor.

[3] Since more than one Contributing Factor could be coded with each incident, the percentages total more than 100%. This procedure was also used by Blower (1998). The denominator for determining the percentages was the total number of LV-HV interactions for that data set (Example: The denominators in Tables 15 and 16 were 246 and 79, respectively).

Table 17. Frequency, Percentage, and Rank Ordering of the Contributing Factors Across all LV-HV Incidents (N_{Total} = 246).

Contributing Factors	Frequency of all LV-HV Incidents	Percentage of all LV-HV Incidents	Combined Rank of all LV-HV Incidents
Driving techniques	122	49.5%	1
Unknown	59	24%	2
Distracted	46	18.7%	3
Aggressive driving	37	15%	4
Drowsy	9	3.7%	5
Purposeful violation of traffic laws	8	3.3%	6.5
Roadway alignment	8	3.3%	6.5
Roadway delineation	3	1.2%	8
Angry	2	0.8%	9.5
Other emotional state	2	0.8%	9.5
Other	1	0.4%	11

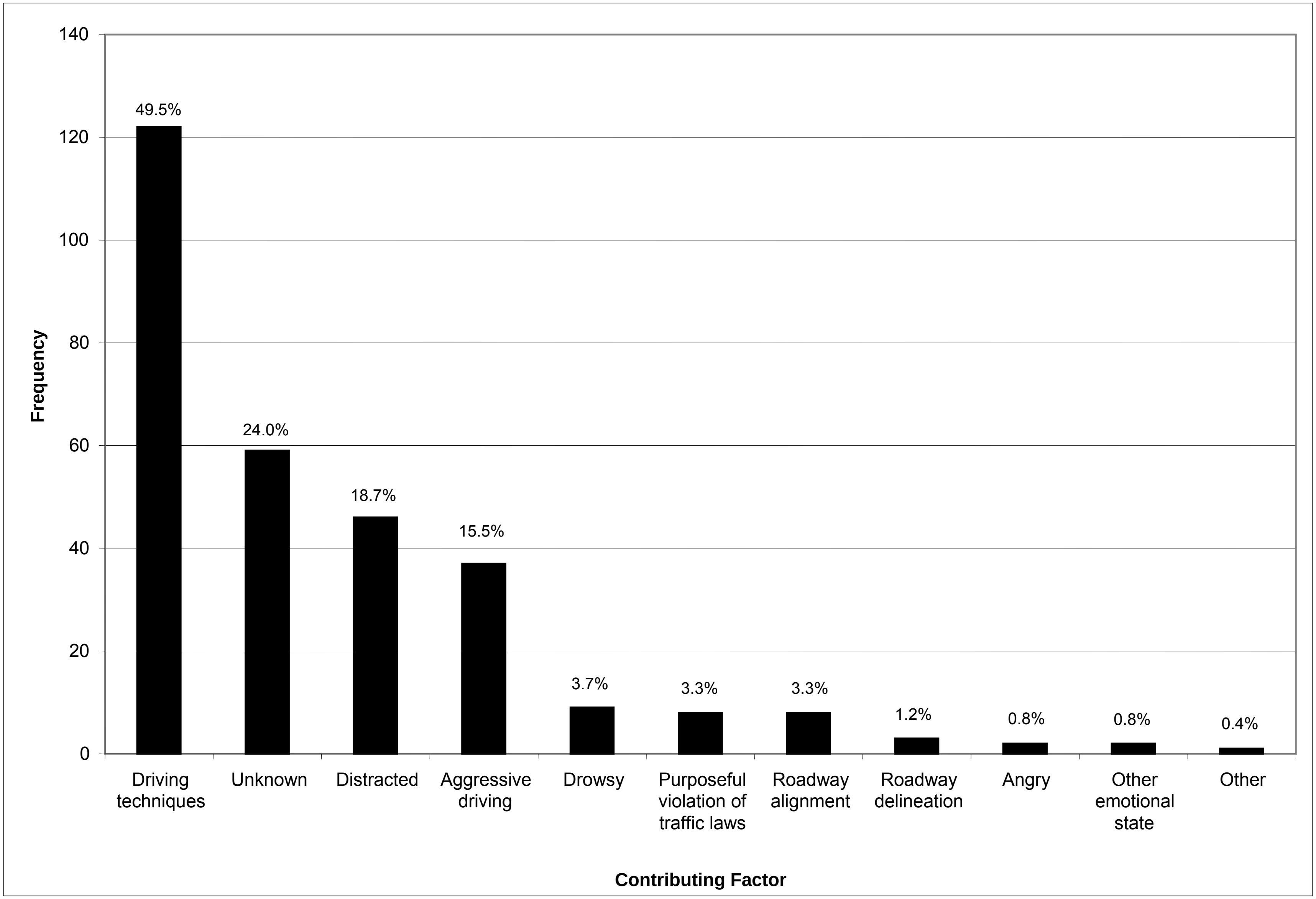


Figure 17. Frequency of Contributing Factors Across all LV-HV Incidents (N_{Total} = 246.)

Table 18 shows the frequency, percentage, and rank ordering of each Contributing Factor for the HV driver at-fault incidents. As can be seen in Table 18, the most frequent Contributing Factor was Unknown (68.4%), followed by Driving Techniques (15.2%), and Distracted (11.4%). Figure 18 shows a bar graph of the 79 HV driver at-fault incidents as a function of the Contributing Factor.

Table 18. Frequency, Percentage, and Rank Ordering of the Contributing Factors for HV Drivers in the HV At-Fault Incidents (n_{HV} = 79).

Contributing Factors	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Combined Rank of HV Driver At-Fault Incidents
Unknown	54	68.4%	1
Driving techniques	12	15.2%	2
Distracted	9	11.4%	3
Aggressive driving	3	3.8%	4
Drowsy	2	2.5%	5.5
Roadway alignment	2	2.5%	5.5
Angry	1	1.3%	8
Other emotional state	1	1.3%	8
Roadway delineation	1	1.3%	8

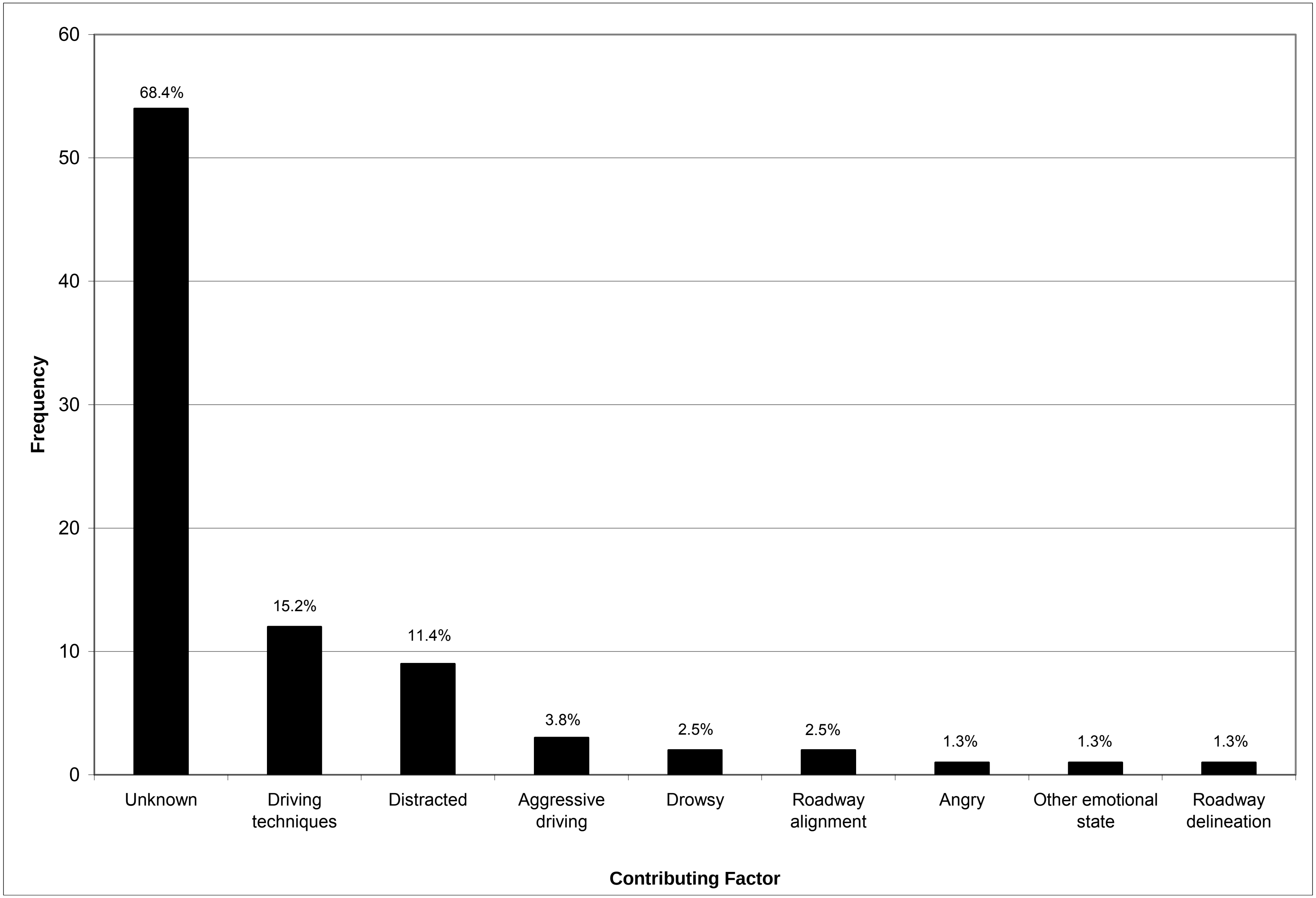


Figure 18. Frequency of Contributing Factors for LV Drivers in the HV At-Fault Incidents (n_{HV} = 79).

Table 19 shows the frequency, percentage, and rank ordering of each Contributing Factor for the LV driver at-fault incidents. As can be seen in Table 19, the most frequent Contributing Factor for LV driver at-fault incidents was Driving Techniques (70.3%), followed by Distracted (22.5%) and Aggressive Driving (22.5%). Figure 19 shows a bar graph of the 138 LV driver at-fault incidents as a function of the Contributing Factor.

Table 19. Frequency, Percentage, and Rank Ordering of the Contributing Factors for the LV Driver At-Fault Incidents (n_{LV} = 138).

Contributing Factors	Frequency of LV Driver At-Fault Incidents (n_{LV} = 138)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 138)	Combined Rank of LV Driver At-Fault Incidents
Driving techniques	97	70.3%	1
Distracted	31	22.5%	2.5
Aggressive driving	31	22.5%	2.5
Purposeful violation of traffic laws	7	5.1%	4
Drowsy	5	3.6%	5
Roadway alignment	3	2.2%	6
Other	1	0.7%	7.5
Other emotional state	1	0.7%	7.5

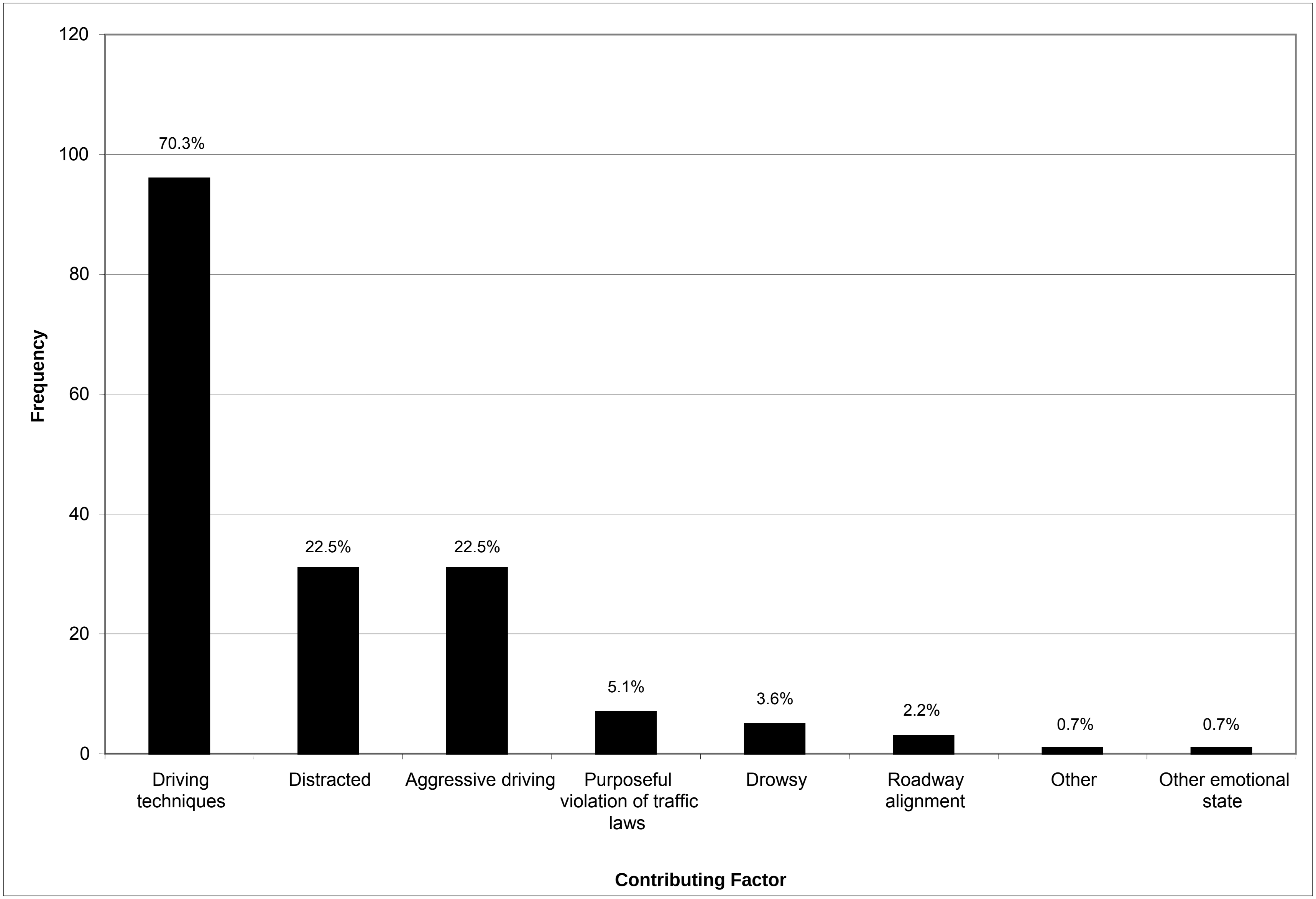


Figure 19. Frequency of Contributing Factors for LV Driver At-fault Incidents (n_{LV} = 138).

Table 20 shows the frequency, percentage, and rank ordering of each Contributing Factor for the Unknown at-fault incidents. As can be seen in Table 20, the most frequent Contributing Factor for Unknown at-fault incidents was Driving Techniques (48.3%), followed by Distracted (20.7%), Unknown (17.2%), Roadway Alignment (10.3%), and Aggressive Driving (10.3%). Figure 20 shows a bar graph of the 29 Unknown at-fault incidents as a function of the Contributing Factor.

Table 20. Frequency, Percentage, and Rank Ordering of the Contributing Factors for the Unknown At-Fault Incidents (n_{Un} = 29).

Contributing Factors	Frequency of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Combined Rank of Unknown Driver At-Fault Incidents
Driving techniques	14	48.3%	1
Distracted	6	20.7%	2
Unknown	5	17.2%	3
Roadway alignment	3	10.3%	4.5
Aggressive driving	3	10.3%	4.5
Drowsy	2	6.9%	6.5
Roadway delineation	2	6.9%	6.5
Angry	1	3.4%	7.5
Purposeful violation of traffic laws	1	3.4%	7.5

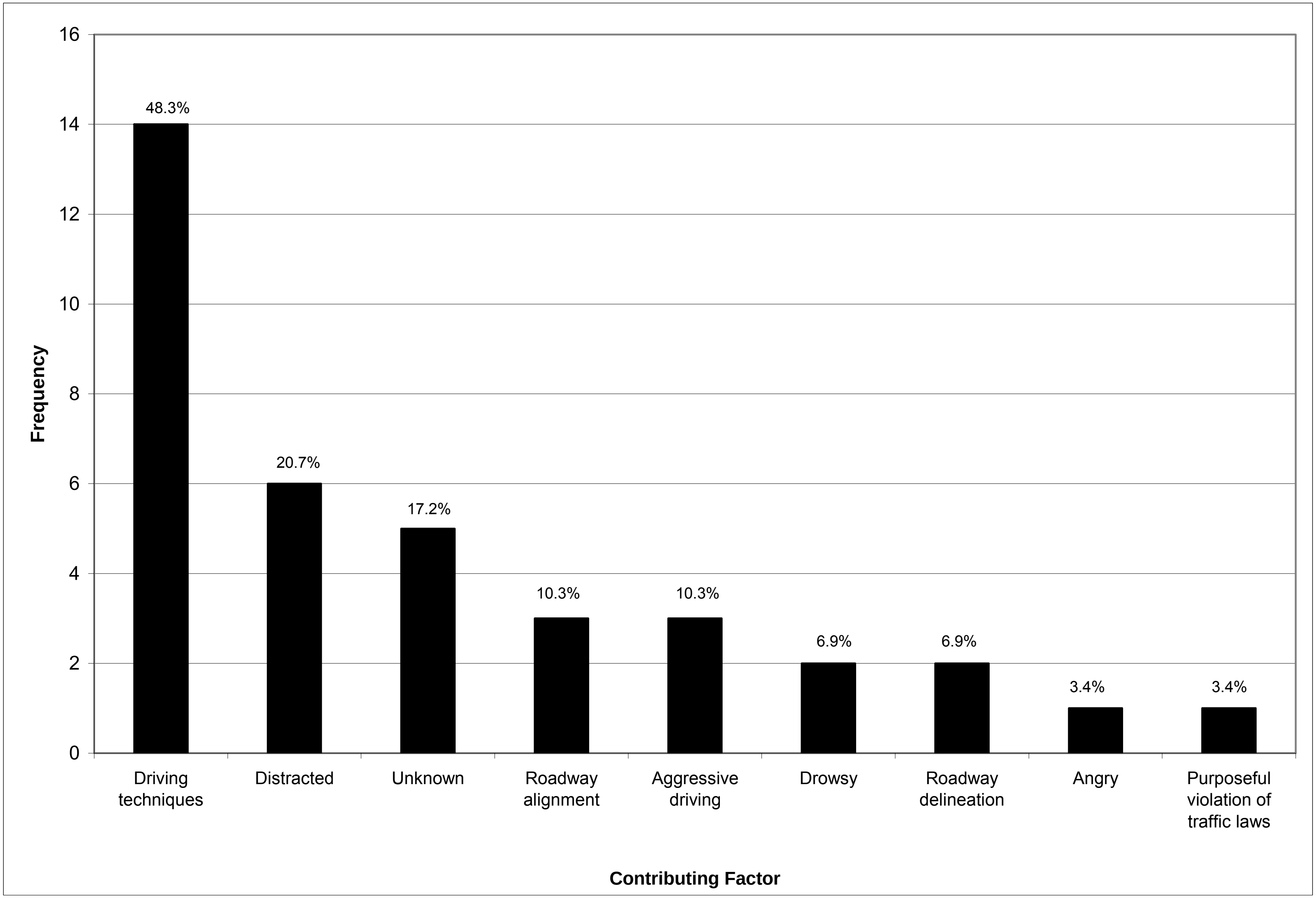


Figure 20. Frequency of Contributing Factors for Unknown At-Fault Incidents (n_{Un} = 29).

Contributing Factors X Incident Type Summary

Table 21 illustrates the frequency of LV driver at-fault incidents by Incident Type as well as Contributing Factor. Table 21 provides a more descriptive and comprehensive illustration of the Contributing Factors for each Incident Type. The far left column lists the Incident Types while the Contributing Factors are listed in the first row. As indicated above, more than one Contributing Factor could be coded to a particular incident, *thus, 176 occurrences of Contributing Factors were coded to* 138 LV driver at-fault incidents.

As can be seen in Table 21, the most frequent Contributing Factors for the Late Braking for Stopped/Stopping Traffic Incident Type was Driving Techniques (*n* = 47) and Distracted (*n* = 20). The Driving Techniques and Distracted Contributing Factors were coded in 82.5% and 35.1% of the LV at-fault Late Braking for Stopped/Stopping Traffic Incident Types, respectively. The most frequent Contributing Factors for the Lane Change Without Sufficient Gap Incident Types were Aggressive Driving (*n* = 16) and Driving Techniques (*n* = 14). The Aggressive Driving and Driving Techniques Contributing Factors were coded in 53.3% and 46.7% of the LV at-fault Lane Change Without Sufficient Gap Incident Types, respectively.

Table 21. Frequency of Incident Types X Contributing Factors Across LV Driver At-Fault Incidents (n_{LV} = 138).

Incident Types / *Contributing Factors*	Driver Impairment				Infrastructure	Willful Behavior		Driver Proficiency	
	Distracted	Drowsy, sleepy, asleep, fatigued	Other	Other emotional state	Roadway alignment	Aggressive driving	Purposeful violation of traffic laws	Driving techniques	
Aborted Lane Change	1	0	0	0	0	1	1	9	**12**
Approaches Traffic Quickly	1	0	0	0	0	1	0	5	**7**
Conflict With Oncoming Traffic	1	0	0	0	1	2	0	0	**4**
Following Too Closely	2	0	0	0	0	0	0	4	**6**
Improper Lane Change	0	0	0	0	0	2	0	2	**4**
Improper Passing	0	1	0	0	0	4	2	6	**13**
Improper Stopping at an Intersection	1	0	0	0	1	0	0	2	**4**
Lane Change Without Sufficient Gap	3	0	0	0	0	16	0	14	**33**
Late Braking for Stopped/Stopping Traffic	20	2	1	1	0	3	2	47	**76**
Lateral Deviation of Through Vehicle	1	0	0	0	0	0	0	3	**4**
Merge without Sufficient Gap	0	2	0	0	0	1	2	2	**7**
Roadway Entrance Without Clearance	0	0	0	0	1	0	0	2	**3**
Roadway Entrance Without Clearance	1	0	0	0	0	1	0	1	**3**
Total	**31**	**5**	**1**	**1**	**3**	**31**	**7**	**97**	**176**

Tree Taxonomy

Figures 21-23 illustrate another way of viewing the data in Figures 18-20. Note that the numbers in the contributing factors boxes do not necessarily sum to the total in the higher at-fault category as multiple contributing factors could have been selected for each incident.

Figure 21 is a tree taxonomy of the General and Specific Contributing Factors for the 79 incidents where the HV driver was at-fault. An important point for the HV driver at-fault incidents is that the Contributing Factors are for the LV driver and not the HV driver. Again, this is due to the methodology used where cameras and other data collection equipment were in the LVs only. As such, the Contributing Factors in Figure 29 should be considered driver behaviors identified when the LV driver was responding to the at-fault HV driver.

Figure 22 provides a tree taxonomy of the 138 incidents where the LV was at-fault and provides a tree taxonomy of the 29 incidents where it was unknown if the HV or LV drivers was at-fault.

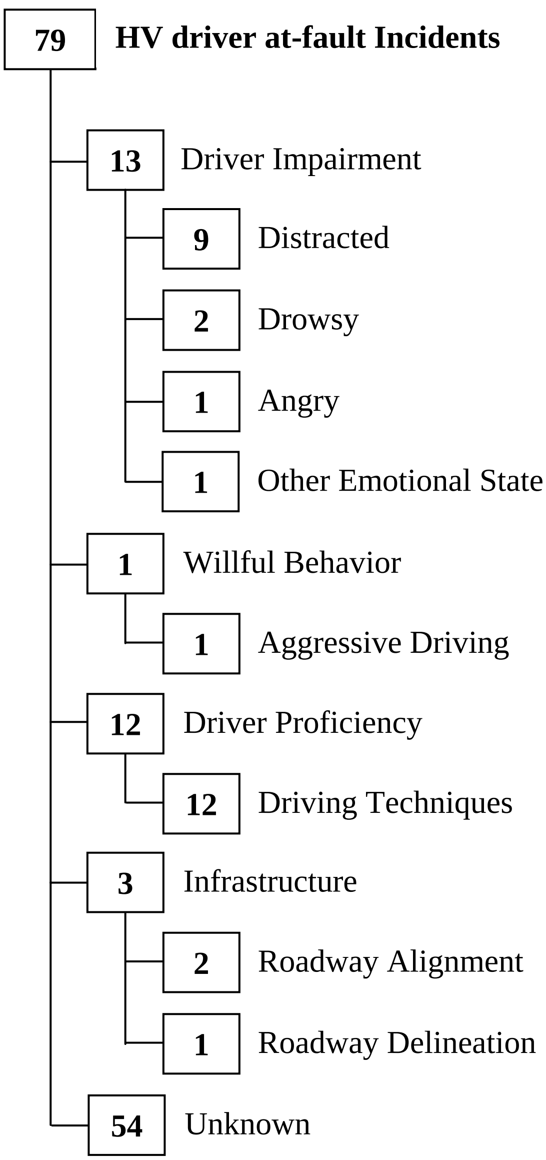


Figure 21. Taxonomy of the Contributing Factors for LV Drivers in the HV At-Fault Incidents (n_{HV} = 79).

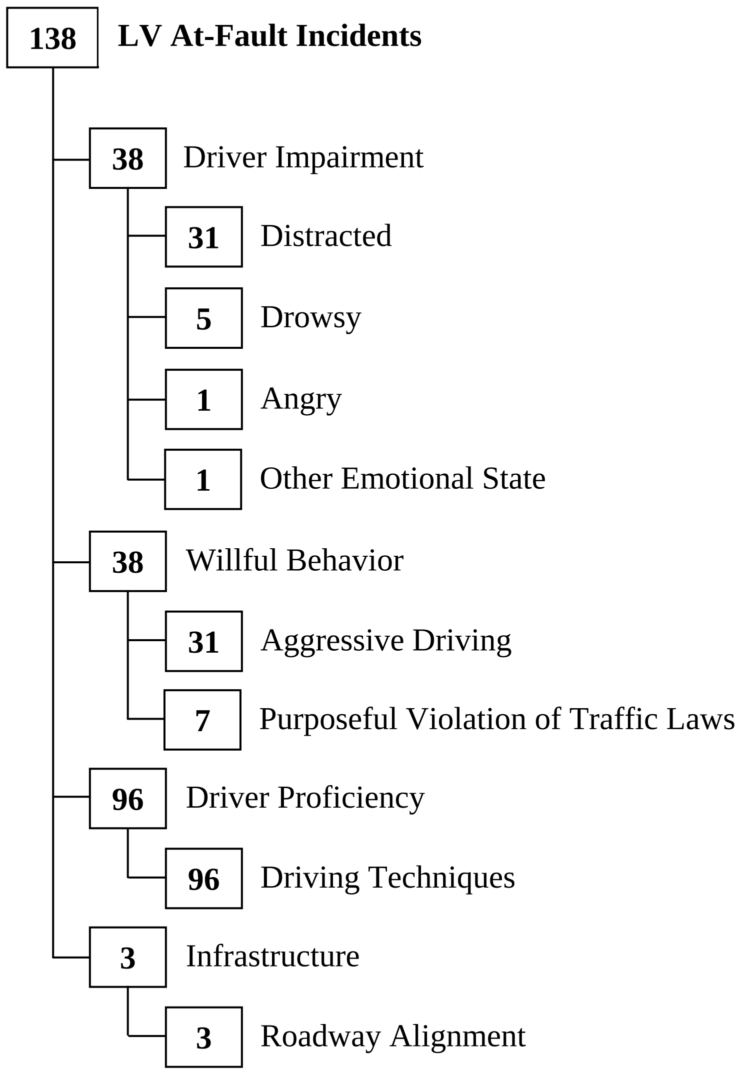


Figure 22. Taxonomy of the Contributing Factors for LV Driver At-Fault Incidents (n_{HV} = 138).

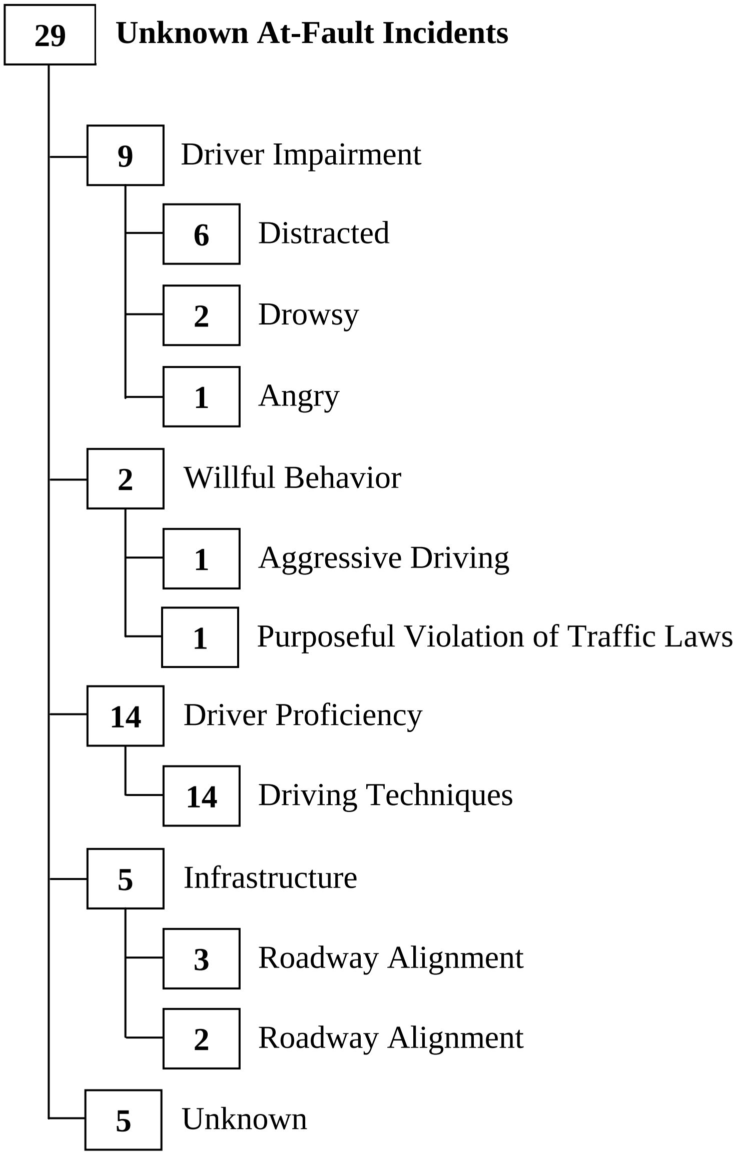


Figure 23. Taxonomy of the Contributing Factors for Unknown At-Fault Incidents (n_{Un} = 29).

<u>Contributing Factor Taxonomy</u>
A taxonomy to highlight the characteristics of the incidents was also developed. The Incident Types, Contributing Factor Categories, and brief descriptions of the incidents were arranged hierarchically to create three taxonomies: (1) Figure 24 illustrates the HV driver at-fault incidents, (2) Figure 25 illustrates the LV driver at-fault incidents, and (3) Figure 26 illustrates the Unknown at-fault incidents. At the highest level of the taxonomy, the events are grouped by the driver who was at-fault for the incident (i.e., HV, LV, or Unknown). The second highest level in the taxonomy is the Incident Type, followed by the General Contributing Factor, Specific Contributing Factor, and brief description of the incident, respectively. The incident descriptions explain the basic cause and result of the incidents. The taxonomy structures are shown below in Figures 24-26.

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(4) Aborted Lane Change	(2) Driver Impairments	(1) Distracted	(1) The LV is traveling to the right of an HV in traffic. The HV driver begins to make a lane change into the LV driver's lane, causing the LV driver to brake and swerve to the right to avoid the HV.
	(2) Driver Impairments	(1) Drowsy	(1) The LV is traveling to the left of an HV. The HV driver begins to change lanes into the LV driver's lane, causing the LV driver to brake hard and change lanes to the left to avoid the HV.
	(2) Unknown		(2) The LV is traveling to the right of an HV. As the LV approaches the side of the HV, the HV driver begins to change lanes into the LV driver's lane. The LV driver brakes and swerves around the edge of the HV.
(1) Backing in Roadway	(1) Driving Proficiency	(1) Driving Techniques	(1) The LV driver makes a left turn at an intersection and approaches a cone in the middle of the road. The LV driver stops and backs up in the middle of the road. There is an HV that has approached from behind and it also has to back up.
	(1) Infrastructure	(1) Roadway Delineation	
(1) Clear Path for Emergency Vehicle	(1) Unknown		(1) An LV is traveling on a straight road. An HV makes a left turn from a side road with its lights on in front of the LV, causing the driver to brake to let the HV go.
(1) Conflict with Oncoming Traffic	(1) Unknown		(1) The LV driver has just made a left turn onto a side road. The LV approaches an oncoming HV that is in the middle of the road. The LV driver stops until the HV moves over and passes the LV.

Figure 24. Taxonomy Structure Used to Characterize the HV Driver At-Fault Incidents (n_{HV} = 79).

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(1) Following Too Closely	(1) Driving Proficiency	(1) Driving Techniques	(1) The LV is traveling behind an HV. The LV driver has to brake hard when the HV slows because the LV is following too close behind the HV.
(1) Improper Lane Change	(1) Unknown		(1) The LV is traveling ahead of an HV as they are on an entrance ramp. As the vehicles merge into traffic, the HV driver changes lanes to the left and speeds up next to the LV blocking the HV from making a lane change which is the intention.
(1) Improper U-turn	(1) Unknown		(1) The LV is traveling on a straight road; the LV approaches an HV trying to make a U-turn and is blocking the driver's path. The LV has to slow until the HV straightens out and continues.
(1) Improperly Covered Debris	(1) Unknown		(1) The LV is traveling to the left and behind an HV with an uncovered load. Debris flies off of the back of the HV startling the LV driver and causing the LV to swerve in their lane slightly before the LV accelerates to pass the HV.

Figure 24. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(21) Lane Change Without Sufficient Gap	(3) Driver Impairments	(3) Distracted	(3) An HV to the right and slightly ahead of the LV changes lanes to the left with very little room in front of the LV, startling and causing them to swerve to the left.
	(2) Willful Behavior	(2) Aggressive Driving	(2) The LV is traveling behind and to the left of an HV. The HV changes lanes to the left in front of the LV, causing them to brake suddenly.
	(1) Driver Proficiency	(1) Driving Techniques	(1) The LV is traveling behind and to the right of an HV. The HV moves to the right in front of the LV without using a blinker, causing the LV to brake hard to avoid the truck.
	(15) Unknown		(15) The LV has just moved into a right turn lane. There is an HV in the left lane who changes lanes directly in front of the LV, causing them to brake suddenly.
(1) Late Braking for Stopped/Stopping Traffic	(1) Driver Impairments	(1) Distracted	(1) The LV is changing lanes to the right across several lanes of traffic. As they change lanes, an HV ahead of them also changes lanes from the same direction into the same lane. The subject driver has to brake as they approach the truck.
	(1) Driver Proficiency	(1) Driving Techniques	

Figure 24. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(17) Lateral Deviation of Through Vehicle	(1) Driver Proficiency	(1) Driver Techniques	(1) The LV is traveling to the left of a bus. The bus crosses into the LV lane. The LV swerves to the left to avoid the bus as they enter an intersection then has to swerve back to the right in front of the bus to avoid oncoming traffic.
	(2) Infrastructure	(2) Roadway Alignment	(2) The LV is in a left most lane next to concrete pillars with an HV in the lane to the right. The HV crosses over their left lane line slightly, causing the subject vehicle to brake and wait for the truck to move.
	(14) Unknown		(14) The LV is traveling on an undivided single lane road. An HV, approaching from the opposite direction, crosses the center line into the LV lane.
(11) Left Turn Without Clearance	(3) Driver Impairments (1) Willful Behavior	(1) Angry (1) Aggressive Driving	(1) The LV is stopped at a traffic signal. The last 2 vehicles (an automobile and a bus) in oncoming traffic in the left turn lane run the red light and are in the intersection as the LV light turns green. The LV driver starts to accelerate slowly and honks the horn.
	(3) Driver Impairment (1) Driver Proficiency	(2) Distracted (1) Driving Techniques	(1) The LV has the right of way going straight through a traffic signal. An HV driver makes a left turn from the opposite direction without enough clearance, causing the LV driver to brake hard before the HV clears the intersection.
	(3) Driver Impairment	(2) Distracted	(1) An HV driver pulls out from the left and merges to the far right lane in front of the LV. The LV driver brakes hard to avoid hitting the HV.
	(8) Unknown		(8) The LV has the right of way going straight when an oncoming HV driver makes a left turn in front of the LV causing the LV driver to brake.

Figure 24. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(3) Merge Without Sufficient Gap	(2) Driver Proficiency	(2) Driving Techniques	(2) The LV is traveling in the right lane. An HV approaches from an entrance ramp and changes lanes to the left in front of the LV before changing lanes to the left again.
	(1) Unknown		(1) An LV is traveling in the right most lane as traffic approaches from a merge lane on the right. The LV slows to let traffic merge and an HV nearly hits the LV as it cuts in too close in front. Traffic is moving quickly in the lane to the left of the LV making it impossible for the LV to move over.
(4) Obstruction in Roadway	(1) Driver Proficiency	(1) Driving Techniques	(1) The LV approaches an HV that is parked in its traffic lane. The LV has to swerve to the left into oncoming traffic to avoid the HV, coming close to another vehicle.
	(3) Unknown		(3) The LV is traveling behind an HV that moves partially into a left turn lane. The LV driver has to brake and go around the HV because the HV is sticking out in the LV's lane.
(2) Roadway Entrance Without Clearance	(2) Unknown		(2) The LV is traveling on a straight wet road. An HV makes a right turn from a side road directly in front of the LV.
(1) Slow Speed	(1) Unknown		(1) The LV is traveling in the left lane on a highway. The LV approaches an HV ahead in the left lane who is traveling much slower than other traffic. The LV driver brakes hard and changes lanes to the right.

Figure 24. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(1) Sudden Braking in Roadway	(1) Driver Proficiency	(1) Driving Techniques	(1) An LV is behind an HV whose driver brakes suddenly for a red light. The LV comes close to the HV and causes the LV driver to brake hard.
(3) Through Traffic Does Not Allow Merge	(1) Driver Proficiency	(1) Driving Techniques	(1) The LV is trying to merge onto the highway. There is an HV in the lane to the left of them that will not move to let the LV merge. The LV has to move over to the shoulder to let the HV pass before the LV can merge into traffic.
	(2) Unknown		(2) The LV is trying to merge onto the highway, but an HV in the lane to the left will not allow the LV to merge.
(1) Turn Without Sufficient Warning	(1) Driver Impairment	(1) Distracted	(1) The LV is traveling behind a HV who slows and pulls off the side of the road. The HV doesn't completely pull off the road, causing the LV driver to go slightly over the double yellow line while there is oncoming traffic.
(1) Turn From Incorrect Lane	(1) Driver Impairment	(1) Other Emotional State	(1) The LV changes lanes to the left at the same time that the lead HV changes lanes to the left. The HV then stops and makes a right turn from the left lane, cutting off vehicles in the right lane and causing the LV driver to brake.
(2) Wide Turn Into Adjacent Lane	(1) Driver Impairment	(1) Drowsy	(1) The LV is traveling on a single lane undivided road. An HV makes a wide right turn from a side road onto the LV's road (oncoming traffic) and crosses over the double yellow line. The LV stops until the HV completes the turn and returns to the HV's lane.
	(1) Unknown		(1) An HV makes a left turn from a side road and enters the LV's lane slightly while turning into their lane. The LV brakes until the HV finishes the turn.

Figure 24. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(11) Aborted Lane Change	(2) Driver Impairments	(1) Distracted	(1) An LV approaches a slow moving HV and starts to change lanes to the right. As the LV driver turns their head to check the blind spot, the HV also starts to change lanes to the right. The LV driver notices this when they turn back and move back into the lane.
	(2) Willful Behavior	(1) Aggressive Driving	(1) The LV driver is changing lanes to the right across several lanes of traffic. As they begin to change lanes again, an HV changes lanes from the left into the same lane. The LV driver aborts their lane change and moves back into the original lane.
	(2) Willful Behavior	(1) Purposeful Violation of Traffic Laws	(1) The LV is traveling two vehicles behind an HV on a single lane undivided road. The vehicle directly behind the HV passes the HV during a dotted yellow line, but the passing zone ends before the LV can pass. The LV begins to pass but the LV driver has to brake.
	(8) Driver Proficiency	(8) Driving Techniques	(8) The LV driver is attempting to change lanes to the right. As they begin the lane change, they notice an HV in the right lane and have to turn the wheel quickly to stay in their lane.

Figure 25. Taxonomy Structure Used to Characterize the LV Driver At-Fault Incidents (n_{LV} = 138).

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(6) Approaches Traffic Quickly	(1) Driver Impairments	(1) Distracted	(1) The LV approaches an HV that is stopped while delivering mail. The LV driver is distracted while trying to light a cigarette and approaches the HV quickly. The LV driver has to brake moderately hard to avoid the HV.
	(5) Driver Proficiency	(5) Driving Techniques	
	(1) Willful Behavior	(1) Aggressive Driving	(1) The LV is changing lanes to the right across two lanes of traffic to get into an exit lane. As the LV driver enters the exit lane, they change lanes behind an HV driver who is braking for the exit. The LV was accelerating during the lane changes and now the LV driver has to brake hard behind the truck.
	(5) Driver Proficiency	(5) Driving Techniques	(4) The LV is traveling behind an HV driver who is at the end of a line of traffic. The LV driver accelerates up to the traffic then has to brake suddenly as they notice the traffic is nearly stopped.
(3) Conflict with Oncoming Traffic	(1) Driver Impairments	(1) Distracted	(1) The LV driver has just made a left turn onto a side road. They approach an oncoming HV that is driving in the middle of the road. The LV driver stops until the HV moves over and passes them.
	(1) Infrastructure	(1) Roadway Alignment	
	(2) Willful Behavior	(2) Aggressive Driving	(2) The LV is traveling on a single lane undivided road behind a slow HV. During a passing zone, they move to the left to pass the HV, but have to brake and move back behind the HV due to an oncoming car.

Figure 25. (Continued.)

INCIDENT TYPE	CONTRIBUTING FACTOR	CONTRIBUTING FACTOR	EVENT DESCRIPTION
(4) Following Too Closely	(2) Driver Impairments	(2) Distracted	(2) The LV is traveling behind an HV in traffic. The HV slows and the LV comes close to the truck before stopping.
	(4) Driver Proficiency	(4) Driving Techniques	
	(4) Driver Proficiency	(4) Driving Techniques	(2) The LV is traveling behind an HV. The LV is traveling too close to the HV and the LV driver has to brake hard when the HV brakes. The roads are wet from the rain.
(3) Improper Lane Change	(2) Willful Behavior	(2) Aggressive Driving	(1) The LV driver moves into the lane towards the right, behind an HV. They then move quickly again into the lane to the right. The LV comes close to the rear of the HV as they pass.
	(2) Willful Behavior	(2) Aggressive Driving	(2) The LV is traveling behind a slow HV. The LV changes lanes to the right (no blinker) before the turn lane starts (crosses solid white line). Moments later the lead HV also changes lanes to the right, causing the LV driver to brake for the HV.
	(2) Driver Proficiency	(2) Driving Techniques	
	(2) Driver Proficiency	(2) Driving Techniques	The LV is first in line at an intersection. Traffic from the other direction was backed up and the LV driver couldn't pass through. They start to move into the lane to the left but brake quickly when they see an HV.

Figure 25. (Continued.)

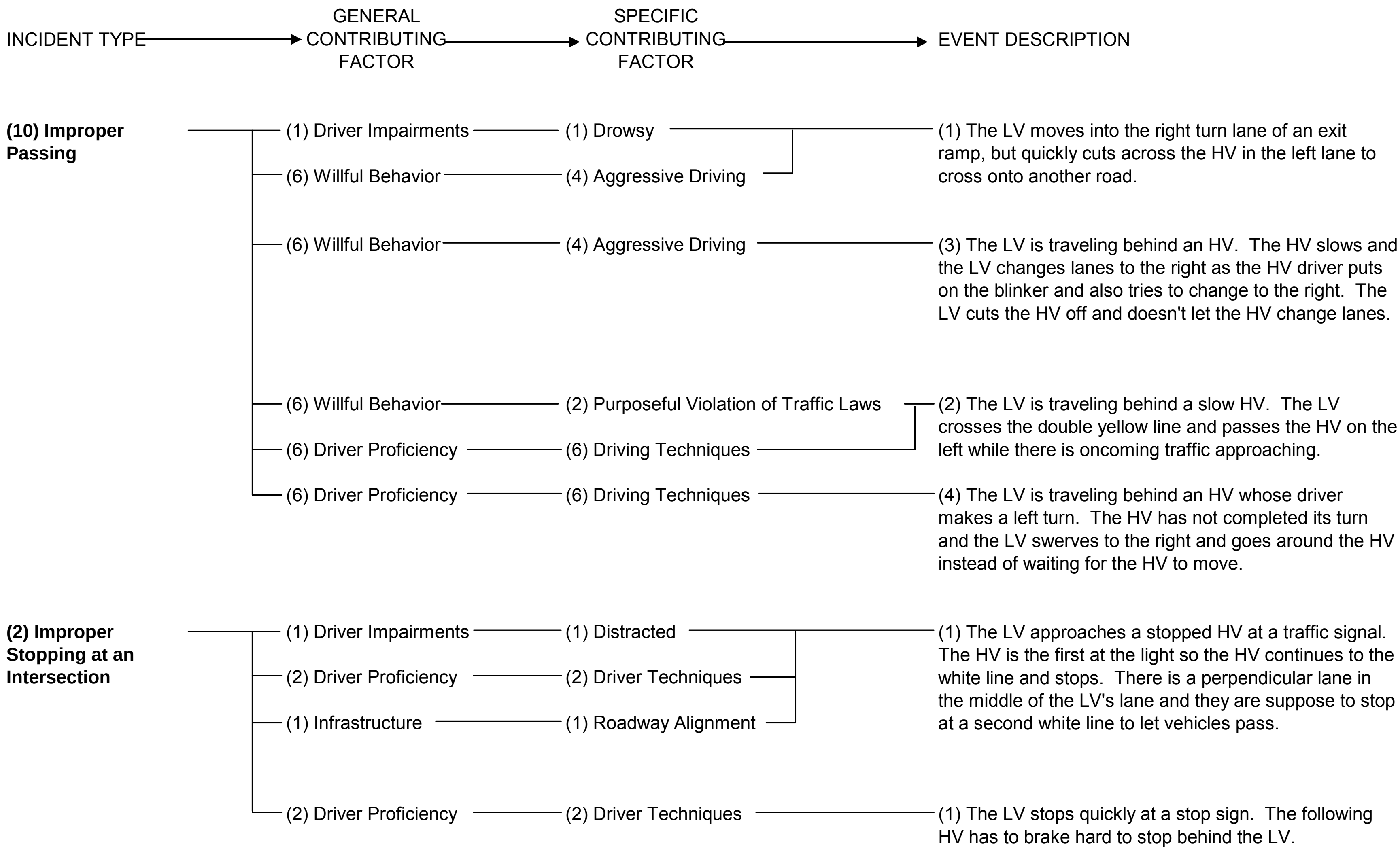


Figure 25. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(30) Lane Change Without Sufficient Gap	(3) Driver Impairments (16) Willful Behavior	(3) Distracted (16) Aggressive Driving	(1) The LV driver is traveling in slow traffic while talking on a cell phone. The LV makes a quick lane change to the left, coming close to the lead HV as the LV changes and cuts in close in front of another HV.
	(3) Driver Impairments (14) Driver Proficiency	(3) Distracted (14) Driving Techniques	(2) The LV driver is distracted while talking on the phone. They change lanes to the right close between two HVs.
	(16) Willful Behavior	(16) Aggressive Driving	(15) The LV is traveling behind a slow vehicle. The LV makes a quick lane change to the right, cutting off the following HV in the new lane.
	(14) Driver Proficiency	(14) Driving Techniques	(12) The LV is traveling in the right lane behind slow traffic and changes lanes to the left in front of an HV.
(57) Late Braking for Stopped/Stopping Traffic	(24) Driver Impairments	(22) Distracted	(5) The LV is traveling behind an HV in a construction zone. The HV driver brakes, causing the LV driver to brake. The LV driver is distracted by adjusting the radio prior to the event.
	(26) Driver Impairments	(1) Other	(1) The LV approaches an HV waiting to make a right turn. The LV driver comes close to the HV and has to brake suddenly as they approach.
	(26) Driver Impairments (47) Driver Proficiency	(1) Other Emotional State (47) Driving Techniques	(1) The LV is traveling behind an HV. The LV driver has to brake moderately hard and comes close to the HV as traffic slows.
	(22) Driver Impairments (47) Driver Proficiency	(17) Distracted (47) Driving Techniques	(17) The LV is traveling behind an HV driver who is braking for traffic. The LV driver seems to be distracted and has to brake hard behind the HV.

Figure 25. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(57) Late Braking for Stopped/Stopping Traffic (con't)	(26) Driver Impairments (47) Driver Proficiency	(2) Drowsy (47) Driving Techniques	(2) A LV is traveling behind an HV who is decelerating to make a left turn. The LV driver has to brake hard and comes close to the HV as the HV is turning. The LV driver looks slightly drowsy during this event.
	(5) Willful Behavior	(3) Aggressive Driving	(2) The LV is traveling behind a slow HV so the LV starts to make a lane change to the right but there is a stopped HV so they move back into their lane. When they move back the lead HV stops and the LV driver has to brake hard behind the HV.
	(5) Willful Behavior (47) Driver Proficiency	(3) Aggressive Driving (47) Driving Techniques	(1) The LV is attempting to change into the right lane. Halfway through the lane change, an HVdriver in the right lane brakes causing the LV driver to brake hard before completing the lane change.
	(47) Driver Proficiency	(47) Driving Techniques	(26) The LV is traveling behind an HV trailing a vehicle. The HV driver slows and makes a right turn onto a side road. The LV driver brakes hard behind the HV.
	(5) Willful Behavior	(2) Purposeful Violation of Traffic Laws	(2) The LV makes a lane change to the left into a lane where there is an HV stopped in traffic. The LV driver has plenty of room to complete the lane change, but has to brake hard as they approach the stopped HV.

Figure 25. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(3) Lateral Deviation of Through Vehicle	(1) Driver Impairments (3) Driver Proficiency	(1) Distracted (3) Driver Techniques	(1) An LV driver is very distracted with something in their lap. The LV is driving on a single lane undivided road and crosses over the double yellow line on a curve. An HV comes in the opposite direction and the LV driver swerves quickly to the right to avoid the HV.
	(3) Driver Proficiency	(3) Driver Techniques	(2) The LV is traveling in the left lane on a two lane undivided highway. The LV is slightly over the double yellow line when an oncoming HV passes. The LV brakes and moves to the right to return to the LV's lane.
(5) Merge Without Sufficient Gap	(2) Driver Impairments	(2) Drowsy	(1) The LV is in the right most lane which is ending. The LV does not merge to the left in time and gets cut off by an HV. The LV driver has to brake and wait for the HV to pass before moving over.
	(2) Driver Impairments (3) Driver Proficiency	(2) Drowsy (3) Driver Techniques	(1) The LV is in the far right lane which is partially blocked by barrels. There is an HV in the lane to the left of the LV which the LV is trying to get in front of. The barrels block the LV's lane before they can merge over and the LV starts to hit the barrels.
	(3) Willful Behavior	(2) Purposeful Violation of Traffic Laws	(2) The LV is in slow traffic. The vehicle in front of them stops to merge to the left into traffic, and the LV goes around the stopped car on the right and tries to merge into traffic on the left behind an HV.
	(3) Driver Proficiency	(3) Driver Techniques	(1) The LV is in an entrance lane and begins to merge before the lead vehicle merges. There is an HV approaching from behind and the LV driver brakes and swerves a little before the HV driver lets them in.

Figure 25. (Continued.)

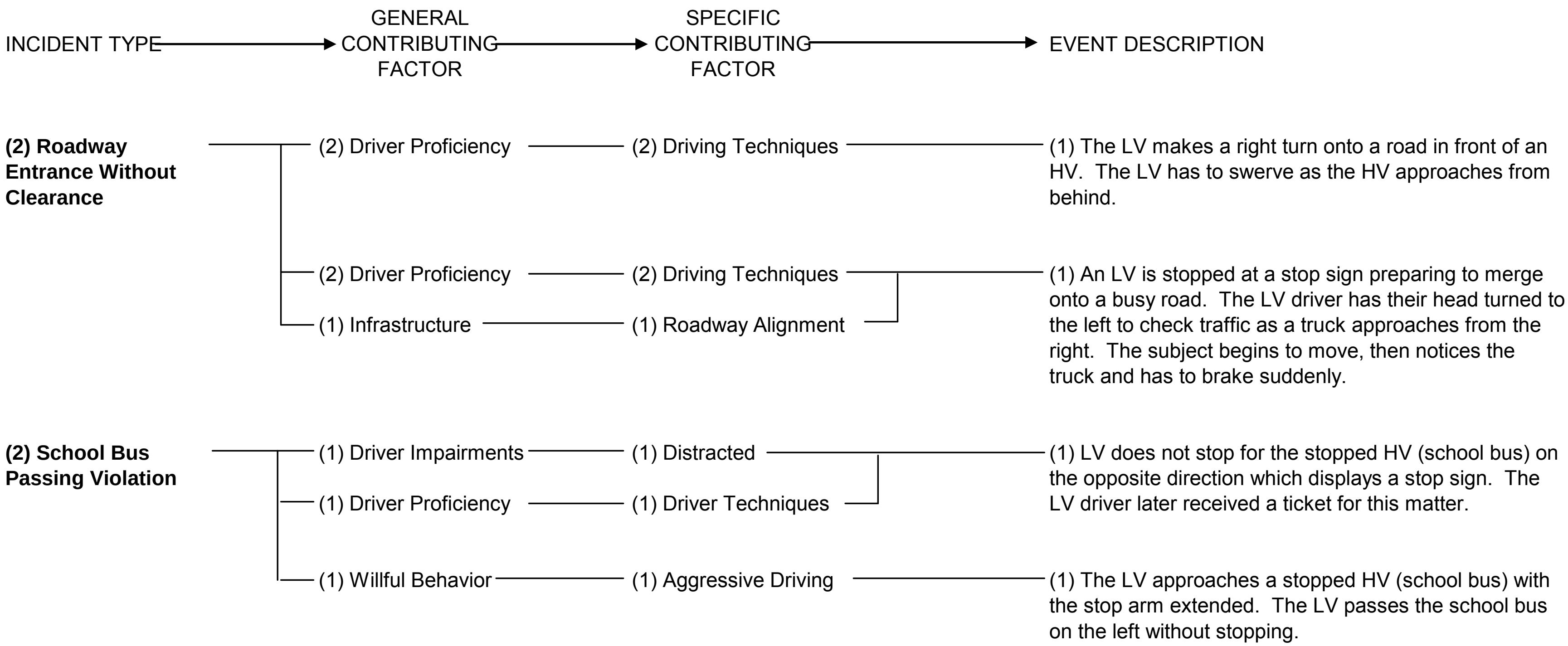


Figure 25. (Continued.)

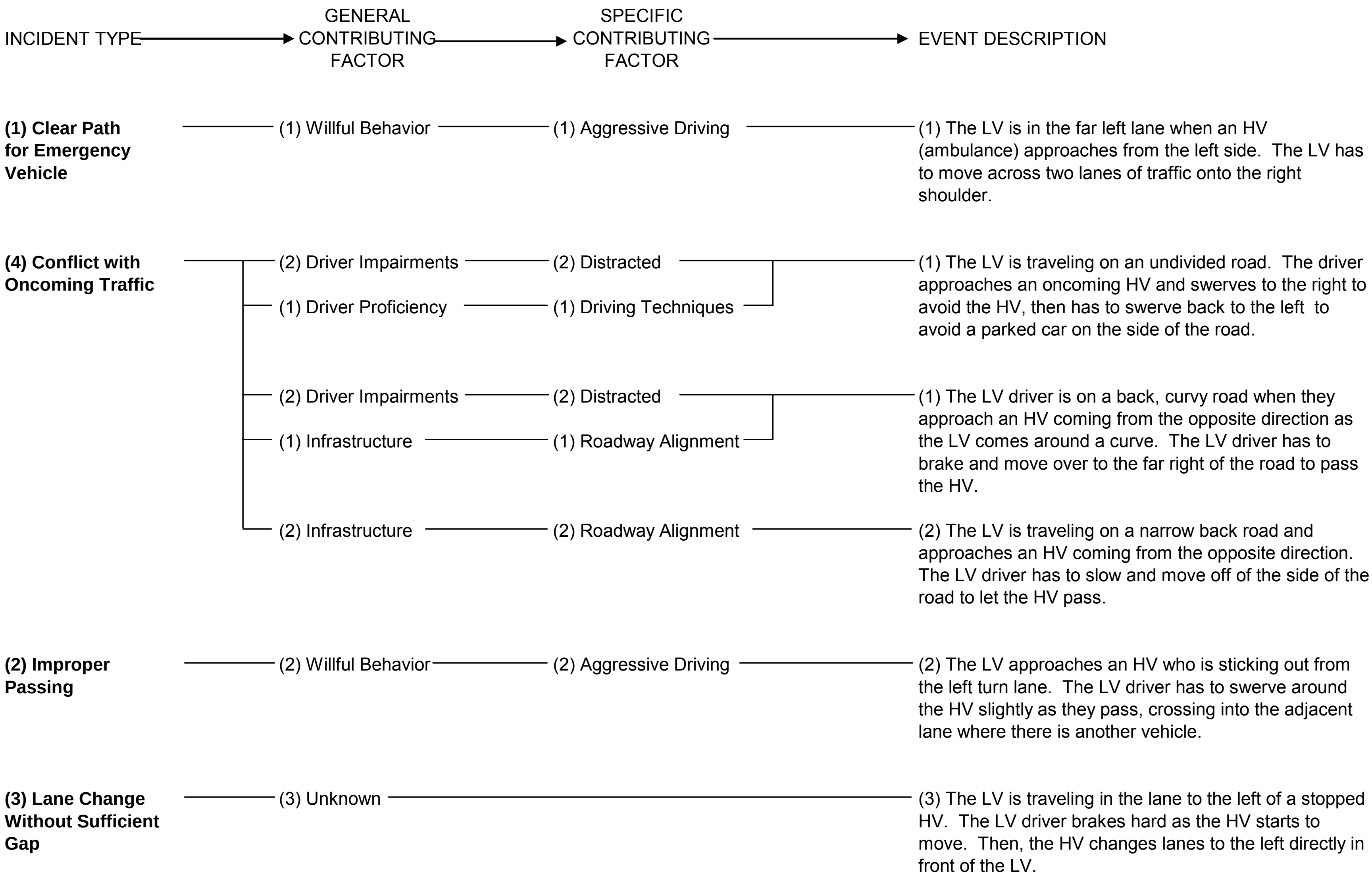


Figure 26. Taxonomy Structure Used to Characterize the Unknown At-Fault Incidents (n_{Un} = 29).

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(8) Late Braking for Stopped/Stopping Traffic	(2) Driver Impairments	(2) Distracted	(1) The LV driver is attempting to change lanes to the right. As the LV driver turns to check the blind spot, the HV ahead slows, causing the LV driver to brake suddenly when they look forward again.
	(2) Driver Impairments	(2) Distracted	(1) The LV driver is traveling in traffic while operating a PDA. The LV driver brakes behind the lead vehicle, and the following HV has to brake hard behind the LV.
	(5) Driver Proficiency	(5) Driving Techniques	
	(5) Driver Proficiency	(5) Driving Techniques	(4) An LV is traveling behind an HV. An HV driver brakes in an exit lane so the LV driver brakes hard.
	(2) Unknown		(2) The LV is traveling behind an HV in busy traffic. The HV slows and the LV driver has to brake hard and comes close to the HV as the LV slows.
(2) Left Turn Without Clearance	(1) Driver Impairments	(1) Distracted	(1) The LV approaches an HV which is stopped perpendicular to them in the middle of an intersection. The LV driver has to stop and wait for the HV to move.
	(1) Driver Proficiency	(1) Driving Techniques	(1) The LV is traveling straight and appears to have the right of way through an intersection. An HV makes a left turn from the opposite direction causing the subject to stop completely until the HV passes through the intersection.
(1) Merge Without Sufficient Gap	(1) Driver Impairments	(1) Distracted	(1) The LV driver is trying to pass an HV on the left where the road merges into one lane (exit ramp). The LV driver runs out of room and brakes to let the HV pass before the LV driver merges into the single lane.
	(1) Infrastructure	(1) Roadway Delieation	

Figure 26. (Continued.)

INCIDENT TYPE	GENERAL CONTRIBUTING FACTOR	SPECIFIC CONTRIBUTING FACTOR	EVENT DESCRIPTION
(1) Obstruction in Roadway	(1) Infrastructure	(1) Roadway Delineation	(1) The LV is traveling in the left lane of a two lane undivided road. There is some construction equipment in the road blocking the lane and causing the LV driver to swerve into the right traffic lane.
(2) Roadway Entrance Without Clearance	(1) Driver Impairments (2) Driver Proficiency	(1) Distracted (2) Driving Techniques	(1) The LV appears to have the right of way traveling straight. An HV enters from a side road in the far right lane causing the LV driver to brake hard because the LV driver thinks the HV is too close to them.
	(1) Willful Behavior	(1) Purposeful Violatiton of Traffic Laws	(1) The LV is traveling on a single lane, undivided road. The LV approaches an HV who is moving onto the road (from the side of the road). The LV brakes hard behind the HV, then the HV brakes and the LV crosses the double yellow line to go around the LV.
(2) Through Traffic Does Not Allow Lane Change	(1) Driver Impairments (2) Driver Proficiency	(1) Drowsy (2) Driving Techniques	(1) The LV is trying to merge into traffic on the highway. There is an HV in the lane to the left of the LV that does not move over to allow the LV to change lanes. The LV driver has to brake and swerve around a little in the lane, coming close to the guardrail.
	(2) Driver Proficiency	(2) Driving Techniques	(1) The LV is traveling to the left and behind an HV. The HV's left blinker has been on for some time and the LV has plenty of room to move over but doesn't. The HV finally moves over to the left lane and the LV changes lanes to the left.
(3) Unable to Determine	(1) Driver Impairments (2) Driver Proficiency	(1) Angry (2) Driving Techniques	(1) The LV approaches an HV stopped at a traffic signal. The LV driver is confused as to what the HV is doing and tries to swerve to the left. The HV starts moving and both vehicles make a left turn.
	(2) Driver Proficiency	(2) Driving Techniques	(2) The LV is in a double left turn lane with an HV to their left. The LV driver steers to the left to avoid the HV, but comes close to the median, and has to steer sharply to the right to avoid hitting the median.

Figure 26. (Continued.)

Contributing Factors Summary

Overall, the most frequent Contributing Factors were Driving Techniques (49.5%), Unknown (24%), Distracted (18.7%), and Aggressive Driving (15%). The most prevalent Contributing Factors for HV driver at-fault incidents were Unknown (68.4%), Driving Techniques (15.2%), and Distracted (11.4%). The most prevalent Contributing Factors for LV driver at-fault incidents were Driving Techniques (70.3%), Distracted (22.5%), and Aggressive Driving (22.5%). Please note that all Contributing Factors were coded with respect to LV driver at-fault incidents.

These findings are similar to what Hankey et al. (1999) found when they conducted a database analysis using the state of Pennsylvania's crash database. The Hankey et al. (1999) study found that 77% of crashes occurring from 1995 to 1996 had "human error" cited as a primary factor in the crashes. By summing the frequency of incidents that had at least one Contributing Factor associated with human error in Figures 18 and 19 (e.g., Driving Techniques, Aggressive Driving, and Purposeful Violation of Traffic Laws) for both HV and LV driver at-fault incidents yields a total of 145 incidents out of 217. Thus, 66.8% of all the LV-HV interactions were determined to have at least one human error as a Contributing Factor. Yet, when only the LV driver at-fault incidents are considered, 94.2% (130 incidents out of 138) of the incidents had at least one human error as a Contributing Factor. It should be noted that in the Hankey et al. (1999) study, human error was the primary factor (i.e., excluding all other factors) in the crash, while in the present study it was a contributing factor. Another difference is that the Hankey et al. (1999) study was a crash database analysis that included PARs, which may be biased as they rely, in part, on verbal reports from drivers. The current study had cameras inside the vehicle recording the behaviors of the driver as the incident occurred; this methodology eliminates driver verbal report bias.

Hankey et al. (1999) also conducted a database analysis using the 1996 FARS database. In this analysis, "Aggressive Driving" was found to be a primary factor in 31.1% of the fatal crashes. The current research found that Aggressive Driving contributed to 15% of all the LV-HV incidents. However, the Hankey et al. (1999) study assessed all crash types. While there are many similarities between the current data and the Hankey et al. (1999) study, the current research assessed LV-HV interactions rather than all crash types (e.g., LV-LV interactions were not considered).

Stuster (1999) assessed driver-related factors in LV-HV fatal crashes. He found that 67.3% of passenger vehicles were cited with a driver-related factor in fatal LV-HV crashes (these were similar to the Willful Behavior and Driver Proficiency categories in Contributing Factors).[4] Stuster's (1999) results are similar to the results in the current research, where 66.8% of the LV-HV interactions were determined to have human error as a Contributing Factor.

Yet, Stuster's (1999) analysis found that only 4.3% of the passenger vehicles were cited with the driver-related factor "Erratic/Reckless Driving" in fatal LV-HV interaction crashes. This is substantially less than the 22.5% of LV driver at-fault incidents cited as "Aggressive Driving" in the current research. This discrepancy could highlight the differences between fatal crashes

[4] Passenger vehicles were only considered because the Contributing Factors in the current research were based solely on the behavior(s) of the LV driver.

(such as those found in Stuster, 1999) and near crashes and incidents (such as the current research). It might also underscore the difference in methodologies (i.e., a crash database approach compared to a naturalistic or *in situ* data collection approach) or the fact that the current study had a disproportionate number of younger drivers who tend to drive more aggressively (Chliaoutakis et al., 2002).

Driver Distraction

A substantial number of the LV-HV incidents had Distraction listed as a Contributing Factor. Again, as indicated previously, the incidents where Driver Distraction was indicated refer to the behavior of the LV driver. The Distraction Contributing Factor was sub-divided into several discrete categories. Table 22 shows the frequency, percentage, and rank ordering for each sub-category in the Distraction Contributing Factor. As can be seen in Table 22, the most frequent sub-category for the Distraction Contributing Factor was Talking/Listening on Cell Phone (21.7%), followed by Passenger in Adjacent Seat (13%) and Dialing Hand-Held Phone (8.7%). Figure 27 displays a bar graph of the 46 Distraction Contributing Factors as a function of the discrete sub-categories.

Table 22. Frequency, Percentage, and Rank Ordering of Each Sub-Category in the Distraction Contributing Factor (n = 46).

Distraction	Frequency of Distraction Incidents	Percentage of Distraction Incidents	Combined Rank of Distraction Incidents
Talking/listening on cell phone	10	21.7%	1
Passenger in adjacent seat	6	13.0%	2
Dialing hand-held cell phone	4	8.7%	3
Looking out center mirror	3	6.5%	4.5
Looking out left window	3	6.5%	4.5
Other external distraction	2	4.3%	9
Adjusting radio	2	4.3%	9
Cognitive - Other	2	4.3%	9
Combing or fixing hair	2	4.3%	9
Lost in thought	2	4.3%	9
Smoking cigar/cigarette	2	4.3%	9
Talking/singing/dancing (not on cell phone)	2	4.3%	9
Eating with utensils	1	2.2%	15.5
Lighting cigar/cigarette	1	2.2%	15.5
Operating PDA	1	2.2%	15.5
Reaching for object (not cell phone)	1	2.2%	15.5
Reading	1	2.2%	15.5
Looking out right window	1	2.2%	15.5

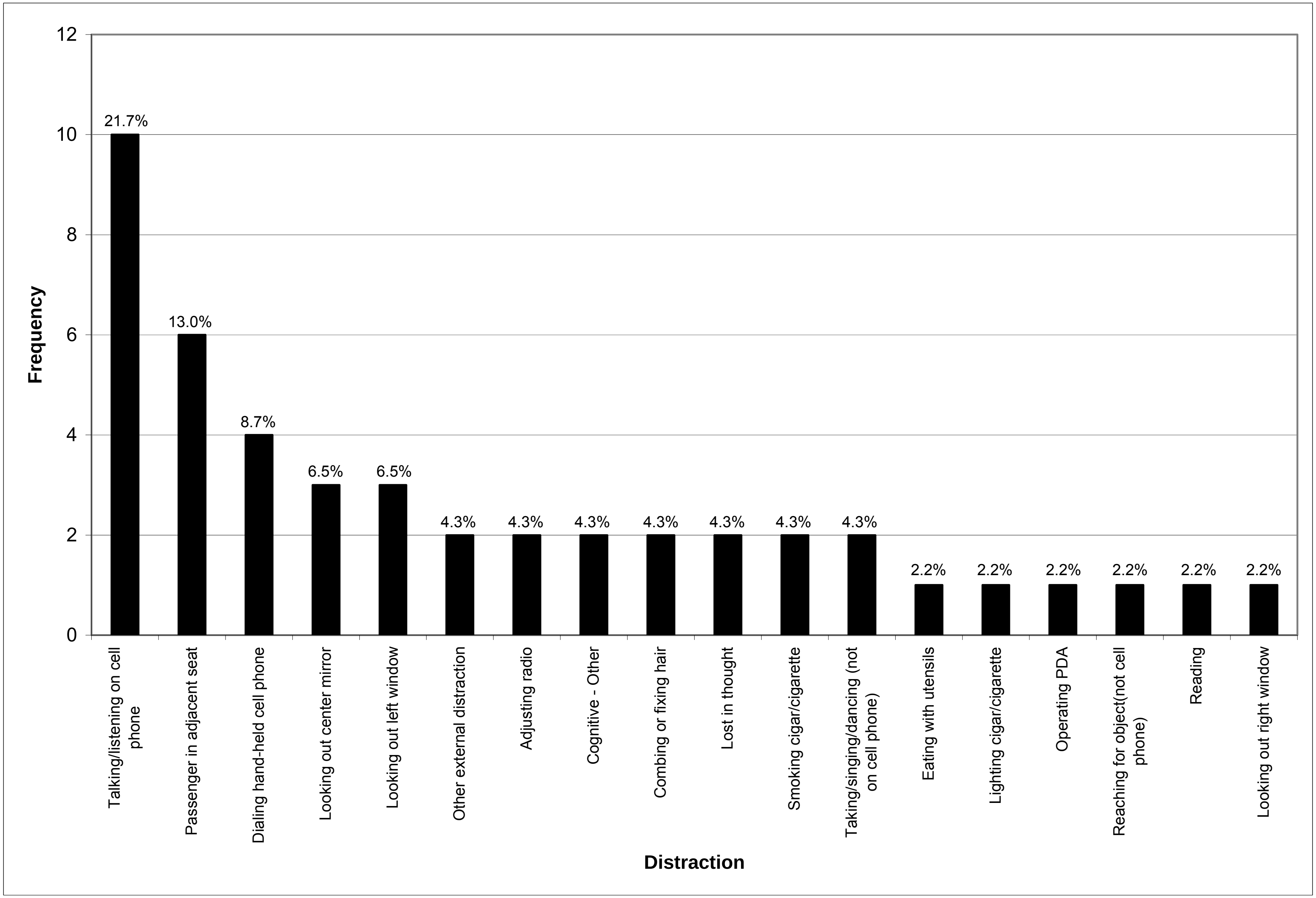


Figure 27. Frequency of the Distraction Contributing Factor in Each Sub-Category.

Table 23 shows the frequency, percentage, and rank ordering for each sub-category in the Distraction Contributing Factor for HV driver at-fault incidents. As can be seen in Table 23, the most frequent Distractions for HV at-fault incidents were Talking/Listening on Cell Phone (22.2%), Combing or Fixing Hair (22.2%), Dialing Hand-Held Cell Phone (22.2%), and Passenger in Adjacent Seat (22.2%).

Table 23. Frequency, Percentage, and Rank Ordering of Each Sub-Category in the Distraction Contributing Factor for the HV At-Fault Incidents (n = 9).

Distraction	Frequency of Distractions in HV At-Fault Incidents	Percentage of Distractions in HV At-Fault Incidents	Combined Rank of Distractions in HV At-Fault Incidents
Talking/listening on cell phone	2	22.2%	2.5
Combing or fixing hair	2	22.2%	2.5
Dialing hand-held cell phone	2	22.2%	2.5
Passenger in adjacent seat	2	22.2%	2.5
Lost in thought	1	11.1%	5

Table 24 shows the frequency, percentage, and rank ordering for each sub-category in the Distraction Contributing Factor for LV driver at-fault incidents. As can be seen in the table, the most frequent Distractions for LV at-fault incidents were Talking/Listening on Cell Phone (19.4%) and Passenger in Adjacent Seat (12.9%).

Table 24. Frequency, Percentage, and Rank Ordering of Each Sub-Category in the Distraction Contributing Factor for the LV At-Fault Incidents (n = 31).

Distraction	Frequency of Distractions in LV At-Fault Incidents	Percentage of Distractions in LV At-Fault Incidents	Combined Rank of Distractions in LV At-Fault Incidents
Talking/listening on cell phone	6	19.4%	1
Passenger in adjacent seat	4	12.9%	2
Looking out center mirror	3	9.7%	3.5
Looking out left window	3	9.7%	3.5
Other external distraction	2	6.5%	7
Dialing hand-held cell phone	2	6.5%	7
Adjusting radio	2	6.5%	7
Smoking cigar/cigarette	2	6.5%	7
Cognitive - Other	2	6.5%	7
Lost in thought	1	3.2%	12
Eating with utensils	1	3.2%	12
Lighting cigar/cigarette	1	3.2%	12
Reaching for object (not cell phone)	1	3.2%	12
Talking/singing/dancing (not on phone)	1	3.2%	12

Table 25 shows the frequency, percentage, and rank ordering for each sub-category in the Distraction Contributing Factor for the Unknown driver at-fault incidents. As can be seen in Table 25, the most frequent Distraction for Unknown at-fault incidents was Talking/Listening on Cell Phone (33.3%).

Table 25. Frequency, Percentage, and Rank Ordering of Each Sub-Category in the Distraction Contributing Factor for the Unknown At-Fault Incidents (n = 6).

Distraction	Frequency of Distractions in Unknown At-Fault Incidents	Percentage of Distractions in Unknown At-Fault Incidents	Combined Rank of Distractions in Unknown At-Fault Incidents
Talking/listening on cell phone	2	33.3%	1
Talking/singing/dancing	1	16.7%	3.5
Operating PDA	1	16.7%	3.5
Reading	1	16.7%	3.5
Right window	1	16.7%	3.5

Summary of Driver Distraction

Overall, Distraction was cited in 18.7% of the LV-HV interaction incidents (see Figure 17). This is higher than what Stutts et al. (2003) found when they reviewed the U.S. Crashworthiness Data System (CDS) from 1995-1999. Stutts et al. (2003) found that 8.3% of drivers involved in a fatal LV-HV interaction crash were identified as "Distracted" in the CDS database. Similarly, Stuster (1999) found that 8.7% of the LV drivers were cited with the driver-related factor "Driving Inattentively." It should be noted that Stuster (1999) only listed the twelve most frequent driver-related factors. Thus, the percentage noted may be incomplete as it only refers to driving inattentively. Hanowski, Olson, Perez, and Dingus (2001) assessed the occurrence of "driver distraction" as a contributing factor in a naturalistic study using long-haul drivers. A total of 2,737 critical incidents were recorded in the Sleeper Berth study. Of these, 178 (6.5%) had "driver distraction" as a contributing factor. As such, there was a considerably higher percentage of "driver distraction" related incidents in the current study as compared to previous studies.

As seen in Figure 17, the Distraction Contributing Factor was divided into discrete sub-categories. When Stutts et al. (2003) assessed the CDS, they also divided the 8.3% of the "Distraction" crashes into more discrete sub-categories. They found that the most frequent distracter in the CDS involved an External Distraction (29.4%), followed by Adjusting Radio/Cassette/CD (11.4%) and Other Occupant (10.9%), respectively. The current research found very different results. For example, as shown in Table 24, External Distractions (summing Left Window, Right Window, Center Mirror, and Other External Distraction) accounted for only 19.5% of the distraction incidents for at-fault LV drivers.[5] Furthermore, Adjusting the Radio and Passenger in Adjacent Seat only accounted for 6.5% and 12.9% of the distraction incidents for LV at-fault drivers, respectively.

The most frequent sub-category for the Distraction Contributing Factor for LV at-fault incidents in current research was Talking/Listening on Cell Phone (19.4%), followed by Passenger in Adjacent Seat (12.9%) and Looking Out Center Mirror (9.7%), and Looking Out Left Window (9.7%). Stutts et al. (2003) found that Using/Dialing Phone was cited in only 1.5% of the distraction crashes, while Other Occupant (similar to Passenger in Adjacent Seat in the current research) was cited in 10.9% of the distraction crashes. Note that Stutts et al. (2003) include both talking/listening and dialing phones in their definition of phone use.

Again, these differences might highlight the discrepancy between crashes and near crashes and/or the methodologies used to obtain the data. Another likely reason for the discrepancy is that the Stutts et al. study used crash data from 1995-1999. There is little doubt that the number of cell phones in use has increased substantially from the time period of 1995-1999, as compared to 2003-2004, when the current data were collected. In addition, in many states, PARs have not been developed to account for cell phone use (Wierwille et al., 2002) and this may have also contributed to the lower percentage found in the Stutts et al. (2003) research.

[5] Only LV at-fault incidents were considered because only the LV drivers had instrumented vehicles.

CLASSIFICATION STRATEGY USED IN THE LTCCS

Accident Types

Each of the 246 LV-HV interactions were grouped by Accident Type based on the methodology used in the LTCCS (Thieriez, Radja, and Toth, 2002). Note that there was only one LV-HV crash recorded in the 100-Car Study. Therefore, using the Accident Types from the LTCCS does not reflect an absolute match, but rather a relative match. However, to facilitate future data comparisons with the near-crash data collected in the current study with other studies using the LTCCS, each of the 246 LV-HV interactions were coded using the LTCCS classification scheme. Because only one crash occurred, the closest match with respect to Accident Types was recorded for each incident. Table 26 shows the LTCCS Accident Type descriptions.

Table 26. Description of the LTCCS Accident Types (Thieriez, Radja, and Toth, 2002).

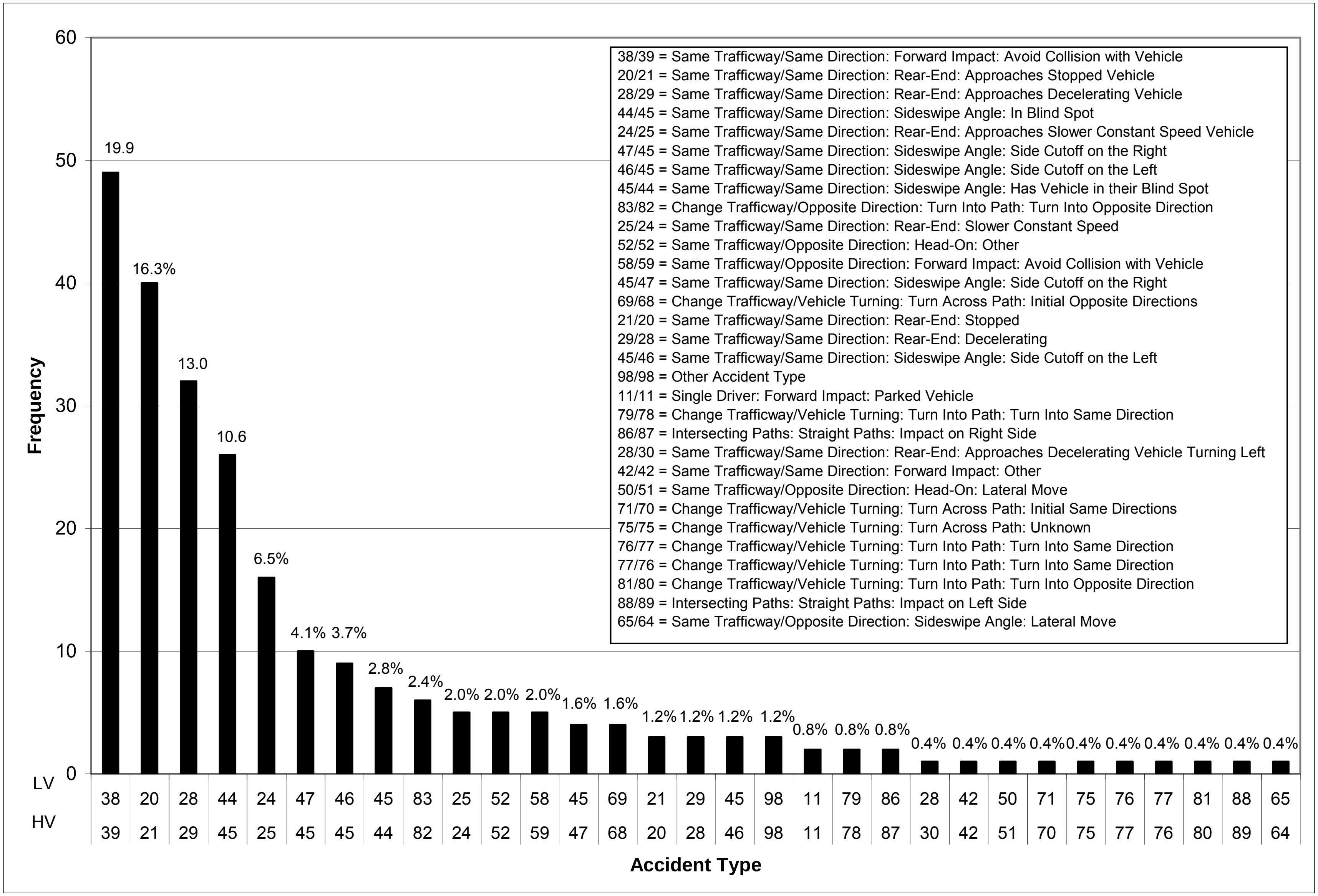
Category	Configuration	ACCIDENT TYPES (Includes Intent)					
I. Single Driver	A. Right Roadside Departure	01 DRIVE OFF ROAD	02 CONTROL/ TRACTION LOSS	03 AVOID COLLISION WITH VEH., PED., ANIM.		04 SPECIFICS OTHER	05 SPECIFICS UNKNOWN
	B. Left Roadside Departure	06 DRIVE OFF ROAD	07 CONTROL/ TRACTION LOSS	08 AVOID COLLISION WITH VEH., PED., ANIM.		09 SPECIFICS OTHER	10 SPECIFICS UNKNOWN
	C. Forward Impact	11 PARKED VEHICLE	12 STATIONARY OBJECT	13 PEDESTRIAN/ ANIMAL	14 END DEPARTURE	15 SPECIFICS OTHER	16 SPECIFICS UNKNOWN
II. Same Trafficway Same Direction	D. Rear-End	20; 22, 21, 23 STOPPED 21, 22, 23	24; 26, 25, 27 SLOWER 25, 26, 27	28; 30, 29, 31 DECELERATING 29, 30, 31		(EACH - 32) SPECIFICS OTHER	(EACH - 33) SPECIFICS UNKNOWN
	E. Forward Impact	34, 35 CONTROL/ TRACTION LOSS	36, 37 CONTROL/ TRACTION LOSS	38, 39 AVOID COLLISION WITH VEHICLE	40, 41 AVOID COLLISION WITH OBJECT	(EACH - 42) SPECIFICS OTHER	(EACH - 43) SPECIFICS UNKNOWN
	F. Sideswipe Angle	44, 45	46, 45, 47			(EACH - 48) SPECIFICS OTHER	(EACH - 49) SPECIFICS UNKNOWN
III. Same Trafficway Opposite Direction	G. Head-On	50, 51 LATERAL MOVE				(EACH - 52) SPECIFICS OTHER	(EACH - 53) SPECIFICS UNKNOWN
	H. Forward Impact	54, 55 CONTROL/ TRACTION LOSS	56, 57 CONTROL/ TRACTION LOSS	58, 59 AVOID COLLISION WITH VEHICLE	60, 61 AVOID COLLISION WITH OBJECT	(EACH - 62) SPECIFICS OTHER	(EACH - 63) SPECIFICS UNKNOWN
	I. Sideswipe/ Angle	64, 65 LATERAL MOVE				(EACH - 66) SPECIFICS OTHER	(EACH - 67) SPECIFICS UNKNOWN
IV. Change Trafficway Vehicle Turning	J. Turn Across Path	68, 69 INITIAL OPPOSITE DIRECTIONS	70, 71, 73, 72 INITIAL SAME DIRECTION			(EACH - 74) SPECIFICS OTHER	(EACH - 75) SPECIFICS UNKNOWN
	K. Turn Into Path	77, 76, 79, 78 TURN INTO SAME DIRECTION	80, 81, 83, 82 TURN INTO OPPOSITE DIRECTIONS			(EACH - 84) SPECIFICS OTHER	(EACH - 85) SPECIFICS UNKNOWN
V. Intersecting Paths (Vehicle Damage)	L. Straight Paths	87, 86	88, 89			(EACH - 90) SPECIFICS OTHER	(EACH - 91) SPECIFICS UNKNOWN
VI. Miscellaneous	M. Backing Etc.	92 BACKING VEHICLE	93 OTHER VEHICLE OR OBJECT			98 OTHER ACCIDENT TYPE 99 UNKNOWN ACCIDENT TYPE 00 NO IMPACT	

Table 27 shows the frequency, percentage, and rank ordering for the Accident Types across the entire data set. As can be seen, the most commonly occurring Accident Type that involved an interaction between a LV and HV was Scenario 38/39: Same Trafficway Same Direction, Forward Impact, Avoid Collision With Vehicle. Again, it is important to note that the Accident Types listed above in Table 26 were intended to be used for crashes and not for near crashes. Since this was the case, a "what if" approach was taken where data analysts coded the Accident Type to reflect what would likely have occurred had there been a crash. Thus, because of this subjective interpretation, not all events fit neatly into a category. As such, the results from the Accident Type categorization are not as "clean" as those from the Incident Type categories used in Hanowski, Keisler, and Wierwille (2004). Figure 28 shows a bar graph of the 246 incidents as a function of Accident Type.

Table 27. Frequency, Percentage, and Rank Ordering of the LTCCS Accident Types Across the Entire Data Set (N_{Total} = 246).

LV Accident Type	HV Accident Type	Accident Type Description	Frequency of Accident Types (N_{Total} = 246)	Percentage of Accident Types (N_{Total} = 246)	Combined Rank of Accident Types
38	39	Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle	49	19.9%	1
20	21	Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle	40	16.3%	2
28	29	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle	32	13.0%	3
44	45	Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot	26	10.6%	4
24	25	Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed	16	6.5%	5
47	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Right	10	4.1%	6
46	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	9	3.7%	7
45	44	Same Trafficway/Same Direction: Sideswipe Angle: Has Vehicle in their Blind	7	2.8%	8
83	82	Change Trafficway/Opposite Direction: Turn Into Path: Turn Into Opposite Direction	6	2.4%	9
25	24	Same Trafficway/Same Direction: Rear-End: Slower Constant Speed	5	2.0%	11
52	52	Same Trafficway/Opposite Direction: Head-On: Other	5	2.0%	11
58	59	Same Trafficway/Opposite Direction: Forward Impact: Avoid Collision with	5	2.0%	11
45	47	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Right	4	1.6%	13.5
69	68	Change Trafficway/Vehicle Turning: Turn Across Path: Initial Opposite Directions	4	1.6%	13.5
21	20	Same Trafficway/Same Direction: Rear-End: Stopped	3	1.2%	16.5
29	28	Same Trafficway/Same Direction: Rear-End: Decelerating	3	1.2%	16.5

LV Accident Type	HV Accident Type	Accident Type Description	Frequency of Accident Types (N_{Total} = 246)	Percentage of Accident Types (N_{Total} = 246)	Combined Rank of Accident Types
45	46	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	3	1.2%	16.5
98	98	Other Accident Type	3	1.2%	16.5
11	11	Single Driver: Forward Impact: Parked Vehicle	2	0.8%	20
79	78	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	2	0.8%	20
86	87	Intersecting Paths: Straight Paths: Impact on Right Side	2	0.8%	20
28	30	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle Turning Left	1	0.4%	26.5
42	42	Same Trafficway/Same Direction: Forward Impact: Other	1	0.4%	26.5
50	51	Same Trafficway/Opposite Direction: Head-On: Lateral Move	1	0.4%	26.5
71	70	Change Trafficway/Vehicle Turning: Turn Across Path: Initial Same Directions	1	0.4%	26.5
75	75	Change Trafficway/Vehicle Turning: Turn Across Path: Unknown	1	0.4%	26.5
76	77	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	1	0.4%	26.5
77	76	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	1	0.4%	26.5
81	80	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Opposite Direction	1	0.4%	26.5
88	89	Intersecting Paths: Straight Paths: Impact on Left Side	1	0.4%	26.5
65	64	Same Trafficway/Opposite Direction: Sideswipe Angle: Lateral Move	1	0.4%	26.5



LV	38	20	28	44	24	47	46	45	83	25	52	58	45	69	21	29	45	98	11	79	86	28	42	50	71	75	76	77	81	88	65
HV	39	21	29	45	25	45	45	44	82	24	52	59	47	68	20	28	46	98	11	78	87	30	42	51	70	75	77	76	80	89	64

Figure 28. Frequency of Accident Types Across the Entire Data Set (N_{Total} = 246).

Table 28 illustrates the frequency, percentage, and rank ordering of the Accident Types for HV driver at-fault incidents. The most frequent Accident Type for the HV driver at-fault incidents was Scenario 44/45: Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot (27.8%), followed by Scenarios 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (15.2%) and 25/25: Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed Vehicle (8.9%). Figure 29 shows a bar graph of the 79 HV driver at-fault incidents as a function of the Accident Type.

Table 28. Frequency, Percentage, and Rank Ordering of the Accident Types for HV Driver At-Fault Incidents (n_{HV} = 79).

LV Accident Type	HV Accident Type	Accident Type Description	Frequency of HV Driver At-Fault Incidents (n_{HV}= 79)	Percentage of HV Driver At-Fault Incidents (n_{HV}= 79)	Combined Rank of HV Driver At-Fault Incidents
44	45	Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot	22	27.8%	1
38	39	Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle	12	15.2%	2
24	25	Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed Vehicle	7	8.9%	3
83	82	Change Trafficway/Opposite Direction: Turn Into Path: Turn Into Opposite Direction	5	6.3%	4
45	44	Same Trafficway/Same Direction: Sideswipe Angle: Has Vehicle in their Blind Spot	4	5.1%	5.5
69	68	Change Trafficway/Vehicle Turning: Turn Across Path: Initial Opposite Directions	4	5.1%	5.5
28	29	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle	3	3.8%	7.5
45	46	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	3	3.8%	7.5
20	21	Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle	2	2.5%	10
45	47	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Right	2	2.5%	10
46	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	2	2.5%	10
79	78	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	2	2.5%	10
11	11	Single Driver: Forward Impact: Parked Vehicle	1	1.3%	18
21	20	Same Trafficway/Same Direction: Rear-End: Stopped	1	1.3%	18
29	28	Same Trafficway/Same Direction: Rear-End: Decelerating	1	1.3%	18
50	51	Same Trafficway/Opposite Direction: Head-On: Lateral Move	1	1.3%	18
58	59	Same Trafficway/Opposite Direction: Forward Impact: Avoid Collision with Vehicle	1	1.3%	18
71	70	Change Trafficway/Vehicle Turning: Turn Across Path: Initial Same Directions	1	1.3%	18
77	76	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	1	1.3%	18
81	80	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Opposite Direction	1	1.3%	18
86	87	Intersecting Paths: Straight Paths: Impact on Right Side	1	1.3%	18
88	89	Intersecting Paths: Straight Paths: Impact on Left Side	1	1.3%	18
98	98	Other Accident Type	1	1.3%	18

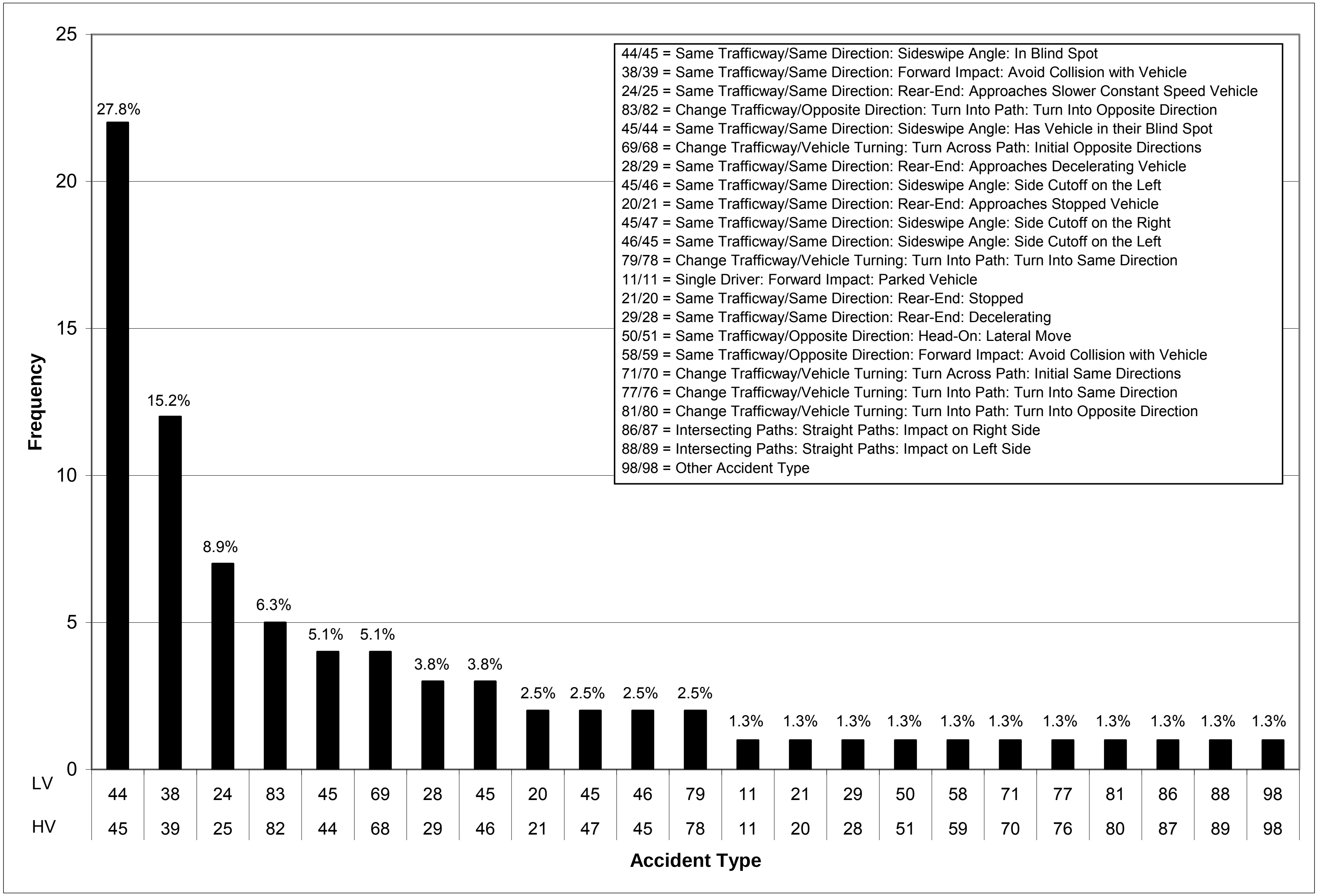


Figure 29. Frequency of Accident Types for HV Driver At-Fault Incidents (n_{HV} = 79).

Table 29 illustrates the frequency, percentage, and rank ordering of the Accident Types for LV driver at-fault incidents. The most frequent Accident Types for HV driver at-fault incidents was Scenario 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle (26.8%), followed by Scenarios 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (22.5%) and 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle (17.4%). Figure 30 shows a bar graph of the 138 LV driver at-fault incidents as a function of the Accident Type.

Table 29. Frequency, Percentage, and Rank Ordering of the Accident Types for LV Driver At-Fault Incidents (n_{LV} = 138).

LV Accident Type	HV Accident Type	Accident Type Description	Frequency of LV Driver At-Fault Incidents (n_{LV}= 138)	Percentage of LV Driver At-Fault Incidents (n_{LV}= 138)	Combined Rank of LV Driver At-Fault Incidents
20	21	Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle	37	26.8%	1
38	39	Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle	31	22.5%	2
28	29	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle	24	17.4%	3
47	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Right	10	7.2%	4
24	25	Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed Vehicle	8	5.8%	5
46	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	6	4.3%	6
25	24	Same Trafficway/Same Direction: Rear-End: Slower Constant Speed	3	2.2%	8
44	45	Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot	3	2.2%	8
58	59	Same Trafficway/Opposite Direction: Forward Impact: Avoid Collision with Vehicle	3	2.2%	8
29	28	Same Trafficway/Same Direction: Rear-End: Decelerating	2	1.4%	11
45	47	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Right	2	1.4%	11
52	52	Same Trafficway/Opposite Direction: Head-On: Other	2	1.4%	11
21	20	Same Trafficway/Same Direction: Rear-End: Stopped	1	0.7%	16
28	30	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle Turning	1	0.7%	16
45	44	Trafficway/Same Direction: Sideswipe Angle: Has Vehicle in their Blind Spot	1	0.7%	16
65	64	Same Trafficway/Opposite Direction: Sideswipe Angle: Lateral Move	1	0.7%	16
75	75	Change Trafficway/Vehicle Turning: Turn Across Path: Unknown	1	0.7%	16
76	77	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	1	0.7%	16
98	98	Other Accident Type	1	0.7%	16

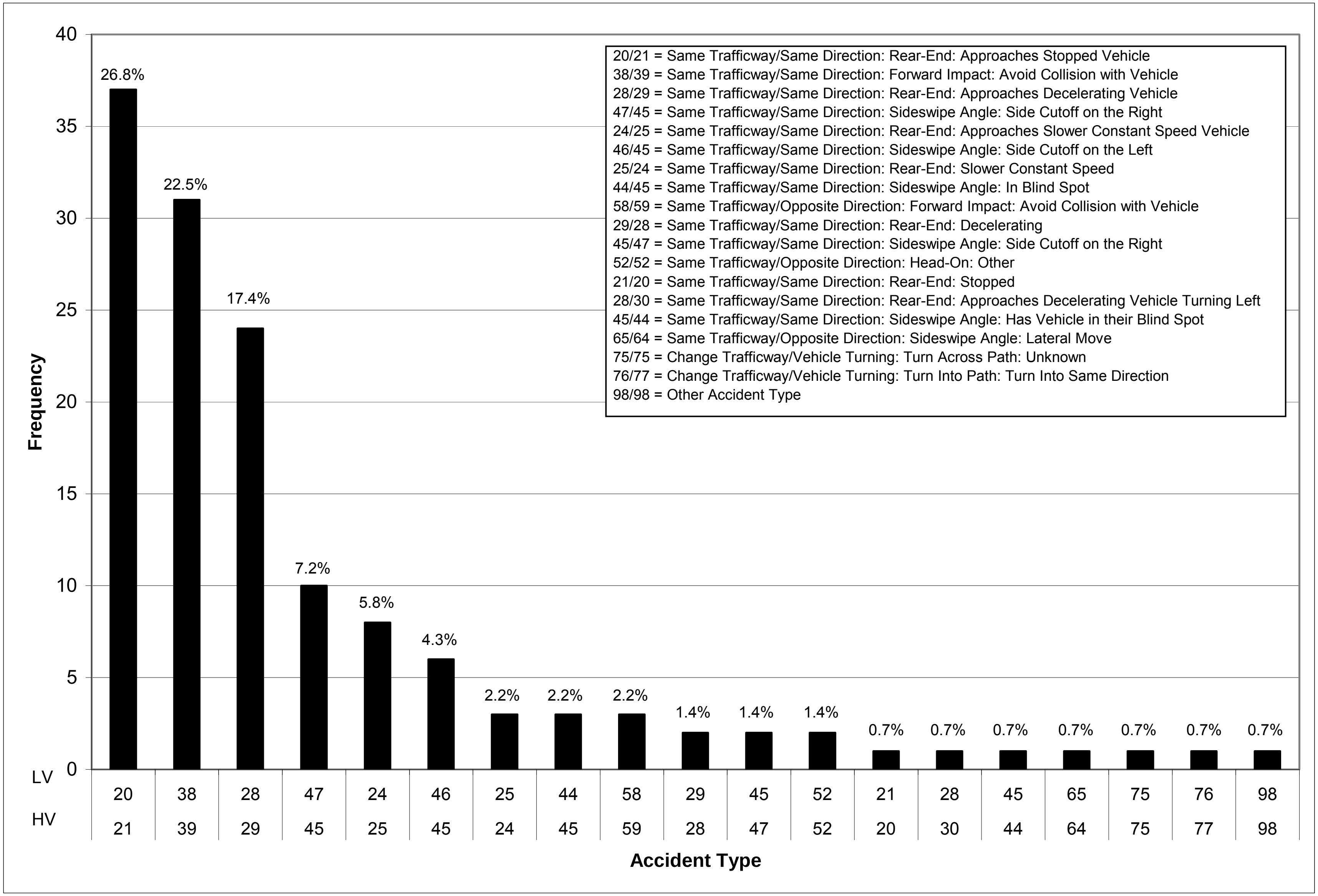


Figure 30. Frequency of Accident Types for LV driver At-Fault Incidents (n_{LV} = 138).

Table 30 shows the frequency, percentage, and rank ordering of the Accident Types for Unknown driver at-fault incidents. The most frequent Accident Type for the Unknown Accident Types was Scenario 38/39: Same Trafficway Same Direction; Forward Impact, Avoid Collision With Vehicle (20.7%); followed by Scenarios 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle (17.2%) and 52/52: Same Trafficway/Opposite Direction: Head-On: Other (10.3%). Figure 31 shows a bar graph of the 29 Unknown at-fault incidents as a function of the Accident Type.

Table 30. Frequency, Percentage, and Rank Ordering of the Accident Types Where It was Unknown if the LV or the HV driver was At-Fault (n_{Un} = 29).

LV Accident Type	HV Accident Type	Accident Type Description	Frequency of Unknown At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown At-Fault Incidents (n_{Un} = 29)	Combined Rank of Unknown At-Fault Incidents
38	39	Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle	6	20.7%	1
28	29	Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle	5	17.2%	2
52	52	Same Trafficway/Opposite Direction: Head-On: Other	3	10.3%	3
45	44	Same Trafficway/Same Direction: Sideswipe Angle: Has Vehicle in their Blind	2	6.9%	4
11	11	Single Driver: Forward Impact: Parked Vehicle	1	3.4%	11
20	21	Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle	1	3.4%	11
21	20	Same Trafficway/Same Direction: Rear-End: Stopped	1	3.4%	11
24	25	Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed	1	3.4%	11
25	24	Same Trafficway/Same Direction: Rear-End: Slower Constant Speed	1	3.4%	11
42	42	Same Trafficway/Same Direction: Forward Impact: Other	1	3.4%	11
44	45	Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot	1	3.4%	11
46	45	Same Trafficway/Same Direction: Sideswipe Angle: Side Cutoff on the Left	1	3.4%	11
58	59	Same Trafficway/Opposite Direction: Forward Impact: Avoid Collision with	1	3.4%	11
79	78	Change Trafficway/Vehicle Turning: Turn Into Path: Turn Into Same Direction	1	3.4%	11
83	82	Change Trafficway/Opposite Direction: Turn Into Path: Turn Into Opposite Direction	1	3.4%	11
86	87	Intersecting Paths: Straight Paths: Impact on Right Side	1	3.4%	11
98	98	Other Accident Type	1	3.4%	11

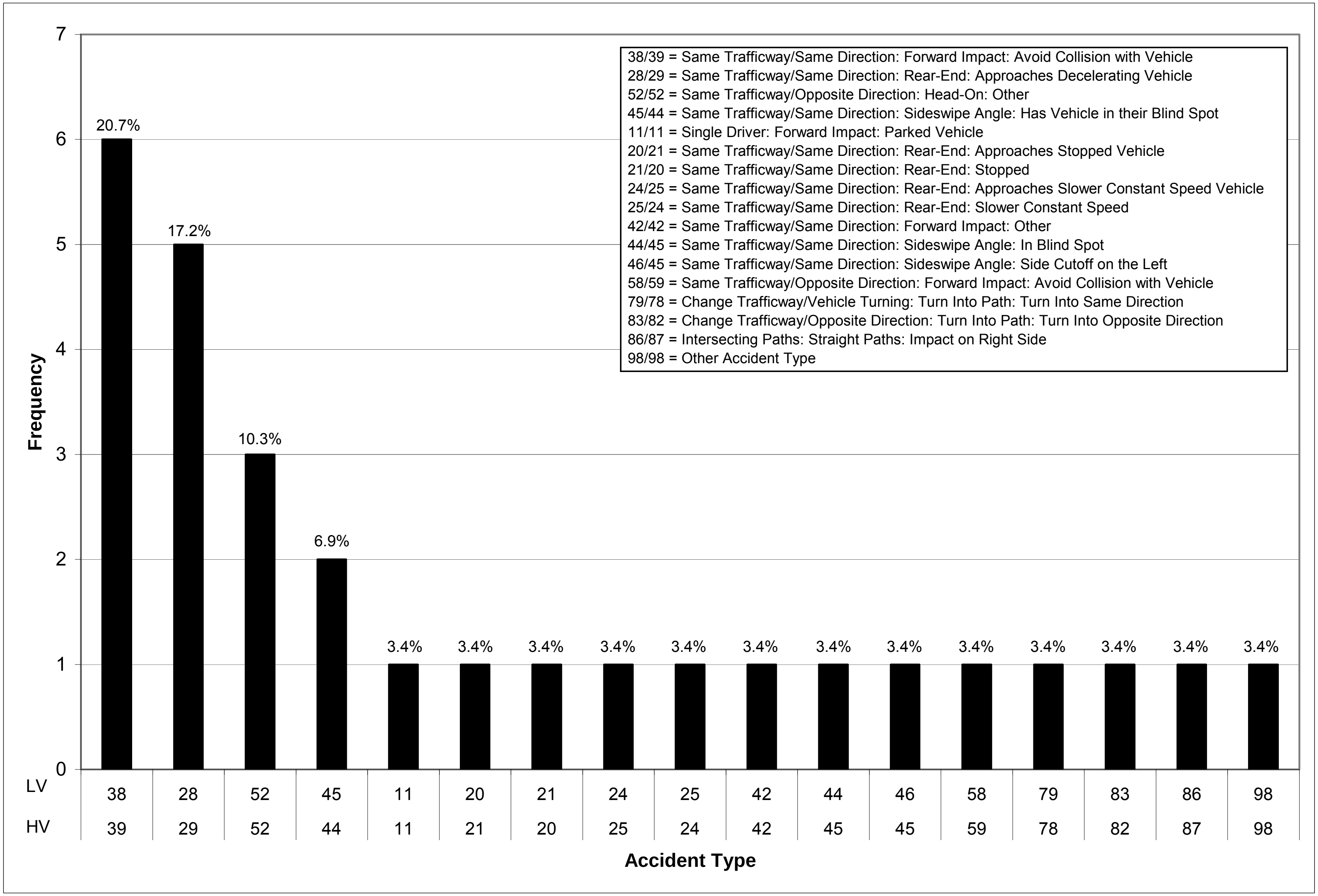


Figure 31. Frequency of Accident Types for Unknown At-Fault Incidents (n_{Un} = 29).

Figure 32 shows a bar graph comparing the Accident Types, with respect to the driver that was assessed to have been at-fault, for the three groups (LV, HV, and Unknown). The figure shows that the Accident Types varied depending on whether the HV or LV driver was at fault. The most commonly occurring Accident Types were Scenarios 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle; 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle; 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle.

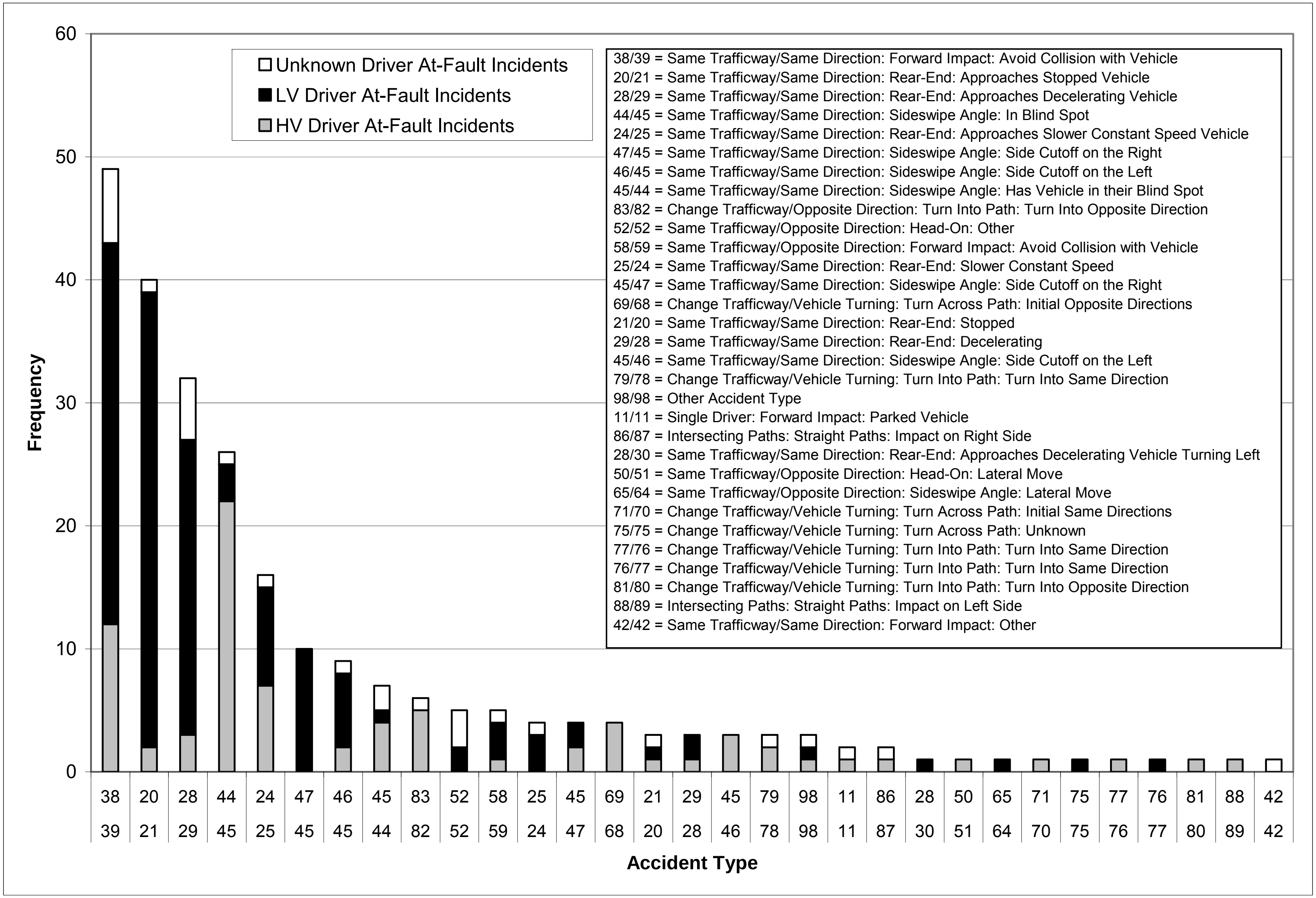


Figure 32. Frequency of Accident Types for HV, LV, and Unknown At-Fault Incidents (n_{HV} = 79, n_{LV} = 130, & n_{Un} = 29).

Accident Types Summary

Overall, the most frequent Accident Types were Scenarios 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (19.9%); 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle (16.3%); and 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle (13%). These three Accident Types represented 49.2% of the Accident Types for all LV-HV incidents.

As can be seen in Figure 32, the Accident Types for HV and LV driver at-fault incidents differed markedly. The most prevalent Accident Types for HV driver at-fault incidents were Scenarios 44/45: Same Trafficway/Same Direction: Sideswipe Angle: In Blind Spot (27.8%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (15.2%); and 25/25: Same Trafficway/Same Direction: Rear-End: Approaches Slower Constant Speed Vehicle (8.9%). These three Accident Types accounted for 51.9% of the HV driver at-fault incidents. The most prevalent Accident Types for LV driver at-fault incidents were Scenarios 20/21: Same Trafficway/Same Direction: Rear-End: Approaches Stopped Vehicle (26.8%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (22.5%); and 28/29: Same Trafficway/Same Direction: Rear-End: Approaches Decelerating Vehicle (17.4%). These three Accident Types accounted for 66.7% at the LV driver at-fault incidents.

Figure 32 highlights some of the differences between HV and LV driver at-fault incidents with respect to Accident Type. The most prevalent Accident Type for HV driver at-fault incidents involved a Sideswipe Angle. By summing all the HV driver at-fault Accident Types that involved a Sideswipe Angle, it was found that 41.8% of the HV driver at-fault incidents were coded with this Accident Type. Conversely, the most prevalent Accident Type for LV driver at-fault incidents involved a Rear-End Approach. By summing all LV driver at-fault Accident Types that involved a Rear-End approach, it was found that 55.1% of the LV driver at-fault incidents were coded with this Accident Type. Thus, most of the HV driver at-fault incidents involved a Sideswipe Angle, while most of the LV driver at-fault incident involved a Rear-End Approach.

These results are quite different than Blower's (1998) review of fatal LV-HV crashes. He found that 13.9% of fatal LV-HV interactions, where only the LV was coded with a driver-related factor, involved a rear-end approach. Further, Blower found that 9.4% of the fatal LV-HV interactions, where only the HV driver was coded with a driver-related factor, involved a sideswipe angle. Similarly, when Council et al. (2003) reviewed all types of LV-HV crashes in North Carolina, they found that 23.2% of the HV driver at-fault crashes involved a sideswipe and 28.5% of the LV driver at-fault crashes involved a rear-end approach. One possible reason for these discrepancies is due to the difference in the event types being classified; that is, non-crashes in the current study and fatal LV-HV crashes in Blower (1998) and all types of crashes in Council et al. (2003). Also, the driver/subject population that was included in the study was skewed towards high mileage and younger drivers, and this may also impacted the types of events that were recorded in this study.

Critical Reason for the Critical Event

To be consistent with the LTCCS (Thieriez, Radja, and Toth, 2002), the LV driver at-fault incidents were coded with a Critical Reason for the incident. The Critical Reason for the incident was considered the primary reason for *why* the incident occurred (as compared to the Contributing Factors where all the factors that contributed to the incident's occurrence were coded). More than one Critical Reason could be coded for each incident, but this was a rare occurrence (ten of the recorded incidents were coded with two Critical Reasons). Only the LV driver at-fault incidents were coded with a Critical Reason because, as noted previously, only those vehicles were equipped with video recording equipment. For the HV driver at-fault incidents, it was not possible to determine with any certainty what the driver was doing that contributed to the event; therefore, all HV driver at-fault incidents were coded as "Unknown reason for the critical event."

Table 31 shows the frequency, percentage, and rank ordering of the Critical Reasons for LV driver at-fault incidents. The most frequent Critical Reason for the LV driver at-fault incidents was Aggressive Driving Behavior (24.6%), followed by Too Fast for Conditions (15.2%) and Internal Distraction (13.8%). As in the previous analysis to determine the Contributing Factors (Chapter 1), more than one Critical Reason could be coded to a particular incident, thus, the percentage total is greater than 100%. Figure 33 shows a bar graph of the 138 LV driver at-fault crashes as a function of the Critical Reason.

Table 31. Frequency, Percentage, and Rank Ordering of the Critical Reasons for LV Driver At-Fault Incidents (n_{LV} = 138).

Critical Reason for the Critical Event	Frequency of LV Driver At-Fault Incidents (n_{LV} = 138)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 138)	Combined Rank of LV Driver At-Fault Incidents
Aggressive driving behavior	34	24.6%	1
Too fast for conditions	21	15.2%	2
Internal distraction	19	13.8%	3
Misjudgment of gap or other's speed	15	10.9%	4
Following too closely to respond to unexpected actions	10	7.2%	5.5
False assumption of other road user's actions	10	7.2%	5.5
Inadequate surveillance (e.g., failed to look)	9	6.5%	7
External distraction	7	5.1%	9.5
Inattention	5	3.6%	8
Sleep or asleep	5	3.6%	9.5
Other recognition error	3	2.2%	11
Glare	2	1.4%	12.5
Illegal Maneuver	2	1.4%	12.5
Blowing debris	1	0.7%	16.5
Overcompensation	1	0.7%	16.5
Poor directional control	1	0.7%	16.5
Other performance error	1	0.7%	16.5
Unknown decision error	1	0.7%	16.5
Unknown recognition error	1	0.7%	16.5

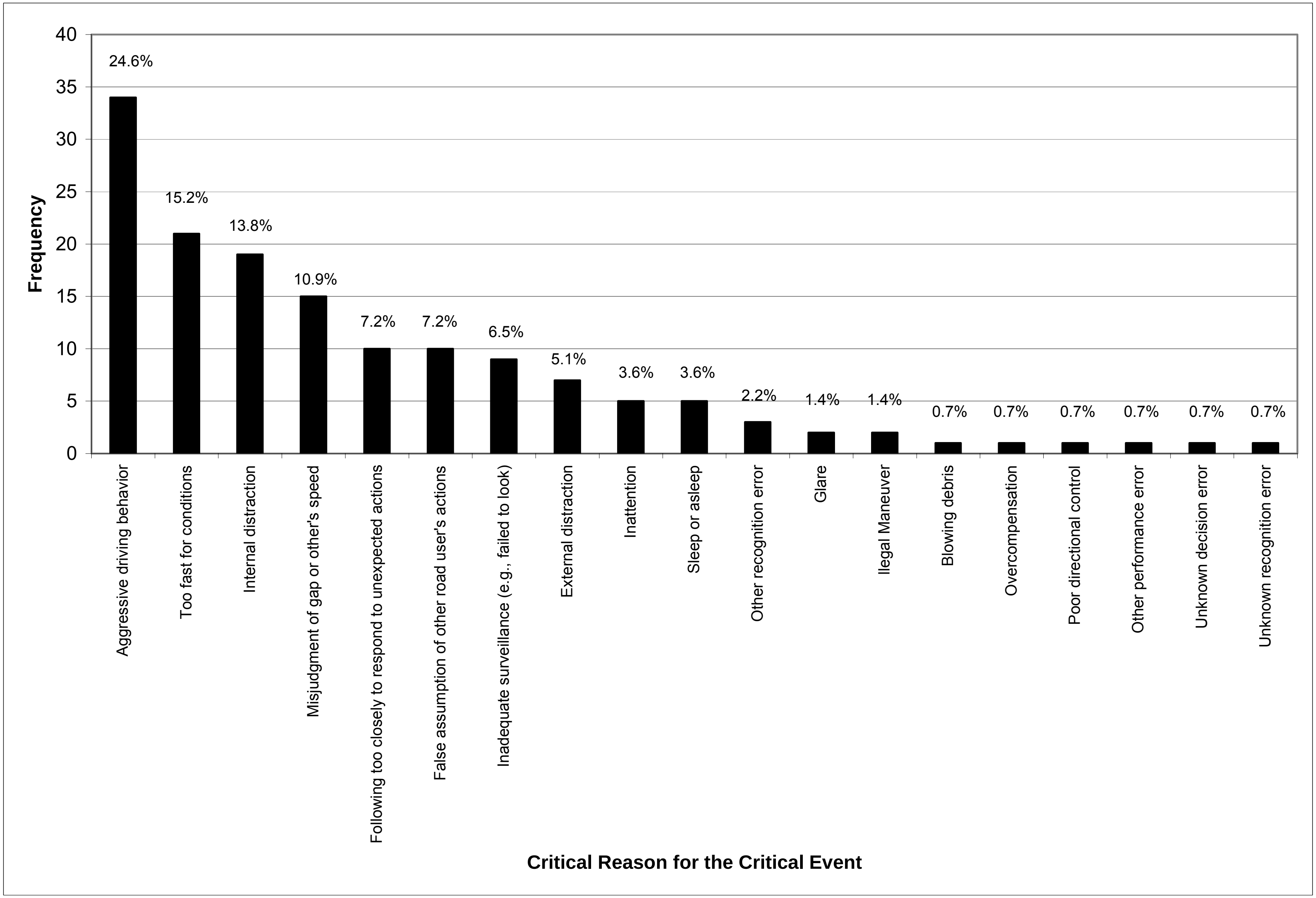


Figure 33. Frequency of Critical Reasons for LV Driver At-Fault Incidents (n_{LV} = 138)

Critical Reasons X Incident Type Summary

Table 32 illustrates the frequency of LV driver at-fault incidents by Incident Type as well as Critical Reason. Table 32 provides a more descriptive and comprehensive illustration of the Critical Reasons for each Incident Type. The Incident Types were chosen, rather than the Accident Types, because, based on the results shown previously, they seen to be more appropriate for classifying near-crashes and incidents. The far left column of Table 32 lists the Incident Types while the Critical Reasons are listed in the first row. As indicated above, more than one Critical Reason could be coded to each incident, thus, there are 147 Critical Reasons coded to 138 LV driver at-fault incidents.

As can be seen, the most frequent Critical Reasons for the Late Braking for Stopped/Stopping Traffic Incident Type was Internal Distraction (n =11) and Too Fast for Conditions (n = 8). The Internal Distraction and Too Fast For Conditions Critical Reasons were coded in 19.3% and 14% LV at-fault Late Braking for Stopped/Stopping Traffic Incident Types, respectively. The most frequent Critical Reasons for the Lane Change Without Sufficient Gap Incident Types were Aggressive Driving (n = 16) and Too Fast for Conditions (n = 6). The Aggressive Driving and Lane Change Without Sufficient Gap Critical Reasons were coded in 53.3% and 20% of the LV at-fault Lane Change Without Sufficient Gap Incident Types, respectively.

Table 32. Frequency of Incident Types X Critical Reasons for LV Driver At-Fault Incidents (n_{LV} = 138).

Incident Type / *Critical Reason*	Sleep or asleep	Inattention	Internal distraction	External distraction	Inadequate surveillance (e.g., failed to look)	Unknown recognition error	Too fast for conditions	Misjudgment of gap	Following too closely to respond to unexpected actions	False assumption of other road user's actions	Aggressive driving behavior	Overcompensation	Glare	Illegal Maneuver	Poor Directional Control	Other Performance Error	Other Recognition Error	Unknown Decision Error	Blowing Debris	**Total**
Aborted Lane Change	0	0	1	0	3	0	1	3	0	1	2	0	0	0	0	0	0	0	0	**11**
Approaches Traffic Quickly	0	0	1	0	0	0	1	1	0	2	1	0	0	0	0	0	0	0	0	**6**
Conflict With Oncoming Traffic	0	1	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	**4**
Following Too Closely	0	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**4**
Improper Lane Change	0	0	0	0	1	0	0	2	0	0	1	0	0	1	0	0	0	0	0	**5**
Improper Passing	1	0	0	0	0	0	2	0	0	0	6	0	0	0	0	0	0	1	0	**10**
Improper Stopping at an Intersection	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Lane Change Without Sufficient Gap	0	0	3	0	2	1	6	2	1	0	16	1	1	1	0	0	0	0	1	**35**
Late Braking for Stopped/Stopping Traffic	2	2	11	7	3	0	8	5	7	6	3	0	1	0	0	1	3	0	0	**59**
Lateral Deviation of Through Vehicle	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	**3**
Merge Without Sufficient Gap	2	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	**5**
Roadway Entrance Without Clearance	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	**2**
School Bus Passing Violation	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Total	**5**	**5**	**19**	**7**	**9**	**1**	**21**	**15**	**10**	**10**	**34**	**1**	**2**	**2**	**1**	**1**	**3**	**1**	**1**	**148**

Critical Reason Summary

The most frequent Critical Reasons for LV driver at-fault incidents were Aggressive Driving Behavior (24.6%), Too Fast for Conditions (15.2%), and Internal Distraction (13.8%). These were markedly different than what Blower (1998) found when he assessed fatal LV-HV interactions. For incidents where only the LV driver was cited with a driver-related factor, Blower (1998) found that only 7.1% of the incidents were coded with the Aggressive Driving Critical Reason, while 19.2% and 0.11% of the incidents were coded with Too Fast for Conditions and Internal Distraction, respectively.

There were other interesting trends in the current data set. Sixty-four of the 138 LV at-fault incidents (46.4%) were coded with at least one Critical Reason that was a risky driving behavior (i.e., Aggressive Driving Behavior, Too Fast for Conditions, Following too Closely, and Illegal Maneuver), while 22.5% of the LV driver at-fault incidents involved some type of awareness variable (i.e., Internal Distraction, Inattention, External Distraction). In comparison, Stuster's (1999) analysis of fatal LV-HV crashes found that 57.2% of the incidents involved the at-risk driving behaviors by LV drivers.[6] Stuster (1999) also found that 10.1% of fatal LV-HV crashes involved the LV driver driving inattentively.

CONCLUSIONS

The analyses that were conducted with the LV-HV interactions captured in the 100-Car Study (Dingus et al., 2004) provide convincing evidence to support the contention that LV-HV interactions are a serious problem. Consider that of the 9,125 critical incidents captured in the 100-Car Study, 246 LV-HV interactions were identified. Put another way, of the large critical incident data set that was obtained in the 100-Car Study, 2.7% of these incidents involved a LV-HV interaction. While 2.7% may appear to represent a small proportion of the overall critical incident picture, it should be noted that LV-HV interactions easily have the potential to become serious, and even fatal because of the tremendous difference in weight between an HV and LV.

There are seven important findings that stem from the analyses conducted on the interactions between HVs and LVs. First, of the 246 interactions that were analyzed, 138 (56.1%) were assessed to have been the fault of the LV driver. HV drivers were at-fault in 79 (32.1%) of the incidents, while in the remaining 29 (11.8%) incidents it was unknown if the HV or LV driver was at-fault. Excluding the incidents where it was unknown if the HV or LV driver was at-fault, 63.6% and 36.4% of the incidents were the fault of the LV and HV drivers, respectively. Thus, LV drivers were responsible for a significant proportion of the LV-HV interactions.

These findings support what the drivers in the Hanowski et al. (1998) focus groups reported about LVs being their most important safety concern. Further, the results are similar to prior published studies that used a crash database approach to assess LV-HV interactions (cf. Blower, 1998; Stuster, 1999; Wang, Knipling, and Blincoe, 1999). Based on these findings, it is suggested that focusing on the LV driver, and their errors, may provide the largest area of opportunity for reducing such events.

[6] It should be noted that Stuster (1999) only listed the twelve most frequent driver-related factors.

The second important finding from these analyses was in regard to the different Incident Types that were frequent among HV and LV drivers. For LV driver at-fault incidents, the most frequent Incident Types were: Late Braking for Stopped/Stopping Traffic (41.3%), Lane Change Without Sufficient Gap (21.7%), and Aborted Lane Change (8%). These particular Incident Types are indicative of at-risk driving behaviors. Once again, the objective data support the sentiment of the L/SH drivers in the Hanowski et al. (1998) focus group who indicated that during their daily travel they were often "cut-off" by LV drivers. And, the data supports the results from the L/SH on-road study (Hanowski, Keisler, and Wierwille, 2004) where the most prevalent Incident Type for LV driver at-fault incident was Lane Change Without Sufficient Gap (accounting for 24.8% of the LV driver at-fault incidents in the L/SH study). In contrast, the most frequent Incident Types for HV drivers were: Lane Change Without Sufficient Gap (26.6%), Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%). There were substantial differences in the most prevalent Incident Types as a function of driver group.

The third finding is the difference in the Primary Maneuvers for HV and LV drivers. The most prevalent Primary Maneuvers for LV driver at-fault incidents were: Braking (32.6%), Stopped (21.7%), and Changing Lanes (16.7%). The two most frequent Primary Maneuvers for LV driver at-fault incidents involved assumed difficulties on the part of the LV driver decelerating or stopping. In contrast, the most frequent Primary Maneuvers for HV driver at-fault incidents were: Changing Lanes (32.9%), Crosses Over Lane Line (20.3%), and Left Turn (15.2%). The two most frequent Primary Maneuvers for HV driver at-fault incidents involved difficulties changing or crossing over the lane line while the vehicle was in motion. These results make intuitive sense because HV drivers have limited visibility and deal with blind spots thereby making lane changes difficult in traffic.

It appears that the most frequent Primary Maneuvers for the HV drivers were fundamentally different than those of LV drivers. Whereas the HV drivers seemed to have difficulty changing lanes (which, it is assumed, reflects the inherent difficulty of driving with significant blind spots), LV drivers exhibited difficulties decelerating or stopping (which supports the findings that a significant proportion of the incidents involved a lack of attention and/or at-risk driving behaviors). Also, it is important to point out that there were few similarities in the Primary Maneuvers for LV and HV drivers. This highlights the fundamental differences in the characteristics of at-fault incidents by HV and LV drivers.

The fourth important finding is related to the Contributing Factors that were most frequent with HV and LV drivers. For LV drivers, the most frequent Contributing Factors for at-fault incidents were: Driving Techniques (70.3%), Distracted (22.5%), and Aggressive Driving (22.5%). The most frequent Contributing Factors for HV driver at-fault incidents were: Unknown (68.4%), Driving Techniques (15.2%), and Distracted (11.4%). The large number of Unknown Contributing Factors for HV driver at-fault incidents is indicative of the methodology used to code these events. Because the HV did not have any video cameras, the Contributing Factor was coded with respect to the behaviors of the LV driver. As the LV driver was not responsible for the incident, it was unlikely they would be coded with a Contributing Factor, thus the high frequency of Unknown Contributing Factors. Further, the methodology used to code the

Contributing Factors also explains the similarities between LVs and HVs (i.e., they were all coded with respect to the LV driver, and therefore, might be expected to be similar).

The fifth noteworthy finding from the current research involves the Accident Types that were most prevalent for LV and HV drivers. The most prevalent Accident Types for LV driver at-fault incidents were: Scenarios 20/21: Same Trafficway/Same Direction: Rear End: Approaches Stopped Vehicle (26.8%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (22.5%); and 28/29: Same Trafficway/Same Direction: Rear End: Approaches Decelerating Vehicle (17.4%). Approximately 55% of the LV driver at-fault incidents involved a Rear-End approach. These Accident Types also support the findings from the analysis of the most prevalent Primary Maneuvers for LV driver at-fault incidents: decelerating or stopped.

Conversely, the most prevalent Accident Types for HV driver at-fault incidents were: Scenarios 44/45: Same Trafficway/Same Direction: Forward Impact: Sideswipe Angle: In Blind Spot (27.7%); 38/39: Same Trafficway/Same Direction: Forward Impact: Avoid Collision with Vehicle (15.2%); and 25/25: Same Trafficway/Same Direction: Rear End: Approaches Constant Speed Vehicle (8.9%). Approximately 42% of the HV driver at-fault incidents involved a Sideswipe Angle. These Accident Types also support the findings from the most prevalent Primary Maneuvers for HV driver at-fault incidents: changing lanes and crossing the lane line.

The seventh noteworthy finding from the current research reflects some of the similarities and discrepancies found between the current study and prior studies using a crash database approach in analyzing LV-HV interactions. While both approaches found that LV drivers were responsible for the majority of LV-HV interactions, the reasons *why* these interactions occurred differed with respect to the methodologies used to assess these interactions. For example, the current research found that 22.5% of the LV driver at-fault incidents were cited with the Contributing Factors of Aggressive Driving. In Stuster's (1999) analysis, only 4.3% of the LVs were cited with the driver-related factor "Erratic/Reckless Driving." Moreover, Hankey et al. (1999) found that 31.1% of the fatal crashes in the FARS database were cited with Aggressive Driving. As such, the results from the current study (22.5%) are within the range reported by Stuster (4.3%) and Hankey (31.1%).

Table 33 compares the Critical Reasons for the LV at-fault incidents in the current study to the LV driver-related factors in the Blower (1998), Stuster (1999), and Council et al. (2003) studies. Although Table 33 provides a convenient way to compare the prior LV-HV interaction studies to the current study, the reader should be aware that there were significant differences in the data and classification strategy used in the different studies. For example, both Blower (1998) and Stuster (1999) assessed only fatal LV-HV crashes, and Council et al. (2003) assessed all types of LV-HV crashes (including fatal crashes). More than one driver-related factor could have been selected in the Blower (1998), Stuster (1999), and Council et al (2003) studies. Lastly, the Stuster (1999) study only reported the twelve most important (or frequent) driver-related factors.

Table 33. Comparison of a Selection of Results in the Current Study with Prior LV-HV Interaction Studies.

Condition	100-Car Study (Current Study)	Hanowski et al. (2004)	Blower (1998)	Stuster (1999)	Council et al. (2003)
LV At-Fault	56.1%	78.1%	70.3%	29%	40.2%
HV At-Fault	32.1%	21.9	16.2%	67%	48%
Distraction Incidents	22.4%	6.5%[7]	11.2%	8.7%[8]	N/A
Too Fast for Conditions Incidents	15.2%	N/A	20.3%	14.1%[9]	5.2% / 14.5%[9, 10]
Following Too Closely Incidents	7.2%	2.9%	3.4%[11]	2.7%	N/A
Aggressive Driving Incidents	24.6%	37%	7.1%[12]	4.3%[12]	N/A

The current research also found that 41.8% of the HV driver at-fault incidents involved a Sideswipe Angle, while 55.1% of the LV driver at-fault incidents involved a Rear End approach. These results differed from Blower's (1998) review of fatal LV-HV crashes. He found that 9.4% of fatal LV-HV interactions involved a sideswipe angle. Further, Blower's (1998) analysis found that 13.9% of the fatal LV-HV interactions involved a rear-end strike. When Council et al. (2003) reviewed all types of LV-HV crashes in North Carolina, they found that 23.2% of the HV driver at-fault crashes involved a sideswipe and 28.5% of the LV driver at-fault crashes involved a rear-end approach. These discrepancies might highlight the differences between analyzing crashes and near crashes and/or the methodologies used analyze the data (i.e., a crash database approach versus a naturalistic or *in situ* data collection approach, and the younger age bias in the current study).

[7] Only includes HV driver initiated events recorded in the Sleeper Berth study (Hanowski, Olson, Perez, and Dingus, 2001).
[8] Only includes driving inattentively.
[9] Called "Unsafe Speed" rather than Too Fast for Conditions in Stuster (1999) and Council et al. (2003).
[10] The first number indicates the percent of all LV-HV crashes, while the second number indicates the percent of fatal LV-HV crashes
[11] Called "Improper Following" rather than Following Too Closely in Blower (1998).
[12] Called "Erratic/Reckless Driving" in both Blower (1998) and Stuster (1999).

CHAPTER 2: COMPARISON OF THE RESULTS FROM THE ANALYSES CONDUCTED WITH THE 100-CAR DATA AND THE LOCAL/SHORT HAUL AND SLEEPER BERTH DATA

Recall in Chapter 1 that analyses were conducted with critical incident data that were collected during the 100-Car Study (Dingus et al., 2004). The method of analysis used in Chapter 1 is almost identical to the approach used in Hanowski, Keisler, and Wierwille (2004). The Hanowski, Keisler, and Wierwille (2004) study assessed LV-HV interactions from the perspective of local/short-haul (L/SH) and sleeper berth (SB) drivers. A total of 142 LV-HV interactions were identified in the L/SH study (see Hanowski, Wierwille, Garness, and Dingus, 2000, for a complete description of the L/SH study). Of these, 117 (82.4%) incidents were judged to have been the fault of the LV driver, while the remaining 25 (17.6%) incidents were the fault of the HV driver (remember that incidents in the L/SH and SB studies used “initiate” to indicate fault. From this point on, “at-fault” will be used rather than “initiate”).

In the SB study, a total of 68 LV-HV interactions were identified (see Dingus et al., 2002, for a complete description of the SB study). Of these, 47 (69.1%) were assessed to have been the fault of the LV driver, while the remaining 21 (38.9%) were the fault of the HV driver. Taken together with the current research, these three studies consistently show that LV drivers appear to be responsible for the majority of LV-HV interactions. Of the 427 LV-HV incidents identified across the three studies (excluding the 29 Unknown at-fault incidents in the current study), 302 (70.7%) were the fault of the LV driver, while the remaining 125 (29.3%) were the fault of the HV driver (a 2.4:1 ratio).

However, one of the weaknesses in the current study was the lack of instrumentation in HVs. Conversely, one of the weaknesses in the Hanowski, Keisler, and Wierwille (2004) study was the lack of instrumentation in LVs. Thus, by integrating the results from the present study with the results from the Hanowski, Keisler, and Wierwille (2004) study, it is believed that a more complete understanding of LV-HV interaction problem can be gained. Chapter 2 has two primary aims: combine the data from the current study with the data from the L/SH and SB studies in Hanowski, Keisler, and Wierwille (2004) to illustrate the overall LV-HV interaction picture, and address the limitation of having only one vehicle instrumented by assessing the differences between the three studies (i.e., are the recorded LV-HV interactions fundamentally different as a function of which vehicle is instrumented?).

INCIDENT TYPES

Table 34 illustrates the frequency, percentage, and rank ordering of Incident Types across all three studies. As can be seen in Table 34, there were a total of 456 LV-HV interactions across the three studies. The most frequent Incident Type was Lane Change Without Sufficient Gap (22.1%), followed by Late Braking for Stopped/Stopping Traffic (17.3%) and Roadway Entrance Without Clearance (7.9%). Figure 34 shows a bar graph of the 456 incidents, across the three studies, as a function of Incident Type.

Table 34. Frequency, Percentage, and Rank Ordering of the Incident Types Across the Three Studies.

Incident Type	Frequency of Incidents Across all Three Studies	Percentage of Incidents Across all Three Studies	Combined Rank
Lane Change Without Sufficient Gap	101	22.1%	1
Late Braking for Stopped/Stopping Traffic	79	17.3%	2
Roadway Entrance Without Clearance	36	7.9%	3
Left Turn Without Clearance	34	7.5%	4
Lateral Deviation of Through Vehicle	25	5.5%	5
Improper Passing	21	4.6%	6
Slow Speed	16	3.5%	7
Aborted Lane Change	15	3.3%	8.5
Turn Without Sufficient Warning	15	3.3%	8.5
Obstruction in Roadway	13	2.9%	10
Following Too Closely	11	2.4%	11
Wide Turn Into Adjacent Lane	10	2.2%	12
Merge Without Sufficient Gap	9	2.0%	13
Backing in Roadway	8	1.8%	15
Conflict With Oncoming Traffic	8	1.8%	15
Through Traffic Does Not Allow Merge	8	1.8%	15
Approaches Traffic Quickly	6	1.3%	17
Turn/Exit From Incorrect Lane	5	1.1%	19
Merge Out Of Turn (Before Lead Vehicle)	5	1.1%	19
Slow Upon Passing	5	1.1%	19
Improper Lane Change	4	0.9%	21.5
Exit Then Re-Entrance onto Roadway	4	0.9%	21.5
Unable to Determine	3	0.7%	23
Clear Path for Emergency Vehicle	2	0.4%	26
Improper Stopping at an Intersection	2	0.4%	26
School Bus Passing Violation	2	0.4%	26
Through Traffic Does Not Allow Lane Change	2	0.4%	26
Conflict Between Merging and Exiting Traffic	2	0.4%	26
Improper U-Turn	1	0.2%	31
Improperly Covered Debris from Lead Vehicle	1	0.2%	31
Sudden Braking in Roadway	1	0.2%	31
Obscene Gesture (To Other Driver)	1	0.2%	31
Proceeding Through Red Traffic Signal	1	0.2%	31

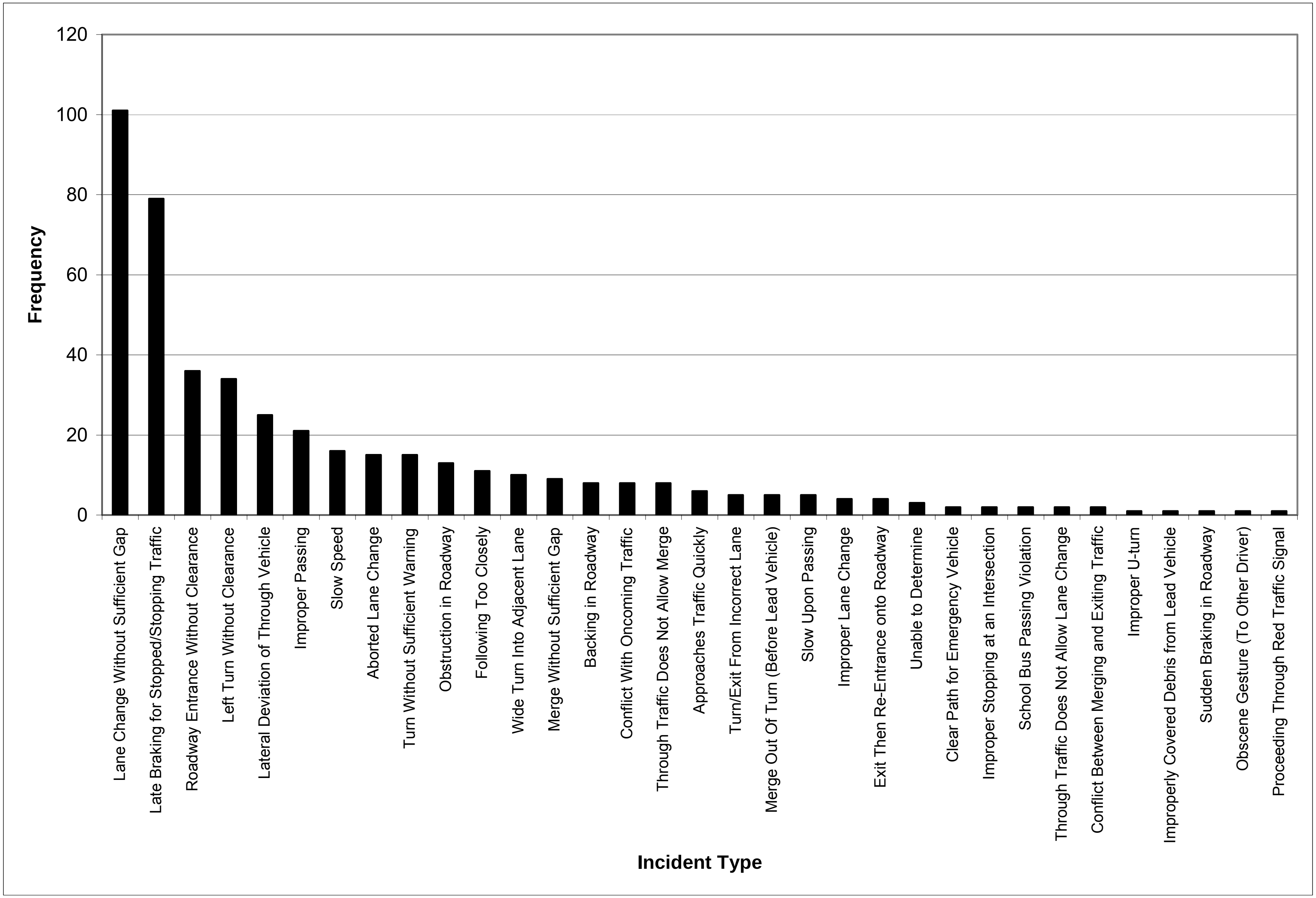


Figure 34. Percentage of Incident Types Across all Three Studies.

Tables 35-37 show the frequency and percentage of each Incident Type in the 100-Car, SB, and L/SH studies, respectively. In the 100-Car Study, the most frequent Incident Types were Late Braking for Stopped/Stopping Traffic (26.8%), Lane Change Without Sufficient Gap (22%), and Lateral Deviation of Through Vehicle (8.1%). In the SB study, the most frequent Incident Types were Lane Change Without Sufficient Gap (25%), Turn Without Sufficient Warning (17.6%), Late Braking for Stopped/Stopping Traffic (14.7%). In the L/SH study, the most frequent Incident Types were Lane Change Without Sufficient Gap (21.1%), Roadway Entrance Without Clearance (14.3%), and Left Turn Without Clearance (14.8%). Figure 35 shows a bar graph that illustrates the percentage of incidents in the 100-Car, SB, and L/SH studies as a function of the Incident Types.

Table 35. Frequency and Percentage of Incident Types for the 100-Car Study.

Incident Type	Frequency of 100-Car Driver At-Fault Incidents ($n_{100\text{-Car}}$ = 138)	Percentage of 100-Car Driver At-Fault Incidents ($n_{100\text{-Car}}$ = 138)	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Frequency of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Frequency of All Incidents (N_{Total} = 246)	Percentage of All Incidents (N_{Total} = 246)
Late Braking for Stopped/Stopping Traffic	57	41.3%	1	1.3%	8	27.6%	66	26.8%
Lane Change Without Sufficient Gap	30	21.7%	21	26.6%	3	10.3%	54	22.0%
Lateral Deviation of Through Vehicle	3	2.2%	17	21.5%	0	0.0%	20	8.1%
Aborted Lane Change	11	8.0%	4	5.1%	0	0.0%	15	6.1%
Left Turn Without Clearance	0	0.0%	11	13.9%	2	6.9%	13	5.3%
Improper Passing	10	7.2%	0	0.0%	2	6.9%	12	4.9%
Merge Without Sufficient Gap	5	3.6%	3	3.8%	1	3.4%	9	3.7%
Conflict With Oncoming Traffic	3	2.2%	1	1.3%	4	13.8%	8	3.3%
Approaches Traffic Quickly	6	4.3%	0	0.0%	0	0.0%	6	2.4%
Roadway Entrance Without Clearance	2	1.4%	2	2.5%	2	6.9%	6	2.4%
Following Too Closely	4	2.9%	1	1.3%	0	0.0%	5	2.0%
Obstruction in Roadway	0	0.0%	4	5.1%	1	3.4%	5	2.0%
Improper Lane Change	3	2.2%	1	1.3%	0	0.0%	4	1.6%
Through Traffic Does Not Allow Merge	0	0.0%	3	3.8%	0	0.0%	3	1.2%
Unable to Determine	0	0.0%	0	0.0%	3	10.3%	3	1.2%
Clear Path for Emergency Vehicle	0	0.0%	1	1.3%	1	3.4%	2	0.8%
Improper Stopping at an Intersection	2	1.4%	0	0.0%	0	0.0%	2	0.8%
School Bus Passing Violation	2	1.4%	0	0.0%	0	0.0%	2	0.8%

Incident Type	Frequency of 100-Car Driver At-Fault Incidents ($n_{100\text{-Car}}$ = 138)	Percentage of 100-Car Driver At-Fault Incidents ($n_{100\text{-Car}}$ = 138)	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Frequency of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Frequency of All Incidents (N_{Total} = 246)	Percentage of All Incidents (N_{Total} = 246)
Through Traffic Does Not Allow Lane Change	0	0.0%	0	0.0%	2	6.9%	2	0.8%
Wide Turn Into Adjacent Lane	0	0.0%	2	2.5%	0	0.0%	2	0.8%
Backing in Roadway	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Improper U-Turn	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Improperly Covered Debris from Lead Vehicle	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Slow Speed	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Sudden Braking in Roadway	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Turn Without Sufficient Warning	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Turn/Exit From Incorrect Lane	0	0.0%	1	1.3%	0	0.0%	1	0.4%

Table 36. Frequency and Percentage of Incident Types for the Sleeper Berth Study.

Incident Type	Frequency of SB Driver At-Fault Incidents (n_{SB} = 21)	Percentage of SB Driver At-Fault Incidents (n_{SB} = 21)	Frequency of LV Driver At-Fault Incidents (n_{LV} = 47)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 47)	Frequency of All Incidents (N_{Total} = 68)	Percentage of All Incidents (N_{Total} = 68)
Lane Change Without Sufficient Gap	2	9.5%	15	31.9%	17	25.0%
Turn Without Sufficient Warning	3	14.3%	9	19.1%	12	17.6%
Late Braking For Stopped/ Stopping Traffic	10	47.6%	0	0.0%	10	14.7%
Low Speed	1	4.8%	8	17.0%	9	13.2%
Following Too Closely	5	23.8%	0	0.0%	5	7.4%
Roadway Entrance Without Clearance	0	0.0%	4	8.5%	4	5.9%
Obstruction In Roadway	0	0.0%	4	8.5%	4	5.9%
Lateral Deviation Of Through Vehicle	0	0.0%	3	6.4%	3	4.4%
Improper Passing	0	0.0%	2	4.3%	2	2.9%
Slow Upon Passing	0	0.0%	2	4.3%	2	2.9%
Left Turn Without Clearance	0	0.0%	0	0.0%	0	0.0%
Wide Turn Into Adjacent Lane	0	0.0%	0	0.0%	0	0.0%
Backing In Roadway	0	0.0%	0	0.0%	0	0.0%
Merge Out Of Turn	0	0.0%	0	0.0%	0	0.0%
Through Traffic Does Not Allow Merge	0	0.0%	0	0.0%	0	0.0%
Exit Then Re-Entrance onto Roadway	0	0.0%	0	0.0%	0	0.0%
Turn/ Exit From Incorrect Lane	0	0.0%	0	0.0%	0	0.0%
Conflict Between Merging and Exiting Traffic	0	0.0%	0	0.0%	0	0.0%
Obscene Gesture (To Other Driver)	0	0.0%	0	0.0%	0	0.0%
Proceeding Through Red Traffic Signal	0	0.0%	0	0.0%	0	0.0%

Table 37. Frequency and Percentage of Incident Types for the Local/Short Haul Study.

Incident Type	Frequency of L/SH Driver At-Fault Incidents ($n_{L/SH}$ = 25)	Percentage of L/SH Driver At-Fault Incidents ($n_{L/SH}$ = 25)	Frequency of LV Driver At-Fault Incidents (n_{LV} = 117)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 117)	Frequency of All Incidents (N_{Total} = 142)	Percentage of All Incidents (N_{Total} = 142)
Lane Change Without Sufficient Gap	1	4.0%	29	24.8%	30	21.1%
Roadway Entrance Without Clearance	5	20.0%	21	17.9%	26	18.3%
Left Turn Without Clearance	0	0.0%	21	17.9%	21	14.8%
Wide Turn Into Adjacent Lane	3	12.0%	5	4.3%	8	5.6%
Improper Passing	1	4.0%	6	5.1%	7	4.9%
Backing In Roadway	3	12.0%	4	3.4%	7	4.9%
Low Speed	2	8.0%	4	3.4%	6	4.2%
Merge Out Of Turn	1	4.0%	4	3.4%	5	3.5%
Through Traffic Does Not Allow Merge	0	0.0%	5	4.3%	5	3.5%
Obstruction In Roadway	1	4.0%	3	2.6%	4	2.8%
Exit Then Re-Entrance onto Roadway	0	0.0%	4	3.4%	4	2.8%
Turn/Exit From Incorrect Lane	1	4.0%	3	2.6%	4	2.8%
Late Braking For Stopped/ Stopping Traffic	3	12.0%	0	0.0%	3	2.1%
Slow Upon Passing	0	0.0%	3	2.6%	3	2.1%
Turn Without Sufficient Warning	0	0.0%	2	1.7%	2	1.4%
Lateral Deviation Of Through Vehicle	1	4.0%	1	0.9%	2	1.4%
Conflict Between Merging and Exiting Traffic	0	0.0%	2	1.7%	2	1.4%
Following Too Closely	1	4.0%	0	0.0%	1	0.7%
Obscene Gesture (To Other Driver)	1	4.0%	0	0.0%	1	0.7%
Proceeding Through Red Traffic Signal	1	4.0%	0	0.0%	1	0.7%

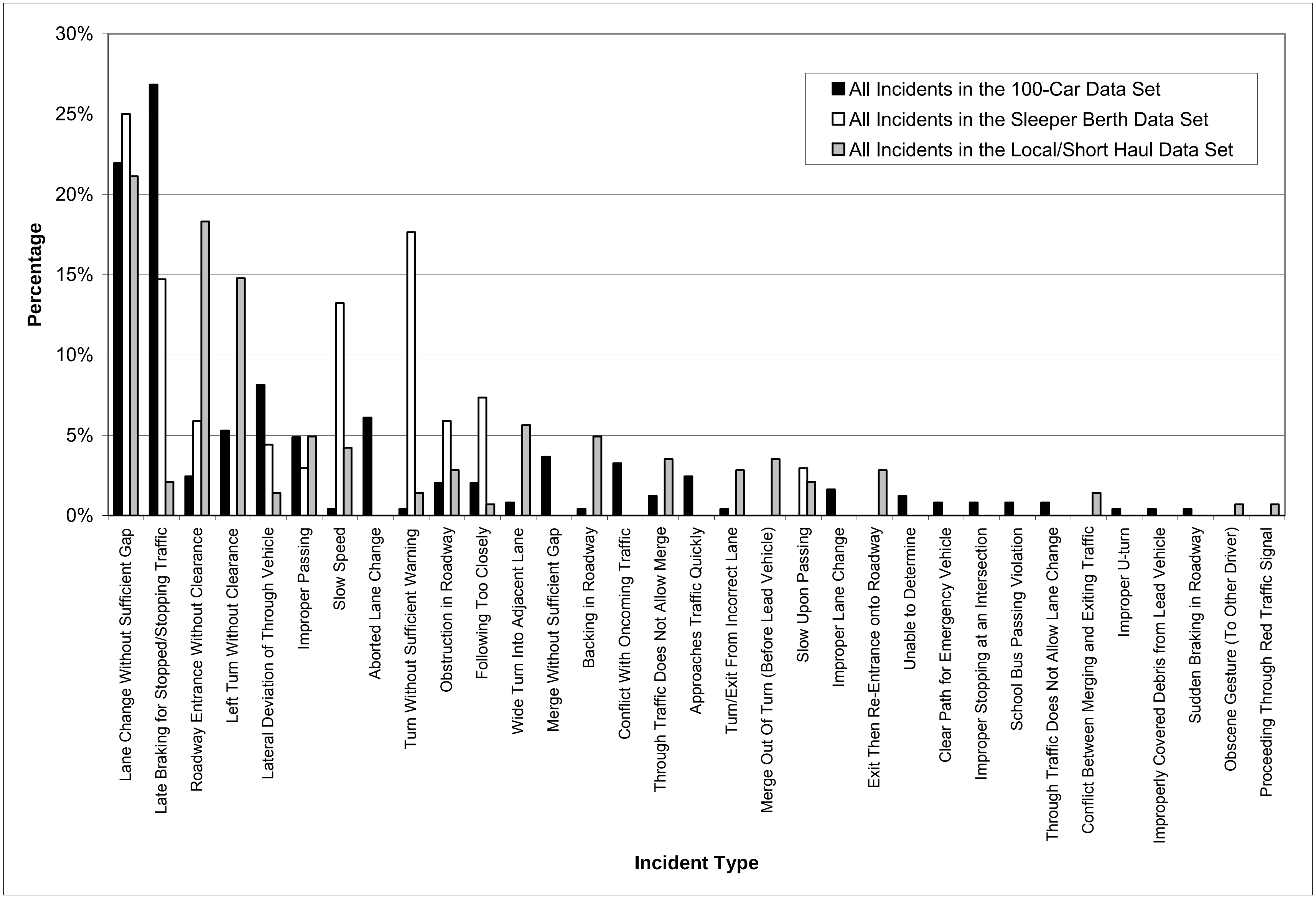


Figure 35. Percentage of Incident Types in the 100-Car, SB, L/SH Studies.

Figure 36 shows the percentage of HV driver at-fault incidents in the 100-Car, SB, and L/SH studies as a function of Incident Type. The black bars in Figure 36 represent HV driver at-fault incidents in the 100-Car data set, while the white and grey bars represent SB and L/SH driver at-fault incidents, respectively. The most frequent Incident Types for HV driver at-fault incidents in the 100-Car Study were Lane Change Without Sufficient Gap (26.6%), Lateral Deviation of Through Vehicle (21.5%), and Left Turn Without Clearance (13.9%). The most frequent Incident Types for HV driver at-fault incidents in the SB study were Late Braking for Stopped/Stopping Traffic (47.6%), Following Too Close (23.8%), and Turn Without Sufficient Warning (14.3%). The most frequent Incident Types for HV driver at-fault incidents in the L/SH study were Roadway Entrance Without Clearance (20%), Backing In Roadway (12%), Late Braking for Stopped/Stopping Traffic (12%), Wide Turn Into Adjacent Lane (12%), and Low Speed (8%).

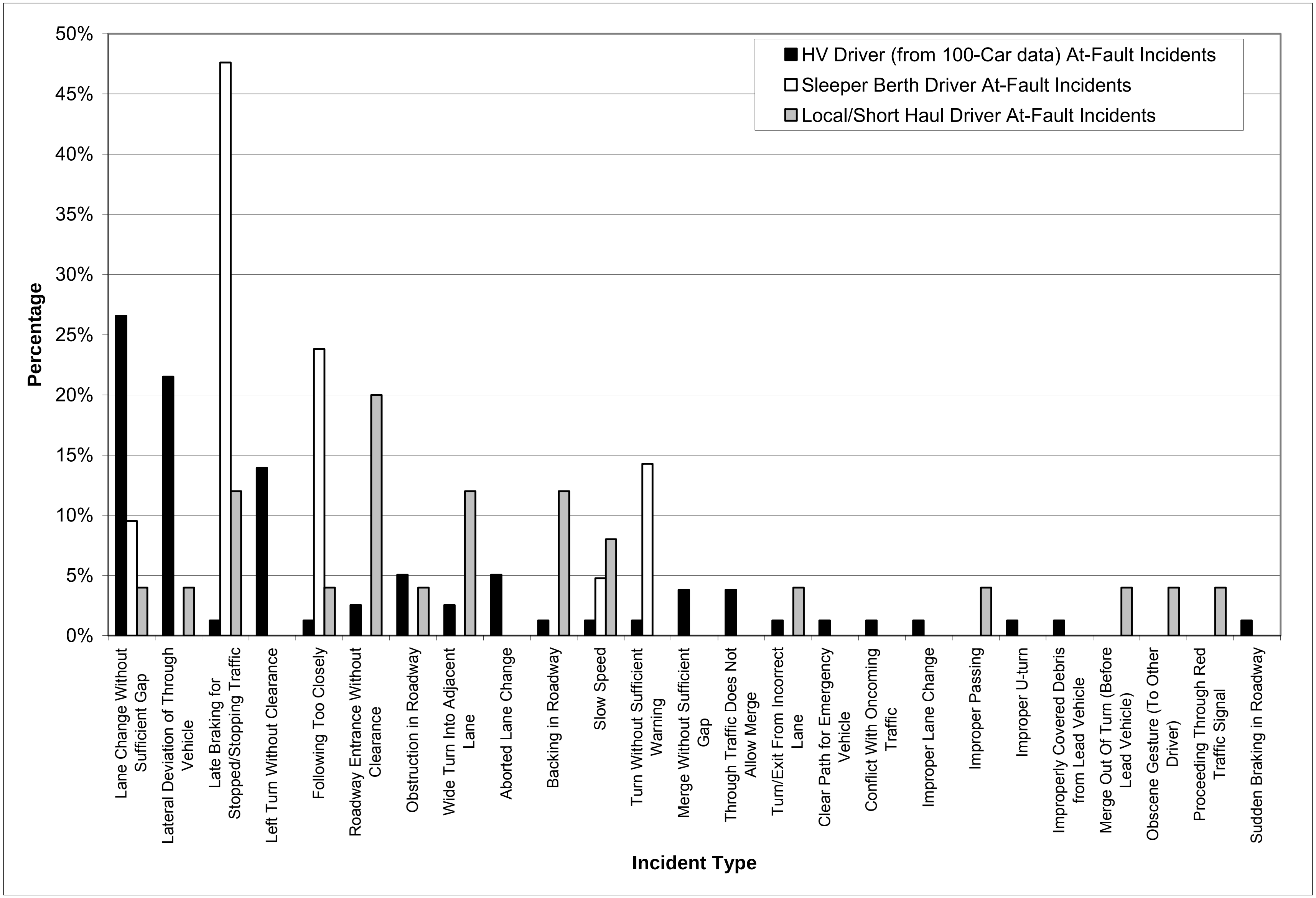


Figure 36. Percentage of HV Driver At-Fault Incident Types in the 100-Car, SB, and L/SH Studies.

Figure 37 shows the percentage of LV driver at-fault incidents in the 100-Car, SB, and L/SH studies as a function of Incident Type. The black bars in Figure 37 represent the 100-Car driver at-fault incidents in the 100-Car Study, while the white and grey bars represent LV driver at-fault incidents in the SB and L/SH data sets, respectively. The most frequent Incident Types for LV driver at-fault incidents in the 100-Car Study were Late Braking for Stopped/Stopping Traffic (41.3%) Lane Change Without Sufficient Gap (21.7%), and Aborted Lane Change (8%). The most frequent Incident Types for LV driver at-fault incidents in the SB study were Lane Change Without Sufficient Gap (32%), Turn Without Sufficient Warning (19.1%), and Low Speed (17%). The most frequent Incident Types for LV driver at-fault incidents in the L/SH study were Lane Change Without Sufficient Gap (24.8%), Roadway Entrance Without Clearance (17.9%), Turn Without Clearance (17.9%), and Improper Passing (5.1%).

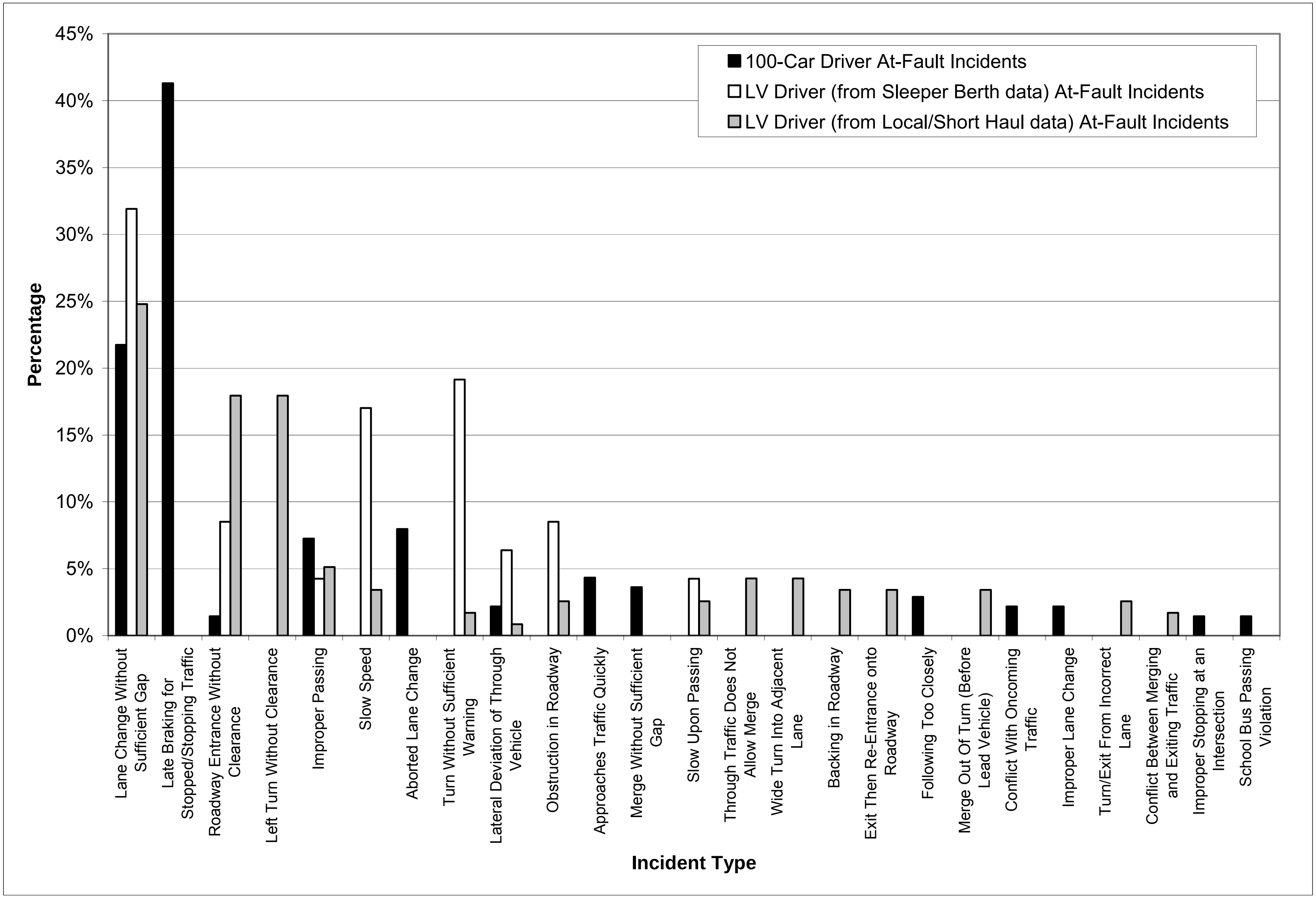


Figure 37. Percentage of LV Driver At-Fault Incident Types in the 100-Car, SB, and L/SH Studies.

As can be seen in Figure 37, the Incident Types differed markedly depending on the study (i.e., 100-Car, SB, and L/SH). One possible explanation for these discrepancies could be the frequency of travel on certain Road Types (i.e., it would be expected that a significant amount of the incidents would occur on the most traveled roadways, similar to exposure). Of course, this is an oversimplification. The geographical area, what the vehicle was used for, and driver preference all dictate the predominant Road Type used in driving. Figure 38 illustrates the percentage of incidents for each of the three studies as a function of Road Type. The black bars in Figure 38 represent 100-Car incidents, while the white and grey bars represent SB and L/SH incidents, respectively. In the 100-Car data set, the highest proportion of incidents occurred on the Urban Divided (60.2%), Urban Undivided (18.7%), and Rural Undivided (9.3%) roads. In the SB data set, the highest proportion of incidents occurred on the Rural Divided (55.9%), Urban Undivided (10.3%), and Rural Undivided (13.2%) roads. In the L/SH data set, the highest proportion of incidents occurred on the Rural Divided (38.7%), Urban Undivided (18.3%), and Rural Undivided (16.2%) roads.

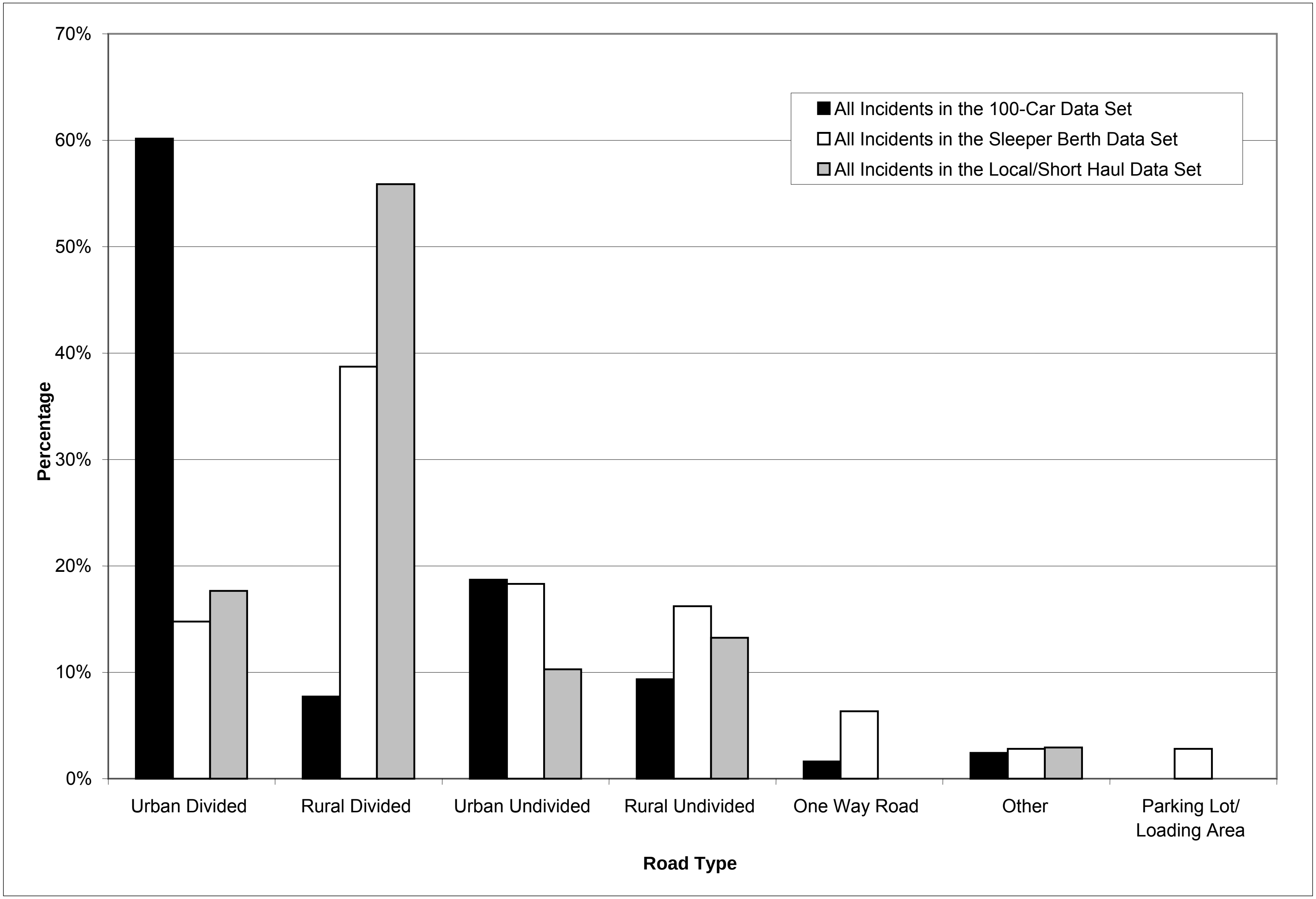


Figure 38. Percent of Incidents in the 100-Car, SB, and L/SH studies as a Function of Road Type.

Summary of Incident Types

Across the three studies, the most frequent Incident Types were Lane Change Without Sufficient Gap (22.1%), Late Braking for Stopped/Stopping Traffic, (17.3%), and Roadway Entrance Without Clearance (7.9%). These three Incident Types accounted for 47.3% of LV-HV interactions across the three studies.

As can be seen in Figure 36, the HV driver at-fault Incident Types differed with respect to the instrumented vehicle. The most frequent Incident Types for HV driver at-fault incidents in the 100-Car Study were Lane Change Without Sufficient Gap (26.6%), Lateral Deviation of Through Traffic (21.5%), and Left Turn Without Clearance (13.9%). These three Incident Types represented 62% of the HV driver at-fault incidents in the 100-Car Study. The most frequent Incident Types for HV driver at-fault incidents in the SB study were Late Braking for Stopped/Stopping Traffic (47.6%), Following Too Closely (23.8%), and Turn Without Sufficient Warning (14.3%). These three Incident Types represented 85.7% of the HV driver at-fault incidents in the SB study. The most frequent Incident Types for the HV driver at-fault incidents in the L/SH study were Roadway Entrance Without Clearance (20%), Wide Turn Into Adjacent Area (12%), and Backing in Roadway (12%). These three Incident Types represented 48% of HV driver at-fault incident in the L/SH study.

As can be seen in Figure 37, the LV driver at-fault Incident Types also differed with respect to the instrumented vehicle. The most frequent Incident Types for LV driver at-fault incidents in the 100-Car Study were Late Braking for Stopped/Stopping Traffic (41.3%) and Lane Change Without Sufficient Gap (21.7%). These two Incident Types represent 63% of the LV driver at-fault incidents in the 100-Car Study. The most frequent Incident Types for LV driver at-fault incidents in the SB study were Lane Change Without Sufficient Gap (31.9%), Turn Without Sufficient Warning (19.1%), and Low Speed (17%). These three Incident Types represent 68% of the LV driver at-fault incidents in the SB study. The most frequent Incident Types for the LV driver at-fault incidents in the L/SH study were Lane Change Without Sufficient Gap (24.8%), Roadway Entrance Without Clearance (17.9%), and Left Turn Without Clearance (17.9%). These three Incident Types represent 60.6% of LV driver at-fault incident in the L/SH study.

There were many differences across the three studies (100-Car, L/SH, and SB) as well between HVs and LVs within each study. This is possible as both the SB and L/SH trucks were instrumented in their respective studies, while the LV was instrumented in the 100-Car Study. Thus, those incidents recorded in the 100-Car Study reflect a diverse range of HVs. Further, the incidents in the SB and L/SH studies are likely to reflect difficulties specific to SB and L/SH operations. Support for this hypothesis was found when the authors assessed the location of each incident (see Figure 38).

Consider the Road Type comparison data shown in Figure 38. The bar graph illustrates the percentage of incidents as a function of different Road Types. Not surprisingly, the Road Types frequented by the 100-Car participants, such as major city roads and streets, are where the majority of 100-Car Study incidents occurred (60.2% of the incidents occurred on an Urban Divided road). The Road Types common to SB operations, such as interstates and highways, are where the majority of SB incidents occurred. That is, rural divided by median (i.e., interstate) and urban divided by median (i.e., highway) accounted for 74% of the SB incidents. Similarly, the Road Types common for L/SH trucks accounted for many of the L/SH incidents. On a percentage basis, there were more incidents for L/SH drivers in town settings (i.e., urban undivided, urban divided, one-way, and parking lot), which is where many L/SH delivery routes are located. By looking at the driving environments, it could be said that the majority of 100-Car and L/SH incidents occurred in and around town/urban areas (lower speeds and higher traffic areas). SB incidents, on the other hand, tended to occur on highways where speeds are relatively high and traffic density is relatively low.

For example, Roadway Entrance Without Clearance accounted for a substantial portion of L/SH incidents (18.3%), whereas this Incident Type only accounted for a small proportion of the incidents in the 100-Car (2.4%) and SB (5.9%) studies. This makes intuitive sense when one considers L/SH operations trucking operations. L/SH drivers have many deliveries during their workday and will, therefore, routinely exit parking lots onto roadways. This provides an opportunity for this particular Incident Type to occur, whereas this maneuver is not characteristic of 100-Car and SB drivers. Much of the time, SB drivers were on limited-access highways having no intersecting side roads, whereas 100-Car drivers were driving on major urban road going to and from their residence. The characteristics of the Road Types traveled by 100-Car, SB, and L/SH drivers appear to explain some of the discrepancies between the three studies.

PRIMARY MANEUVERS

Table 38 shows the frequency, percentage, and rank ordering of the Primary Maneuvers across the 100-Car, SB, and L/SH studies. The most frequent Primary Maneuver across all three studies was Changing Lanes (23.2%), followed by Braking (12.3%) and Left Turn (11.2%). Figure 39 shows a bar graph of the 456 incidents, across the three studies, as a function of Primary Maneuver.

Table 38. Frequency, percentage, and rank ordering of Primary Maneuvers across the three studies.

Primary Maneuver	Frequency of Incidents Across all Three Studies	Percentage of Incidents Across all Three Studies	Combined Rank
Changing Lanes	106	23.2%	1
Braking	56	12.3%	2
Left Turn	51	11.2%	3
Through Traffic	44	9.6%	4
Stopped	38	8.3%	5
Traveling Ahead	28	6.1%	6
Right Turn	26	5.7%	7
Merging	25	5.5%	8
Crossing Over Lane Line	19	4.2%	9
Slower Speed	15	3.3%	10
Aborted Lane Change	8	1.8%	12.5
Enters Roadway	8	1.8%	12.5
U-Turn	8	1.8%	12.5
Roadway Exit	8	1.8%	12.5
Backing	6	1.3%	15
Avoiding Vehicle	3	.7%	17
Moved to Shoulder	3	.7%	17
Incomplete Lane Change	2	.4%	17
Drifts to the Left	1	.2%	19.5
Parked	1	.2%	19.5

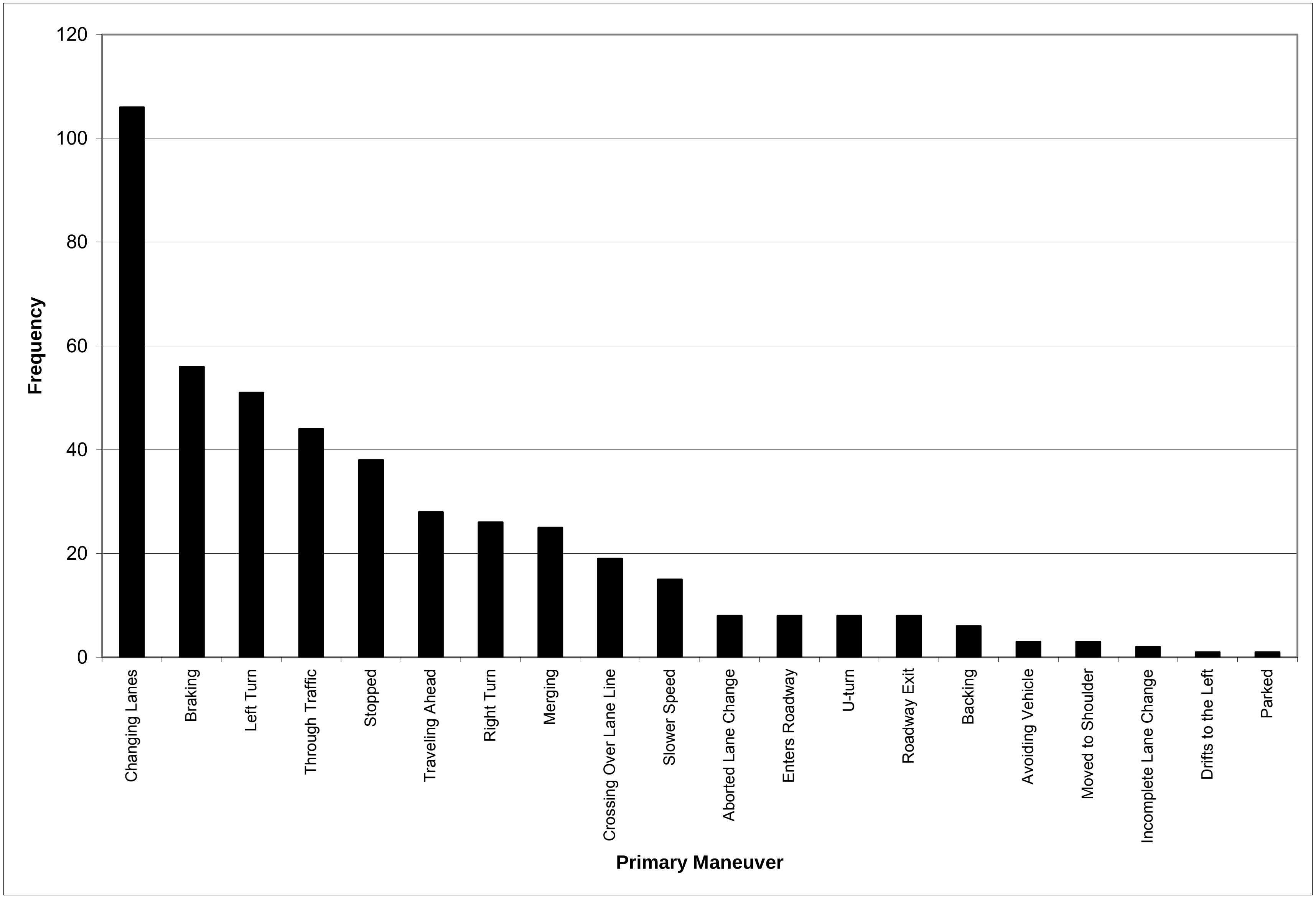


Figure 39. Frequency of Primary Maneuvers Across the Three Studies.

Tables 39-41 show the frequency and percentage of each Primary Maneuver in the 100-Car, SB, and L/SH studies, respectively. In the 100-Car Study, the most frequent Primary Maneuvers were Braking (22.8%), Changing Lanes (21.1%), and Stopped (15%). In the SB study, the most frequent Primary Maneuvers were Through Traffic (39.7%), Changing Lanes (32.4%), Roadway Exit (8.8%), and Left Turn (8.8%). In the L/SH study, the most frequent Primary Maneuvers were Changing Lanes (22.5%), Left Turn (20.4%), and Through Traffic (19%). Figure 40 shows a bar graph illustrating the incidents for the 100-Car, SB, and L/SH studies as a function of Primary Maneuver.

Table 39. Frequency and Percentage of Primary Maneuvers for the 100-Car Study.

Primary Maneuver	Frequency of 100-Car Driver At-Fault Incidents ($N_{100\text{-}Car}$ = 138)	Percentage of 100-Car Driver At-Fault Incidents ($N_{100\text{-}Car}$ = 138)	Frequency of HV Driver At-Fault Incidents (N_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (N_{HV} = 79)	Frequency of Unknown Driver At-Fault Incidents (N_{Un} = 29)	Percentage of Unknown Driver At-Fault Incidents (N_{Un} = 29)	Frequency of All 100-Car Incidents (N_{Total} = 246)	Percentage of All 100-Car Incidents (N_{Total} = 246)
Braking	45	32.6%	3	3.8%	8	27.6%	56	22.8%
Changing Lanes	23	16.7%	26	32.9%	3	10.3%	52	21.1%
Stopped	30	21.7%	4	5.1%	3	10.3%	37	15.0%
Crossing Over Lane Line	2	1.4%	16	20.3%	1	3.4%	19	7.7%
Left Turn	1	0.7%	12	15.2%	3	10.3%	16	6.5%
Through Traffic	6	4.3%	4	5.1%	6	20.7%	16	6.5%
Slower Speed	13	9.4%	1	1.3%	1	3.4%	15	6.1%
Aborted Lane Change	7	5.1%	1	1.3%	0	0.0%	8	3.3%
Merging	3	2.2%	3	3.8%	0	0.0%	6	2.4%
Right Turn	3	2.2%	2	2.5%	1	3.4%	6	2.4%
Avoiding Vehicle	3	2.2%	0	0.0%	0	0.0%	3	1.2%
Moved to Shoulder	1	0.7%	1	1.3%	1	3.4%	3	1.2%
Enters Roadway	0	0.0%	1	1.3%	1	3.4%	2	0.8%
Incomplete Lane Change	0	0.0%	1	1.3%	1	3.4%	2	0.8%
Drifts to the Left	1	0.7%	0	0.0%	0	0.0%	1	0.4%
Backing	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Parked	0	0.0%	1	1.3%	0	0.0%	1	0.4%
Traveling Ahead	0	0.0%	1	1.3%	0	0.0%	1	0.4%
U-Turn	0	0.0%	1	1.3%	0	0.0%	1	0.4%

Table 40. Frequency and Percentage of Primary Maneuvers for the Sleeper Berth Study.

Primary Maneuver	Frequency of SB Driver At-Fault Incidents (n_{SB} = 21)	Percentage of SB Driver At-Fault Incidents (n_{SB} = 21)	Frequency of LV Driver At-Fault Incidents (n_{LV} = 47)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 47)	Frequency of All SB Incidents (n_{Total} = 68)	Percentage of All SB Incidents
Through Traffic	15	71.4%	12	25.5%	27	39.7%
Changing Lanes	2	9.5%	20	42.6%	22	32.4%
Left Turn	2	9.5%	4	8.5%	6	8.8%
Roadway Exit	1	4.8%	5	10.6%	6	8.8%
Merge Onto Roadway	0	0%	4	8.5%	4	5.9%
Right Turn	1	4.8%	1	3.7%	2	2.9%
Stopped in Roadway	0	0%	1	3.7%	1	1.5%
Backing	0	0%	0	0%	0	0%
Roadway Entrance	0	0%	0	0%	0	0%
U-Turn	0	0%	0	0%	0	0%

Table 41. Frequency and Percentage of Primary Maneuvers for the Local/Short Haul Study.

Primary Maneuver	Frequency of L/SH Driver At-Fault Incidents ($n_{L/SH} = 25$)	Percentage of L/SH Driver At-Fault Incidents ($n_{L/SH} = 25$)	Frequency of LV Driver At-Fault Incidents ($n_{LV} = 117$)	Percentage of LV Driver At-Fault Incidents ($n_{LV} = 117$)	Frequency of All L/SH Incidents ($N_{Total} = 142$)	Percentage of All L/SH Incidents ($N_{Total} = 142$)
Changing Lanes	1	4%	31	26.5%	32	22.5%
Left Turn	3	12%	26	22.2%	29	20.4%
Through Traffic	11	44%	16	13.7%	27	19%
Right Turn	6	24%	12	10.3%	18	12.7%
Merge Onto Roadway	1	4%	14	12%	15	10.6%
U-Turn	2	8%	5	4.3%	7	4.9%
Roadway Entrance	0	0%	6	5.1%	6	4.2%
Backing	1	4%	4	3.4%	5	3.5%
Roadway Exit	0	0%	2	1.7%	2	1.4%
Stopped in Roadway	0	0%	1	.9%	1	.7%

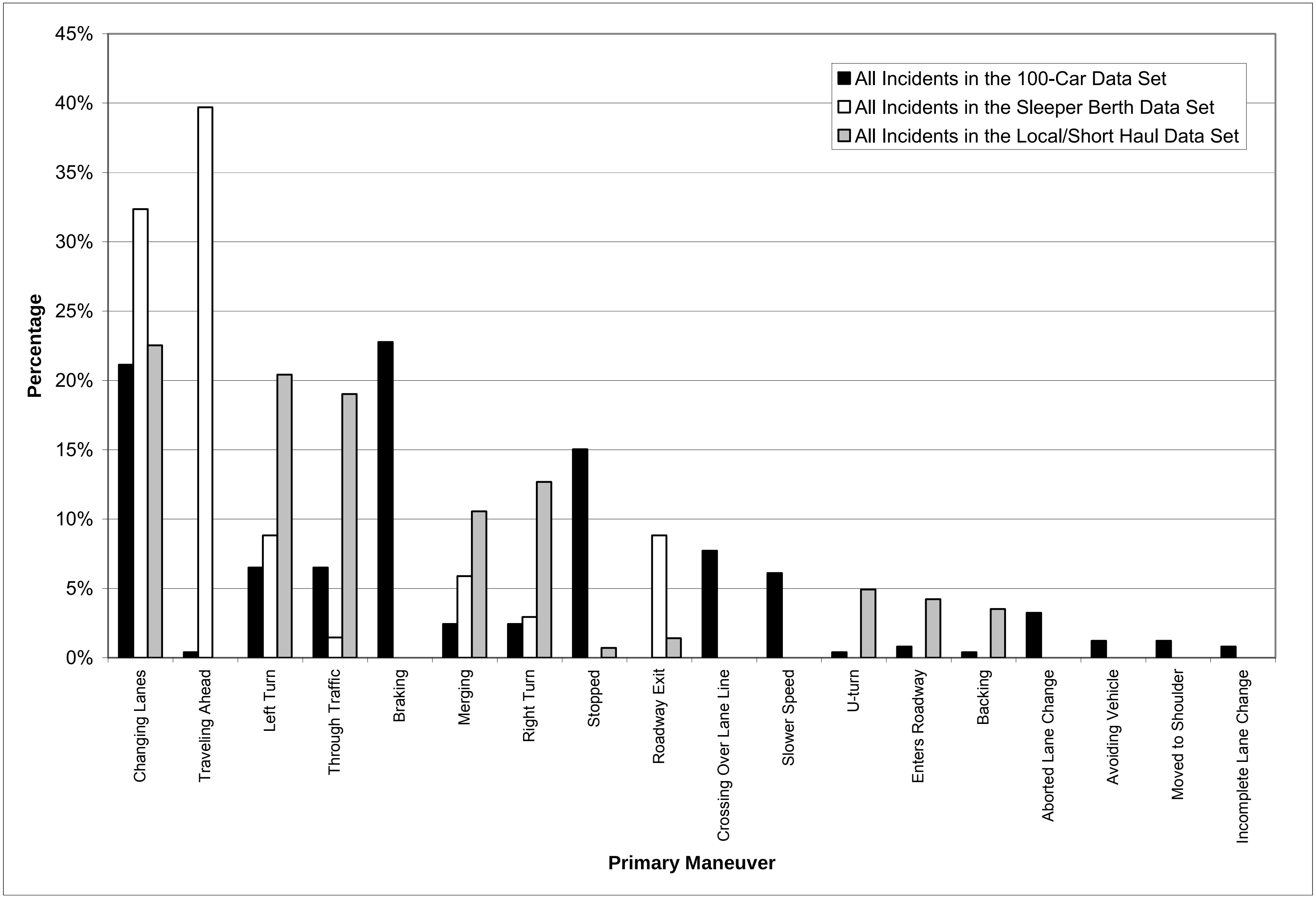


Figure 40. Percentage of Primary Maneuvers in the 100-Car, SB, and L/SH Studies.

Figure 41 shows the percentage of HV driver at-fault incidents in the 100-Car, SB, and L/SH studies as a function of Primary Maneuver. The black bars in Figure 41 represent the HV driver at-fault incidents in the 100-Car Study, while the white and grey bars represent HV driver at-fault incidents in the SB and L/SH studies, respectively. The most frequent Primary Maneuvers for HV driver at-fault incidents in the 100-Car Study were Changing Lanes (32.9%), Crossing Over Lane Line (26.3%), and Left Turn (15.2%). The most frequent Primary Maneuvers for HV driver at-fault incidents in the SB study were Through Traffic (71.4%), Changing Lanes (9.5%), and Left Turn (9.5%). The most frequent Primary Maneuvers for HV driver at-fault incidents in the L/SH study were Through Traffic (44%), Right Turn (24%), and Left Turn (12%).

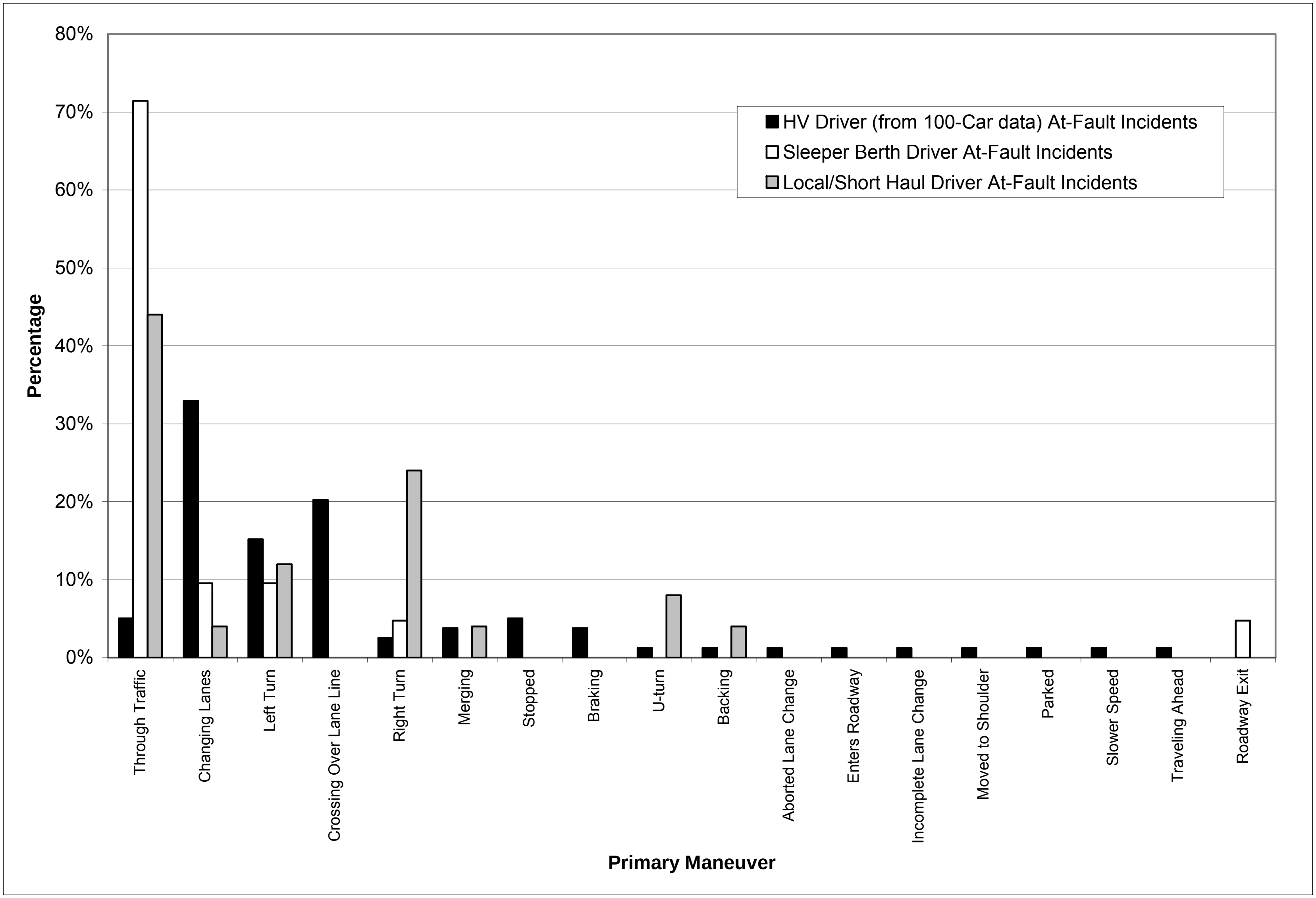


Figure 41. Percentage of HV Driver At-Fault Incidents in the 100-Car, SB, and L/SH Studies as a Function of Primary Maneuver.

Figure 42 shows the percentage of LV driver at-fault incidents in the 100-Car, SB, and L/SH studies as a function of Primary Maneuver. The black bars in Figure 42 represent the LV driver at-fault incidents in the 100-Car Study, while the white and grey bars represent LV driver at-fault incidents in the SB and L/SH studies, respectively. The most frequent Primary Maneuvers for LV driver at-fault incidents in the 100-Car Study were Braking (32.6%), Stopped (21.7%), and Changing Lanes (16.7%). The most frequent Primary Maneuvers for LV driver at-fault incidents in the SB study were Changing Lanes (42.6%), Through Traffic (25.5%), and Roadway Exit (10.6%). The most frequent Primary Maneuvers for LV driver at-fault incidents in the L/SH study were Changing Lanes (26.5%), Left Turn (22.2%), and Through Traffic (13.7%).

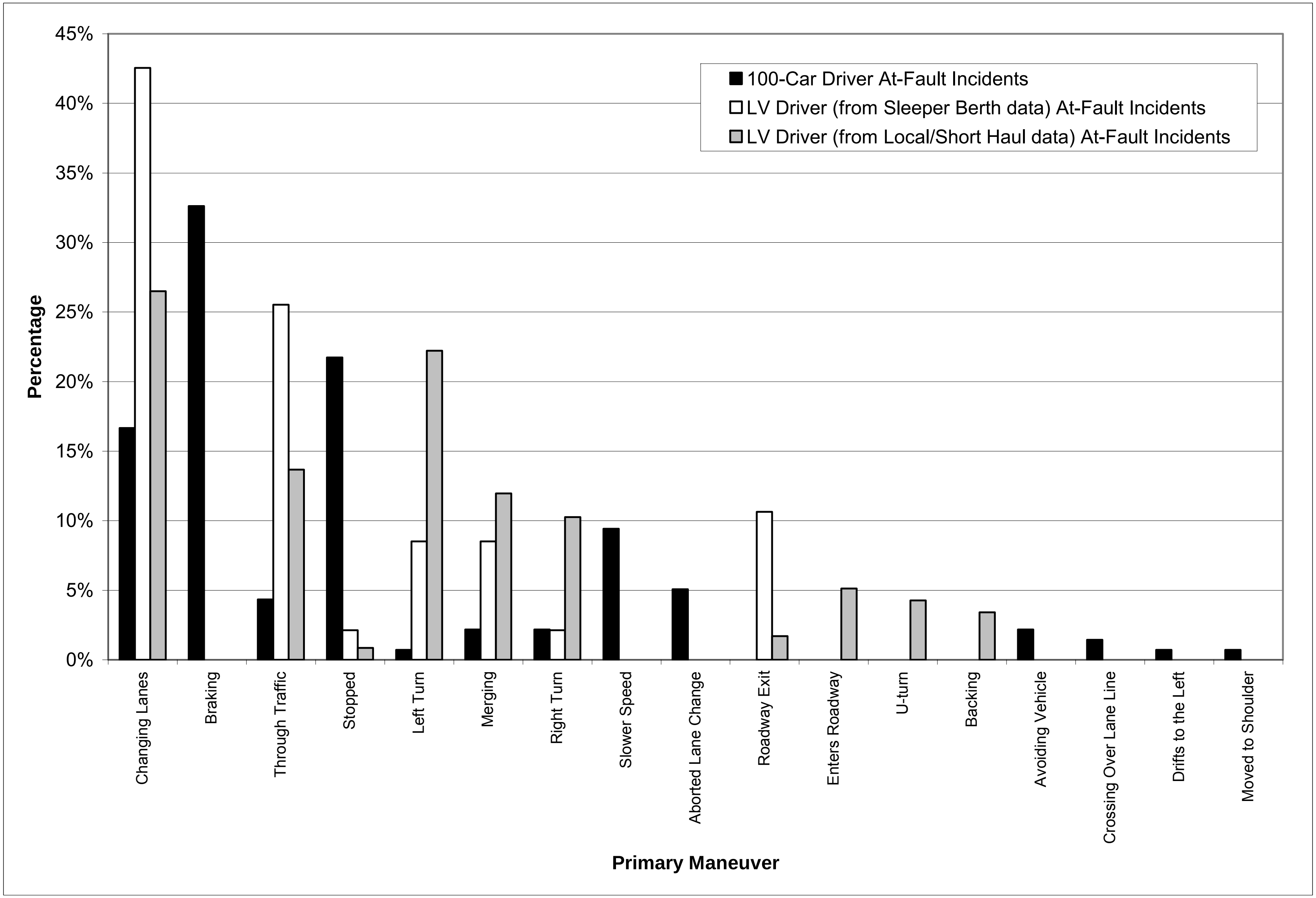


Figure 42. Percentage of LV Driver At-Fault Incidents in the 100-Car, SB, and L/SH Studies as a Function of Primary Maneuver.

Summary of Primary Maneuvers Across Studies

Across the three studies, the most frequent Primary Maneuvers were Changing Lanes (23.2%), Braking (12.3%), and Left Turn (11.2%). These three Primary Maneuvers represented 46.5% of the Primary Maneuvers across the three studies. As can be seen in Figures 40-42, the Primary Maneuvers differed depending on whether the LV or HV was judged to have been at fault.

As can be seen in Figure 41, the most frequent Primary Maneuvers for HV driver at-fault incidents in the 100-Car Study were Changing Lanes (32.9%), Crossing Over the Lane Line (26.3%), and Left Turn (15.2%). These three Primary Maneuvers represented 74.4% of the HV driver at-fault incidents in the 100-Car Study. In the SB study, the most frequent Primary Maneuvers for HV driver at-fault incidents were Through Traffic (71.4%), Changing Lanes (9.5%), and Left Turn (9.5%). These three Primary Maneuvers accounted for 90.4% of the HV driver at-fault incident in the SB study. In the L/SH study, the most frequent Primary Maneuvers for HV driver at-fault incidents were Through Traffic (44%), Right Turn (24%), and Left Turn (12%). These three Primary Maneuvers accounted for 80% of the HV driver at-fault incidents in the L/SH study. From the data it appears that HV drivers had the most difficulties when traveling forward on a roadway or straight through an intersection and changing lanes.

As can be seen in Figure 42, the most frequent Primary Maneuvers for LV driver at-fault incidents in the 100-Car Study were Braking (32.6%), Stopped (21.7%), and Changing Lanes (16.7%). These three Primary Maneuvers accounted for 71% of the LV driver at-fault incidents in the 100-Car Study. In the SB study, the most frequent Primary Maneuvers for LV driver at-fault incidents were Changing Lanes (42.6%), Through Traffic (25.5%), and Roadway Exit (10.6%). These three Primary Maneuvers represented 78.7% of the LV driver at-fault incidents in the SB study. In the L/SH study, the most frequent Primary Maneuvers for LV driver at-fault incidents were Changing Lanes (26.5%), Left Turn (22.2%), and Through Traffic (13.7%). These three Primary Maneuvers accounted for 62.4% of the LV driver at-fault incidents in the L/SH study. From the data it appears that LV drivers had the most difficulties when braking or decelerating and changing lanes.

In the SB study, the Through Traffic (i.e., vehicle traveling forward on a roadway or straight through an intersection) and Changing Lanes Primary Maneuvers accounted for 72% of the total incidents recorded. The Primary Maneuvers associated with LV-HV interactions in the L/SH and 100-Car studies were more varied. Changing Lanes (22.5%), Left Turn (20.4%), Through Traffic (19%), Right Turn (12.7%), and Merge onto Roadway (10.6%) accounted for the majority of incidents recorded in the L/SH study, while Braking (22.8%), Changing Lanes (21.1%), Stopped (15%), and Crossing Over Lane Line (7.7%) represented the majority of Primary Maneuvers in the 100-Car Study. Further investigation of these maneuver types indicated that Through Primary Maneuver was the most frequent type for HVs in both the SB and L/SH studies: 71% and 44%, respectively. However, Changing Lanes (32.9%) was the most predominant Primary Maneuver for HVs in the 100-Car Study.

The Changing Lanes Primary Maneuver was the predominant type for LVs in both the SB and L/SH studies: 42.6% and 26.5%, respectively. However, in the 100-Car Study, the Braking (32.6%) Primary Maneuver was the most predominant type for LVs. Note that the predominant Primary Maneuvers for each group of drivers is consistent with the Incident Type classification presented in the previous section. For example, one would expect that the Primary Maneuver for Late Braking for Stopped/Stopping Traffic would be Through Traffic, which as indicated by the SB at-fault incidents, was the case.

SPECIFIC CONTRIBUTING FACTORS

Table 42 shows the frequency, percentage, and rank ordering of the Contributing Factors across all three studies. The most frequent Contributing Factor across the three studies was Driving Techniques (41%), followed by Aggressive Driving (24.1%), Unknown (17.1%), and Distracted (10.5%). The reader should bear in mind that more than one Contributing Factor could be selected for a single incident in the 100-Car Study. Figure 43 shows a bar graph of the 456 incidents, across the three studies, as a function of the Contributing Factors.

Table 42. Frequency, Percentage, and Rank Ordering of the Contributing Factors across the 100-Car, SB, and L/SH Studies (n_{Total} = 456).

Specific Contributing Factor Category	Frequency of Incidents Across all Three Studies	Percentage of Incidents Across all Three Studies	Combined Rank
Driving Techniques	187	41%	1
Aggressive Driving	110	24.1%	2
Unknown	78	17.1%	3
Distracted	48	10.5%	4
Roadway Alignment	26	5.7%	5
Purposeful Violation of Traffic Laws	15	3.3%	6
Drowsy	11	2.4%	7
Vehicle Kinematics, Physics	8	1.8%	8
Roadway Sight Distance	7	1.5%	9
Driver Capabilities and Limitations	6	1.3%	10
Angry	2	0.4%	12
Other Emotional State	2	0.4%	12
Unfamiliar With Roadway/ Traffic Pattern	2	0.4%	12
Other	1	0.2%	15
Roadway Delineation	1	0.2%	15
Use of Vehicle For Improper Purposes	1	0.2%	15

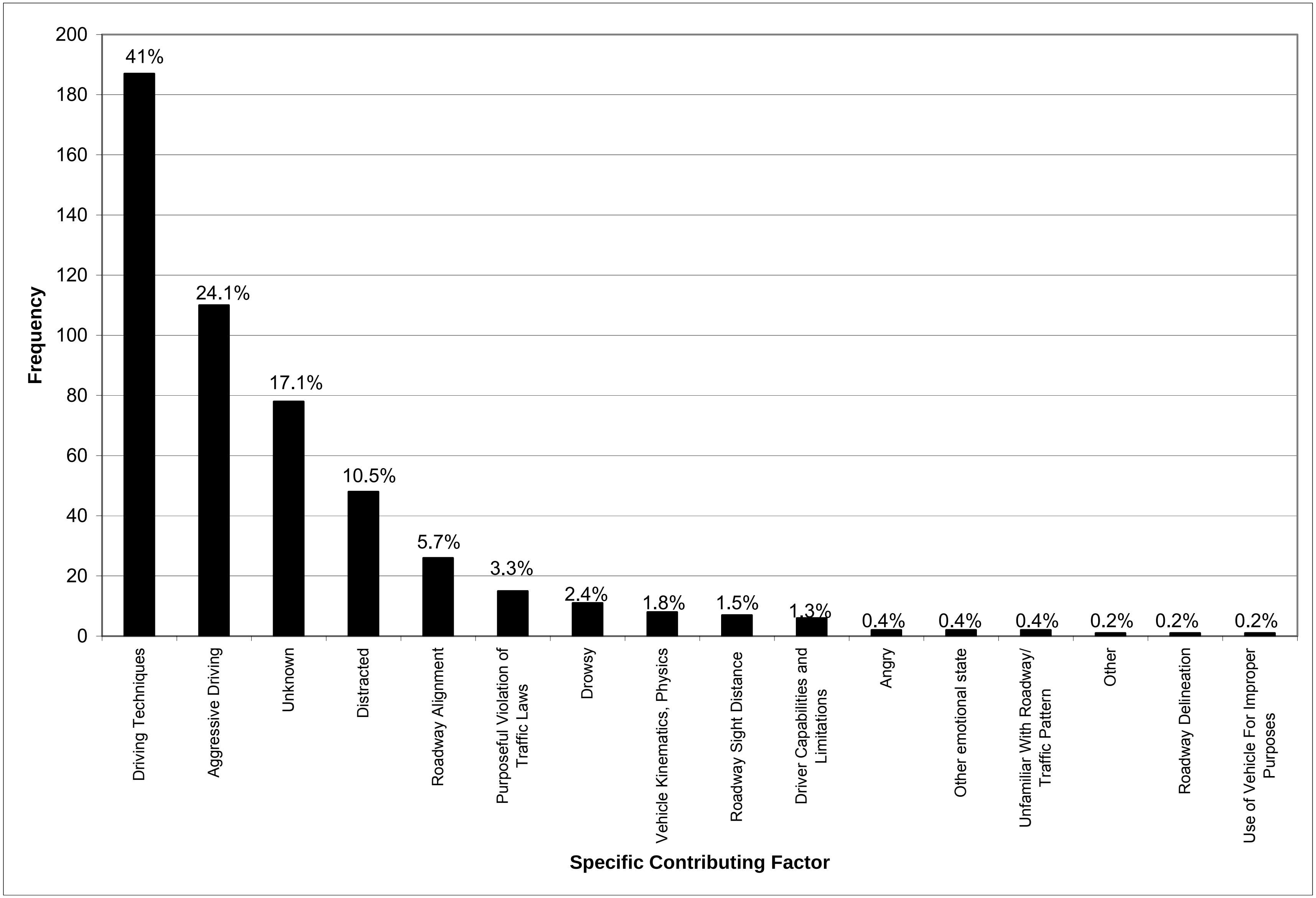


Figure 43. Frequency of Contributing Factors across the 100-Car, SB, and L/SH Studies.

Tables 43-45 show the frequency and percentage of each Contributing Factor in the 100-Car, SB, and L/SH studies, respectively. In the 100-Car Study, the most frequent Contributing Factors were Driving Techniques (49.5%), Unknown (24%), Distracted (18.7%), and Aggressive Driving (15%). In the SB data set, the most frequent Contributing Factors were Driving Techniques (46%) and Aggressive Driving (35%). In the L/SH study, the most frequent Contributing Factors were Aggressive Driving (37%), Driving Techniques (24%), Roadway Alignment (11%), and Unknown (11%). Figure 44 shows a bar graph illustrating the 456 incidents in the 100-Car, SB, and L/SH studies as a function of the Contributing Factors.

Table 43. Frequency and Percentage of Contributing Factors for the 100-Car Study.

Specific Contributing Factor	Frequency of LV At-Fault Incidents (n_{100Car} = 138)	Percentage of LV At-Fault Incidents (n_{100Car} = 138)	Frequency of HV Driver At-Fault Incidents (n_{HV} = 79)	Percentage of HV Driver At-Fault Incidents (n_{HV} = 79)	Frequency of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Percentage of Unknown Driver At-Fault Incidents (n_{Un} = 29)	Frequency of All Drivers (N_{Total} = 246)	Percentage of All Drivers (N_{Total} = 246)
Driving Techniques	96	54.2%	12	14.5%	14	40%	122	49.5%
Unknown	0	0%	54	65.1%	5	14.3%	59	24%
Distracted	31	18.6%	9	10.8%	6	17.1%	46	18.7%
Aggressive Driving	31	17.5%	3	1.2%	3	2.9%	37	15%
Drowsy	5	2.8%	2	2.4%	2	5.7%	9	3.7%
Purposeful Violation of Traffic Laws	7	4%	0	0%	1	2.9%	8	3.3%
Roadway Alignment	3	1.7%	2	2.4%	3	5.7%	8	3.3%
Roadway Delineation	0	0%	0	0%	3	8.6%	3	1.2%
Angry	0	0%	1	1.2%	1	2.9%	2	.8%
Other Emotional State	1	.6%	1	1.2%	0	0%	2	.8%
Other	1	.6%	0	0%	0	0%	1	.4%
Vehicle Kinematics, Physics	0	0%	0	0%	0	0%	0	0%
Driver Capabilities and Limitations	0	0%	0	0%	0	0%	0	0%
Unfamiliar With Roadway/ Traffic Pattern	0	0%	0	0%	0	0%	0	0%
Roadway Sight Distance	0	0%	0	0%	0	0%	0	0%
Use of Vehicle For Improper Purposes	0	0%	0	0%	0	0%	0	0%

Table 44. Frequency and Percentage of Contributing Factors for the Sleeper Berth Study.

Specific Contributing Factor Category	Frequency of SB Driver At-Fault Incidents (n_{SB} = 21)	Percentage of SB Driver At-Fault Incidents (n_{SB} = 21)	Frequency of LV Driver At-Fault Incidents (n_{LV} = 47)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 47)	Frequency of All Drivers (N_{Total} = 68)	Percentage of All Drivers (N_{Total} = 68)
Driving Techniques	11	52%	20	42.6%	31	45.6%
Aggressive Driving	5	24%	19	40.4%	24	35.3%
Roadway Alignment	0	0%	4	8.5%	4	5.9%
Unknown	0	0%	4	8.5%	4	5.9%
Vehicle Kinematics, Physics	3	14%	0	0%	3	4.5%
Driver Capabilities and Limitations	1	5%	0	0%	1	1.5%
Fatigue and Drowsiness	1	5%	0	0%	1	1.5%
Purposeful Violation of Traffic Laws	0	0%	0	0%	0	0%
Roadway Sight Distance	0	0%	0	0%	0	0%
Unfamiliar With Roadway/ Traffic Pattern	0	0%	0	0%	0	0%
Use of Vehicle For Improper Purposes	0	0%	0	0%	0	0%

Table 45. Frequency and Percentage of Contributing Factors for the Local/Short Haul Study.

Specific Contributing Factor Category	Frequency of L/SH Driver At-Fault Incidents ($n_{L/SH}$ = 25)	Percentage of L/SH Driver At-Fault Incidents ($n_{L/SH}$ = 25)	Frequency of LV Driver At-Fault Incidents (n_{LV} = 117)	Percentage of LV Driver At-Fault Incidents (n_{LV} = 117)	Frequency of All Drivers (N_{Total} = 142)	Percentage of All Drivers (N_{Total} = 142)
Aggressive Driving	3	12%	50	42.7%	53	37.3%
Driving Techniques	8	32%	26	22.2%	34	23.9%
Roadway Alignment	7	28%	8	6.8%	15	10.6%
Unknown	0	0%	15	12.8%	15	10.6%
Purposeful Violation of Traffic Laws	2	8%	5	4.3%	7	4.9%
Roadway Sight Distance	0	0%	7	6%	7	4.9%
Driver Capabilities and Limitations	2	8%	3	2.6%	5	3.5%
Vehicle Kinematics, Physics	1	4%	1	.9%	2	1.4%
Unfamiliar With Roadway/ Traffic Pattern	0	0%	2	1.7%	2	1.4%
Fatigue and Drowsiness	1	4%	0	0%	1	.7%
Use of Vehicle For Improper Purposes	1	4%	0	0%	1	.7%

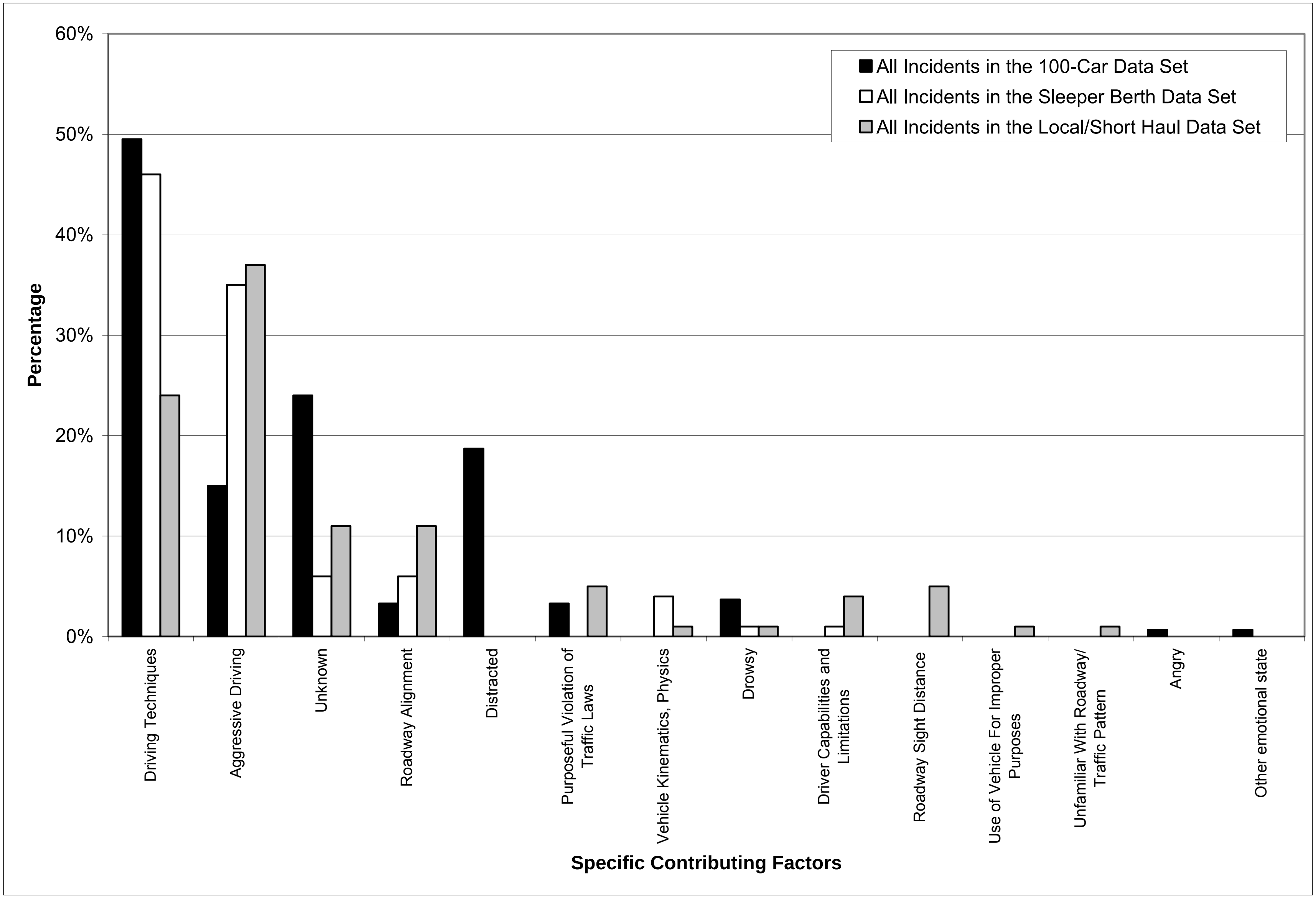


Figure 44. Percentage of Incidents in the 100-Car, SB, and L/SH Studies as a Function of Contributing Factors.

Figure 45 shows the percentage of HV driver at-fault incidents for the 100-Car, SB, and L/SH studies as a function of Contributing Factor. The black bars in Figure 45 represent the HV driver at-fault incidents in the 100-Car Study, while the white and grey bars represent HV driver at-fault incidents in the SB and L/SH studies, respectively. In the 100-Car Study, the most frequent Contributing Factors were Unknown (68.4%), Driving Techniques (15.2%), and Distracted (11.4%). In the SB study, the most frequent Contributing Factors were Driving Techniques (52%), Aggressive Driving (24%), and Vehicle Kinematics, Physics (14%). In the L/SH study, the most frequent Contributing Factors for HV driver at-fault incidents were Driving Techniques (32%), Roadway Alignment (28%), and Aggressive Driving (12%).

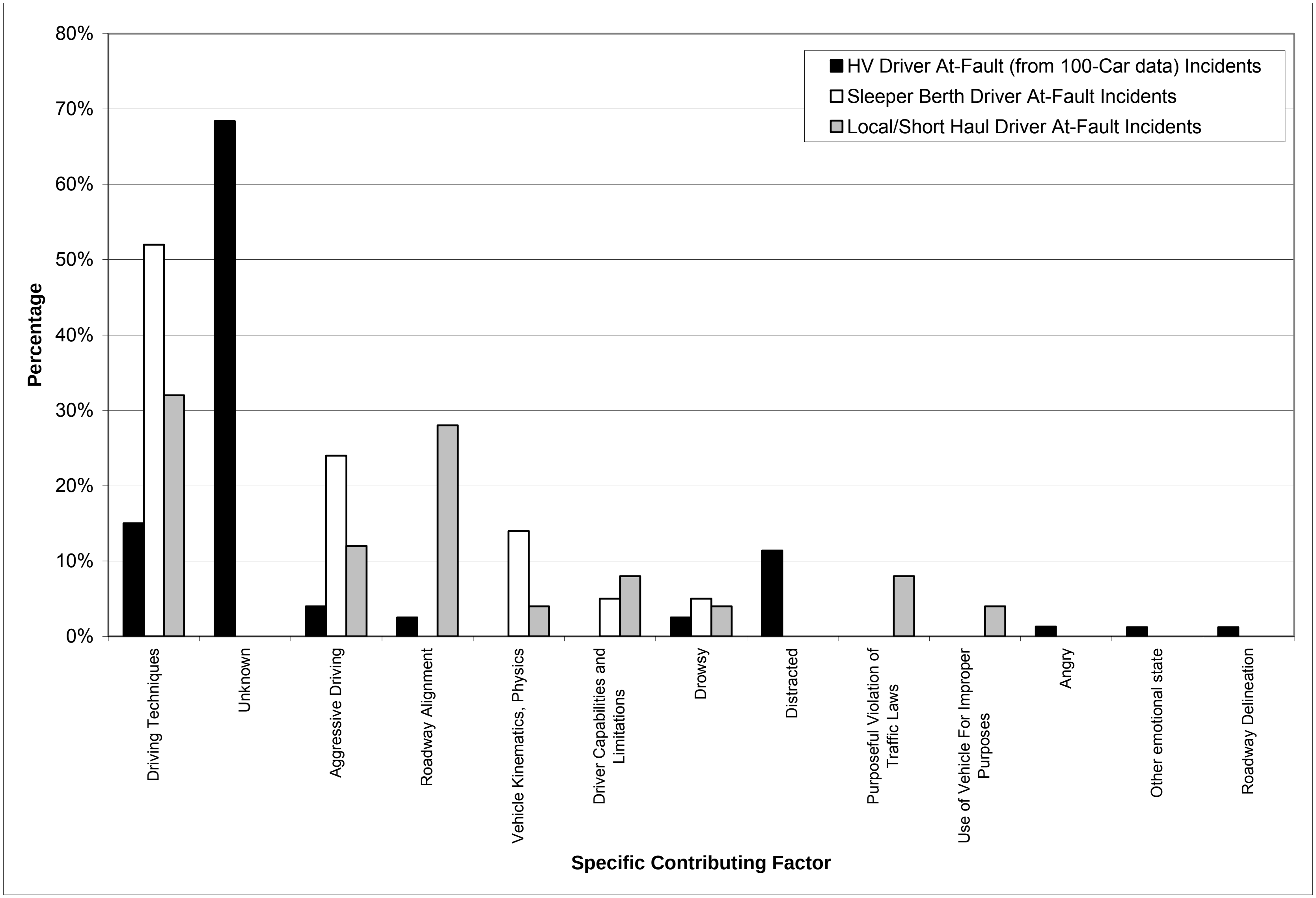


Figure 45. Percentage of HV At-Fault Incidents in the 100-Car, SB, and L/SH Studies as a Function of Contributing Factors for LV Drivers.

Figure 46 shows the percentage of LV driver at-fault incidents in the 100-Car, SB, and L/SH studies as a function of Contributing Factor. The black bars in Figure 46 represent the LV driver at-fault incidents in the 100-Car Study, while the white and grey bars represent LV driver at-fault incidents in the SB and L/SH studies, respectively. In the 100-Car Study, the most frequent Contributing Factors for LV driver at-fault incidents were Driving Techniques (70.3%), Distracted (22.5%), and Aggressive Driving (22.5%). In the SB study, the most frequent Contributing Factors for LV driver at-fault incidents were Driving Techniques (42.6%) and Aggressive Driving (40.4%). In the L/SH study, the most frequent Contributing Factors for LV driver at-fault incidents were Aggressive Driving (42.7%), Driving Techniques (22.2%), and Unknown (12.8%).

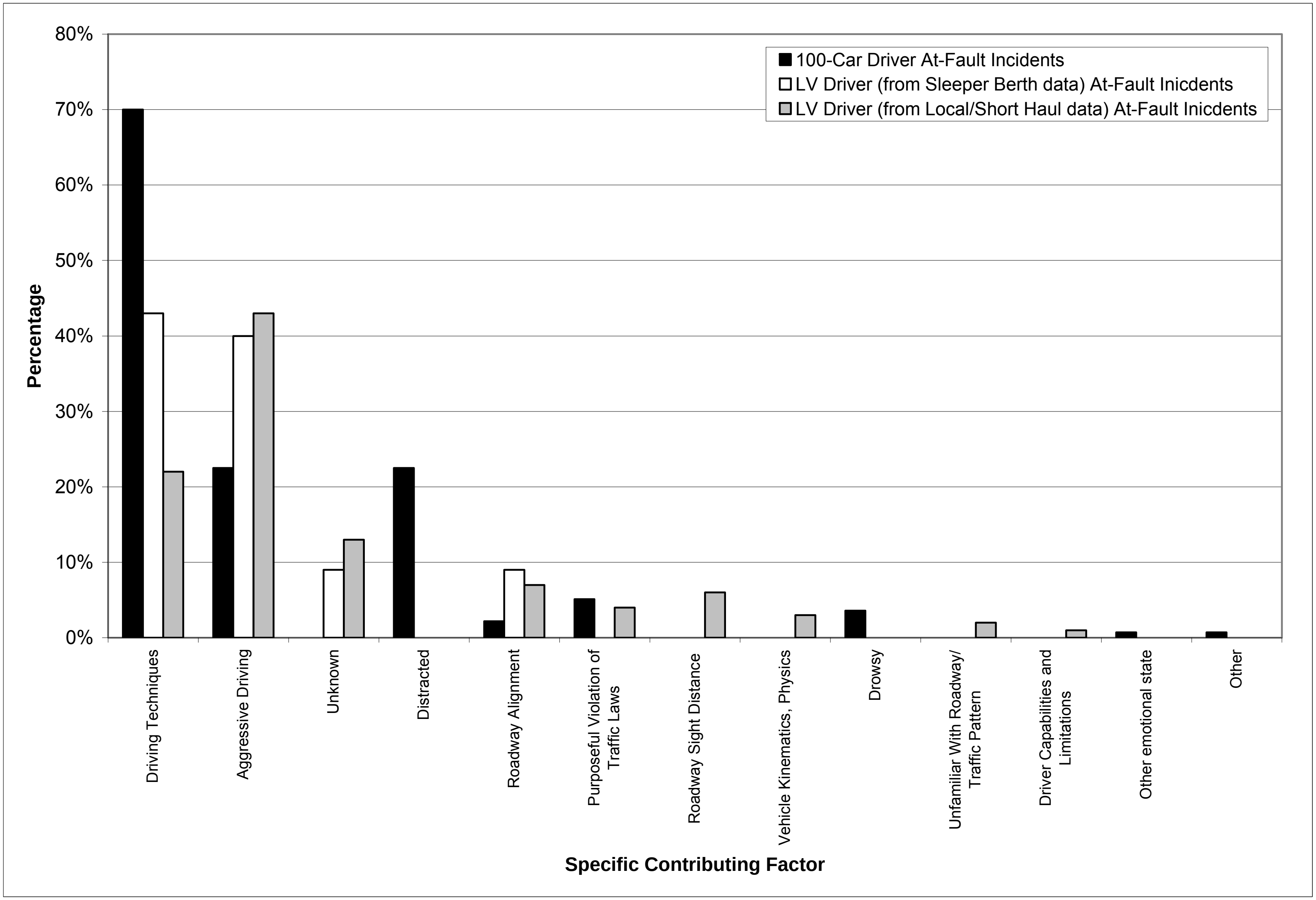


Figure 46. Percentage of LV Driver At-Fault Incidents in the 100-Car, SB, and L/SH Studies as a Function of Contributing Factor.

Summary of Contributing Factors Across Studies

Across the three studies, the most frequent Contributing Factors were Driving Techniques (41%), Aggressive Driving (24.1%), and Unknown (17.1%). As can be seen in Figures 44-46, the Contributing Factors were relatively the same depending on whether the LV or HV was at-fault.

As can be seen in Figure 45, the most frequent Contributing Factors for HV driver at-fault incidents in the 100-Car Study were Unknown (68.4%), Driving Techniques (15.2%), and Distracted (11.4%). In the SB study, the most frequent Contributing Factors were Driving Techniques (52%), Aggressive Driving (24%), and Vehicle Kinematics, Physics (14%). In the L/SH study, the most frequent Contributing Factors were Driving Techniques (32%), Roadway Alignment (28%), and Aggressive Driving (12%). From the data it appears that the majority of at-fault HV drivers were classified with poor driving techniques.

It is important to note that the HV driver at-fault Contributing Factors in both the SB and L/SH studies are relatively the same, yet, different from the HV driver at-fault Contributing Factors in the 100-Car Study. The reader should bear in mind that the Contributing Factor was coded with respect to the instrumented vehicle, thus, the high frequency of Unknown Contributing Factors in the 100-Car Study. If a LV driver was not at-fault, it was unlikely they would be coded with a Contributing Factor in the LV-HV interaction (as supported by the data in the 100-Car Study).

As can be seen in Figure 46, the most frequent Contributing Factors for LV driver at-fault incidents in the 100-Car Study were Driving Techniques (70.3%), Distracted (22.5%), and Aggressive Driving (22.5%). In the SB study, the most frequent Contributing Factors for LV driver at-fault incidents were Aggressive Driving (42.6%) and Driving Techniques (40.4%). In the L/SH study, the most frequent Contributing Factors for LV driver at-fault incidents were Aggressive Driving (42.7%), Diving Techniques (22.2%), and Unknown (12.8%). From the data it appears that the majority of at-fault LV drivers were classified with poor driving techniques and aggressive driving.

Recall that Hankey et al. (1999) found that 77% of crashes in the Pennsylvania crash database from 1995-1996 were cited with “human error” as the primary factor in the crash. By adding the frequency of Contributing Factors associated with human error in the three studies, a total of 294 incidents out of 427, or 68.9%, of the LV-HV interactions had at least one human error as a Contributing Factor (excluding the Unknown at-fault incident in the 100-Car Study).

Yet, there were differences when only HV and LV driver at-fault incidents were considered. For example, 35.2% of the HV driver at-fault incidents across the 100-Car, SB, and L/SH studies had at least one human error Contributing Factor (for either driver), while 82.8% of the LV driver at-fault incidents across the 100-Car, SB, and L/SH studies had at least one human error Contributing Factor. Thus, LV driver at-fault incidents were found to be similar to what Hankey et al. (1999) found when they analyzed the Pennsylvania crash database. But, it also suggests that at-fault LV drivers were more likely than at-fault HV drivers to be coded with “human error” as a Contributing Factor in the LV-HV interactions. As the majority of crashes involve LVs rather than HVs (NHTSA, 2004), it is not all that surprising that LV drivers were more similar than HV drivers when comparing the results of the 100-Car, SB, and L/SH studies to the Hankey et al. (1999) study.

However, the Hankey et al. (199) study looked at all types of crashes. Stuster (1999) assessed driver-related factors in only LV-HV fatal crashes and found that 67.7% of LVs were cited with the driver-related factors similar to the Willful Behavior and Driver Proficiency Contributing Factor categories related to human error, while 23.8% of HVs were cited with the same driver-related factors. These results have a similar ratio to the LV (84.1%) and HV (33.6%) at-fault incidents attributed to human error across the 100-Car, SB, and L/SH studies.

Hankey et al. (1999) also conducted analysis with the 1996 FARS database. They found that 31.1% of the fatal crashes involved aggressive driving as a primary factor. This is relatively similar (within 10%) to what was found across the 100-Car, SB, and L/SH studies, where 24.1% of the LV-HV interactions were coded with the Aggressive Driving Contributing Factors.

Across the 100-Car, SB, and L/SH studies it was found that 33.1% of the LV at-fault incidents were coded with the Aggressive Driving Contributing Factor, while 7.2% of the HV driver at-fault incidents were coded with the same Contributing Factor (excluding the Unknown at-fault incidents). Stuster's (1999) analysis of fatal LV-HV interactions found that 2.1% of the HVs were cited with the driver-related factor "Erratic/Reckless Driving," while 4.3% of the LVs were cited with this same driver-related factor. Thus, when comparing the same type of event (i.e., LV-HV interaction), keeping in mind that the events were different in intensity, the current analysis resulted in different results from the Stuster (1999) findings.

DISCUSSION OF THE RESULTS COMPARING THE 100-CAR, SB, AND L/SH STUDIES

The primary aims of Chapter 2 were to combine the data from the current study with the data from the L/SH and SB studies in Hanowski, Keisler, and Wierwille (2004) to illustrate the overall crash picture, and address the limitation of having only one vehicle instrumented by assessing the differences between the three studies (i.e., are LV-HV interactions fundamentally different as a function of which vehicle is instrumented?). The results from the 100-Car Study were presented in Chapter 1, while the results from both the SB and L/SH studies can be found in Hanowski, Keisler, and Wierwille (2004).

In the 100-Car Study, a total of 246 LV-HV interactions were identified. Of these, 138 (56.1%) and 79 (32.1%) incidents were found to be the fault of the LV and HV drivers, respectively. In the remaining 29 (11.8%) incidents it was unknown whether the LV or HV driver was at-fault. In the L/SH study, a total of 142 LV-HV interactions were identified. Of these, 117 (82.4%) incidents were the fault of the LV driver, while the remaining 25 (17.6%) incidents were the fault of the HV driver. In the SB study, a total of 68 LV-HV interactions were identified. Of these, 47 (69.1%) were the fault of the LV driver, while the remaining 21 (38.9%) were the fault of the HV driver. Taken together with the current research, these three studies consistently show that LV drivers appear to be responsible for the majority of LV-HV interactions. Of the 427 LV-HV incidents identified across the three studies (excluding the 29 Unknown at-fault incidents in the current study), 302 (70.7%) were judged to have been the fault of the LV driver, while the remaining 125 (29.3%) were the fault of the HV driver (a 2.4:1 ratio). The high ratio presented here emphasizes the role that LV drivers play in LV-HV interaction incidents. Given that LV drivers were more likely to have initiated an incident, it is believed that efforts at addressing the LV-HV interaction problem should include focusing on the LV driver.

There were a number of interesting findings from the comparisons between the 100-Car, SB, and L/SH studies. Comparisons were conducted with respect to the Incident Type, Primary Maneuver, and Contributing Factor. The Incident Type comparison indicated that Lane Change Without Sufficient Gap was the most frequent Incident Type across all three studies. A breakdown of incidents as a function of the at-fault driver showed that Lane Change Without Sufficient Gap incidents were primarily attributed to LV drivers. Critical incidents that involved a LV driver changing lanes in front of an HV, leaving the HV driver with very little headway between vehicles, were a common Incident Type that was captured in all three studies.

While the Incident Types for the LV driver at-fault incidents shared some similarities across the three studies, the Incident Types for the HV driver at-fault incident were more varied across the studies. In the 100-Car Study, 48.1% of the HV driver at-fault Incident Types included Lane Change Without Sufficient Gap and Lateral Deviation of Through Traffic. In the SB study, 71.4% of the HV driver at-fault incidents included Late Braking for Stopped/Stopping Traffic and Following Too Closely. In the L/SH study, 48% of the Incident Types included Roadway Entrance Without Clearance, Wide Turn Into Adjacent Lane, and Late Braking for Stopped/Stopping Traffic. One possible explanation for these differences was the predominant Road Type traveled (see Figure 38), as well as the type of trucking operations included in the SB and L/SH studies. It could be argued that the HVs in the 100-Car Study represent a more diverse population of HVs since they were not limited to L/SH and SB trucks. In fact, as shown in Table 3 (page 15), 25 different HVs were identified as being involved in LV-HV interactions in the 100-Car Study. Thus, it is likely the results for at-fault HV drivers in the 100-Car Study might be more representative of HV drivers in general, while the results for HV drivers in the SB and L/SH studies are more representative of drivers in those specific operations.

The Primary Maneuver comparison indicated that Changing Lanes was the most frequent Primary Maneuver across all three studies. A breakdown of incidents as a function of the at-fault driver showed that Through Traffic incidents were primarily attributed to HV drivers. Critical incidents that involved an HV driver traveling forward on the roadway or straight though an intersection were a common Primary Maneuver in the three studies. However, while Through Traffic was the most frequent Primary Maneuver for HV driver at-fault incidents in both the SB and L/SH studies, the most frequent Primary Maneuvers for HV driver at-fault incidents in the 100-Car Study were Changing Lanes and Crossing Over the Lane Line. This suggests that, for the general population of HV drivers, changing lanes and crossing the lane line are difficult maneuvers. This make intuitive sense, as HVs are likely to have blind spots that make it difficult to change lanes or attempt to change a lane.

The most predominant Primary Maneuver for LV driver at-fault incidents was Changing Lanes. While in all three studies the LV driver was likely to be coded with the Changing Lanes Primary Maneuver, there were also differences across the three studies. LV drivers in the 100-Car Study also had difficulties when they were braking or stopped. LV drivers in the SB study encountered difficulties in through traffic, while LV drivers in the L/SH study had difficulties when they were making left turns.

The Contributing Factors category allows researchers to describe why the incident occurred. The most frequent Contributing Factor across the three studies was Driving Techniques. A breakdown of incidents as a function of the at-fault driver showed that Driving Techniques were primarily attributed to HV drivers. Thus, when the Contributing Factor was known, this was the most frequent Contributing Factor for HV driver at-fault incidents in each of the studies.

The most frequent Contributing Factors for LV driver at-fault incidents across the three studies were Driving Techniques and Aggressive Driving. These two Contributing Factors accounted for a substantial number of the LV driver at-fault incidents across the three studies. However, a large proportion of the LV driver at-fault incidents in the 100-Car Study involved the Distracted Contributing Factor. In fact, the only time a LV driver at-fault incident was coded with the Distracted Contributing Factors was in the 100-Car Study. This is almost certainly due to the fact that the LVs in the 100-Car Study were instrumented (thereby allowing analysis of the LV drivers' behaviors while driving), while the LVs in both the SB and L/SH studies were not instrumented.

Summary

The results of the current study in conjunction with Hanowski, Keisler, and Wierwille (2004) indicated that LV-HV interactions represent a serious problem. While there were several differences across the three studies, the results consistently showed that LV drivers are more likely to be responsible for the LV-HV interaction than HV drivers. It is believed that the results from the 100-Car, SB, and L/SH studies provide a more complete description of the LV-HV interaction picture. Further, the comparisons among these three studies address the limitations of not having LVs and HVs instrumented. The detailed analyses that were conducted provide insight into how this problem might be addressed. Listed below are several suggestions that should be considered for reducing LV-HV interactions:

- Addressing the LV-HV interaction problem should focus on the driving behaviors of the LV driver. The LV driver was at-fault in 70.7% of the LV-HV interaction incidents recorded across the three studies.
- The primary area for LV that should be addressed involves their driving techniques and aggressive driving behaviors. Also, the instrumented LVs in the 100-Car Study showed that distraction was a significant problem in LV-HV interactions. Thus, the three studies identified three areas for LV drivers that should be targeted: distraction, aggressive driving, and driving techniques. Also, distraction, particularly from cell phones, appears to be a much bigger problem then has been reported in previous studies (e.g., Stutts et al., 2003).
- The primary area for HV drivers that should be addressed involves driving techniques. One possible method of addressing this is through improved truck driver training programs. For example, consideration should be given to ongoing (e.g., yearly) training courses. Given the high incidence of Aggressive Driving on the part of LV drivers, one of the primary areas of focus for a truck driving training program should be on defensive driving and hazard identification.

- Infrastructure was found to play a role in HV driver at-fault incidents in the L/SH study. Drivers and/or company dispatchers should be cognizant of problematic sections of routes, and avoid such locations to the greatest extent possible.
- Technology has progressed to the point where it is possible to collect data on almost any driving-related variable. *In situ* data collection is one way to study a wide range of safety-related issues in a naturalistic environment. The video and performance/behavior data collected from the 100-Car, SB, and L/SH studies have been archived and provide a rich source of information that can be used for studying critical incidents, as was the case in the current effort, or other issues that might be identified at a later time.

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