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Crash Factors in Intersection-Related Crashes: An On-Scene Perspective

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16. Abstract

Crashes often occur at intersections because these are the locations where two or more roads cross each other and activities such as turning left, crossing over, and turning right have the potential for conflicts resulting in crashes. In order to understand the crash scenarios at intersections, this study examines general characteristics of motor vehicle traffic crashes at intersections by analyzing the association of the critical reason with several crash factors such as driver's sex and age, traffic control device, critical pre-crash event, and atmospheric condition. The National Motor Vehicle Crash Causation Survey data collected at crash scenes between 2005 and 2007 is used in statistical analyses such as descriptive analysis, generalized logit model, and configural frequency analysis.

Descriptive statistics are first used to highlight characteristics of the intersection-related crashes. The results from this analysis provide guidelines for in-depth analysis. Close associations of crash factors with critical reasons of an event that made the crash imminent are revealed through the analysis of generalized logit model. Subsequently, the configural frequency analysis is used to identify patterns of driver-attributed critical reasons in the intersection-related crashes in terms of crash factors such as traffic control devices, pre-crash event, and driver's age and sex.

Many interesting findings are obtained in this study. For example, crash occurrence may be attributed to illegal maneuver or inattention while crossing over at intersections controlled by traffic signals or stop signs. For both male and female drivers 55 and older, crash occurrence may be attributed to misjudgment of gap or other's speed and inadequate surveillance. Male drivers of all ages are likely to be involved in intersection-related crashes due to illegal maneuver or driving aggressively or too fast for conditions.

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Executive summary

Crashes often occur at intersections because these are the locations where two or more roads cross each other and activities such as turning left, crossing over, and turning right have the potential for conflicts resulting in crashes. Based on the Fatality Analysis Reporting System (FARS) and National Automotive Sampling System-General Estimates System (NASS-GES) data, about 40 percent of the estimated 5,811,000 crashes that occurred in the United States in 2008[1] were intersection-related crashes. Identifying characteristics of intersection-related crashes (traffic control device, critical pre-crash event, and atmospheric condition) as well as of the crash-involved drivers (age, sex, and driving behavior) can provide useful guidelines for crash prevention.

This study examines general characteristics of motor vehicle traffic crashes that occur at intersections using the National Motor Vehicle Crash Causation Survey (NMVCCS). The NMVCCS data, collected at the crash scene, pertain to only those crashes that occurred between 6 a.m. and midnight. Additionally, at least one of the first three crash-involved vehicles had to be a light passenger vehicle that was towed due to damage. The focus of analysis is on studying the association of the critical reasons, i.e., the immediate reasons for the critical pre-crash event, with crash factors. The crash factors considered in this analysis include the critical pre-crash event (an event or action that puts a vehicle on the course that makes the collision unavoidable), driver's sex and age, traffic control device, and atmospheric condition. All statistics presented in this report are based on the weighted frequencies.

In this study, intersection-related crashes refer to crashes that have critical pre-crash events coded as turning left, crossing over, or turning right at an intersection. Descriptive statistics show that 36 percent (787,236) of the estimated 2,188,969 NMVCSS crashes were intersection-related crashes. Of the 787,236 intersection-related crashes, about 96 percent (756,570 crashes) had critical reasons attributed to drivers, while the vehicle- or environment-attributed critical reasons were assigned in less than 3 percent of these crashes. Similarly, about 92 percent (1,289,283 crashes) of the non-intersection-related crashes had critical reasons attributed to drivers. However, the distributions of the driver-attributed critical reasons in intersection-related and non-intersection-related crashes were quite different. Of the 756,570 intersection-related crashes with driver-attributed critical reasons, the most frequent critical reasons were inadequate surveillance (44.1%), followed by false assumption of other's action (8.4%), turned with obstructed view (7.8%), illegal maneuver (6.8%), internal distraction (5.7%), and misjudgment of gap or other's speed (5.5%). In contrast, the most frequent critical reasons in non-intersection-related crashes were too fast for conditions/aggressive driving (22.8%), followed by driver performance error (overcompensation, poor directional control) (15.9%), internal distraction (13.4%), critical non-performance errors (10.8%), inadequate surveillance (7.3%) and external distraction (4.7%).

The relative ratio analysis shows that intersection-related crashes are almost 335 times as likely to have "turned with obstructed view" as the critical reason than non-intersection-related crashes. The second highest relative ratio of intersection-related crashes versus non-intersection-related crashes is for "inadequate surveillance," followed by "illegal maneuver," "false assumption of other's action," "misjudgment of gap or other's speed," etc. "Inadequate surveillance" is likely to happen about 6 times more often in intersection-related crashes than in non-intersection-related crashes. Also, the intersection-related crashes are likely to have "illegal maneuver" and "false assumption of other's action" as critical reasons about 4 times more than non-intersection-related crashes. The critical reasons with high relative ratio of intersection-related crashes as compared with non-intersection-related crashes form a major portion of intersection-related crashes.

The analysis of a generalized logit model reveals statistically significant association of critical reason with crash factors and their two-factor interaction effects (traffic control device and critical pre-crash event;

traffic control device and driver's age; driver's sex and critical pre-crash event; driver's sex and age; driver's sex and traffic control device). Configural frequency analysis (CFA) identifies the patterns of driver-attributed critical reasons in terms of the statistically significant two-factor interaction effects in intersection-related crashes. The main findings of these statistical analyses include:

- Crash occurrence may be attributed to "illegal maneuver" or "inattention" while crossing over at intersections controlled by traffic signals or stop signs; "turned with obstructed view" or "misjudgment of gap or other's speed" while turning left at intersections controlled by traffic signals or stop signs; and "false assumption of other's action" while turning right at stop signs.

- Regarding driver age as a crash factor, crash occurrence at intersections controlled by traffic signals involving drivers 24 and younger may be attributed to "internal distraction," "false assumption of other's action," "too fast for conditions or aggressive driving," or "external distraction." On the other hand, the crash occurrence at intersections controlled by traffic signals involving drivers 25 to 54 years old may be attributed to "critical non-performance error," "illegal maneuver," "inattention," and "too fast for conditions or aggressive driving." Also, the crash occurrence at intersections controlled by stop signs involving drivers 55 and older may be attributed to "inadequate surveillance" and "misjudgment of gap or other's speed," while the crash occurrence involving drivers 24 and younger may be attributed to "turned with obstructed view."

- For both male and female drivers, the crash occurrence at intersections while turning left may be attributed to "turned with obstructed view," "misjudgment of gap or other speed," "inadequate surveillance," or "false assumption of others action." Also, the crash occurrence while crossing over at intersection may be attributed to "illegal maneuver" or "internal distraction." However, in the case of female drivers crossing over at intersections, the crash occurrences may also be attributed to recognition errors such as "inattention", or "internal or external distractions," while for male drivers crossing over at intersections, the crash occurrences may be due to "illegal maneuver," "too fast for conditions or aggressive driving," or "critical non-performance error," where critical non-performance error includes sleeping, heart attack, other physical impairment, and being passed out as a result of alcohol or drug ingestion.

- The analysis also shows an interaction effect of driver sex and age in crash occurrence at intersections. For both male and female drivers 55 and older, crash occurrence may be attributed to "misjudgment of gap or other's speed" and "inadequate surveillance." The crash occurrence at intersections may be due to "illegal maneuver" for male drivers and "internal distraction" or "inattention" for female drivers, irrespective of their ages. The crash occurrence involving female drivers 24 and younger at intersections may be attributed to "turned with obstructed view" or "internal distraction," while for male drivers 24 and younger it may be attributed to "internal or external distraction," "illegal maneuver," or "false assumption of other's action."

- At intersections controlled by traffic signals, the crash occurrence may be attributed to "false assumption of others action," "inattention," or "internal distraction" for female drivers, while for male drivers it may be attributed to "critical non-performance error," "illegal maneuver," "false assumption of other's action," "too fast for conditions or aggressive driving," or "internal distraction." At intersections controlled by traffic control devices (traffic signals or stop signs), crash occurrence may be attributed to "inattention" of female drivers and "illegal maneuver" by male drivers. The crash occurrence at intersections with no traffic control devices may be attributed to "misjudgment of gap or other's speed" for both female and male drivers.

The findings about the intersection-related crashes, presented in this report, can be used in the evaluation and development of the design of intersection collision avoidance technologies, such as the Cooperative Intersection Collision Avoidance System (CICAS), which would warn a driver about an imminent violation of the traffic control device at the intersection. These findings may also help improve road design, use of traffic control device, and driver training.

1. Introduction

Crashes often occur at intersections because these are the locations where two or more roads cross each other and activities such as turning left, crossing over, and turning right have the potential for conflicts. Even though intersections constitute only a small proportion of the entire roadway system, a significantly large proportion of crashes occur at intersections. Based on FARS and GES data, an estimated 2,307,000 crashes[1] occurred at intersections across the country in 2008. This accounts for about 40 percent of the 5,811,000 crashes that occurred in the United States in 2008. Among these, 7,421 were fatal crashes and in 733,000 crashes one or more occupants suffered injuries. In order to understand and prevent crashes at intersections, efforts have been made in the past by federal and State highway departments, law enforcement agencies, automobile manufacturers, and other safety organizations. For instance, intersection collision avoidance technologies such as Cooperative Intersection Collision Avoidance Systems-Violation (CICAS-V) have been in various stages of design, development, and refinement. These technologies use vehicle- and infrastructure-based communication to warn drivers about conditions at intersections to avoid crashes.[2] Identifying characteristics of intersection-related crashes (traffic control device, critical pre-crash event, and atmospheric condition) as well as of the crash-involved drivers (age, sex, and driving behavior) can provide useful guidelines for crash prevention measures.

This study considers some general characteristics of motor vehicle traffic crashes that were investigated at the crash scenes. The data is analyzed to examine the association of the critical reason of intersection-related crashes with several factors such as critical pre-crash event (event or action that puts a vehicle on the course that makes the collision unavoidable), driver sex and age, traffic control device, and atmospheric condition. The results can be used to evaluate intersection collision avoidance systems designed to help prevent intersection-related crashes. This may also help improve road design, use of traffic control device, and driver training. The study is aimed at providing a better understanding of the scenarios of intersection-related crashes and the state of the crash-involved drivers' activities such as inattention, distraction, illegal maneuver, etc.

2. Data and Methodology

The data used in this report is from the National Motor Vehicle Crash Causation Survey. The NMVCCS data is a nationally representative sample of crashes that contains on-scene information on the events and associated factors leading up to a crash. The NMVCCS data pertains to only those crashes that occurred between 6 a.m. and midnight. Additionally, at least one of the first three crash-involved vehicles had to be a light passenger vehicle that was towed due to damage. A variety of descriptive variables on several aspects of vehicles, drivers, and environment are included in this data. The data was collected from January 2005 to December 2007. The data contains both weighted and unweighted cases. However, only the weighted cases are used in the analysis; all statistics presented in this report are based on the weighted frequencies.

NMVCCS considers a crash as a simplified linear chain of events[3] that would mainly include the elements of critical pre-crash event, movement prior to critical crash envelope, critical reason for the critical pre-crash event, and the crash-associated factors. Among these elements, the critical pre-crash event refers to the action or the event that puts a vehicle on the course that makes the collision unavoidable, given reasonable driving skills and vehicle handling. The movement prior to critical crash envelope refers to movement of the vehicle immediately before the occurrence of the critical pre-crash event. The critical reason, often the last failure in the causal chain, is the immediate reason for the critical pre-crash event and can be attributed to a driver, vehicle, or environment. More detailed information is available in *NMVCCS Field Coding Manual*[4] and *NMVCCS Report to Congress*.[5]

Descriptive analysis, relative ratio, generalized logit modeling, and configural frequency analysis are used to look into the characteristics of intersection-related crashes and to identify patterns of critical reasons in these crashes with

respect to traffic control devices, pre-crash event, and driver's age and sex. The generalized logit model is fit to the data with critical reason as a nominal response variable, where several variables possibly associated with critical reason are considered. CFA, used for pattern recognition in this study, is a multivariate statistical technique that identifies those sectors of the data where the association among variables is locally prominent. The method compares the observed frequencies to the expected frequencies in a cross-tabulation and determines whether the difference between observed and expected frequency for a given cell configuration in the contingency table is statistically significant – a significant difference indicates that in the corresponding sector of the data space the variables are locally associated with each other, thereby showing patterns in the data. Statistical software SAS 9.1[6] is used for these analyses.

3. Analysis and Results

This study focuses on crashes that have critical pre-crash event coded as turning left, crossing over, or turning right at the intersection. These crashes are specifically referred to as intersection-related crashes in the remainder of this report.

Descriptive statistics are first used to highlight characteristics of intersection-related crashes. The results from the descriptive analysis provide a guideline for generalized logit modeling. Subsequently, CFA is applied to identify patterns of critical reason in the intersection-related crashes by factors such as traffic control devices, pre-crash event, and driver's age and sex.

3.1 IDENTIFICATION OF RELEVANT CRASH POPULATION

In order to identify the crash population of interest with respect to critical reasons of the intersection-related crashes, some of relevant variables such as critical pre-crash event, traffic control devices, driver sex, driver age, and atmospheric condition are explored. Note that generally one vehicle was assigned a critical reason in a NMVCCS crash. This analysis considers only the vehicles assigned critical reasons.

Critical pre-crash event

In NMVCCS, the variable "critical pre-crash event" is defined as an event that made the crash imminent (i.e. something occurred that made the collision inevitable). It is coded for each vehicle in the crash and documents the circumstances leading to this vehicle's first impact in the crash sequence.

Figure 1 shows the distribution of crashes over critical pre-crash events. In the estimated **!The Formula Not In Table** NMVCCS crashes, for about 36 percent (787,236) the critical pre-crash events of the vehicles with a critical reason (the immediate reason for the occurrence of the critical event) were turning or crossing at intersections. In the case of 22.2 percent of crashes, the critical event was turning left; it was crossing over for 12.6 percent and turning right at the intersection for a very small percentage (1.2%) of vehicles.

The data used for the charts (Figure 1 to Figure 6) in this section is provided in Table A1 through Table A6 (Appendix A) that include unweighted frequencies, weighted frequencies, and weighted percentages.

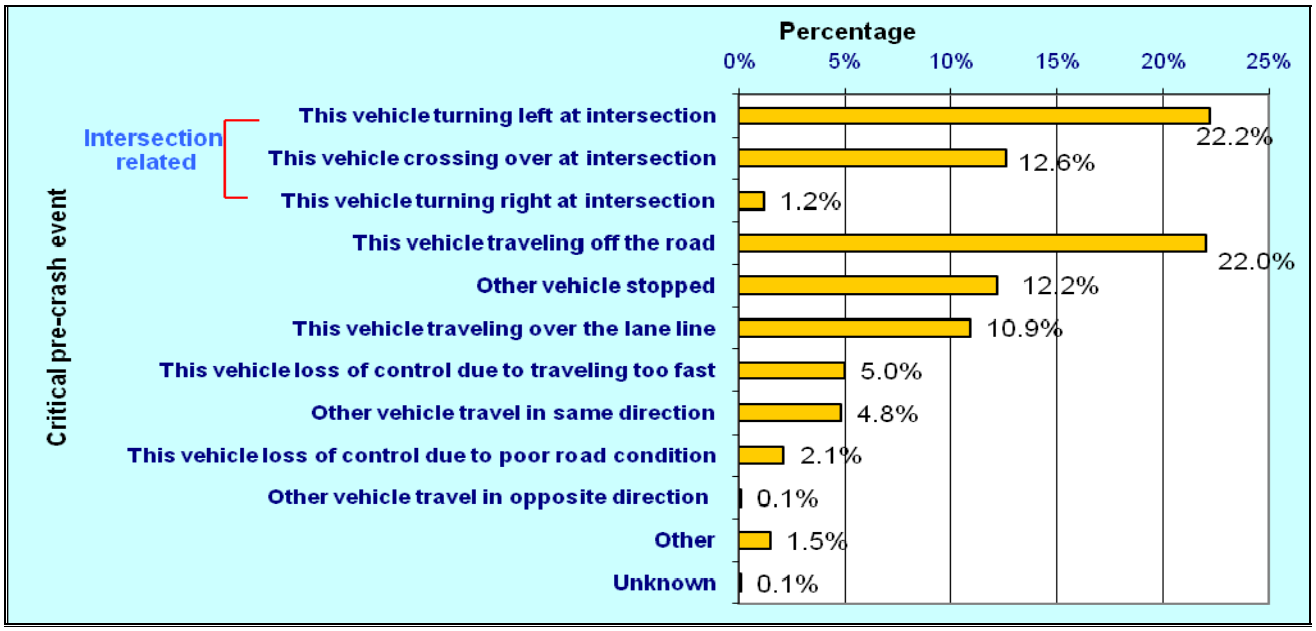

Figure 1: Distribution of critical pre-crash event
Data Source: NMVCCS 2005-2007

Traffic control device

The variable "traffic control device" includes all traffic control devices that regulate vehicular traffic on the roadway on which a vehicle is traveling just prior to critical pre-crash event. This excludes devices that solely regulate pedestrians, such as walk signals. Note that the coding of this variable is based on multiple choices per vehicle.

Intersections are often controlled by traffic signals or stop signs but some have neither. Figure 2 shows the distribution of intersection-related crashes over traffic control devices. In an estimated 787,236 intersection-related crashes, about 52.5 percent (413,140) of the vehicles that were assigned a critical reason were traveling on roadways that were controlled by at least one traffic signal and 31.3 percent (246,385) by at least one stop sign. About 15.9 percent (125,022) of vehicles were traveling on the roadways with no traffic control device. Due to the multiple choice nature of this variable, the totals presented may not match the actual totals of crashes, vehicles, or drivers. For the same reason, the percentages in some of the tables may not add up to 100 percent.

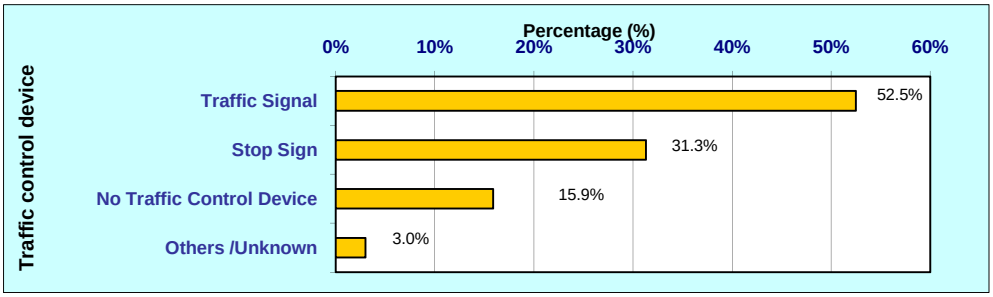

Figure 2: Distribution of traffic control devices
Data Source: NMVCCS 2005-2007

Driver's age group

Figure 3 shows that of all the crashes in which drivers 20 and younger were involved, 33 percent were intersection-related crashes. Similarly, 26.7 percent of crashes involving drivers 21 to 24 years old, about 35 percent involving 25 to 54 years old, 43.4 percent involving 55 to 64 years old, and 53.9 percent involving 65 and older were intersection-related crashes. Overall, the proportion of intersection-related crashes shows an increasing trend over age of drivers involved in crashes.

Driver's sex

Figure 4 shows that 41.1 percent of crashes involving female drivers were intersection-related. In contrast, 32.2 percent of crashes involving male drivers were intersection-related crashes.

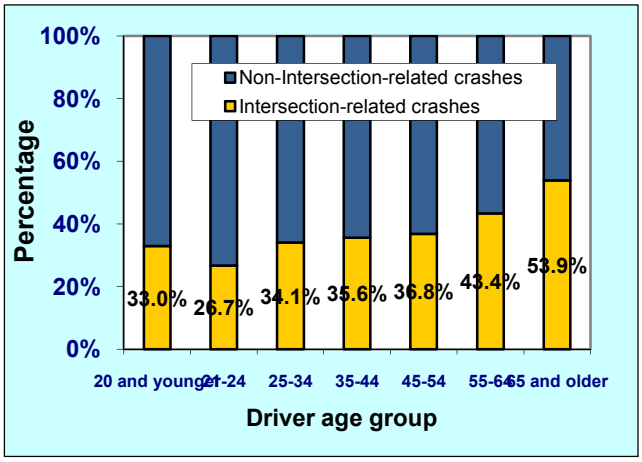

Figure 3: Percentage of intersection-related crashes by driver age group
Data source: NMVCCS 2005-2007

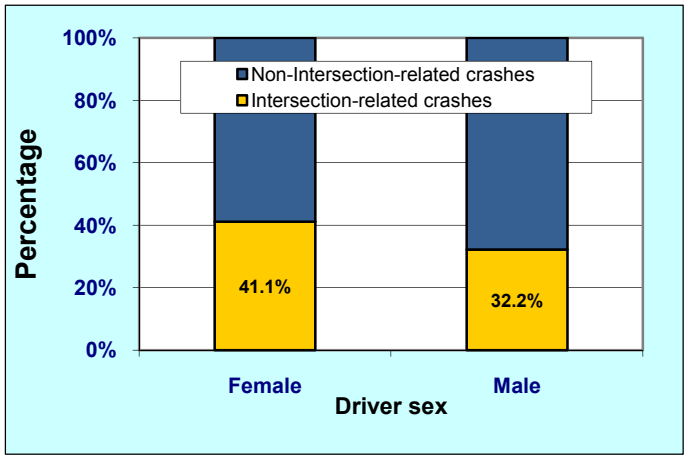

Figure 4: Percentage of intersection-related crashes by driver sex
Data Source: NMVCCS 2005-2007

Atmospheric condition

NMVCCS recorded atmospheric conditions at the time of the crashes. More than one atmospheric condition may have been coded for some crashes. As a result, the total in Figure 5 presenting breakdown of crashes based on atmospheric conditions is larger than 100 percent. Most of the intersection-related crashes (78.6%) occurred in clear weather.

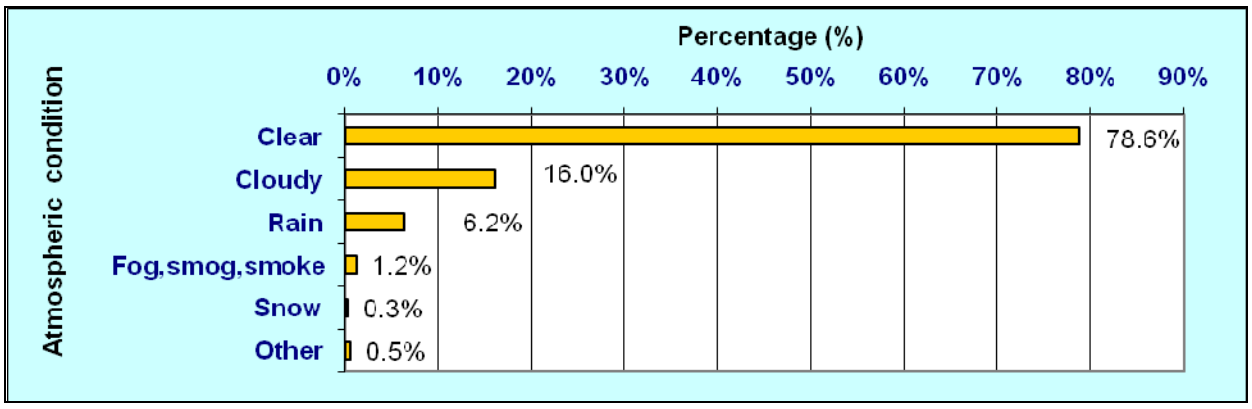

Figure 5: Distribution of weather condition for intersection-related crashes
Data Source: NMVCCS 2005-2007

Critical reason

The critical reason is the immediate reason for the critical event and may be attributed to a driver, vehicle, or environment. Only one critical reason is generally assigned per crash. Although the critical reason is an important element in the sequence of events leading up to a crash, it is subjective in nature and may not be the cause of the crash nor does it imply the assignment of fault to a vehicle, driver, or environment.

Figure 6 shows the distribution of critical reasons for intersection-related crashes, where the critical reasons are classified into eight broad categories. Of the 787,236 intersection-related crashes, in about 96.1 percent crashes the critical reasons were attributed to drivers. This includes 55.7 percent (438,194) drivers with recognition error (inattention, internal and external distractions, inadequate surveillance, etc.) and 29.2 percent (230,047) with decision errors (too fast for conditions or aggressive driving, false assumption of other's actions, illegal maneuver, and misjudgment of gap or other's speed). A comparatively smaller percentage of drivers (11.2%) were assigned other critical reasons: performance error (e.g., overcompensation, poor directional control) and critical non-performance error (e.g., sleep, heart attack). On the other hand, the vehicle or environment attributed critical reasons were assigned in less than 3 percent of crashes. Since in a significantly high percentage (96.1%) of intersection-related crashes, the critical reasons were attributed to drivers, only crashes with driver-attributed critical reasons are considered for further analysis.

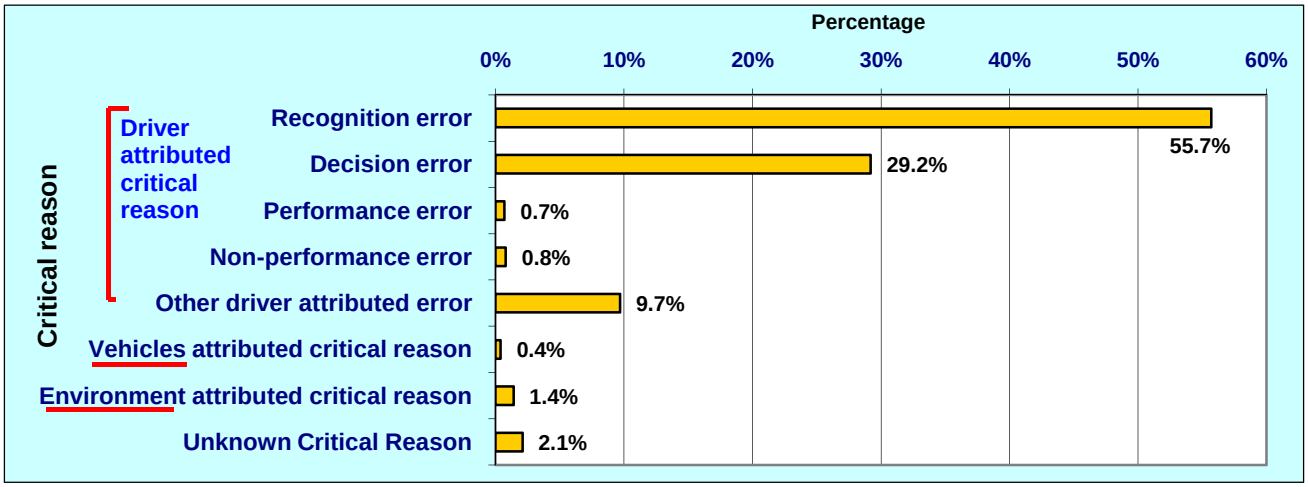

Figure 6: Distribution of critical reasons for intersection-related crashes
Data Source: NMVCCS 2005-2007

Figure 7 shows the distribution of the critical reasons attributed to drivers in intersection-related crashes. Of the 756,570 intersection-related crashes with driver attributed critical reason, the most frequently assigned critical reason was inadequate surveillance (44.1%). In comparison, about 92 percent (1,289,283 crashes) of the non-intersection-related crashes had a critical reason attributed to drivers. The most frequent critical reason in the 1,289,283 non-intersection crashes with driver attributed critical reason was too fast for conditions/curve (22.8%) followed by performance error (15.9%), internal distraction (13.4%), and critical non-performance errors (10.8%).

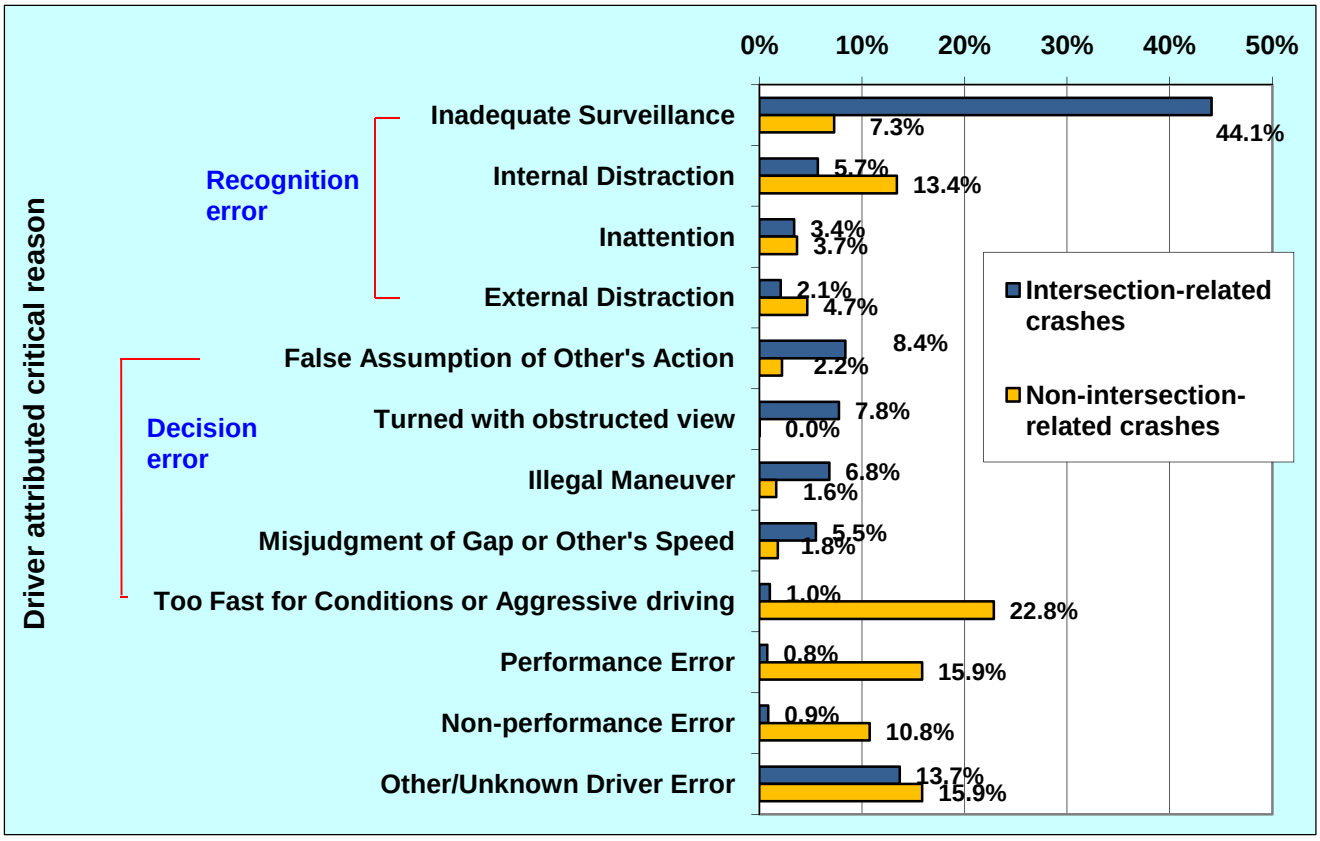

Figure 7: Driver attributed critical reasons of intersection-related and non-intersection-related crashes
Data Source: NMVCCS 2005-2007

3.2 RELATIVE RATIO ASSOCIATED WITH CRITICAL REASONS

Relative ratio of critical reasons of intersection-related crashes is estimated as the ratio of two proportions of crashes having a certain critical reason in intersection-related and non-intersection-related crashes. Relative ratio identifies the critical reasons that need more attention in the intersection-related crashes as compared to non-intersection-related crashes. Computational details of the relative ratio estimates are provided in Appendix B. The relative ratio estimates for different critical reasons are shown in Table 1, where the estimates are based on the weighted frequencies.

The results show that the critical reason "turned with obstructed view" has the highest relative ratio 335. It means that intersection-related crashes are almost 335 times as likely to occur in the presence of "turned with obstructed view" as a critical reason than in non-intersection-related crashes. The second highest relative ratio is for inadequate surveillance (6.1 times) followed by illegal maneuver (4.1 times), false assumption of other's action (3.8 time), msisjudgment of gap or other's speed (3.1 times), and so on. That is, inadequate surveillance appears about 6 times more often in intersection-related crashes than in non-intersection-related crashes. The intersection-related crashes are likely to have illegal maneuver and false assumption of other's action as critical reasons about 4 times more than in non-intersection-related crashes. These critical reasons with high relative ratio of intersection-related crashes as compared with non-intersection-related crashes form a major portion of intersection-related crashes and are of interest in the traffic safety community.

Table 1: Relative ratio of driver-attributed critical reason in intersection-related versus non-intersection-related crashes		
Critical Reason	Relative ratio	Relative ratio index
Turned With Obstructed View	335.0	1
Inadequate Surveillance	6.1	2
Illegal Maneuver	4.1	3
False Assumption of Other's Action	3.8	4
Misjudgment of Gap or Other's Speed	3.1	5
Inattention	0.9	6
External Distraction	0.4	7
Internal Distraction	0.4	8
Critical Non-Performance Error	0.1	9
Performance Error	0.0	10
Too Fast for Conditions or Aggressive Driving	0.0	11

Data Source: NMVCCS 2005-2007

3.3 ASSOCIATION OF CRASH FACTORS WITH CRITICAL REASON

A generalized logit model is used to study if critical reasons of the intersection-related crashes have any association jointly with driver age and sex, critical pre-crash event, traffic control devices and atmospheric condition. In the subsequent discussion, only intersection-related crashes with driver-attributed critical reasons are considered. Thus, the following analysis is focused on an estimated 756,570 number of intersection-related crashes, i.e., only weighted cases are used in the analysis.

Selection of analysis variables

Table 2 presents factors that possibly have close association with the critical reason. Contingency analysis [6] is performed (without controlling for potential confounders) to identify factors that have significant individual association with the critical reason. For this purpose, the categorization of the preliminarily selected variables is shown in Table 2, where to avoid computational difficulties, some of variables such as driver age and atmospheric condition have been recategorized.

Table 2: Categorization of analysis variables	
VARIABLES	**CATEGORIES USED**
Driver Attributed Critical Reason	1: Inadequate surveillance, 2: Internal distraction, 3: Inattention (daydreaming, etc.), 4: External distraction, 5: False assumption of other's action, 6: Illegal maneuver, 7: Misjudgment of gap or other's speed behavior, 8:Turned with obstructed view, 9: Too fast for conditions or aggressive driving, 10: Performance error (panic/freezing, overcompensation, etc.), 11: Critical non-performance error (sleeping, heart attack, etc.)
Driver Age	24 and younger, 25-54, 55 and older
Driver Sex	Male, Female
Critical Pre-Crash Event	1: Turning left, 2: Crossing over, 3: Turning right
Traffic Control Device	1: Traffic signal, 2: Stop sign, 3: Non-traffic-control devices
Atmospheric Condition	1: Normal, 2: Adverse weather condition (rain, snow, cloudy, etc)

The statistical software SAS 9.1 [6] is used to compute chi-square values and the associated p-values for each of the selected variables. The results are presented in Table 3.

Table 3: Individual association of crash factors with critical reasons in intersection-related crashes		
CRASH VARIABLE	**Chi-Square**	**P-Value**
Driver Age Group	40.60[+]	0.0109*
Critical Pre-Crash Event	143.70	<< 0.0001*
Driver Sex	20.00	0.0477*
Traffic Control Device	90.09	<< 0.0001*
Atmospheric Condition	13.58[+]	0.2625

[+] Categories adjusted due to 0 frequency cells
*Statistically significant at 95 percent confidence level
Data Source: NMVCCS 2005-2007

The chi-square values with low p-value in this table indicate significant association of the corresponding variables with the critical reason. Specifically, the results show that the driver's age and sex are significantly associated with the critical reasons assigned in crashes. In addition, the critical pre-crash event of the vehicle involved in a crash as well as the traffic control devices controlling the roads at the intersection are significantly associated with the critical reason. However, atmospheric condition shows no significant association with critical reason. This may be due to combining all adverse atmospheric conditions (cloudy, snow, rain, fog, rain, sleet, hail, etc.) into a broad category (adverse weather condition). The broad categorization may have subdued the effect of adverse atmospheric conditions. However, this is considered necessary to sustain a minimum sample size for each category for the analysis. All the variables found to be significantly associated with critical reason are subjected to further analysis.

Generalized logit model

The contingency analysis performed above gives an idea about the individual association of each crash factor with the critical reasons. To study their joint association (main and interaction effects) with the critical reasons, the generalized logit model[7 8] is fitted with critical reason as nominal response variable and crash factors such as driver's age and sex, traffic control devices, and critical pre-crash event as independent variables. In addition to the main effects of crash factors, two-factor interaction effects are also considered in the model. SAS 9.1 is used for this analysis.

Based on the Wald chi-square statistics,[6] Table 4 shows that in addition to the main effects, five of the two-factor interaction effects: traffic control device and critical pre-crash event, traffic control device and driver's age, driver's sex and critical pre-crash event, driver's sex and age, driver's sex and traffic control device are significantly associated with the critical reasons ($p<<0.0001$). These significant interaction effects are further considered for an in-depth analysis.

Table 4: Analysis of effects of association of crash factors with critical reasons of intersection-related crashes

Effect	DF	Wald Chi-Square	P-value
TRAFFIC CONTROL DEVICE	19	637.3493	<.0001
PRE-CRASH EVENT	12	71659.3330	<.0001
DRIVER'S SEX	10	72.3728	<.0001
DRIVER'S AGE	20	1546.0452	<.0001
SEX * TRAFFIC CONTROL DEVICE	19	286.4592	<.0001
TRAFFIC CONTROL DEVICE * PRE-CRASH EVENT	40	2061.1646	<.0001
DRIVER'S AGE * TRAFFIC CONTROL DEVICE	39	794.2026	<.0001
DRIVER'S SEX * PRE-CRASH EVENT	18	477.8156	<.0001
DRIVER'S SEX * DRIVER'S AGE	20	281.6791	<.0001

Data Source: NMVCCS 2005-2007

3.4 DATA SEGMENTATION OF CRITICAL REASONS

The analysis conducted in the previous section reveals close association of the critical reasons with crash factors: main effects (traffic control device, critical pre-crash event, driver's age and sex) as well as their two-factor interaction effects (traffic control device and critical pre-crash event, traffic control device and driver's age, driver's sex and critical pre-crash event, driver's sex and age, driver's sex and traffic control device). However, in some factor-based sectors of the population of intersection-related crashes (e.g., the sector comprising crashes in which a male driver is involved and for which the critical pre-crash event is turning right) the association with certain types of critical reasons may be stronger as compared to other sectors. To identify such sectors in an effective way, CFA is performed. This analysis can visually describe their patterns even though the critical reason and all crash factors have two or more categories. The analysis consists of comparing observed and expected frequencies for each cell configuration, where weighted frequencies are used. If the difference between observed and expected frequencies under the assumption of complete independence of the respective factors (variables) for certain cell configuration is significant at certain level of confidence (95% in this study), then the variables are locally associated with each other in the corresponding sector of the data. The Z-statistic obtained from CFA is used to test the significance of each difference. Computational details of Z-statistics are provided in Appendix C. A significantly positive difference (observed-expected > 0) is referred to as a "type" and a significantly negative difference an "antitype."[9] The following analysis is focused on "type" only.

General Interpretation of CFA: For the intersection-related crashes with driver-attributed critical reasons, tables in this section show observed and expected reasons and the corresponding Z-values. The highlighted cells indicate types. All positive differences (observed-expected > 0) are tested using Z-statistics at 99 percent confidence level (after a priori determined confidence level 95% is adjusted using Bonferroni adjustment[10]) as shown in the tables that present CFA results. A significant Z-value indicates a significant association in the corresponding sector of the data as defined by the corresponding configuration. For example, significant z-value for the configuration "internal distraction, crossing over, traffic signal" shows that significantly more than expected vehicles were assigned a critical reason of "internal distraction" when they were "crossing over" at intersections controlled by "traffic signals." This in turn means that the crash occurrence at intersections controlled by traffic signals while crossing over may be attributed to "internal distraction." Note that the value of Z-statistic, which is based on weighted frequencies, is considered statistically valid when the unweighted frequency in the corresponding cell is at least 5.

Driver attributed critical reasons by traffic control devices and critical pre-crash event

Table 5 shows observed and expected frequencies of critical reasons and the corresponding z-values by traffic control devices and critical pre-crash event, where expected frequencies are obtained under the assumption that traffic control devices and critical pre-crash event have no association with driver-attributed critical reasons. Note that traffic control device is based on multiple choices per vehicle. Thus, the totals presented for such variables may not match the actual totals of crashes, vehicles, or drivers. Also, the unweighted frequencies corresponding to cell configurations crossing-over with critical reason internal distraction or illegal maneuver are very small.

- The results show that significantly more than expected drivers were assigned critical reasons such as external distraction, false assumption of other's action, misjudgment of gap or other's speed and turned with obstructed view when they were turning left at intersections controlled by traffic signals. Also, significantly more than expected drivers were assigned critical reasons such as internal distraction, inattention, illegal maneuver, too fast or aggressive driving behavior, and critical non-performance error when they were crossing over at intersections controlled by traffic signals.

- The results also show that significantly more than expected drivers were assigned critical reasons such as inadequate surveillance, misjudgment of gap or other's speed and turned with obstructed view when they were turning left at intersections controlled by stop signs. In addition, significantly more than expected drivers were assigned critical reasons such as inadequate surveillance, inattention, external distraction, and illegal maneuver when they were crossing over at intersections controlled by stop signs. The crashes characterized by turning-right at stop sign have false assumption of other's action assigned as critical reason significantly more than expected.

- In contrast to the above two scenarios, crashes characterized by turning-left at intersections with no traffic control device have critical reason such as inadequate surveillance, external distraction, misjudgment of gap or other's speed, and turned with obstructed view significantly more than expected. The crossing-over and turning-right crashes have no critical reason assigned significantly more than expected.

Table 5. Driver-attributed critical reasons by traffic control device and critical pre-crash event

Traffic Control Device	CRITREASON	Z-values			Observed frequency			Expected frequency		
		Turn left	Cross over	Turn right	Turn left	Cross over	Turn right	Turn left	Cross over	Turn right
Traffic Signal	Inadequate Surveillance	6	-62	-20	110,785	51,116	2,076	108,923	67,223	3,232
	Internal Distraction	-82	144*	37	4,092	21,780	1,160	13,740	8,480	408
	Inattention	-66	109*	-16	2,371	12,996	0	8,362	5,161	248
	External Distraction	12*	-1	-12	5,974	3,063	0	5,090	3,142	151
	False Assumption of Other's Action	151*	-73	-10	42,327	4,542	375	20,681	12,764	614
	Illegal Maneuver	-89	167*	41	4,388	25,830	1,339	15,471	9,548	459
	Misjudgment of Gap or Other's Speed	12*	-89	28	14,856	181	957	13,415	8,279	398
	Too Fast for Conditions or Aggressive Driving	-42	84*	2	187	4,340	79	2,123	1,310	63
	Turned With Obstructed View	29*	-108	-17	22,684	0	165	18,747	11,570	556
	Performance Error	-21	9	6	735	1,251	88	1,574	971	47
	Critical Non-Performance Error	-6	92*	-8	1,875	4,676	0	2,147	1,325	64
Stop Sign	Inadequate Surveillance	39*	37*	-39	51,385	59,007	1,102	43,336	50,614	3,400
	Internal Distraction	-64	5	-19	709	6,792	35	5,467	6,385	429
	Inattention	-45	45*	-16	760	6,720	0	3,327	3,886	261
	External Distraction	-45	26*	-13	0	3,614	0	2,025	2,365	159
	False Assumption of Other's Action	-49	-50	127*	3,819	4,691	3,882	8,228	9,610	646
	Illegal Maneuver	-35	36*	2	3,437	10,226	518	6,156	7,189	483
	Misjudgment of Gap or Other's Speed	39*	-8	-20	8,186	5,640	0	5,337	6,234	419
	Too Fast for Conditions or Aggressive Driving	-29	-11	-8	0	641	0	845	986	66
	Turned With Obstructed View	84*	-91	9	14,675	210	800	7,459	8,711	585
	Performance Error	3	-22	25	689	130	227	626	731	49
	Critical Non-Performance Error	-29	-30	-8	0	38	0	854	998	67
None	Inadequate Surveillance	10*	9	-33	53,639	4,254	874	51,274	3,729	2,507
	Internal Distraction	-17	70	10	5,106	1,993	497	6,468	470	316
	Inattention	-18	-17	-14	2,812	0	0	3,936	286	192
	External Distraction	12*	-13	-11	2,969	0	0	2,396	174	117
	False Assumption of Other's Action	-64	-24	-7	3,451	58	317	9,735	708	476
	Illegal Maneuver	-78	13	-3	595	836	308	7,283	530	356
	Misjudgment of Gap or Other's Speed	63*	-19	-18	11,287	58	0	6,315	459	309
	Too Fast for Conditions or Aggressive Driving	-23	-9	134	285	0	983	999	73	49
	Turned With Obstructed View	97*	-25	28	17,974	0	1,019	8,825	642	432
	Performance Error	5	-7	134	866	0	843	741	54	36
	Critical Non-Performance Error	-32	-9	-7	0	0	0	1,011	73	49

Note: * statistically significant

Data Source: NMVCCS 2005-2007

Table 6 summarizes the results of CFA by listing the significant critical reasons in order of significance (in terms of Z-values), where "---" stands for no critical reason with statistically significant difference between observed and expected frequencies. It is found that regardless of type of traffic control device, traffic signal, or

stop sign, illegal maneuver and inattention were observed significantly more than expected in crossing-over crashes, while turned with obstructed view and misjudgment of gap or other's speed in turning-left crashes. False assumption of other's action was found as the most significant critical reason in turning-left crashes at traffic signal and in turning-right crashes at stop sign.

Table 6. Significant critical reasons by traffic control device and critical pre-crash event

Traffic control device	Critical pre-crash event	Critical reasons
Traffic Signal	Turn Left	1. False Assumption of Other's Action, 2. Turned With Obstructed View, 3. External Distraction, 4.Misjudgment of Gap or Other's Speed
	Cross Over	1. Illegal Maneuver, 2. Internal Distraction, 3. Inattention, 4. Critical Non-Performance Error, 5.Too Fast for Conditions or Aggressive Driving
	Turn Right	---
Stop Sign	Turn Left	1. Turned With Obstructed View, 2. Inadequate Surveillance, 3. Misjudgment of Gap or Other's Speed
	Cross Over	1. Inattention, 2. Inadequate Surveillance, 3. Illegal Maneuver, 4. External Distraction
	Turn Right	1.False Assumption of Other's Action
None	Turn Left	1. Turned With Obstructed View, 2. Misjudgment of Gap or Other's Speed, 3. External Distraction, 4. Inadequate Surveillance
	Cross Over	---
	Turn Right	---

--- no significant critical reason

Driver attributed critical reason by driver age and traffic control device

Table 7 shows the observed and expected frequencies of critical reasons and the corresponding values of Z-statistic obtained from CFA for the factors drivers' age group and traffic control device, where expected frequencies are obtained under the assumption that the driver's age and traffic control devices have no association with driver-attributed critical reasons.

- In crashes occurring at intersections controlled by a traffic signal, 24-and-younger drivers were observed with critical reasons, internal distraction, external distraction, false assumption of other's action, and too fast for conditions/aggressive driving significantly more than expected. Drivers 25 to 54 were observed with critical reasons, inattention, illegal maneuver, too fast for conditions/aggressive driving, and critical non-performance error significantly more than expected.

- In crashes occurring at intersections controlled by stop signs, drivers 55 and older had as critical reasons inadequate surveillance and misjudgment of gap or other's speed assigned significantly more than expected. For the 24-and-younger driver group, turned with obstructed view was assigned as the critical reason in cases significantly more than expected.

- In crashes occurring at intersections with no traffic control devices, the drivers 55 and older had as critical reasons misjudgment of gap or other's speed assigned significantly more number of cases than expected. For the 24-and-younger driver group, internal distraction and turned with obstructed view were observed significantly more than expected. For the driver group 25 to 54, misjudgment of gap or other's speed and turned with obstructed view were observed more than expected as critical reason.

Table 7. Driver-attributed critical reasons by driver age and traffic control devices										
Driver Age	CRITREASON	Z-values			Observed frequency			Expected frequency		
		Traffic signal	Stop sign	None	Traffic signal	Stop sign	None	Traffic signal	Stop sign	None
24 and younger	Inadequate Surveillance	-81	-8	-42	37,233	35,684	13,600	56,342	37,226	19,392
	Internal Distraction	79*	-41	54*	13,777	1,871	5,105	7,107	4,696	2,446
	Inattention	-28	-21	-16	2,469	1,752	881	4,325	2,858	1,489
	External Distraction	15*	-7	8	3,415	1,434	1,136	2,633	1,740	906
	False Assumption of Other's Action	71*	-60	-31	17,992	2,005	1,789	10,698	7,068	3,682
	Illegal Maneuver	-18	7	-37	6,400	5,780	836	8,003	5,288	2,754
	Misjudgment of Gap or Other's Speed	-36	-28	-8	3,968	2,711	1,998	6,939	4,585	2,388
	Too Fast for Conditions or Aggressive Driving	20*	-3	1	1,756	641	396	1,098	726	378
	Turned With Obstructed View	-61	28*	28*	3,710	8,658	4,970	9,697	6,407	3,338
	Performance Error	-10	-15	38	515	190	923	814	538	280
	Critical Non-Performance Error	-13	-27	-20	675	0	0	1,110	734	382
25-54	Inadequate Surveillance	-91	-25	-22	73,064	39,819	28,352	102,041	45,054	32,286
	Internal Distraction	-23	-26	-25	10,212	3,741	2,491	12,872	5,683	4,073
	Inattention	21*	-21	-28	9,656	2,253	1,090	7,834	3,459	2,479
	External Distraction	4	-4	-2	5,061	1,937	1,434	4,769	2,106	1,509
	False Assumption of Other's Action	1	1	-65	19,451	8,620	1,071	19,375	8,554	6,130
	Illegal Maneuver	24*	-12	-56	17,438	5,449	797	14,494	6,399	4,586
	Misjudgment of Gap or Other's Speed	-56	8	13*	6,237	6,160	4,795	12,568	5,549	3,976
	Too Fast for Conditions or Aggressive Driving	13*	-30	10	2,556	0	872	1,989	878	629
	Turned With Obstructed View	-9	-31	75*	16,380	5,062	11,168	17,563	7,754	5,557
	Performance Error	-3	-8	6	1,359	456	601	1,475	651	467
	Critical Non-Performance Error	68*	-30	-25	5,045	0	0	2,011	888	636
55 and older	Inadequate Surveillance	-1	17*	3	53,681	35,992	16,815	53,894	32,925	16,380
	Internal Distraction	-46	-35	-45	3,042	1,923	0	6,798	4,153	2,066
	Inattention	-14	19	-12	3,242	3,475	841	4,137	2,528	1,257
	External Distraction	-39	-33	-13	561	243	400	2,519	1,539	766
	False Assumption of Other's Action	-4	-57	-38	9,801	1,767	966	10,233	6,251	3,110
	Illegal Maneuver	1	-25	-46	7,718	2,952	106	7,655	4,677	2,327
	Misjudgment of Gap or Other's Speed	-10	14*	56*	5,788	4,956	4,553	6,638	4,055	2,017
	Too Fast for Conditions or Aggressive Driving	-23	-25	-18	294	0	0	1,050	642	319
	Turned With Obstructed View	-68	-49	1	2,760	1,964	2,854	9,276	5,667	2,819
	Performance Error	-21	-3	-3	200	400	185	779	476	237
	Critical Non-Performance Error	-7	-24	-18	830	38	0	1,062	649	323

Note: * statistically significant

Data Source: NMVCCS 2005-2007

Table 8 summarizes the results of CFA presented in Table 7 by listing the significant critical reasons in order of significance (in terms of the Z-values), where "---" stands for no critical reason with statistically significant difference between observed and expected frequencies.

Table 8. Significant critical reasons by driver age and traffic control device

Driver age	Traffic control device	Critical reasons
24 and younger	Traffic Signal	1. Internal Distraction, 2. False Assumption of Other's Action, 3. Too Fast for Conditions or Aggressive Driving, 4. External Distraction
	Stop Sign	1. Turned With Obstructed View
	None	1. Internal Distraction, 2.Turned With Obstructed View
25-54	Traffic Signal	1. Critical Non-Performance Error, 2. Illegal Maneuver, 3. Inattention, 4. Too Fast for Conditions or Aggressive Driving
	Stop Sign	---
	None	1. Turned With Obstructed View, 2.Misjudgment of Gap or Other's Speed
55 and older	Traffic Signal	---
	Stop Sign	1. Inadequate Surveillance, 2. Misjudgment of Gap or Other's Speed
	None	1. Misjudgment of Gap or Other's Speed
--- no significant critical reason		

Driver-attributed critical reason by driver sex and critical pre-crash event

Table 9 shows the observed and expected frequencies of critical reasons and the corresponding z-statistics by pre-crash event and driver sex, where expected frequencies are obtained under the assumption that driver sex and critical pre-crash event have no association with critical reasons.

- In turning-left vehicles, regardless of driver's sex, significantly more than expected drivers were observed with critical reasons such as inadequate surveillance, false assumption of other's action, misjudgment of gap or other's speed behavior, and turned with obstructed view.

- In the crossing-over vehicles, significantly more than expected female drivers were observed to have critical reasons such as internal distraction, inattention, external distraction and illegal maneuver. Significantly more than expected male drivers were observed to have critical reasons such as internal distraction, illegal maneuver, too fast for conditions or aggressive driving, and critical non-performance error.

- In the turning-right vehicles, significantly more than expected male drivers were observed to have critical reasons of false assumption of other's action. Note that unweighted frequencies of turning-right vehicles that was assigned critical reason were very small.

Table 9. Driver-attributed critical reasons by driver sex and critical pre-crash event										
		Z-values			Observed frequency			Expected frequency		
Driver Sex	CRITICAL REASON	Turn left	Cross over	Turn right	Turn left	Cross over	Turn right	Turn left	Cross over	Turn right
Female	Inadequate Surveillance	25*	-3	-33	118,674	61,108	2,543	110,213	61,816	4,832
	Internal Distraction	-66	88*	24	6,157	15,547	1,194	13,903	7,798	610
	Inattention	-47	147*	-19	4,101	14,848	0	8,461	4,746	371
	External Distraction	-7	18*	-15	4,665	3,877	0	5,151	2,889	226
	False Assumption of Other's Action	21*	-56	-9	23,897	5,705	648	20,926	11,737	918
	Illegal Maneuver	-98	46*	14	3,427	13,092	1,064	15,655	8,780	686
	Misjudgment of Gap or Other's Speed	29*	-78	13	16,999	801	907	13,574	7,613	595
	Too Fast for Conditions or Aggressive Driving	-46	22	92	0	1,976	983	2,148	1,205	94
	Turned With Obstructed View	104*	-103	12	33,304	0	1,165	18,969	10,639	832
	Performance Error	-10	12	90	1,194	1,251	825	1,593	893	70
	Critical Non-Performance Error	-39	-2	-10	348	1,132	0	2,172	1,218	95
Male	Inadequate Surveillance	12*	-27	-43	97,136	53,270	1,510	93,320	59,750	4,307
	Internal Distraction	-74	86*	-2	3,750	15,018	497	11,772	7,537	543
	Inattention	-63	4	-18	1,842	4,868	0	7,164	4,587	331
	External Distraction	-1	0	-14	42,79	2,800	0	4,361	2,792	201
	False Assumption of Other's Action	60*	-73	109*	25,701	3,586	3,926	17,719	11,345	818
	Illegal Maneuver	-72	166*	20	4,993	23,800	1,100	13,255	8,487	612
	Misjudgment of Gap or Other's Speed	54*	-27	-21	17,330	5,078	51	11,494	7,359	530
	Too Fast for Conditions or Aggressive Driving	-32	54*	-1	471	3,006	79	1,819	1,165	84
	Turned With Obstructed View	47*	-99	3	22,028	210	819	16,062	10,284	741
	Performance Error	-7	-25	34	1,097	130	334	1,349	863	62
	Critical Non-Performance Error	-7	70*	-9	1,527	3,582	0	1,839	1,178	85
Note: * statistically significant										

Data Source: NMVCCS 2005-2007

Table 10 summarizes the results of CFA presented in Table 9 by listing the significant critical reasons in order of significance (in terms of Z-values), where "---" stands for no critical reason with statistically significant difference between observed and expected frequencies. It shows that both female and male drivers involved in turning-left crashes often have critical reasons such as turned with obstructed view, misjudgment of gap or other speed, inadequate surveillance, or false assumption of other's action significantly more than expected. In crossing-over crashes both male and female drivers were observed doing illegal maneuver and internal distraction significantly more than expected. However, among drivers involved in crashes while crossing over, significantly more than expected female drivers were observed with recognition errors such as inattention, internal and external distractions. Male drivers were observed with illegal maneuver, too fast for conditions/ aggressive driving, or critical non-performance error significantly more than expected. Note that critical non-performance error includes sleeping, heart attack, other physical impairment, and being passed out as a result of alcohol or drug ingestion.

Table 10. Significant critical reason by driver sex and pre-crash event		
Driver sex	Critical pre-crash event	Critical reasons
Female	Turn Left	1. Turned With Obstructed View, 2. Misjudgment of Gap or Other's Speed, 3. Inadequate Surveillance, 4.False Assumption of Other's Action
	Cross Over	1. Inattention, 2.Internal Distraction, 3.Illegal Maneuver, 4.External Distraction
	Turn Right	---
Male	Turn Left	1. False Assumption of Other's Action, 2. Misjudgment of Gap or Other's Speed 3. Turned With Obstructed View, 4. Inadequate Surveillance
	Cross Over	1. Illegal Maneuver, 2. Internal Distraction, 3. Critical Non-Performance Error, 4. Too Fast for Conditions or Aggressive Driving
	Turn Right	1. False Assumption of Other's Action
--- no significant critical reason		

Driver attributed critical reason by driver sex and age

Table 11 shows the observed and expected frequencies of critical reasons and the corresponding z-statistics by driver sex and age, where expected frequencies are obtained under the assumption that driver age and sex have no association with critical reasons.

- Significantly more than expected female drivers 24 and younger were observed to have critical reasons such as internal distraction and turned with obstructed view, while significantly more than expected male drivers of the same age group were observed to have critical reasons such as internal and external distraction, false assumption of other's action, and illegal maneuver.

- Female drivers 25 to 54 were observed with critical reasons such as inattention, external distraction, turned with obstructed view, and performance error significantly more than expected. Male drivers of the same age group were observed in the vehicles with critical reason such as illegal maneuver, misjudgment of gap or other's speed behavior, too fast for conditions or aggressive driving, turned with obstructed view, and critical non-performance error significantly more than expected.

- Significantly more than expected female drivers 55 and older were observed in the vehicles with critical reasons such as inadequate surveillance, inattention, and misjudgment of gap or other's action. Significantly more than expected male drivers of the same age group were assigned critical reason such as inadequate surveillance, illegal maneuver, and misjudgment of gap or other's speed behavior.

Table 11. Driver-attributed critical reasons by driver sex and age										
		Z-values			Observed frequency			Expected frequency		
Driver Sex	CRITREASON	24 and younger	25-54	55 and older	24 and younger	25-54	55 and older	24 and younger	25-54	55 and older
Female	Inadequate Surveillance	-9	-25	64*	44,955	72,556	64,813	46,988	79,491	50,383
	Internal Distraction	35*	3	-30	8,630	10,344	3,924	5,927	10,027	6,356
	Inattention	5	28*	47*	3,896	8,270	6,782	3,607	6,102	3,868
	External Distraction	-14	48*	-41	1,541	6,631	371	2,196	3,715	2,355
	False Assumption of Other's Action	10	-7	-35	9,854	14,228	6,167	8,922	15,093	9,566
	Illegal Maneuver	-49	4	-46	2,655	11,696	3,231	6,674	11,291	7,156
	Misjudgment of Gap or Other's Speed	-25	-27	19*	3,872	7,111	7,723	5,787	9,790	6,205
	Too Fast for Conditions or Aggressive Driving	26	-15	-22	1,693	972	294	916	1,549	982
	Turned With Obstructed View	49*	42*	-58	12,536	18,623	3,311	8,087	13,681	8,672
	Performance Error	15	13*	-4	1,077	1,584	608	679	1,149	728
	Critical Non-Performance Error	-30	-3	-30	0	1,439	40	926	1,567	993
Male	Inadequate Surveillance	-31	-13	25*	41,561	68,679	41,675	48,466	72,090	36,822
	Internal Distraction	77*	-31	-53	12,124	6,099	1,041	6,114	9,094	4,645
	Inattention	-41	-11	-39	1,205	4,729	776	3,721	5,534	2,827
	External Distraction	46*	-27	-21	4,444	1,801	834	2,265	3,369	1,721
	False Assumption of Other's Action	28*	10	-7	11,932	14,914	6,367	9,202	13,688	6,991
	Illegal Maneuver	42*	17*	32*	10,361	11,987	7,545	6,884	10,240	5,230
	Misjudgment of Gap or Other's Speed	-15	13*	45*	4,805	10,080	7,575	5,969	8,879	4,535
	Too Fast for Conditions or Aggressive Driving	5	28*	-27	1,100	2,455	0	945	1405	718
	Turned With Obstructed View	-39	14*	-26	4,803	13,988	4,267	8,342	12,408	6,337
	Performance Error	-6	-7	-15	552	832	177	700	1,042	532
	Critical Non-Performance Error	-9	58*	4	675	3,606	827	955	1,421	726
Note: * statistically significant										

Data Source: NMVCCS 2005-2007

Table 12 summarizes the results of CFA presented in Table 11 by listing the significant critical reasons in order of significance in terms of Z-values. Regardless of their sex, drivers 55 and older were observed with critical reasons such as misjudgment of gap or other's speed and inadequate surveillance significantly more than expected. For male drivers of all age groups, illegal maneuver was assigned as critical reason in more than expected cases, while more than expected female drivers were assigned internal and external distraction or inattention as critical reasons. However, for female drivers 24 and younger involved in intersection-related crashes, the most significant critical reasons were turned with obstructed view and internal distraction. For young male driver 24 and younger internal and external distraction, illegal maneuver, and false assumption of other's action were the significant critical reasons. It may be noted that the critical reason "turned obstructed view" means driver's sightline to approaching traffic was not clear typically by an intervening in-transport vehicle.

Table 12. Significant critical reason by driver sex and age		
Driver sex	Driver age	Critical reasons
Female	24 and younger	1. Turned With Obstructed View, 2. Internal Distraction
	25-54	1. External Distraction, 2. Turned With Obstructed View, 3. Inattention, 4. Performance Error
	55 and older	1. Inadequate Surveillance, 2. Inattention, 3. Misjudgment of Gap or Other's Speed
Male	24 and younger	1. Internal Distraction, 2. External Distraction, 3. Illegal Maneuver, 4. False Assumption of Other's Action
	25-54	1. Critical Non-Performance Error, 2. Too Fast for Conditions or Aggressive Driving, 3. Illegal Maneuver, 4. Turned With Obstructed View, 5. Misjudgment of Gap or Other's Speed
	55 and older	1. Misjudgment of Gap or Other's Speed, 2. Illegal Maneuver, 3. Inadequate Surveillance
--- no significant critical reason		

Driver-attributed critical reason by driver sex and traffic control devices

Table 13 shows the observed and expected frequencies of driver attributed critical reasons and the corresponding values of Z-statistics obtained from CFA by driver sex and traffic control device, where the expected frequencies are obtained under the assumption that driver sex and traffic control devices have no association with critical reasons.

- In crashes occurring at intersections controlled by traffic signals, significantly more than expected female drivers were observed with critical reasons such as internal distraction, inattention, and false assumption of other's action. Significantly more than expected male drivers were observed to have critical reason such as internal distraction, false assumption of other's action, illegal maneuver, too fast for conditions or aggressive driving, and critical non-performance error.

- In crashes occurring at the intersection controlled by stop signs, significantly more than expected female drivers were observed with critical reasons such as inadequate surveillance, inattention, and turned with obstructed view. Significantly more than expected male drivers were observed in the vehicles with critical reason such as inadequate surveillance, illegal maneuver, and misjudgment of gap or other's speed.

- In crashes occurring at intersections with no traffic control device, significantly more than expected female drivers were observed in the vehicles with critical reasons such as misjudgment of gap or other's action, turned with obstructed view and performance errors., Significantly more than expected male drivers were observed in vehicles with critical reason such as inadequate surveillance, external distraction, and misjudgment of gap or other's action.

Table 13. Driver-attributed critical reasons by driver sex and traffic control devices										
		Z-values			Observed frequency			Expected frequency		
Driver Sex	CRITREASON	Traffic signal	Stop sign	None	Traffic signal	Stop sign	None	Traffic signal	Stop sign	None
Female	Inadequate Surveillance	-4	43*	-18	96,832	60,744	24,748	98,000	51,071	27,791
	Internal Distraction	25*	-36	12	15,089	3,576	4,234	12,362	6442	3,506
	Inattention	45*	39*	-20	11,405	6,344	1,200	7,523	3,921	2,133
	External Distraction	5	3	-5	4,894	2,533	1,115	4,580	2,387	1,299
	False Assumption of Other's Action	53*	-60	-65	25,860	3,829	560	18,607	9,697	5,277
	Illegal Maneuver	-19	-17	-61	11,631	5,807	145	13,920	7,254	3,947
	Misjudgment of Gap or Other's Speed	-41	-14	43*	7,618	5,146	5,943	12,070	6,290	3,423
	Too Fast for Conditions or Aggressive Driving	-8	-18	19	1,556	420	983	1,910	995	542
	Turned With Obstructed View	-43	11*	124*	11,284	9,832	13,354	16,867	8,790	4,783
	Performance Error	3	-14	48*	1,539	361	1,369	1,416	738	402
	Critical Non-Performance Error	-10	-32	-23	1,479	0	0	1,932	1,007	548
Male	Inadequate Surveillance	-50	21*	25*	67,146	50,751	34,019	81,379	46,279	29,720
	Internal Distraction	17*	-25	-6	11,943	3,959	3,363	10,266	5,838	3,749
	Inattention	-29	-41	-14	3,962	1,136	1,612	6,247	3,553	22,82
	External Distraction	6	-23	12*	4,143	1,081	1,854	3,803	2,163	1,389
	False Assumption of Other's Action	48*	-2	-32	21,384	8,563	3,266	15,451	8,787	5,643
	Illegal Maneuver	78*	22*	-40	19,926	8,373	1,594	11,559	6,574	4,221
	Misjudgment of Gap or Other's Speed	-16	39*	29*	8,376	8,681	5,403	10,023	5,700	3,660
	Too Fast for Conditions or Aggressive Driving Behavior	37*	-23	-12	3,050	221	285	1,586	902	579
	Turned With Obstructed View	-21	-24	7	11,566	5,852	5,639	14,006	7,965	5,115
	Performance Error	-19	1	-4	535	686	340	1,176	669	429
	Critical Non-Performance Error	87*	-29	-24	5,071	38	0	1,604	912	586
Note: * statistically significant										

Data Source: NMVCCS 2005-2007

Table 14 summarizes the results of CFA presented in Table 13 by listing the significant critical reasons in order of significance (i.e., high z-values). In crashes occurring at intersections controlled by traffic control devices, female drivers were observed with critical reasons such as false assumption of others action, inattention, and internal distraction significantly more than expected, while more than expected male drivers were assigned critical reasons critical non-performance error, illegal maneuver, false assumption of other's action, too fast for conditions or aggressive driving, and internal distraction. Regardless of type of traffic control devices, traffic signal or stop sign, inattention was one of the significant critical reasons for female drivers while it was illegal maneuver for male drivers. At intersections with no traffic control device, misjudgment of gap or other's speed was the critical reason for both female and male drivers.

Table 14. Significant critical reasons by driver sex and traffic control devices		
Driver sex	Traffic control devices	Critical reasons
Female	Traffic Signal	1. False Assumption of Other's Action, 2. Inattention, 3. Internal Distraction
	Stop Sign	1. Inadequate Surveillance, 2. Inattention, 3. Turned With Obstructed View
	None	1. Turned With Obstructed View, 2. Performance Error, 3. Misjudgment of Gap or Other's Speed
Male	Traffic Signal	1. Critical Non-Performance Error, 2. Illegal Maneuver, 3. False Assumption of Other's Action, 4. Too Fast for Conditions or Aggressive Driving, 5. Internal Distraction
	Stop Sign	1. Misjudgment of Gap or Other's Speed, 2. Illegal Maneuver, 3. Inadequate Surveillance
	None	1. Misjudgment of Gap or Other's Speed, 2. Inadequate Surveillance, 3. External Distraction
--- no significant critical reason		

4. Summary and Conclusions

Descriptive statistics showed that 36 percent (787,236) of the estimated **!The Formula Not In Table** crashes in NMVCCS were intersection-related crashes. Of the 787,236 intersection-related crashes, about 96.1 percent had critical reason attributed to drivers, while the vehicle- or environment-attributed critical reasons were assigned in less than 3 percent of these crashes. The distributions of driver-attributed critical reasons in the intersection-related and non-intersection-related crashes are found to be quite different. Of the 756,570 intersection-related crashes with driver-attributed critical reason, the most frequent critical reasons were inadequate surveillance (44.1%), false assumption of other's action (8.4%), turned with obstructed view (7.8%), illegal maneuver (6.8%), internal distraction (5.7%), and misjudgment of gap or other's speed (5.5%). In contrast, the most frequent critical reasons in non-intersection-related crashes were too fast for conditions/aggressive driving (22.8%), performance error (15.9%), internal distraction (13.4%), critical non-performance errors (10.8%), inadequate surveillance (7.3%) and external distraction (4.7%).

The relative ratio analysis shows that intersection-related crashes are almost 335 times as likely to have "turned with obstructed view" as critical reason than non-intersection-related crashes. The second highest relative ratio of intersection-related versus non-intersection-related crashes is for "inadequate surveillance" followed by "illegal maneuver," "false assumption of other's action," "misjudgment of gap or other's speed." "Inadequate surveillance" happens about 6 times more often in intersection-related crashes than in non-intersection-related crashes. Also, the intersection-related crashes are likely to have "illegal maneuver" and "false assumption of other's action" as critical reasons about 4 times more than in non-intersection-related crashes. The critical reasons with high relative ratio of intersection-related crashes as compared with non-intersection-related crashes form a major portion of the intersection-related crashes.

The analysis of a generalized logit model reveals statistically significant association of critical reason with crash factors and their two-factor interaction effects: traffic control device and critical pre-crash event, traffic control device and driver's age, driver's sex and critical pre-crash event, driver's sex and age, driver's sex and traffic control device. CFA identifies these patterns of driver-attributed critical reasons in intersection-related crashes in terms of the significant two-factor interaction effects as follows:

- Crash occurrence while crossing over at intersections controlled by traffic signals or stop signs may be attributed to “illegal maneuver” or “inattention,” while crash occurrence while turning left at intersections controlled by traffic signals or stop signs may be attributed to “turned with obstructed view” or “misjudgment of gap or other’s speed.” In addition, crash occurrence while “turning right” at stop sign may be attributed to “false assumption of other’s action.’

- Crash occurrence in the case of drivers 24 and younger driving at intersections controlled by traffic signals may be attributed to “internal distraction,” “false assumption of other’s action,” “too fast for conditions/aggressive driving,” or “external distraction.” Crash occurrence involving drivers 25 to 54 who were driving at intersections controlled by traffic signals may be attributed to “critical non-performance error,” “illegal maneuver,” “inattention,” and “too fast for conditions or aggressive driving.” Crash occurrence involving 55 and older drivers driving at intersections controlled by stop signs may be attributed to “inadequate surveillance” and “misjudgment of gap or other‘s speed.” In the case of drivers 24 and younger driving at intersections controlled by stop signs, crash occurrence may be attributed to “turned with obstructed view.”

- For both male and female drivers turning left at intersections, crash occurrence may be attributed to “turned with obstructed view,” “misjudgment of gap or other speed,” “inadequate surveillance,” or “false assumption of others action.” For both female and male drivers crossing over at intersections, crash occurrence may be attributed to “illegal maneuver” or “internal distraction.” Also, for female drivers crossing over at intersections, crash occurrence may be attributed to recognition errors such as “inattention”, “internal and external distractions.” In the case of male drivers crossing over at intersections, crash occurrence may be attributed to “illegal maneuver,” “too fast for conditions or aggressive driving,” or “critical non-performance error,” where critical non-performance error includes sleeping, heart attack, other physical impairment, and being passed out as a result of alcohol or drug ingestion.

- In the case of both male and female drivers 55 and older driving at intersections, crash occurrence may be attributed to “misjudgment of gap or other’s speed” and “inadequate surveillance.” Also, crash occurrence at intersections may be attributed to “illegal maneuver” for male drivers of all age groups, while for female drivers it may be due to “internal distraction” or “inattention.” For young female drivers 24 and younger, crash occurrence at intersections may be attributed to “turned with obstructed view” or “internal distraction”. For young male drivers 24 and younger, it may be due to “internal or external distraction,” “illegal maneuver,” or “false assumption of other’s action”. It may be noted that “turned with obstructed view” means driver’s sightline to approaching traffic was not clear typically by an intervening in-transport vehicle.

- At intersections controlled by traffic signals, crash occurrence may be attributed to “false assumption of others action,” “inattention,” or “internal distraction” for female drivers, while “critical non-performance error,” “illegal maneuver,” “false assumption of other’s action,” “too fast for conditions or aggressive driving,” or “internal distraction” for male drivers. At intersections controlled by traffic control devices (traffic signals or stop signs), crash occurrence may be attributed to “inattention” of female drivers and “illegal maneuver” of male drivers. At intersections with no traffic control device, crash occurrence may be attributed to “misjudgment of gap or other’s speed” for both female and male drivers.

In summary, crash occurrence while crossing over at traffic signals or stop signs as well as while turning left at traffic signals at intersections may be attributed to “distraction,” “inattention,” “illegal maneuver,” “driving too

fast for conditions or aggressive driving." Also, drivers 54 and younger are generally involved in crashes at intersections controlled by traffic signals due to "distraction," "inattention," "illegal maneuver," or "too fast for conditions/aggressive driving." The involvement of female drivers of all ages in the intersection-related crashes may be attributed to "distraction" or "inattention." On the other hand, male drivers of all ages are likely to be involved in such crashes due to "illegal maneuver," or "too fast for conditions/aggressive driving."

The findings pertaining to the crashes at intersections, presented in this report, can be used in the evaluation and development of the design of intersection collision avoidance technologies such as the Cooperative Intersection Collision Avoidance System (CICAS), which would warn a driver about an imminent violation of the traffic control device at the intersection. These findings may also help improve road design, use of traffic control device, and driver training.

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6. Appendix A

Table A1: Critical Pre-Crash Event for Vehicles With Critical Reason				
Critical Pre-Crash Event		**Unweighted**	**Weighted**	
			Estimate	**Percentage**
Turning or Crossing at Intersection	Turning Left	1289	485,649	22.2 %
	Crossing Over	820	275,868	12.6 %
	Turning Right	74	25,719	1.2 %
	Subtotal	2,183	787,236	36.0 %
Off the Edge of the Road		1,083	481,139	22.0 %
Stopped		641	267,780	12.2 %
Over the Lane Line		567	239,339	10.9 %
Traveling Too Fast		207	109,118	5.0 %
Traveling in Same Direction		317	105,717	4.8 %
Poor Road Condition		81	45,632	2.1 %
Traveling in Opposite Direction		7	2,510	0.1 %
Other		82	33,725	1.5 %
Unknown		4	1,155	0.1 %
Total		5,470	2,188,969	100 %
Estimates may not add up to totals due to independent rounding.				
Data Source: NMVCCS 2005-2007				

Table A2: Intersection-related Crashes by Traffic Control Devices (Based on multiple choices per crash)			
Traffic Control Devices	**Unweighted**	**Weighted**	
		Estimate	**Percentage**
Traffic Signal	1,183	413,140	52.5 %
Stop Sign	604	246,385	31.3 %
No Traffic Control Device	387	125,022	15.9 %
Others/Unknown	75	23,625	3.0 %
Total	2,249	808,173	102.7 %†
Estimates may not add up to totals due to independent rounding. † Percentage greater than 100, due to multiple choices.			
Data Source: NMVCCS 2005-2007			

Table A3. Critical Pre-Crash Event of Intersection-Related Crashes by Age Group															
Critical Pre-Crash Event		Age group													
		20 and below		21-24		25-34		35-44		45-54		55-64		65 and above	
		Weighted		Weighted		Weighted		Weighted		Weighted		Weighted		Weighted	
		Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%
Intersection-Related Crashes	Turning Left	105,715	23.3	42,211	16.2	96,019	21.6	61,356	19.8	58,492	22.0	42,115	26.2	74,628	32.3
	Crossing Over	40,816	9.0	24,719	9.5	52,902	11.9	44,581	14.4	35,865	13.5	25,658	15.9	46,483	20.1
	Turning Right	3,349	0.7	2,863	1.1	2,915	0.7	4,626	1.5	3,263	1.2	2,128	1.3	3,454	1.5
Subtotal (intersection)		149,880	33	69,793	26.7	151,836	34.1	110,562	35.6	97,620	36.8	69,901	43.4	124,564	53.9
Others/Unknown		304,442	67	191,338	73.3	293,672	65.9	199,939	64.4	167,932	63.2	91,005	56.6	106,367	46.1
Total		454,322	100	261,131	100	445,508	100	310,501	100	265,552	100	160,906	100	230,931	100

Data Source: NMVCCS 2005-2007

Table A4. Critical Pre-Crash Event of Intersection-Related Crashes by Sex					
Critical Pre-Crash Event		Age group			
		Female		Male	
		Weighted		Weighted	
		Num	%	Num	%
Intersection-Related Crashes	Turning Left	254,571	25.8	228,339	19.5
	Crossing Over	136,404	13.8	137,526	11.8
	Turning Right	14,382	1.5	11,229	1.0
Subtotal (intersection)		405,357	41.1	377,095	32.2
Others/Unknown		581,741	58.9	792,979	67.8
Total		987,098	100	1,170,074	100

Data Source: NMVCCS 2005-2007

Table A5: Intersection-Related Crashes by Atmospheric Conditions (Based on multiple choices per crash)			
Traffic Control Devices	Unweighted	Weighted	
		Estimate	Percentage
Clear	1,699	609,432	78.6 %
Cloudy	359	124,143	16.0 %
Rain	127	47,825	6.2 %
Fog, Smog, Smoke	10	9,255	1.2 %
Snow	13	2,139	0.3 %
Other	17	3,938	0.5 %
Total	2,225	796,732	102.8 %†

Estimates may not add up to totals due to independent rounding.

† Percentage greater than 100, due to multiple choices.

Data Source: NMVCCS 2005-2007

Table A6. Critical Reasons of Intersection-Related Crashes				
Critical Reasons		Number of Crashes		Weighted Percentage
		Unweighted	Weighted	
Driver Attributed Critical Reason	Recognition Error	1,163	438,194	55.7 %
	Decision Error	724	230,047	29.2 %
	Performance Error	27	5,771	0.7 %
	Critical Non-Performance Error	17	6,588	0.8 %
	Other/Unknown Driver Error	171	75,971	9.7 %
Sub-total (Drivers)		2,102	756,570	96.1 %
Vehicles Attributed Critical Reason		12	2,932	0.4 %
Environment Attributed Critical Reason		35	10,813	1.4 %
Unknown Critical Reason		34	16,920	2.1 %
Total		2,183	787,236	100.0 %
Data Source: NMVCCS 2005-2007				

Table A7. Driver Attributed Critical Reason of Intersection-related crashes				
Critical Reason		Number of Crashes		Weighted Percentage
		Unweighted	Weighted	
Recognition Error	Inadequate Surveillance	860	333,666	44.1%
	Internal Distraction	121	43,019	5.7 %
	Inattention (daydreaming, etc.)	87	25,659	3.4 %
	External Distraction	59	15,651	2.1 %
	Other/Unknown Recognition Error	36	20,199	2.7 %
Decision Error	False Assumption of Other's Action	202	63,317	8.4 %
	Illegal Maneuver	155	51,465	6.8 %
	Misjudgment of Gap or Other's Speed	162	41,567	5.5 %
	Too Fast for Conditions/Aggressive Driving Behavior	28	7,688	1.0 %
	Turned With Obstructed View	155	58,702	7.8 %
	Other/Unknown Decision Error	22	7,307	1.0 %
Performance Error		27	5,771	0.8 %
Critical Non-Performance Error		17	6,588	0.9 %
Other/Unknown Driver Error		171	75,971	10 %
Total		2,102	756,570	100.0 %

Data Source: NMVCCS 2005-2007

7. Appendix B

As an example, the relative ratio of inadequate surveillance is obtained as follows:

Table B1. Crashes With Inadequate Surveillance as Critical Reason by Intersection-Related and Non-Intersection-Related Crashes			
	Critical Reason of Inadequate Surveillance		
	Yes	No	Total
Intersection-Related Crashes	(a) 333,666	(b) 422,904	756,570
Non-Intersection-Related Crashes	(c) 93,841	(d) 1,195,441	1,289,283

$$\text{Relative ratio} = \frac{a/(a+b)}{c/(c+d)} = \frac{333{,}666/756{,}570}{93{,}841/1{,}289{,}283} = 6.1$$

8. Appendix C

As an example, Z-statistics based on CFA is obtained as follows:

$$Z = \frac{O-E}{\sqrt{E}},$$

Where O is the observed frequency and E, the expected frequency, is calculated from the marginal distributions of the variables. More details are provided in Von Eye (2002).

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