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What Effect Does Driver Maneuvers Have on The Safety of Pedestrians and Cyclists? An In-Depth Descriptive Analysis of Vulnerable User Crashes and Near-Misses

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What Effect Does Driver Maneuvers Have on The Safety of Pedestrians and Cyclists? An In-Depth Descriptive Analysis of Vulnerable User Crashes and Near-Misses

A Thesis Presented for the

Master of Science

Degree

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Abdul Rashid Kanda Mussah
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Dedicated to my parents
Abdul Rahman and
Vivian

my siblings
and my family

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I thank my parents, for their unconditional love, encouragement, and support. I am grateful for the guidance of my academic advisor, Asad Khattak. And Dr. Shashi Nambisan for your mentorship, and for your continuous support.

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ABSTRACT

Vulnerable Road user safety is a leading issue in the effort to create safer driving environment and reduce the instances of crashes on the roadways. The research approach here is to conduct an in-depth descriptive analysis of pedestrian and bicyclist pre-incident behaviors and evasive maneuvers in near-miss or crash-like situations and to seek an understanding of how different driving behaviors put these road users at risk. By analysing naturalistic driving data from the 2nd Strategic Highway Research Program (SHRP-2), the pre-incident maneuvers of both drivers are analysed to determine the risk factors of each maneuver to other road users, in comparison to a baseline situation where no crashes were involved. Regarding the analysis, two event scenarios of vehicle-to-vehicle situations and, pedestrians and cyclists involved situations, were identified as main categories of interest to create a more in-depth representation of the risk factors of specific driving maneuvers. These two categories were compared to a baseline scenario where no crashes or near-misses occurred. From the observed descriptive statistics, it can be inferred that unsafe and/or illegal maneuvers increase the instance of crash like events, these values increased from a baseline proportion, of a combined total of 7%, to making-up 17% of PedBike involved events, and 26% of vehicle-to-vehicle events. The proportions can further be broken down for the baseline as 2% safe but illegal, 4% unsafe and illegal, and 1% unsafe but legal. For PedBike involved events we have a breakdown of 1% safe but illegal, 11% unsafe and illegal, and 5% unsafe but legal. Finally, in the instance of vehicle only involved events the breakdown of the proportions is represented as 1% safe but illegal, 16% unsafe and illegal, and 9% unsafe but legal. What the findings suggests is that each driving maneuver requires a certain level of awareness in response to many environmental factors to ensure a safe outcome at the end of the maneuver. This study therefore stresses the importance of driver awareness in successfully initiating and executing all driving maneuvers for the safest possible outcome for pedestrians, cyclists and other drivers.

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION 1
CHAPTER TWO: LITERATURE REVIEW 3
2.1. Naturalistic Driving 4
2.1.1. Event Categorization 4
2.2. Research Objective & Contribution 4
CHAPTER THREE: DATA AND METHODOLOGY 5
3.1. Description of Data 5
3.1.1. Data Preparation 6
3.2. Statistical Models for Analyzing Driving Behavior 8
3.2.1. Multinomial logistic regression 8
CHAPTER FOUR: RESULTS 10
4.1. Descriptive Statistics 10
4.2. Modeling Results 22
CHAPTER FIVE: DISCUSSION AND FUTURE RESEARCH 25
5.1. Limitations/future work 25
5.2. Conclusions 25
REFERENCES 27
APPENDIX 30
VITA 36

LIST OF TABLES

Table 1. Independent variables for MNL model 9
Table 2: Descriptive Statistics of Key Variables 11
Table 3. Model Estimation Results for Pre-Incident Driving Maneuvers in Naturalistic Driving Environment (Stepwise elimination of all the other variables) 23
Table 4. Percentage proportion of observed Baseline Driver Behaviors of complete dataset 31
Table 5. Percentage proportion of observed Vehicle Only Involved Events Driver Behaviors of complete dataset 32
Table 6. Percentage proportion of observed PedBike Involved Events Driver Behaviors of complete dataset 33
Table 7. Percentage difference between different event categories 34
Table 8. Maneuver Judgement Detail Table 35

LIST OF FIGURES

Figure 1. Flowchart showing the categorization of the dataset. 6
Figure 2. Conceptualization of sampling and data preparation. 7
Figure 3. Percentage distribution and categorical comparison of pre-incident maneuvers of complete data set. 12
Figure 4. Percentage Distribution of Pedestrian and Driver Pre-Incident Maneuvers 13
Figure 5. Percentage Distribution of Pedestrian and Driver Pre-Incident Driving behaviors 16
Figure 6. Percentage Distribution of Pedestrian and Driver Pre-Incident Driving Maneuver judgements 19

CHAPTER ONE: INTRODUCTION

Bicyclists and pedestrians, known collectively as vulnerable road users are the greatest at risk on the roadways as the demand for transportation increases around the world. Pedestrians are one of the most unprotected road users with around 22% of all worldwide traffic deaths involving pedestrians (World Health Organization, 2015). This is not withstanding the fact that rate of commuter home-based-work trips by bicycle has increased by a proportion of about 60% over the last decade in the United States of America alone (United States Department of Commerce. Bureau of the 2014). This also ties into the shifting housing preference in walkable and bike-able mixed-use environments, which have been tied to a healthier lifestyle and lower cases of obesity as reported by many studies such as those done by Ewing et. al (2005, 2006) and Rundle et. al (2007)

As we have realised the growing trend of preference in cycling as a transportation mode choice, the safety of these road users is paramount in the discussion aimed towards a safer all-inclusive transportation network of the future which includes connected and automated vehicles. Determining which driver behaviors puts these road users at greatest risk allows us to develop a more pragmatic approach to ensuring their safety on our roadways. The more of an insight we can get to realising the sort of actions and behaviors of both drivers and pedestrians, as they interact on the shared roadway, the better we will be in addressing those issues, with solutions ranging from intelligent transportation applications, to improved roadway design measures which a more bicycle and pedestrian friendly.

Driving behavior has been extensively studied in an effort to improve safety on our roadways. Inattentiveness and inexperience have been identified by Aberg and Rimmo (1998), as two factors which comprise “harmless lapses” of driving error linked behaviors, which are quite prevalent in observed driving behaviors. The issue of inattentiveness has recently been researched in study by Zendrive (2017) in the largest ever distracted driving behavior study. This study found out that a shocking proportion of as many as 88% of driver use their mobile phones while behind the wheel, an issue that is quite alarming owing to the fact that a 2 second distractions is suggested to increase the likelihood of the event of a crash by over 2 to 24 times. (Hurwitz et. al. 2015).

Previous studies of the issue of driver behavior effects on pedestrian and cyclist crashes have approached it by exploring data which doesn’t tell the whole story of what the major influencers of the outcome of an event are due to reports based solely on the retelling of events from a biased viewpoint. The major source of data used in the multitude of studies which have delved into this issue are obtained from police crash reports, which aren't always as accurate and nuanced in presenting the causes of the incidents.

The Naturalistic Driving Study (NDS) data allows us to circumvent this issue by detailing all the subtleties from moments before an event takes place till after the event occurs. The data presented by the NDS study is organized into 73 variables of 9393 events, and a final narrative of each event which gives us the ability to delve a little better into extra detail about the situations that make each crash individually different and categorically the same.

The focus of this study is to explore the different driver behaviors and maneuvers which put these vulnerable road users at greatest risk. The approach of this study involves an in-depth descriptive analysis of the NDS data pertaining to driver maneuvers and behaviors before an event occurs. A multinomial logistic regression model is used to delve a little more into the detail of which behaviors, between the observed range of likely contributors to crashes, have a higher likelihood of contributing to crashes. This also gives us the advantage of looking at near-miss events where these was an increased likelihood of an unsafe outcome, although the situation was averted, which generally go unreported. Using near-miss data as a surrogate for crashes, owing to the issue of the very little observed crashes in the naturalistic driving study, is a concept which has been previously investigated as very plausible by Dingus et al (2010).

CHAPTER TWO: LITERATURE REVIEW

The National Highway Traffic Safety Administration (NHTSA) in their Crash Statistics report on driver and pedestrian fatalities, with data from the Fatality Analysis Reporting System (FARS), reported 4779, 4910 and 5376 pedestrian fatalities and statistics of 66000, 65000, and 70000 pedestrian injuries for the years 2013, 2014 and 2015 respectively. These values suggest on average, a pedestrian roadway fatality occurs every 2 hours, and injured every 7 minutes in traffic crashes, accounting for up to 15 of total roadway fatalities (NHTS, 2012).

Pedal cyclist fatality statistics reported a decrease from 749 in 2013 to 729 in 2014, but this slight progression was not observed in 2015 with an increased reportage of 818 pedal cyclist fatalities. The trend of injuries to pedal cyclists on the other hand was opposite to that of the fatalities, where an increase was observed from 2013 to 2014 from 48,000 to 50,000 and a decrease to 45,000 in 2015 (NHTS, 2015).

According to Zegeer and Bushell (2012), the trends in pedestrian fatal crash statistics continue to show even greater problems for children and senior citizen pedestrians. Citing a study by Chang (2008), they reported that in almost the decade between 1997 and 2006, children under age 15, accounting for about 21% of the U.S. population, accounted for 23% of fatal pedestrian crashes. FARS statistics also suggest that this category of children (under 15 years old) account for 8.67% of pedestrian fatalities, and senior citizens on the other hand (65 years and older) accounted for 18.64% of pedestrian fatalities (NHTS, 2015).

Agran et al. (1990) detailed the underreporting of pediatric pedestrian and bicycle motor vehicle crashes by police to be conservatively estimated at 20% for pedestrians and 10% for bicyclists. There was also an issue of poor correlation of police injury severity scale with medical diagnoses.

These issues have created a system of pedestrian crash reportage where crucial information, pertaining to the preceding contributory factors of the crash, are either not accounted for or underreported. The difficulty of attaining such information on pre-crash events has been resolved in this study by taking advantage of the real-time monitoring and recording of driver actions, and the driving environment of the Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study (NDS).

2.1. Naturalistic Driving

Naturalistic driving studies have the advantage of reporting detailed information into traffic events including "near-miss" scenarios which generally go unreported. Given the very objective nature of the NDS data set, it is possible to analyse pre-conditions which led towards both cases of crashes and near-misses as previously carried out by Jonasson and Rootzen (2014). Research base on the use of near-misses have also previously been investigated by Dingus et al (2006), Guo and Fang (2012), Lee et al. (2010) and McLaughlin et al (2008) in areas such as safety and fatigue, risk variation, novice crash experience and collision avoidance systems, proving how effective the analysis of such situations can further add to the benefits of highway safety research. Hankey et al. (2016) presents detailed definitions of the different maneuver judgements and response outcome categories.

2.1.1. Event Categorization

From the predefined dataset, one main variable stands out in aiding us to recategorize all the events into our 3 main categories of interest, which is the "Event Severity 1" variable. Alone, the "Event Severity 1" variable allows us to do a presorting of all the events into a safe outcome (baseline) or unsafe outcome (crash, near-crash, non-subject conflict). Coupling the "Event Severity 1" variable with other variables such as "Event Nature 1" and "Incident Type" variables, we can further recategorize the date into our final three subsets of "Baseline" where the outcome was safe, "Vehicle Only Involved Events" where an unsafe outcome of a crash or near miss involved only vehicles, and "PedBike Involved Events" where a crash or near miss involved at least one pedestrian or cyclist.

2.2. Research Objective & Contribution

The main objective of this research is to provide a detailed analysis of the different degrees of safety risk factors of driver maneuvers which pose threats to vulnerable road users. To achieve this goal, the different effects of each driving behavior, within the scenarios of a safe outcome (baseline), a crash or near-miss involving two or more vehicles (vehicle only related event) and a crash or near-miss which involved at least one pedestrian or cyclist (PedBike related event), are analysed to evaluate the varying degrees of safety risk per each maneuver in each situation. This study makes use of naturalistic driving data, which makes it possible to assess the immediate pre-incident behaviors of both drivers and pedestrians wherever possible.

CHAPTER THREE: DATA AND METHODOLOGY

Naturalistic driving data provides real-time information which is very critical in analysing driver behaviors prior to any roadway incident, and key environmental factors which allow for detailed evaluation of the causal effects and outcomes of these behaviors. Naturalistic driving studies are traditionally conducted using kinematic triggers (Dingus et al. 2005), though in recent years, steps have been taken to improve upon the richness of information being gathered using other triggers such as video capture from onboard cameras to be able to capture the whole dynamics of events as they unfold (SHRP2). The data from on-board cameras can allow researchers to draw viable conclusions of the different levels of driver spatial awareness and actions through analysis of video feedback generated from these cameras. These videos allow for a general taxonomy of the different and diverse driver actions, as well as impairments to be drawn out and analysed for their safety risks. These video feedbacks also provide a rich resource of data on environmental factors ranging from lighting and weather conditions, to traffic congestion and roadway geometry. The richness of this data with variables generated directly from the driver's perspective allows researchers to approach issues directly from the driver's point-of-view which creates a less biased assessment of the situations which leads to crashes and near-misses.

3.1. Description of Data

The data used by this study was derived from the Naturalistic Driving Study (NDS) conducted during the 2nd Strategic Highway Research Program (SHRP2). With a participation pool of an estimated 3,400 drivers and over 4000 years of real world naturalistic driving data, the SHRP2 NDS is the largest naturalistic driving study carried out till date (Hankey et al, 2016). With detailed information provided by the event data table, factor ranging from driving behavior and pre-incident maneuvers, to roadway and traffic conditions, and even a final narrative of the event log, are provided for detailed statistical analysis and text analytics.

For the purpose of this study near crashes have been included as crash surrogates. Guo et al. (2010) in their analysis of the potential for using near crashes as crash surrogates indicated combined crash and near-crash data, although might underestimate the risk of contributing factors compared to use of crash data alone, do also increase the precision of the estimates of the analysis. As such, true high-risk behaviors can easily be identified while qualitatively assessing potential bias. These finding provide proof of the benefit of combining crash and near-crash data for studies where there aren't large enough numbers for statistical analysis.

Moving forward, I extracted a total of 7589 baseline, 1839 near-miss and crash like situations involving only vehicles, and 74 near-miss and crash like events involving at least one pedestrian. From the event log data of these three categories of interest, the data allows us to work within a statistical framework of comparing the safety risks of these three categories in the instance of driver pre-incident maneuvers and behaviors, as well as other contributory environmental factors which may increase the safety risk of vulnerable road users.

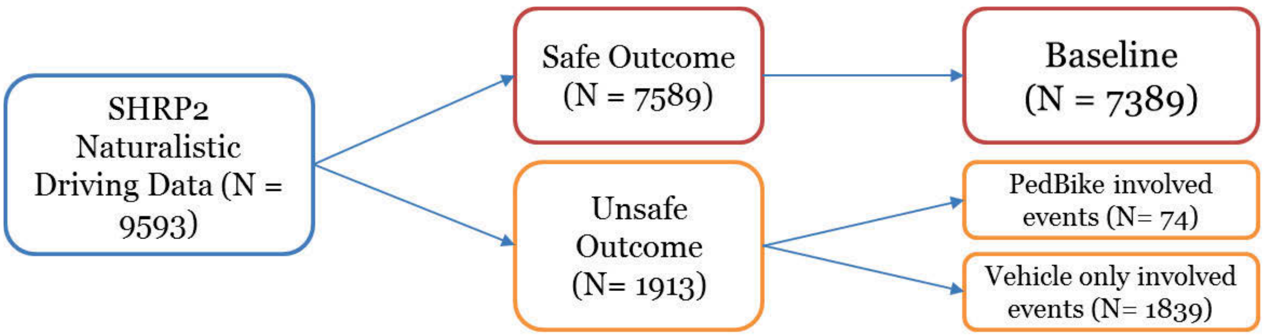


Figure 1. Flowchart showing the categorization of the dataset.

3.1.1. Data Preparation

To prepare the data appropriately for the analysis to be carried out, a random sampling exercise was carried out to extract 74 baseline and vehicle only events, which is important for the purpose of the comparative analysis using multinomial logistic regression. This sampling was done multiple times to ensure representation of the common pre-incident behaviors of the three categories of the data to reduce the instance of sampling error. The prepared data were finally combined into one dataset and coded with the three different categories of interest to this study.

Figure 2. Conceptualization of sampling and data preparation.

3.2. Statistical Models for Analyzing Driving Behavior

The relationships of the different variables observed in both instances of crash and near crashes for the three data categories are evaluated here. The analysis involves two stages: An evaluation of the general descriptive statistics of the different variables of the three categories, and a regression analysis to measure the probability of each type event under different situations.

3.2.1. Multinomial logistic regression

Since the nature of this research focuses on three categories of data in question, it is sensible to utilize a multinomial logistic regression in the evaluation of the probability (P) of the outcome of these driving behaviors and this model has been outlines in the equations (1,2,3) below. In the equations b_0, b_1, … b_n and x_1, x_2, …x_n represent the beta estimates and the different behavioral variables respectively. The value n corresponds to the number of the behavioral variables and the values (2) and (3) represent the code for the categorical representations of vehicle only involved events and PedBike involved events respectively.

$$P(2\colon vehicle\ only\ involved\ events) = \frac{exp[b_0 + b_1x_1(2) + \cdots + b_nx_n(2)]}{1 + exp[b_0 + b_1x_1(2) + \cdots + b_nx_n(2)]} \quad \ldots (1)$$

$$P(3\colon pedbike\ involved\ events) = \frac{exp[b_0 + b_1x_1(3) + \cdots + b_nx_n(3)]}{1 + exp[b_0 + b_1x_1(3) + \cdots + b_nx_n(3)]} \quad \ldots (2)$$

$$P(1\colon baseline) = 1 - P(2\colon vehicle\ events) - P(3\colon pedbike\ events) \quad \ldots (3)$$

The multinomial logistic regression is advantageous against other models such as the probit model in the sense that it is robust against multivariate normality and therefore better suited for smaller samples, which is the case of our analysis in this study. Although our prepared sample size is 222 events in total per sample of 74 events in each category, we limit our included variables in our study to measures which account for direct influences on driver actions such as observable environmental factors. Table 1 below details the included variables in our model.

Table 1. Independent variables for MNL model

Variable Name	Description
Pre-Incident Maneuver	The last type of action or driving maneuver that the subject vehicle driver engaged in or was engaged in just prior (2 to 6 seconds) to the occurrence of the event
Maneuver Judgement	Judgment of the safety and legality of the Pre-Incident Maneuver
Driving Behavior	Driver behaviors which include what the driver did to cause or contribute to the crash or near-crash
Lighting Details	Lighting condition at the time of the start of the Precipitating Event
Weather Details	Weather condition at the time of the start of the Precipitating Event
Surface Condition Details	The type of roadway surface condition that would affect the vehicle's coefficient of friction at the start of the Precipitating Event

(source: https://insight.shrp2nds.us/info/printable/38?type=dataset)

One final advantage of the multinomial logistic regression is the ability to conduct a stepwise multinomial regression for all the main variables and interaction effects. This way it is possible to eliminate insignificant interaction effects in the model and improve the goodness of fit for the model.

CHAPTER FOUR: RESULTS

4.1. Descriptive Statistics

Table 2 below details the general descriptive statistics of the distributions of pre-incident maneuvers relevant to the study. It is well to note that driver pre-incident behaviors fall within a very broad range of defined actions in the collection of the data, yet only those occurring in more than one of the data categories have been provided for the sake of the study.

There are a great number of important insights to be derived from this study. As this study focuses on the pre-incident behaviors of both drivers and vulnerable road users, the descriptive statistics of the pre-incident maneuvers and driver behaviors/impairments present a general idea of specific driver behaviors which have a high instance of leading to unsafe outcomes for vulnerable road users. A further in depth statistical probing of these behaviors utilizing the multinomial logistic regression allows us to derive a comparative baseline to what measure or degree these unsafe combinations of maneuvers increase the safety risk of the vulnerable road users. The general descriptive reporting of these behaviors suggests that four main pre-incident maneuvers showed the greatest frequency percentages for PedBike involved crashes/near misses which were, "decelerating in traffic lane" (18.92%) "going straight while accelerating" (21.62%) "going straight at a constant speed" (16.22%), and "turning left" (16.22%).

Figures 2 and 3 define a clearer visual outlook on the many different taxonomical representations of driver behaviors with respect to pre-incident maneuvers and driving impairments. The proportions of these behaviors in the wider context shows how diverse the combinations of these two driving behaviors are, but this has been aggregated to a simpler taxonomy of maneuver judgement present in Figure 4. It should be noted however, that the definition of 'safe' in the case of maneuver judgement does not take into account the behavior or impairments of the driver as the maneuver was being carried out, but solely on the manner in which the maneuver takes place (this is highlighted in table 8 in the appendix).

Looking at these figures, we realize that in the category of vehicle involved event and PedBike involved events, there is a significant increase in the percentage proportions of unsafe and illegal maneuvers from baseline values of 5% unsafe and 6% illegal to values of 25% unsafe and 17% illegal in the instance of vehicle only involved events, and 16% unsafe and 12% illegal for PedBike involved events. We can make thus the intuitive assertion that an increase in the proportion of both unsafe, and illegal maneuvers greatly increases the risk associated with crashes and near-misses.

Table 2: Descriptive Statistics of Key Variables

Pre-Incident Maneuver	Baseline			Vehicle Only Events			PedBike Involved Events		
	N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev
Changing lanes	7589	0.0331	0.17884	1839	0.0576	0.23312	74	0.0541	0.22767
Decelerating in traffic lane	7589	0.1683	0.37413	1839	0.1849	0.38831	74	0.1892	0.39433
Going straight, accelerating	7589	0.0984	0.29792	1839	0.1387	0.34569	74	0.2162	0.41447
Going straight, constant speed	7589	0.5409	0.49836	1839	0.2414	0.42807	74	0.1622	0.37112
Maneuvering to avoid a pedestrian/pedal cyclist	7589	0.0004	0.01988	1839	0.0005	0.02332	74	0.0135	0.11625
Merging	7589	0.002	0.04442	1839	-	-	74	0.0135	0.11625
Negotiating a curve	7589	0.0951	0.29342	1839	0.0582	0.23415	74	0.0135	0.11625
Passing or overtaking another vehicle	7589	0.0045	0.06679	1839	-	-	74	0.0135	0.11625
Starting in traffic lane	7589	0.0003	0.01623	1839	0.0348	0.18333	74	0.0405	0.19857
Stopped in traffic lane	7589	-	-	1839	0.0392	0.19401	74	0.0676	0.25272
Turning left	7589	0.0191	0.13691	1839	0.0636	0.24414	74	0.1622	0.37112
Turning right	7589	0.0207	0.14235	1839	0.0843	0.27789	74	0.0541	0.22767

Notes: N is sample size; Std.Dev is standard deviation

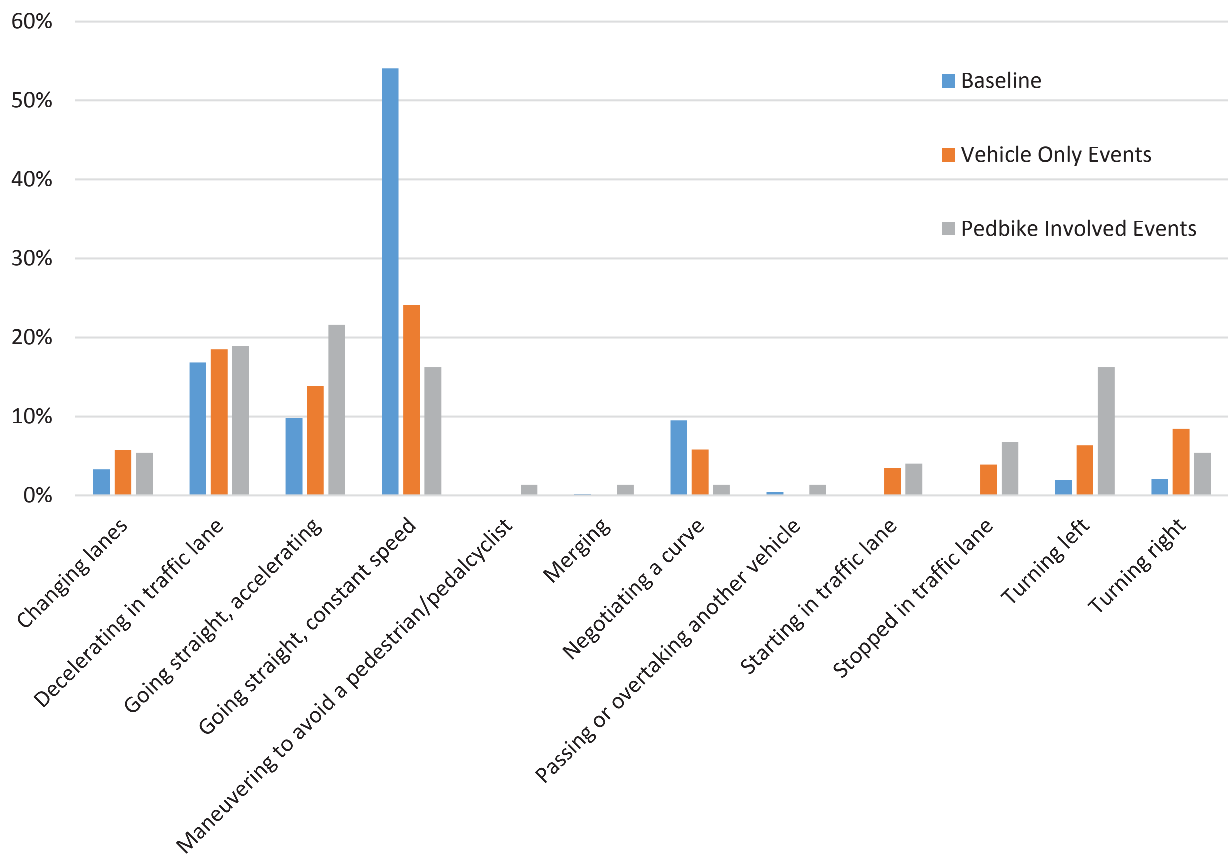
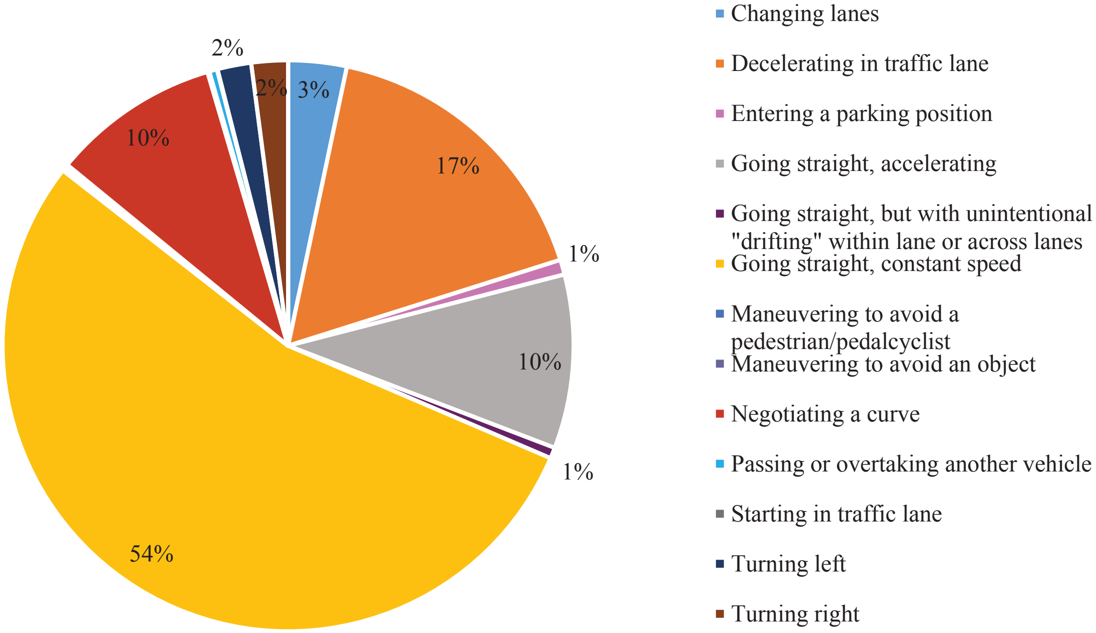
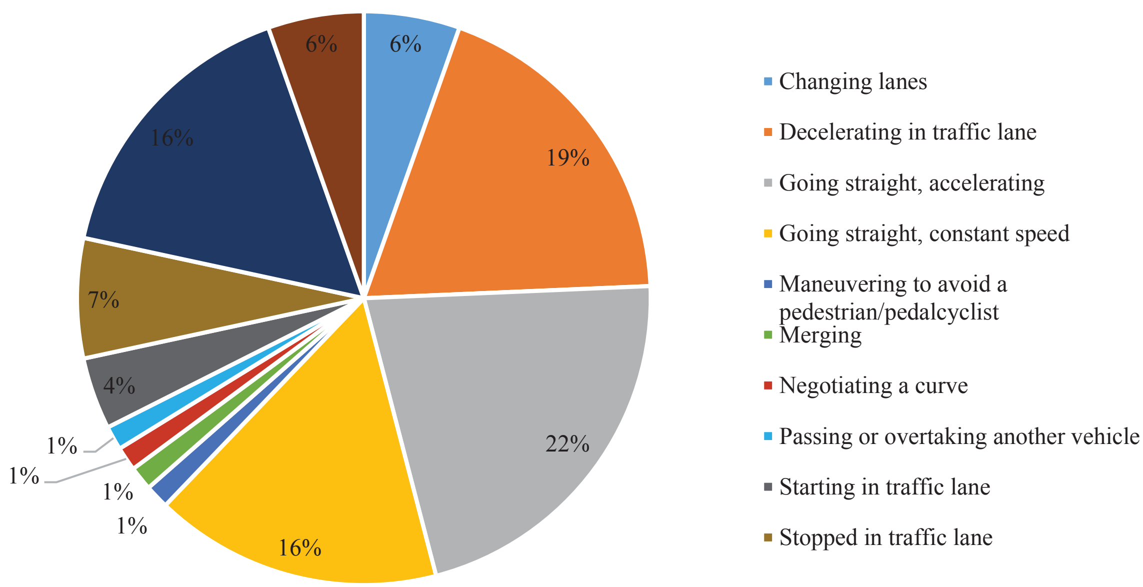


Figure 3. Percentage distribution and categorical comparison of pre-incident maneuvers of complete data set.

Figure 4. Percentage Distribution of Pedestrian and Driver Pre-Incident Maneuvers

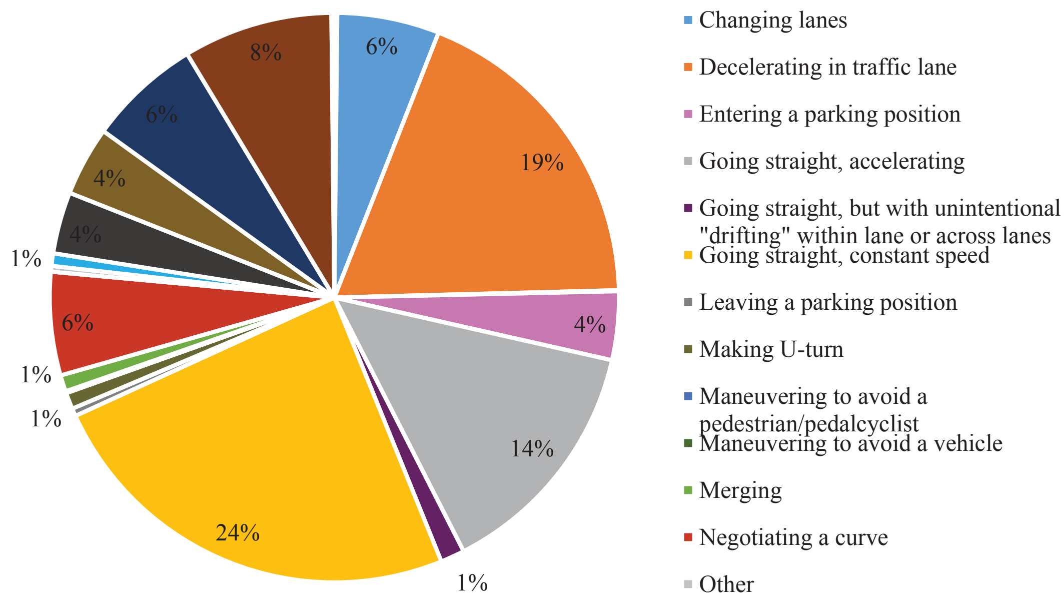


a) Distributions of Baseline Pre-incident manuevers (N=7,589)



b) Distributions of Pedbike Invovled Events Pre-Incident manuevers (N=74)

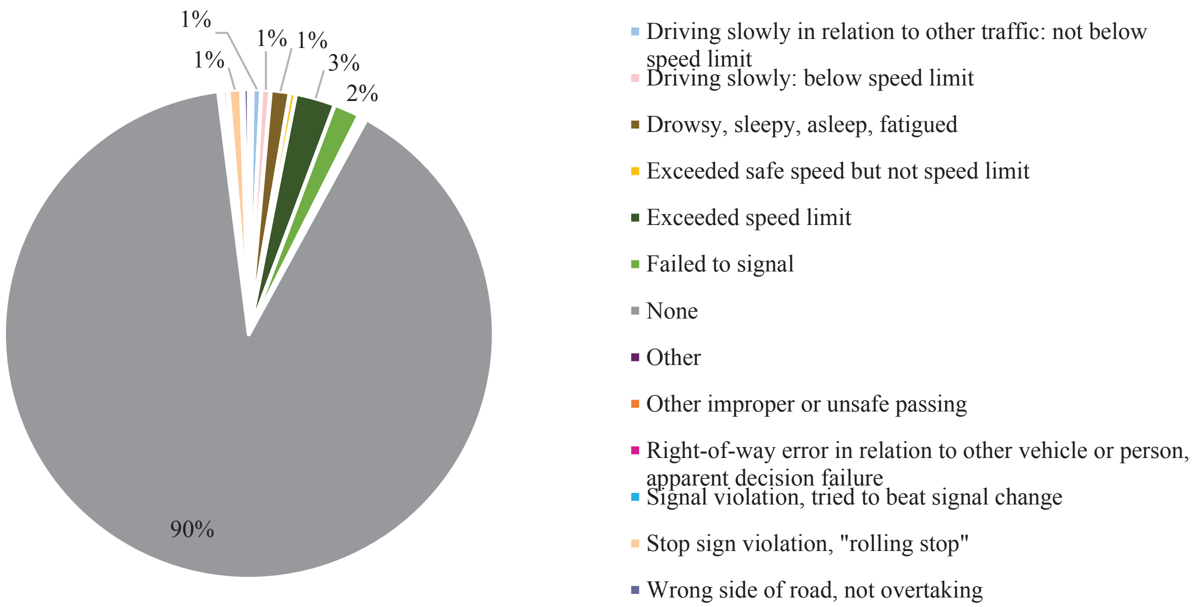
Figure 4 continued.



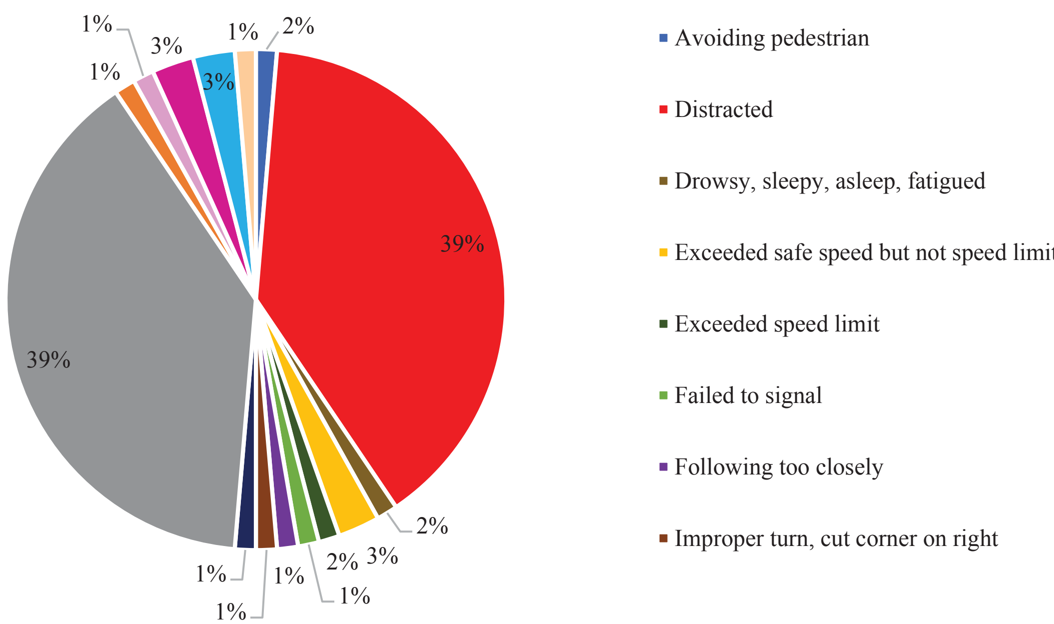
c) Distributions of Vehicle Only Events Pre-Incident maneuvers (N=1839)

Figure 4 continued.

Figure 5. Percentage Distribution of Pedestrian and Driver Pre-Incident Driving behaviors

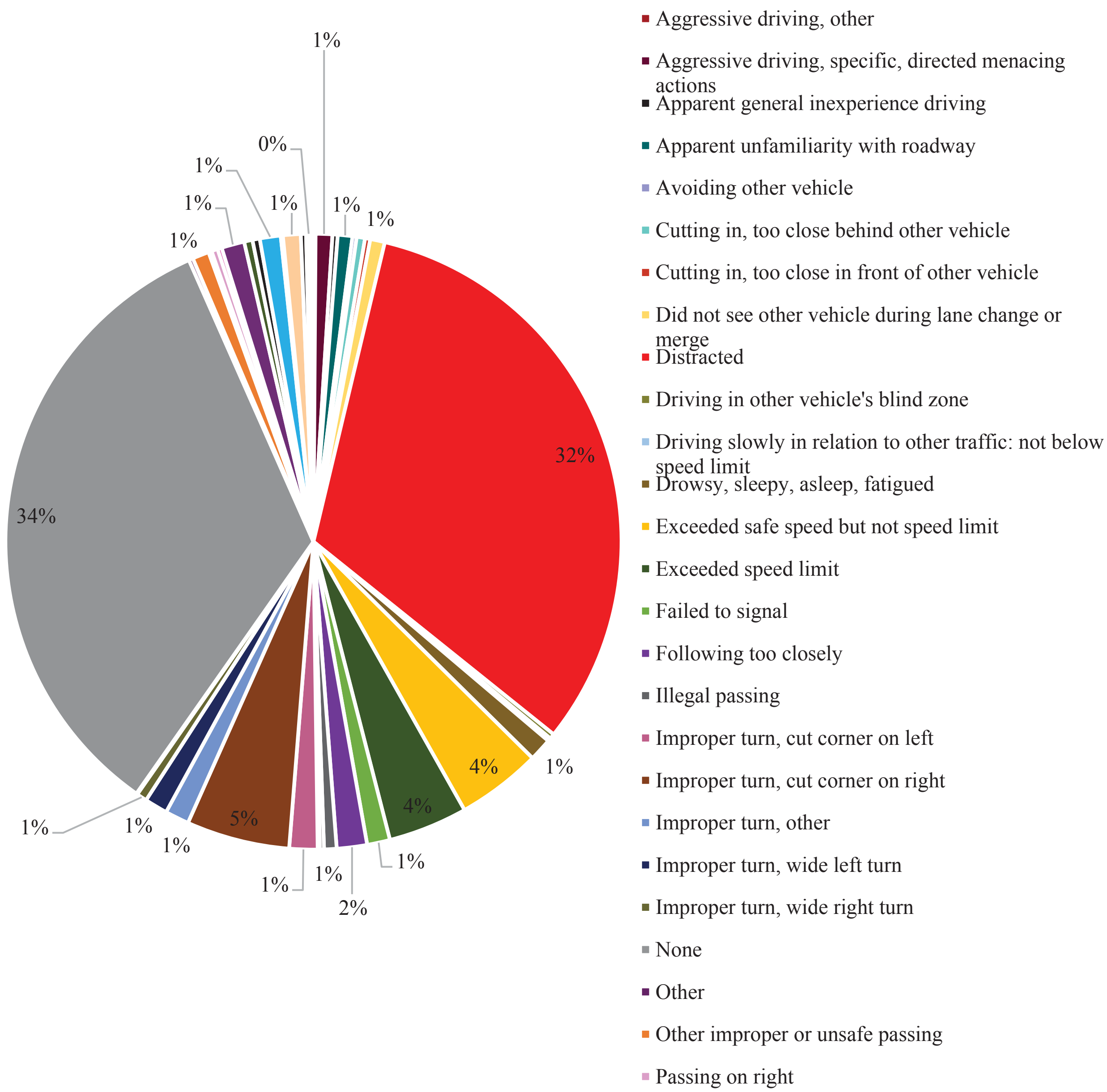


a) Distributions of Baseline Pre-incident Driving behaviors (N=7,589)



b) Distributions of Pedbike Invovled Events Pre-Incident Driving behaviors (N=74)

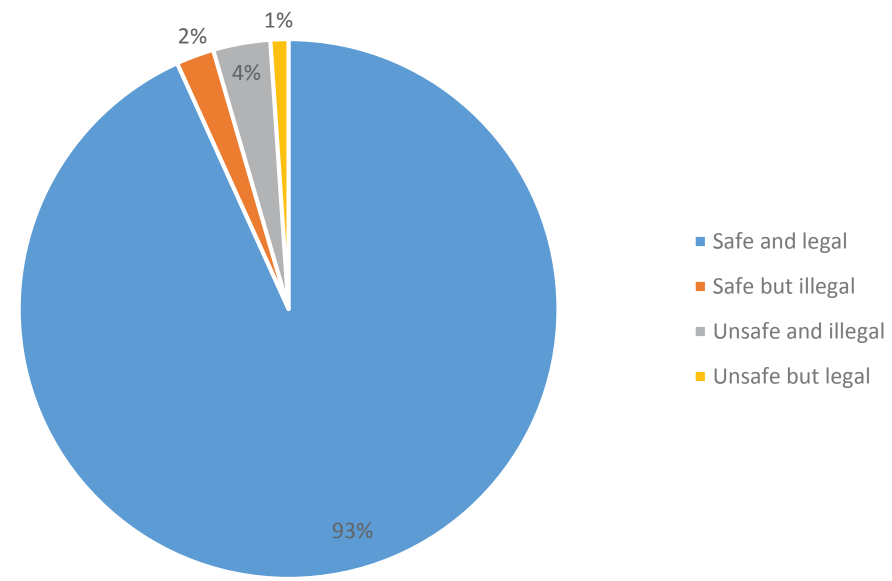
Figure 5 continued.



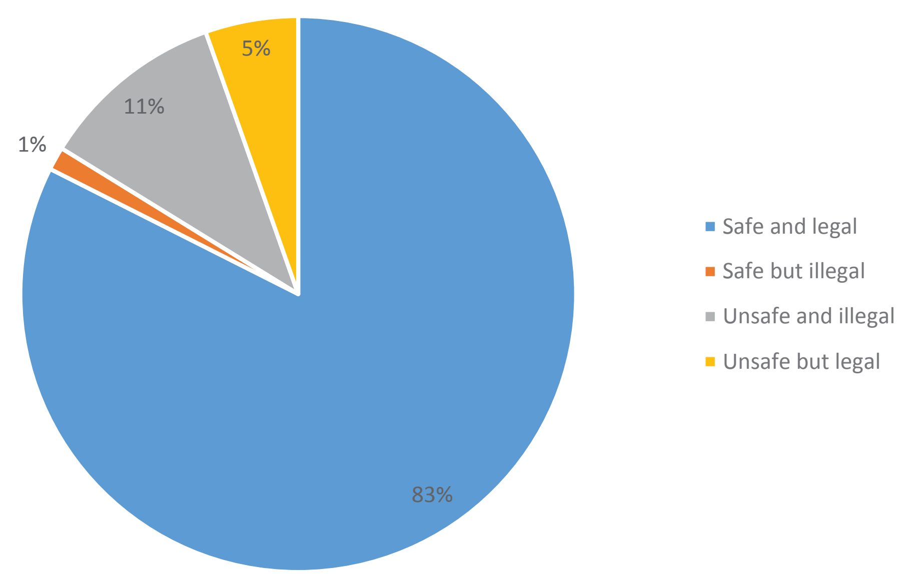
c) Distributions of Vehicle Only Events Pre-Incident Driving behaviors (N=1839)

Figure 5 continued.

Figure 6. Percentage Distribution of Pedestrian and Driver Pre-Incident Driving Maneuver judgements

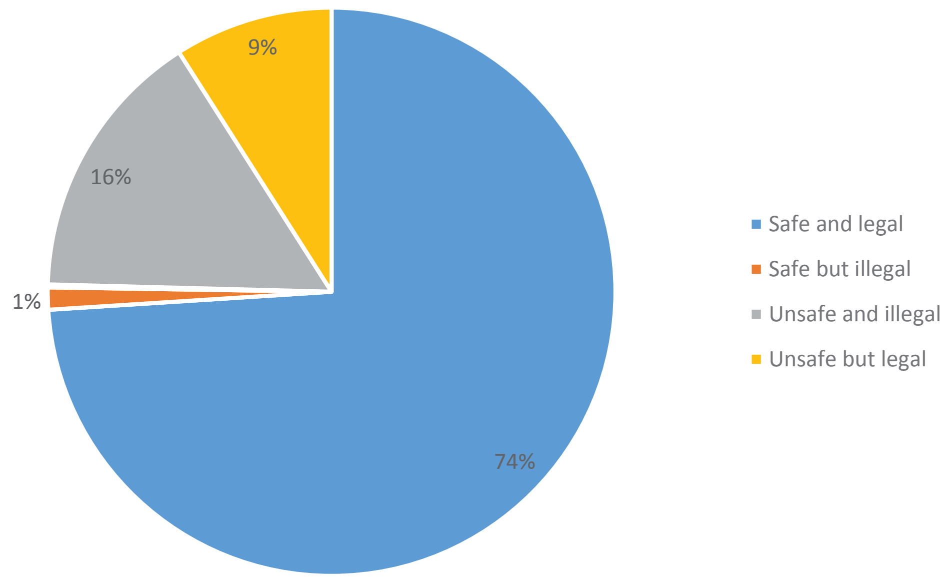


a) Distributions of Baseline Maneuver judgement (N=7,589)



b) Distributions of Pedbike Invovled Events Maneuver judgement (N=74)

Figure 6 continued.



c) Distributions of Vehicle Only Events Maneuver judgement (N=1839)

Figure 6 continued.

4.2.Modeling Results

The initial modeling framework constituted a combined dataset of 74 individual cases of baseline, vehicle only involved event and PedBike Involved events to create a data sample of 222 events with representation of the main four pre-incident maneuver variables which reported high percentage outcome in the general descriptive statistics. The 74 samples of each category included in the combined dataset were coded as 1 for Baseline, 2 for vehicle only involved events and 3 for PedBike involved events.

The multinomial logit regression model carried out on the combined samples was conducted in a manner where the baseline elements of the sample (code 1) were selected as the base variables and vehicle only involved events and PedBike involved events were compared to this base. The independent variables of the regression model were the different pre-incident maneuvers.

Of 25 sample combinations created, 12 of the modeled results showed significance (+95%) or marginal significance (90-95%) for at least 1 maneuver for both non-PedBike and PedBike events in the regression model results. Pre-incident maneuvers which showed statistical significance in many of the results included decelerating in traffic lane. going straight while accelerating, going straight at a constant speed, and negotiating a curve. These preliminary results reported back 3 of the 4 maneuvers of interest with 1 other maneuver which is negotiating a curve.

The best resulting model was selected and the regression was carried out again with included variables of driving behavior, traffic flow, lighting condition and surface conditions.

The regression was carried out 3 different times, the first model included all variables and their effects, the second model was a stepwise model which eliminated the effect of insignificant variables, and the third model included the effects of all pre-incident maneuvers with a stepwise elimination of all the other variables. The outcome of the final model showed a greater McFadden goodness R-squared value of 0.378

Table 3. Model Estimation Results for Pre-Incident Driving Maneuvers in Naturalistic Driving Environment (Stepwise elimination of all the other variables)

		β	Std. Error	Wald	Sig.	Exp(β)	95% Confidence Interval for Exp(β)	
							Lower Bound	Upper Bound
2	***Intercept***	2.752	0.818	11.33	0.001**			
	Decelerating in traffic lane	-0.485	0.713	0.461	0.497	0.616	0.152	2.493
	Going straight, accelerating	0.135	0.883	0.023	0.878	1.145	0.203	6.461
	Going straight, constant speed	-2.608	0.633	16.948	0.000**	0.074	0.021	0.255
	Negotiating a curve	-2.154	0.903	5.696	0.017**	0.116	0.02	0.68
	Turning left	0.529	1.038	0.26	0.610	1.698	0.222	12.991
	Turning right	1.295	1.169	1.226	0.268	3.65	0.369	36.093
	Divided (median strip or barrier)	-0.632	0.438	2.084	0.149	0.531	0.225	1.254
	Darkness, not lighted	-2.881	1.261	5.221	0.022**	0.056	0.005	0.664
	Surface Condition, Dry	-1.515	0.633	5.73	0.017**	0.22	0.064	0.76
3	***Intercept***	2.706	0.832	10.578	0.001**			
	Decelerating in traffic lane	-0.451	0.732	0.38	0.538	0.637	0.152	2.675
	Going straight, accelerating	0.867	0.874	0.982	0.322	2.379	0.429	13.2
	Going straight, constant speed	-2.305	0.637	13.083	0.000**	0.1	0.029	0.348

Table 3 continued.

		β	Std. Error	Wald	Sig.	Exp(β)	95% Confidence Interval for Exp(β)	
							Lower Bound	Upper Bound
3	*Negotiating a curve*	-3.206	1.221	6.891	0.009**	0.041	0.004	0.444
	Turning left	1.032	1.036	0.992	0.319	2.806	0.368	21.362
	Turning right	0.084	1.25	0.004	0.947	1.087	0.094	12.61
	Divided (median strip or barrier)	-1.594	0.487	10.725	0.001**	0.203	0.078	0.527
	Darkness, not lighted	-3.056	1.349	5.132	0.023**	0.047	0.003	0.662
	Surface Condition, Dry	-1.326	0.651	4.155	0.042**	0.265	0.074	0.95

Notes: **β** is parameter estimate; The reference category is: 1 (baseline); 2 represents vehicle only events and 3 represents PedBike involved events; (**) indicates statistical significance to a 95% confidence level.

CHAPTER FIVE: DISCUSSION AND FUTURE RESEARCH

The multinomial logistic regression results of the pre-incident maneuver and driving behavior, including other factors such as traffic control, lighting conditions and roadway surface conditions, are discussed here. It can be observed that the statistically significant negative correlations are found for the pre-incident maneuvers of going straight at a constant speed and negotiating a curve. This is observed in both scenarios of vehicle only involved events and PedBike involved events. The results suggest that there are significant reductions in the instance of being involved in vehicle only crash/near miss or PedBike involved crash/near miss when drivers are in the state of carrying out such maneuvers. The other significant variables reported from the model are lighting conditions where there is a prevalent darkness and no lighting, and surface conditions when the roadway is dry. The negative correlation of these two variables in both categories suggest also that there are significant decreases in the instance of vehicle only involved crashes and near misses and PedBike involved crashes and near misses under these conditions of driving.

5.1. Limitations/future work

The major limitation of this study is the is the base sample of 74 PedBike involved events extracted from the 9502 available data events. Due to the lack of the total 36,816 records the SHRP2 NDS Event Detail Table (EDT) currently has, it is not possible to derive a greater sample size for the statistical analysis which could very much increase the accuracy and reliability of this study. The methodological framework of this study, utilizing the multinomial logistic regression required a sampling of 74 events from the baseline and vehicle only involved datasets to create the combined data framework for the analysis. This represents a 1% and 4% utilization of the two respective datasets. The limited sample number for the model data framework also created a very large opportunity for the occurrence of sampling errors.

5.2. Conclusions

The purpose of this study was to explore the effects of pre-incident maneuver and behaviors of drivers' influence on the instance of vehicle only involved crashes and near misses, and PedBike involved crashes and near misses. From an event data table of 9502 events, of which 7589 (79.98%) were baseline, 1839 (19.24%) were vehicle only involved crashes and near-misses and 74 (0.78%) were PedBike involved crashes and near-misses, a detailed descriptive statistic of driver maneuvers, driver behavior, and maneuver judgement was carried out to explore the proportions of the variables and identify variables of interest.

From the observed descriptive statistics, it can be inferred that unsafe and/or illegal maneuvers increase the instance of crash like events, these values increased from a baseline proportion, of a combined total of 7%, to making-up 17% of PedBike involved events, and 26% of vehicle-to-vehicle events. The proportions can further be broken down for the baseline as 2% safe but illegal, 4% unsafe and illegal, and 1% unsafe but legal. For PedBike involved events we have a breakdown of 1% safe but illegal, 11% unsafe and illegal, and 5% unsafe but legal.

A multinomial logistic regression statistical framework was built to explore the effects of these key variables in the instance of their probabilistic outcome to the above-mentioned scenarios. Although from the descriptive statistics it may seem that certain maneuvers and behaviors have high proportions to end up in an unsafe outcome, the results concluded that some of these actions significantly reduced the probability of the unsafe outcomes. Of the observed proportions of driving behaviors which showed high percentage proportions for crash-like and near-miss outcomes, going straight at a constant speed reported a 92.6% reduction in probability of ending up in a vehicle only involved crash or near miss and a 90% reduction the probability of ending up in a PedBike involved crash or near-miss. Due to the current lack of availability of the entire SHRP2 NDS database, the model of this study has great potential to be expanded further in the future by delving into other probable quantifiable metrics which can be explored to detect nuances in the issues that separate one event outcome from another.

I conclude by presenting this study as an exploration into the behavior of drivers and their direct effect on the outcomes of their interaction with other road users, specifically, vulnerable road users. Furthermore, the NDS event dataset, although seemingly lacking in the proportion of crashes involving vulnerable road users, has been shown to provide very valuable insight into the relationships of different factors pertaining to environmental and user characteristics that play a role in the outcome of a roadway situation involving all parties. It should be well noted that the analysis carried out here stresses on events of interest to build towards a specific safety management application.

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APPENDIX

Table 4. Percentage proportion of observed Baseline Driver Behaviors of complete dataset

Baseline	Count	%
Aggressive driving, other	1	0.01
Aggressive driving, specific, directed menacing actions	1	0.01
Apparent unfamiliarity with roadway	5	0.07
Avoiding another vehicle	3	0.04
Avoiding pedestrian	4	0.05
Driving in another vehicle's blind zone	4	0.05
Driving slowly in relation to other traffic: not below speed limit	43	0.57
Driving slowly: below speed limit	46	0.61
Driving without lights or with insufficient lights	1	0.01
Drowsy, sleepy, asleep, fatigued	95	1.25
Exceeded safe speed but not speed limit	31	0.41
Exceeded speed limit	199	2.62
Failed to signal	130	1.71
Following too closely	6	0.08
Illegal passing	2	0.03
Illegal passing	1	0.01
Improper turn, cut corner on left	17	0.22
Improper turn, cut corner on right	5	0.07
Improper turn, other	4	0.05
Improper turn, wide right turn	7	0.09
None	6832	90.03
Other	17	0.22
Other improper or unsafe passing	4	0.05
Parking in improper or dangerous location	1	0.01
Passing on right	23	0.30
Right-of-way error in relation to other vehicle or person, apparent decision failure	1	0.01
Signal violation, intentionally disregarded signal	1	0.01
Signal violation, tried to beat signal change	2	0.03
Speeding or other unsafe actions in work zone	2	0.03
Stop sign violation, "rolling stop"	63	0.83
Stop sign violation, intentionally ran stop sign at speed	6	0.08
Sudden or improper braking	5	0.07
Wrong side of road, not overtaking	27	0.36

Table 5. Percentage proportion of observed Vehicle Only Involved Events Driver Behaviors of complete dataset

Vehicle Only Involved Crashes and Near-misses	Count	%
Aggressive driving, other	2	0.11
Aggressive driving, specific, directed menacing actions	16	0.88
Apparent general inexperience driving	5	0.27
Apparent unfamiliarity with roadway	14	0.77
Avoiding another vehicle	4	0.22
Cutting in, too close behind other vehicle	8	0.44
Cutting in, too close in front of another vehicle	5	0.27
Did not see another vehicle during lane change or merge	14	0.77
Distracted	585	32.04
Driving in another vehicle's blind zone	5	0.27
Driving slowly in relation to other traffic: not below speed limit	2	0.11
Driving without lights or with insufficient lights	1	0.05
Drowsy, sleepy, asleep, fatigued	22	1.20
Exceeded safe speed but not speed limit	81	4.44
Exceeded speed limit	76	4.16
Failed to signal	22	1.20
Following too closely	29	1.59
Illegal passing	12	0.66
Improper backing, did not see	4	0.22
Improper backing, other	1	0.05
Improper start from parked position	1	0.05
Improper turn, cut corner on left	27	1.48
Improper turn, cut corner on right	99	5.42
Improper turn, other	23	1.26
Improper turn, wide left turn	22	1.20
Improper turn, wide right turn	10	0.55
Making turn from wrong lane	1	0.05
None	614	33.63
Other	4	0.22
Other improper or unsafe passing	16	0.88
Other sign (e.g., Yield) violation, apparently did not see sign	1	0.05
Other sign violation	2	0.11
Passing on right	6	0.33
Right-of-way error in relation to other vehicle or person, apparent decision failure	4	0.22
Right-of-way error in relation to other vehicle or person, apparent recognition failure	22	1.20
Signal violation, apparently did not see signal	8	0.44
Signal violation, intentionally disregarded signal	7	0.38

Table 5 continued.

Vehicle Only Involved Crashes and Near-misses	Count	%
Signal violation, tried to beat signal change	20	1.10
Speeding or other unsafe actions in work zone	2	0.11
Stop sign violation, "rolling stop"	17	0.93
Stop sign violation, apparently did not see stop sign	5	0.27
Stop sign violation, intentionally ran stop sign at speed	2	0.11
Sudden or improper braking	1	0.05
Wrong side of road, not overtaking	3	0.16

Table 6. Percentage proportion of observed PedBike Involved Events Driver Behaviors of complete dataset

PedBike involved Crashes and Near-misses	Count	%
Avoiding pedestrian	1	1.35
Distracted	29	39.19
Drowsy, sleepy, asleep, fatigued	1	1.35
Exceeded safe speed but not speed limit	2	2.70
Exceeded speed limit	1	1.35
Failed to signal	1	1.35
Following too closely	1	1.35
Improper turn, cut corner on right	1	1.35
Improper turn, wide left turn	1	1.35
None	29	39.19
Other improper or unsafe passing	1	1.35
Passing on right	1	1.35
Right-of-way error in relation to other vehicle or person, apparent recognition failure	2	2.70
Signal violation, tried to beat signal change	2	2.70
Stop sign violation, "rolling stop"	1	1.35

Table 7. Percentage difference between different event categories

Driving Behavior	BL_VO %	BL_PB %	VO_PB %
Aggressive driving, other	0.0964	-0.0132	0.1095
Aggressive driving, specific, directed menacing actions	0.8631	-0.0132	0.8762
Apparent general inexperience driving	0.2738	0.0000	0.2738
Apparent unfamiliarity with roadway	0.7008	-0.0659	0.7667
Avoiding another vehicle	0.1795	-0.0395	0.2191
Avoiding pedestrian	-0.0527	1.2986	-1.3514
Cutting in, too close behind other vehicle	0.4381	0.0000	0.4381
Did not see another vehicle during lane change or merge	0.7667	0.0000	0.7667
Distracted	32.0372	39.1892	-7.1519
Driving in another vehicle's blind zone	0.2211	-0.0527	0.2738
Exceeded safe speed but not speed limit	4.0274	2.2942	1.7332
Exceeded speed limit	1.5399	-1.2709	2.8108
Illegal passing	0.6176	-0.0395	0.6572
Improper turn, cut corner on left	1.2546	-0.2240	1.4786
Improper turn, cut corner on right	5.3558	1.2855	4.0703
Improper turn, other	1.2069	-0.0527	1.2596
Improper turn, wide right turn	0.4554	-0.0922	0.5476
Making turn from wrong lane	0.0548	0.0000	0.0548
None	-56.3996	-50.8358	-5.5638
Other	-0.0050	-0.2240	0.2191
Other improper or unsafe passing	0.8235	1.2986	-0.4751
Other sign (e.g., Yield) violation, apparently did not see sign	0.0548	0.0000	0.0548
Other sign violation	0.1095	0.0000	0.1095
Parking in improper or dangerous location	-0.0132	-0.0132	0.0000
Passing on right	0.0255	1.0483	-1.0228
Right-of-way error	1.4107	2.6895	-1.2788
Signal violation, apparently did not see signal	0.4381	0.0000	0.4381
Signal violation, intentionally disregarded signal	0.3702	-0.0132	0.3834
Signal violation, tried to beat signal change	1.0689	2.6763	-1.6074
Speeding or other unsafe actions in work zone	0.0832	-0.0264	0.1095
Stop sign violation, "rolling stop"	0.1008	0.5212	-0.4204

*BL_VO = Baseline and Vehicle Only Involved events, BL_PB = Baseline and PedBike Involved events, VO_PB = Vehicle Only Involved events and PedBike Involved events.

Positive values show increase in percentage difference between events
Negative values show decrease in percentage difference between events

Table 8. Maneuver Judgement Detail Table

Value	Definition	Example and Hints
Safe and legal	The pre-incident maneuver engaged in by the subject vehicle (V1) was both safe and legal based on vehicle kinematics.	
Unsafe but legal	The pre-incident maneuver engaged in by the subject vehicle (V1) was legal but NOT safe based on vehicle kinematics.	Subject is traveling at the speed limit on snow covered roads. Legal, but not safe.
Safe but illegal	The pre-incident maneuver engaged in by the subject vehicle (V1) was safe but NOT legal based on vehicle kinematics.	Subject is making an illegal U-Turn on an empty road. Safe but not legal.
Unsafe and illegal	The pre-incident maneuver engaged in by the subject vehicle (V1) was NOT safe and NOT legal based on vehicle kinematics.	Subject is drifting across the center double yellow line with oncoming traffic present. Unsafe and illegal.
Unknown	Unable to determine if Pre-Incident Maneuver is safe and legal due to limitations video views, lighting, visual obstructions, or limited perspective.	Part of the video is missing or there is insufficient information in the video to decide

(source: https://insight.shrp2nds.us/info/printable/38?type=dataset)

VITA

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