Comprehensive Evaluation of DT4000 Data Quality for Pedestrian and Bicycle Crashes

Xiao Qin, Ph.D., PE
Robert J. Schneider, Ph.D.
Yang Li, Ph.D.
Farah Jazi Al-Mahameed, Ph.D.

Institute for Physical Infrastructure and Transportation (IPIT)
University of Wisconsin-Milwaukee

WisDOT ID FG-2020-UW-MILWA-05070 & FG-2021-UW-MILWA-05642

September 2021

RESEARCH & LIBRARY UNIT

WISCONSIN DOT
PUTTING RESEARCH TO WORK

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Comprehensive Evaluation of DT4000 Data Quality for Pedestrian and Bicycle Crashes		**5. Report Date** September 2021 **6. Performing Organization Code**
7. Author(s) Xiao Qin, Robert J. Schneider, Yang Li, Farah Jazi Al-Mahameed		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Institute for Physical Infrastructure and Transportation (IPIT) University of Wisconsin-Milwaukee Milwaukee, WI 53201-0784		**10. Work Unit No.** **11. Contract or Grant No.** FG-2020-UW-MILWA-05070 & FG-2021-UW-MILWA-05642
12. Sponsoring Agency Name and Address Wisconsin Department of Transportation Research & Library Unit 4822 Madison Yards Way Room 911 Madison, WI 53705		**13. Type of Report and Period Covered** Final Report October 2019-September 2021 **14. Sponsoring Agency Code**

15. Supplementary Notes

If applicable, enter information not included elsewhere, such as translation of (or by), report supersedes, old edition number, alternate title (e.g. project name), or hypertext links to documents or related information.

16. Abstract

On January 1, 2017, the motor vehicle crash report form (MV4000) was replaced with a new form, DT4000, which provides more relevant and comprehensive crash information. The new information includes expanded fields related to crashes involving pedestrians and bicyclists, also known as vulnerable road users (VRU). This project examines whether the new attributes in DT4000 add significant value to the data when compared to data provided by MV4000. The evaluation achieved three major goals: (i) an assessment of the data quality in terms of the percentage of completion for the DT4000 crash form, focusing specifically on the pedestrian/bicycle-vehicle crash-related data fields; (ii) a comparison of the changes in attributes in the common data fields that are recategorized in DT4000; and (iii) a quantification of the value of new and recategorized data fields in DT4000 related to enhancing the prediction of pedestrian/bicycle injury severity. The study findings advance the knowledge of the conditions and circumstances that contribute to VRU traffic crashes, detailing specific enhancements from the DT4000 crash form that add value to the data. The study provides useful examples of how the new DT4000 crash data can be applied to the Wisconsin transportation system, making it safer for VRU groups such as pedestrians and bicyclists.

17. Key Words	**18. Distribution Statement**
Crash Data, Non-Motorist Safety, Pedestrian/Bicycle-Vehicle Crash, MV4000, DT4000, Data Quality, Crash Injury Severity Analysis	No restrictions.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	160	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DISCLAIMER

This research was funded by the Wisconsin Department of Transportation through the National Highway Traffic Safety Administration (NHTSA) under project FG-2020-UW-MILWA-05070 & FG-2021-UW-MILWA-05642. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Wisconsin Department of Transportation (WisDOT) or National Highway Traffic Safety Administration (NHTSA) at the time of publication.

This document is disseminated under the sponsorship of the Wisconsin Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. This report does not constitute a standard, specification or regulation.

The United States Government does not endorse products or manufacturers. Trade and manufacturers' names appear in this report only because they are considered essential to the object of the document.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. BACKGROUND

Traffic safety continues to be a major public health issue as the numbers of motor vehicle crash injuries and deaths increase. Based on 2018 statistics by the World Health Organization (WHO), traffic crashes result in 1.35 million deaths yearly worldwide (*1*). Figure 1-1 shows that between 1913 and 2018 in the United States (U.S.), there has been a slight decrease in traffic fatalities (the blue solid line) since the early 1970s, with sharp reductions during economic recessions. The number of fatalities starts to rise after 2015. Although the fatality rate measured by traffic fatalities per 100 million vehicle miles of travel (the red dashed line) has decreased significantly since the federal government began officially collecting crash data, 2016 and 2017 marked the deadliest and second deadliest years in a decade – 37,806 and 37,473 recorded motor vehicle traffic deaths, respectively (*2*).

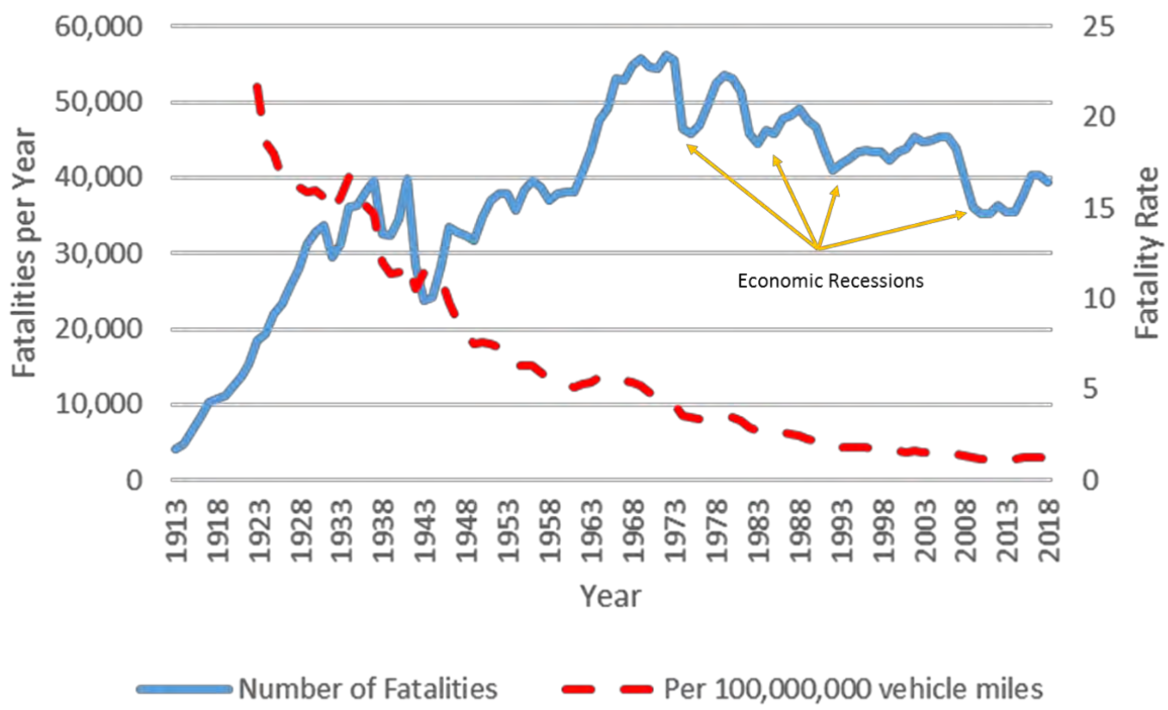


Figure 1-1: Historical Statistics in Traffic Fatalities in the U.S. between 1913 and 2018

It should be noted that among all traffic crashes, those involving pedestrians/bicyclists are of serious concern because they have a high injury severity level and consistently make up 12-15 percent of the total traffic fatalities in the U.S. In 2019, 6,205 pedestrian and 846 bicyclist fatalities resulted from crashes with motor vehicles – 19.5% of all traffic fatalities that year. Furthermore, pedestrians and bicyclists, also known as vulnerable road users (VRUs), represent a growing share of the total U.S. traffic fatalities. VRU fatalities have increased by 49% in the ten-year period from 2010 to 2019. In Wisconsin, data from Wisconsin Department of Motor Vehicles (DMV) shows that between 2017 and 2018, a total of 1,611 bicycle crashes killed 18 bicyclists and injured 1,430. During the same period, 2,965 pedestrian crashes killed 110 pedestrians and injured 2,784 (*3*).

One of the initiatives that was adopted to better understand the factors that contribute to VRU crashes in Wisconsin, and also comply with the continuously updated Model Minimum Uniform Crash Criteria (MMUCC), is to convert the previous MV4000 crash reporting form into the new DT4000 form. The forms were switched statewide on January 1, 2017. The previous MV4000 crash form had several issues, including poor reporting of roadway curvature, no data field to indicate driver distraction, no specification of the exact traffic barrier, no information about whether the motorist or VRU utilized safety equipment, limited information about VRU characteristics, and imprecise location of the VRU at the time of the crash. The new DT4000 crash form incorporates new crash elements and more detailed attributes. This project examined the value of DT4000's newly added data fields, specifically whether these new attributes add significant value to the data when compared to that obtained with MV4000.

The findings of this study may provide insight as to whether data from the new DT4000 form can be applied to make the Wisconsin transportation system safer, especially for VRUs. The study had three major goals:

1) Investigate the percentage of completion of data fields by law enforcement for the DT4000 crash form, with a focus on VRU-vehicle crash-related data fields;
2) Assess whether the changes in attributes of the common data fields that were re-categorized in DT4000 enhance the knowledge about the conditions/circumstances that may have contributed to these crashes; and
3) Examine if the new and re-categorized data fields in the DT4000 crash form enhance the VRU injury severity model prediction.

2. LITERATURE REVIEW

This section focuses on discussing different variables contributing to VRU crashes that have been identified and studied throughout the years for modeling and analyzing VRU crashes. Generally, such variables could be classified into two main categories: a) site-level contributing variables that are linked to a specific facility, and b) area-level contributing variables that are linked within an area. In the meantime, this section also serves as a base for conducting data analysis with variables included in the crash datasets.

2.1 Site-Level VRU-Related Variables

Site-level contributing variables can be categorized into four groups: a) design/infrastructure characteristics, such as speed limit, median type, and on/off-road bike lanes, bus stop density, sidewalk presence, paved/unpaved shoulders, traffic control devices, and number of lanes; b) demographic and socioeconomic characteristics, such as employment (*4*), population density, and land use; and c) individual's characteristics, such as visibility (fluorescent clothing), vehicle's size and age, pedestrian/bicyclist age. Table 2-1 shows contributing variables influencing pedestrian/bicyclist safety at the site-level.

Table 2-1: List of Site-level Variables to VRU Crashes

Risk Factor Category	Previous Studies	Contributing Variables
Design/Infrastructure characteristics	Aziz et al. (*5*), C. Lee and Abdel-Aty (*6*), DaSilva et al. (*7*), Fitzpatrick et al. (*8*), Haleem et al. (*9*), Hamann and Peek-Asa (*10*), Dixon et al. (*11*), Karl Kim et al. (*12*), Marshall et al. (*13*), McMahon et al. (*14*), Miranda-Moreno et al. (*15*), Obaidat et al. (*16*), Risley (*17*), Shaw et al. (*18*), Strauss et al. (*19*), Sullivan and Flannagan (*20*), Teschke et al. (*21*), Ulfarsson et al. (*22*), Wang and Kockelman (*23*), Wei and Lovegrove (*24*), Zegeer et al. (*25*)	▪ Bus-stop density ▪ Posted speed limit ▪ Off-road bike lanes ▪ Paved/unpaved shoulders ▪ Number of lanes ▪ Roadway lighting conditions ▪ Intersection density ▪ Motorized traffic volume ▪ Shoulder width ▪ Median type; Work Zones ▪ Paved/unpaved sidewalks ▪ On-street parking ▪ Traffic control type ▪ Marked/unmarked crosswalks ▪ Total lane kilometers, Bicycle Lane kilometers ▪ Arterial–local intersection percentage
Demographic and socioeconomic characteristics	DaSilva et al. (*7*), Kim et al. (*12*), Amoh-Gyimah et al. (*26*), Lee et al. (*27*), arayanamoorthy et al. (*28*), Siddiqui et al. (*29*), Ukkusuri et al. (*30*)	▪ Population ▪ Employment density ▪ Median household income ▪ Land use ▪ Non-motorized traffic volume ▪ Living under the poverty level ▪ Job count

Risk Factor Category	Previous Studies	Contributing Variables
Individual's characteristics (VRUs/drivers)	Lee and Abdel-Aty (*6*), Atkins et al. (*31*), Das and Sun (*32*), DiMaggio and Durkin (*33*), Ernst (*34*), Harruff et al., Huemer (*35*), Luoma et al. (*36*), Öström and Eriksson (*37*), Rodgers (*38*), Stoker et al. (*39*), Wiechel and Guenther (*40*)	▪ Pedestrian distraction (using cellphone) ▪ VRU Age ▪ Visibility (wearing visible clothing) ▪ Driver age ▪ Driver gender ▪ Driver distraction ▪ VRU gender ▪ Vehicle size ▪ Number of vehicle occupants ▪ Crossing from non-crosswalk locations ▪ VRU blood alcohol concentration (BAC)

2.2 Area-Level VRU-Related Variables

A considerable amount of the studies were conducted at the area-level to explore VRU crash related features (*10*, *15*, *19*, *24*, *28*, *29*, *41–44*). (*37*, *45*, *46*) listed the area-level risk factors used in previous studies such as land use, population density, VRU age, and lower income. Some area-level studies (*28*, *44*) use data aggregated at the census tract level, other studies (*24*, *41*) used traffic analysis zone (TAZ)-level aggregated data; and one study (*43*) used the uniform grid layout cell for conducting safety analysis. **Table 2-2** shows common risk factors influencing VRU safety at an aggregated level (area-level).

Table 2-2: List of Area-level Variables to VRU Crashes

Risk Factor Category	Previous Studies	Contributing Variables
Traffic characteristics	Hamann and Peek-Asa (*10*), Dixon et al. (*11*), Lee et al. (*27*), Siddiqui et al. (*29*), Lee and Abdel-Aty (*45*), Abdel-Aty et al. (*41*), Demetriades (*47*), Elvik (*48*), Jacobsen (*49*), Kaplan and Giacomo Prato (*50*), Loukaitou-Sideris et al. (*51*), Prato et al. (*52*), Retting (*53*), Wier et al. (*54*),	▪ Vehicle traffic volume ▪ Speed limit ▪ Walking/biking trips ▪ Truck percentage
Land use characteristics	Wang and Kockelman (*23*), Amoh-Gyimah et al. (*26*), Siddiqui et al. (*29*), Ukkusuri et al. (*30*), Abdel-Aty et al. (*41*), Retting (*53*), Wier et al. (*54*), Kim et al. (*55*), LaScala et al. (*56*), Noland and Quddus (*57*), Roberts et al. (*58*), Wang et al. (*59*)	▪ Mixed land use ▪ Density of public schools ▪ Income level

Risk Factor Category	Previous Studies	Contributing Variables
Demographic and socioeconomic characteristics	Qin and Ivan (*4*), McMahon et al. (*14*), Miranda-Moreno et al. (*15*), Lee et al. (*27*), Siddiqui et al. (*29*), Ukkusuri et al. (*30*), Abdel-Aty et al. (*41*), Loukaitou-Sideris et al. (*51*), LaScala et al. (*56*), Noland and Quddus (*57*), Roberts et al. (*58*), Cottrill and Thakuriah (*60*), Greene-Roesel et al. (*61*), Noland et al. (*62*)	▪ Population density ▪ Number of licensed drivers ▪ Density of minority households ▪ Poor neighborhoods ▪ Vehicle ownership ▪ Unemployment rate ▪ Household income ▪ Percentage of the low-income population ▪ Education percentage ▪ Crime density ▪ Household size ▪ Vehicle ownership
Individual's characteristics (VRUs/drivers)	Wang and Kockelman (*23*), Wei and Lovegrove (*24*), Lee et al. (*27*), Abdel-Aty et al. (*41*), Chen (*42*), Demetriades (*47*), Elvik (*48*), Jacobsen (*49*), Prato et al. (*52*), Wier et al. (*54*), Wang et al. (*59*), Cai et al. (*63*), Dai and Jaworski (*64*), Guo et al. (*65*), Moeinaddini et al. (*66*), Pucher et al. (*67*), Zhang et al. (*68*)	▪ Presence of bike paths ▪ Number of pedestrian crossings ▪ Off-arterial bicycle routes ▪ Signal density ▪ Presence of parking signs ▪ Number of vehicle trips ▪ Minor and major arterial length ▪ Road density ▪ Percentage of 3-leg intersections ▪ Average intersection spacing ▪ Transit stop density ▪ School access ▪ Sidewalk density ▪ Street network size ▪ Roadway length ▪ Density of major roads ▪ Number of intersections ▪ Clustered road networks ▪ Segments with fixed gradients ▪ Distance to transit trips ▪ VRU and driver age ▪ Signalized intersections density ▪ Sidewalk length, road density ▪ Network pattern (irregular, grid)

2.3 Summary

Although a wide range of variables have been investigated in the past studies for site- and area-level VRU crash risk, many only used a limited number of contributing variables due to data unavailability or data collection complexity. The findings may be biased due to the omission of important variables. In addition, some site-level variables, such as median type and work zone sites, and area-level variables, such as signalized intersection density and number of pedestrian crossings, have only been tested in a small number of studies, often with mixed results; thus, it is recommended that more comprehensive research be conducted.

3. METHODOLOGY

In order to conduct a comprehensive analysis, a number of analytical methods have been applied. Figure 3-1 illustrates the methodologies and their purposes. Exploratory data analyses (EDA) were employed, including the univariate and multivariate analysis, to produce the descriptive statistics of a selected list of MV4000 and DT4000 data fields. Z-tests were used to screen each variable resulting from a multi-variable analysis regarding injury severity proportion. The Chi-square automatic interaction detector (CHAID) and random forest (RF) were utilized to select and rank variables by their prediction power on the VRU injury severity levels. The multinomial logit (MNL) models were developed to predict the crash injury severity and quantify the effect of variables on prediction through their coefficient estimates and statistical inferences. Below is a brief introduction of each method.

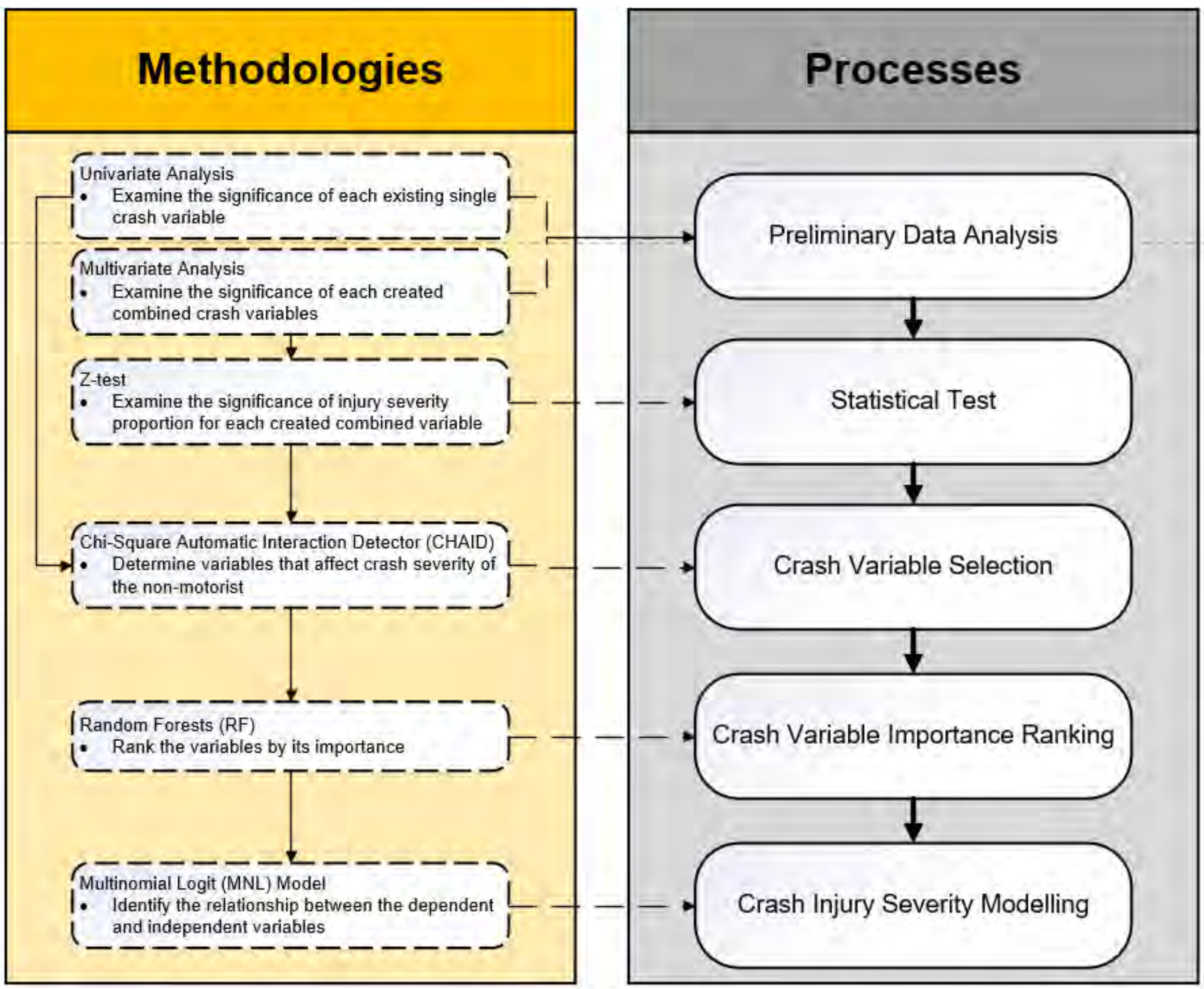


Figure 3-1: The Applied Methods and Their Purposes

3.1 Univariate and Multivariate Analysis

The univariate analysis involves all the data fields that are considered to be useful for VRU safety study. The descriptive statistics show the distribution of attribute values and highlight the ones that are overrepresented in the crash data. Multivariate analysis is carried out using the cross-classification method. The percentage of combined values from two or more attributes is presented and their association is explored.

3.2 Z-Test Concerning Injury Severity Proportion

The Z-test for proportions is a statistical test to indicate if a particular attribute of roadway, driver, pedestrian, bicyclist-related or bicyclist-related variables has significantly higher (K+A) injuries proportion than the proportion of (K+A) injuries of the population. Note that the formula of the Z-test statistics is valid when sample size (n) is large enough, i.e., np, nq should be ≥ 5. In case of small sample size, the Fisher Exact probability test is used for comparing the two proportions.

$$Z = \frac{\hat{p} - p}{\sqrt{p(1-p)/n}} \quad (1)$$

Where, $\hat{p}$ = sample proportion; p = population proportion; q = 1- p; n = sample size.

The test can be conducted in RStudio using the "prop. test" function at a 95% confidence level.

3.3 Chi-Square Automatic Interaction Detector (CHAID)

Since pedestrian or bicyclist related crashes involve a multitude of factors, it is beneficial to study them with CHAID because its representation is easy to comprehend, and able to distinguish between a complex structure of many factors. In the CHAID decision tree, the injury severity for the crash is calculated using the most severe injury sustained among the crash participants within 30 days. Three injury severity levels were used: K (fatal crash), A (severe injury crash), and B+C (evident/possible injury crash), following the path of many researchers who studied crash injury severity of pedestrians and bicyclists involved in vehicle crashes (*69*). A potential drawback of CHAID is the instability issue: the random procedure of choosing training and test samples depends on the seed number, which may produce different results.

3.4 Random Forest (RF)

Random forests (RF) are a scheme proposed by Leo Breiman in the 2000's for building a predictor ensemble with a set of decision trees that grow in randomly selected subspaces of data (*70*). This technique has been commonly used to label important variables in splitting response variables such in several previous studies (*71–74*). In general, a random forest model combines a set of unpruned decision trees (DT) (i.e., CART). Readers who are interested in understanding CART procedure may refer to Das et al. (*75*) and Hossain and Muromachi (*76*) as they present an extensive description of the CART algorithm. Classification trees are used to classify observations through recursively partitioning the predictor space. As the number of trees in a RF increase, the misclassification rate converges to a limit. Hence, RF models with many trees can overcome the overfitting problem. As the forest building improves, RF uses an internal mechanism that achieves unbiased generalization error estimate.

To build the trees, two datasets are generated from the complete dataset: a training dataset and a test dataset. On average, about one-third of observations are in the test dataset which are named as Out-of-Bag (OOB) samples by Breiman (*77*) and used to estimate the RF classifier generalization error. The OOB is a RF measurement method for prediction error. The rest forms the training dataset where each tree is trained on bootstrap samples of this dataset. The RF model performance may be enhanced by decreasing the bias of each tree through growing the tree to the maximum depth. Also, by decreasing the correlations between trees through applying two sources of randomization in each tree: a) each tree is grown on a bootstrap sample of the training dataset (randomly drawn, with replacement); b) at each node of a tree, a certain number of variables "mtry" are randomly selected from the complete explanatory variables to compete for the best split. "mtry" is the number of input variables randomly chosen at each split, and it can be tuned by increasing or decreasing from an initial value until the minimized error rate is obtained (*71*).

3.5 Multinomial Logit (MNL) Model

Even though each model used in the crash severity-related literature has its advantages, MNL models are the most widely used approach to identify the relationship between the dependent and independent variables (*78*). Shankar and Mannering (1996) provided a detailed discussion of MNL models. The MNL model is a discrete choice model which deals with three or more levels of the response variable, without taking into consideration the order of the levels.

Using discrete crash severity categories, one can develop a statistical model that may be used to predict the crash likelihood of a specific severity level. Equation below displays the probability of a crash *n* with an *i*th severity level:

$$P_n(i) = P(U_{in} \geq U_{jn}) \ \forall j \neq i \quad (2)$$

Where, $P_n(i)$ = the probability of crash *n* to occur with a severity level of *i*; *P* = probability; U_{in} = function to determine the utility of a crash *n* to occur resulting severity level of *i*.

The linear function of U_{in} maybe demonstrated as:

$$U_{in} = \beta_i X_n + \varepsilon_{in} \quad (3)$$

Where, X_n = explanatory variable's vector which determines the crash severity; β_i = estimable coefficient vector for the injury outcome i, using the standard maximum likelihood methods (*79*, *80*); $\beta_i X_n$ = is an observable component; ε_{in} = error term, unobserved component, and is assumed to be independently distributed -accounts for the unobserved factors affecting crash severity-.

Combining Equation (2) and Equation (3), Equation (4) may be formed as:

$$P_n\,(i) = P\big(\beta_i X_n - \beta_j X_n \geq \varepsilon_{jn} - \varepsilon_{in}\big)\;\forall\, j \neq i \tag{4}$$

Replacing the error term by a generalized extreme value (GEV) form, the MNL severity model can be obtained as:

$$P_n\,(i) = exp(\beta_i X_n) / \sum_{j}^{0} exp\,(\beta_j X_n) \tag{5}$$

In summary, five methods have been presented in this section, from simple to more sophisticated. Method selection relies on the underlying objectives of the study: using descriptive and predictive data mining techniques to identify factors contributing to fatal and serious injury crashes and obtaining the highest possible accuracy for crash injury severity prediction. The rest sections offer an overview of the data and the detailed results of the statistical analysis.

4. DATA COLLECTION AND PROCESSING

In Wisconsin, 403,632 crashes occurred during the four-year (2017-2020) period. Table 4-1 sows the distribution of pedestrians, bicyclists, and drivers involved based on the crash injury severity.

Table 4-1: Injury Severity Distribution of Road Users Involved in Crashes (2017-2020).[1]

Road User / Injury Severity	Drivers only		At least a pedestrian		At least a bicyclist	
	N	%	N	%	N	%
K (fatal injury)	1,767	0.45%	210	4.82%	38	1.28%
A (suspected serious injury)	8,836	2.23%	887	20.34%	297	10.01%
B (suspected minor injury)	41,919	10.58%	1,969	45.16%	1,654	55.73%
C (possible injury)	48,222	12.17%	1,031	23.65%	697	23.48%
O (no apparent injury)	295,563	74.58%	263	6.03%	282	9.50%
Subtotal	396,307	100.00%	4,360	100.00%	2,968	100.00%

According to Table 4-1, the majority of the crashes involve drivers only. For VRU, there are a total of 4,360 crashes involving at least one pedestrian and 2,968 crashes involving at least one bicyclist. It should be noted that the proportions of fatal injury (K) and suspected serious injury (A) for crashes involving pedestrians (K: 4.82% and A: 20.34%) and bicyclists (K: 1.28% and A: 10.01%) are much higher than drivers only (K: 0.45 % and A: 2.23%). This confirms the vulnerability of non-motorists in traffic crashes compared to drivers.

The crash data were downloaded from WisTransportal Crash Retrieval Facility in the old MV4000 crash report and new DT4000 crash report, respectively. Comparing the same crash data coded in different forms allow us to determine if the new or expanded data elements in DT4000

[1] It should be noted that the sum of crashes for all road user categories (403,635) is larger than the total retrieved crashes (403,632), which means there are some crashes have been overcounting (i.e., both pedestrian and bicyclist have been involved in the crash).

provide value-added information for gaining a better understanding of pedestrian/bike crashes in Wisconsin. A total of 7,325 crashes were retrieved after applying the following query:

```
"SELECT * FROM DTCRPRD.SUMMARY_COMBINED C WHERE C.CRSHDATE BETWEEN TO_DATE('2017-JAN','YYYY-MM') AND LAST_DAY(TO_DATE('2020-DEC','YYYY-MM')) AND (C.DEERFLAG IS NULL OR UPPER(C.DEERFLAG) != 'Y') AND (C.BIKEFLAG = 'Y' OR C.PEDFLAG = 'Y') AND C.LOCTYPE IN ('I','N') ORDER BY C.DOCTNMBR"
```

According to the crash data user guide, "[1,2] Denotes unit level information, where a unit is any vehicle, bicycle, pedestrian, or equipment involved in a crash. Unit level element names in the data file are appended with "1" or "2", representing the first or second unit involved in the crash". When more than two units are involved including VRU, it is possible that a VRU is coded as neither unit 1 or 2. Table 4-2 shows how the data fields are processed and analyzed, through referring to the ROLE [1, 2] data field indicating driver, pedestrian, and bicyclist roles in a crash. Distinguishing the role of unit 1 and unit 2 as a driver or a VRU is essential for us to determine the level of injury severity sustained by a VRU during a motor vehicle crash. For any analysis regarding injury severity, the primary interest is in the ones that a VRU sustained equal or more severe injury, which excluded 22 crashes where a motorist sustained more severe injury than a VRU, and 241 crashes where both units are not the combinations of one motorist and one VRU. **Note that this study is limited to analyzing the actions and behavior of the first two units and one of them is a VRU**. Finally, crashes with results of "O (no apparent injury)" (525 crashes) were excluded. This results in a total of 6,537 crash records to be analyzed in this study.

Table 4-2: Types of Persons Involved in a Crash in DT4000.

ROLE 2 (or Unit 2)	ROLE 1 (or Unit 1)							
	Bicyclist		Driver		Pedestrian		Total	
	N	%	N	%	N	%	N	%
Bicyclist			2,052	31.39%			2,052	31.39%
Driver	600	9.18%			240	3.67%	840	12.85%
Pedestrian			3,645	55.76%			3,645	55.76%
Total	600	9.18%	5,697	87.15%	240	3.67%	6,537	100.00%

The data show that the driver involved in a crash with VRU is entered as unit 1 in 5,697 (87.15%) cases and as unit 2 in 840 (12.85%) cases; the bicyclist in a crash is entered as unit 1 in 600 (9.18%) cases, and as unit 2 in 2,052 (31.39%) cases, which result in a total of 2,652 (40.57%) bicyclist crashes; and the pedestrian in a crash is entered as unit 1 in 240 (3.67%) cases, and as unit 2 in 3,645 (55.76%) cases, which lead to a total of 3,885 (59.43%) pedestrian crashes. **So, in most cases involving VRUs, VRUs are usually coded as unit 2, but not always.**

The selected data fields, description, and type of changes are shown in Table 4-3. Note that (blank) value denotes that the field was left blank/missed and was not filled with any value, whereas; BLANK value denotes that the field involves an option to report a blank value if the field is not related to the situation (i.e., VEHDMG [1, 2] is a field in the MV4000 crash form dataset which involves several attributes identifying the extent to which the damage affects the vehicles' operability, and a BLNK attribute that can be filled when the vehicle damage was not investigated). Moreover, the detailed crash user guides for both MV4000 and DT4000 are appended at the end of the report in Appendix B and Appendix C

Table 4-3: A List of the Selected Data Fields for the Analysis.

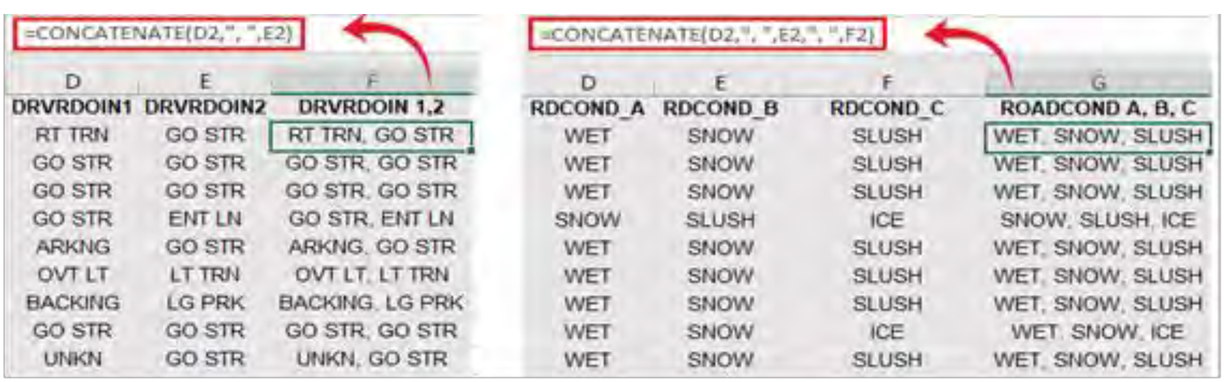
MV4000 Crash	DT4000 Crash	Description	Changes
Roadway Level			
ROADHOR	ROADHOR [1,2]	Horizontal Road Terrain	More detailed attributes
ROADVERT	ROADVERT [1,2]	Vertical Road Terrain	
ROADCOND	RDCOND [A,B,C]	Road Surface Condition	
TRFCWAY	TRFCWAY [1,2]	Trafficway Description	
RLTNRDWY	RLTNRDWY	Location of First Harmful Event	
ACCDLOC	LOCTYPE	Crash Location Type	
TRFCNTL [1,2]	TRFCCNTL [1,2]	Traffic Control Device (TCD) in Effect	
---	SURFTYPE [1,2]	Road Surface Type	New data fields
---	TOTLANES [1,2]	Total Number of Lanes	
---	RLTNTRWY	Crash Location with Respect to Trafficway	
---	INTTYPE	Intersection Type Where the Crash Occurred	
---	TRFCINOP [1,2]	Status of the TCD	
---	RLTNJNIC	Crash Occurrence within An Interchange Area	
---	RLTNJNLC	Crash Occurrence in A Junction/Interchange Area	
Environmental Level			
WTHRCOND	WTCOND [A, B]	Prevailing Atmospheric Conditions	More detailed attributes
LGTCOND	LGTCOND	Light Conditions	
HWYPC [1,2]	RDWYPC [A, B, C]	Apparent Factors of the Road/ Highway	
---	ENVPC[A,B,C]	Contributing Environmental Conditions	New data field

Driver Level			
DRVRPC [1,2]	DRVRPC [1,2] [A,B,C,D]	Driver Contributing Actions/Circumstances	More detailed attributes
DRVRDO [1,2]	DRVRDOIN [1,2]	Controlled Maneuver by the Driver	
SAFETY [1,2]	SFTYEQP [1, 2]	Safety Equipment Used by the Driver	
---	RACE [1,2]	Driver Race	New data fields
---	TEENDRVR	Teen Driver	
---	DISTFLAG	Distraction/Inattentive Driving Flag	
---	DNMFTR [1,2] [A,B]	Individual Condition Relevant to the Crash	
Pedestrian Level			
NMTACT [1,2] [A,B]	NMTACT [1,2] [A,B]	Pedestrian Actions/Circumstances Contributing to the Crash	More detailed attributes
NMTLOC [1,2]	NMTLOC [1,2]	Pedestrian Location with Respect to the Roadway	
---	NMTSFQ [1,2] [A,B]	Safety Equipment Used by the Pedestrian	New data fields
	DNMFTR [1,2] [A,B]	Individual Condition Relevant to the Crash	
	NMTPRIOR [1,2]	Pedestrian Actions Immediately Prior to the Crash	
Bicyclist Level			
NMTACT [1,2] [A,B]	NMTACT [1,2] [A,B]	Bicyclist Actions/Circumstances Contributing to the Crash	More detailed attributes
NMTLOC [1,2]	NMTLOC [1,2]	Bicyclist Location with Respect to the Roadway	
---	NMTSFQ [1,2] [A,B]	Safety Equipment Used by the Bicyclist	New data fields
	DNMFTR [1,2] [A,B]	Individual Condition Relevant to the Crash	
	NMTPRIOR [1,2]	Bicyclist Actions Immediately Prior To The Crash	
Crash Level			

ACCDTYPE	MOSTHARM [1,2]	Events Resulting in the Most Severe Injury	More detailed attributes
SPEEDFLAG	SPEEDFLAG	Vehicle Speeding Status	---
HITRUN	HITRUN	Hit and Run	---
ALCFLAG	ALCFLAG	Alcohol Involvement	---
DRUGFLAG	DRUGFLAG	Drug Involvement	---
---	SCHZONE	School Zone	New data field
Vehicle Level			
VEHTYPE [1,2]	VEHTYPE [1,2]	Vehicle Type Involved in the Crash	More detailed attributes
VEHDMG [1,2]	VEHDMG [1,2]	Extent of Vehicle Damage	

When there is more than one crash contributing factor in data fields such as circumstances, driver actions, behavior, multi-valued elements are used and denoted as [A, B, C]. [1,2][A,B] denotes combined unit level and multi-valued elements. For example, DRVRPC1A and DRVRPC1B describe the first two contributing factors listed for the driver of the first unit on the DT4000 crash report. When necessary, the "*concatenate*" function in Excel is used in the analysis to join data from unit 1 and 2, as well as from A, B, C, etc. Concatenation is the operation of joining character strings end-to-end and a string can be a text, number, or a Boolean value.

For same data types (i.e., DRVRDOIN 1 and DRVRDOIN 2), concatenation is used to join the two text strings into one text string (DRVRDOIN 1,2). A filter may be used to filter values of DRVRDOIN 1 data field when Role 1 is a driver, and the same way when Role 2 is a driver, values of DRVRDOIN 2 data field are filtered, creating (DRVRDOIN 1,2) data field. Whereas, for data fields that take multiple values (i.e., ROADCOND A, ROADCOND B, ROADCOND C), direct concatenation separated by a comma creates (ROADCOND A, B, C) data field. Simple examples for the "concatenate" function could be illustrated in Figure 4-1. Note that the number of attributes provided in each element varies and is based on the minimum set of data elements recommended by the Model Minimum Uniform Crash Criteria (MMUCC) standard (*81*).



=CONCATENATE(D2,", ",E2)

DRVRDOIN1	DRVRDOIN2	DRVRDOIN 1,2
RT TRN	GO STR	RT TRN, GO STR
GO STR	GO STR	GO STR, GO STR
GO STR	GO STR	GO STR, GO STR
GO STR	ENT LN	GO STR, ENT LN
ARKNG	GO STR	ARKNG, GO STR
OVT LT	LT TRN	OVT LT, LT TRN
BACKING	LG PRK	BACKING, LG PRK
GO STR	GO STR	GO STR, GO STR
UNKN	GO STR	UNKN, GO STR

=CONCATENATE(D2,", ",E2,", ",F2)

RDCOND_A	RDCOND_B	RDCOND_C	ROADCOND A, B, C
WET	SNOW	SLUSH	WET, SNOW, SLUSH
WET	SNOW	SLUSH	WET, SNOW, SLUSH
WET	SNOW	SLUSH	WET, SNOW, SLUSH
SNOW	SLUSH	ICE	SNOW, SLUSH, ICE
WET	SNOW	SLUSH	WET, SNOW, SLUSH
WET	SNOW	SLUSH	WET, SNOW, SLUSH
WET	SNOW	SLUSH	WET, SNOW, SLUSH
WET	SNOW	ICE	WET, SNOW, ICE
WET	SNOW	SLUSH	WET, SNOW, SLUSH

Figure 4-1: Examples of the "Concatenate" Function

After concatenation, many new attribute values may be created due to the combination of strings; thus, attributes with small percentage values (e.g., <1%) are not analyzed separately but as one category (i.e., Total including other combinations). This could be seen from Figure 4-2. Note that multi-value attributes (i.e., DRY, WET, SNOW) are a result of applying the concatenation function to the data field attributes.

Row Labels	**Count of DOCTNMBR**	**Count of DOCTNMBR2**
DRY,,	5465	83.60%
DRY,GRAVL,	1	0.02%
DRY,ICE,	1	0.02%
DRY,MUD,	1	0.02%
DRY,OTHR,	1	0.02%
DRY,SNOW,	1	0.02%
DRY,UNKN,	3	0.05%
DRY,WET,SNOW	1	0.02%
GRAVL,,	3	0.05%
ICE,,	20	0.31%
MUD,,	1	0.02%
MUD,GRAVL,	1	0.02%
SLUSH,,	10	0.15%
SLUSH,ICE,	1	0.02%
SNOW,,	57	0.87%
SNOW,ICE,	13	0.20%
SNOW,ICE,SAND	1	0.02%
SNOW,SLUSH,	5	0.08%
SNOW,SLUSH,ICE	5	0.08%
UNKN,,	26	0.40%
WATER,,	1	0.02%
WET,,	845	12.93%
WET,ICE,	5	0.08%
WET,MUD,	1	0.02%
WET,SAND,	1	0.02%
WET,SLUSH,	7	0.11%
WET,SLUSH,ICE	2	0.03%
WET,SLUSH,WATER	1	0.02%
WET,SNOW,	20	0.31%
WET,SNOW,ICE	4	0.06%
WET,SNOW,SLUSH	30	0.46%
WET,UNKN,	2	0.03%
WET,WATER,	1	0.02%
Grand Total	**6537**	**100.00%**

	N	**%**
DRY	5465	83.60%
WET	845	12.93%
Other	227	3.47%
Total	6537	100.00%

Figure 4-2: Examples of New Classification Schema after Applying the "Concatenate" Function (Data Field: RDCOND)

5. VALIDATION OF INTERSECTION INFORMATION IN DT4000

The DT4000 form includes several intersection-related data fields that have either been enhanced (e.g., TRFCWAY [1,2] and TRFCCNTL [1,2]), created (e.g., TOTLANES [1,2] and INTTYPE) or derived from external data sources (e.g., URBRURAL). The current chapter compares these data fields with those in the Wisconsin State Trunk Network (STN) (i.e., Intersection Network Screening data) for consistency and necessity and to identify any benefits of including intersection information in the crash form.

5.1 Validation Process

The DT4000 dataset and the intersection information from the STN data were integrated into ArcGIS, a suite of geographic information system (GIS) services developed and maintained by Esri. Figure 5-1 and Figure 5-2 show the spatial distribution of DT4000 crashes and intersection locations in the STN data, respectively. Although intersection crashes can occur anywhere in the state, STN data limits this study to Wisconsin state highway intersections.

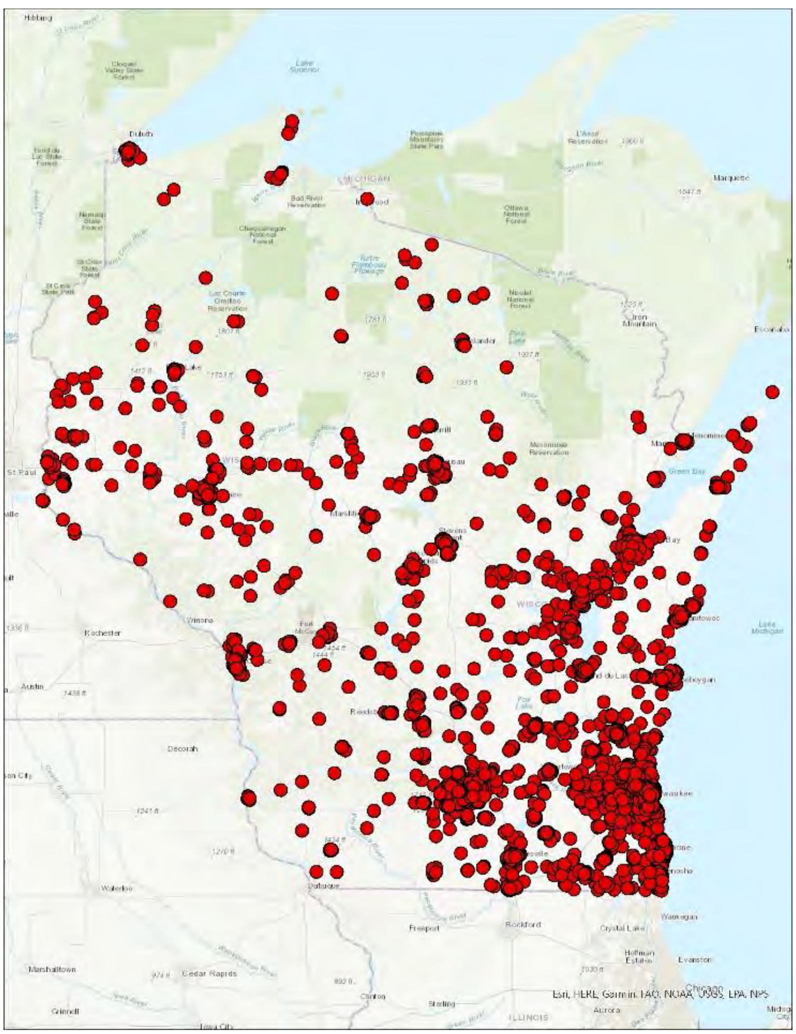


Figure 5-1: Spatial Distributions of Crashes from 2017-2020

Figure 5-2: Spatial Distributions of Intersections from STN Data

The following data fields from STN were compared with intersection-related data fields in DT4000 (i.e., INTTYPE, TRFCCNTL [1,2], TOTLANES [1,2], and TRFCWAY [1,2]) and "URBRURAL" in the DT4000 data): 1) IX_CONFIG (intersection configuration), 2) CONTROL (traffic control), 3) MAJ_LNS (lanes of major road), 4) MEDIAN_TYP (median type), and 5) ARTYP_FED (area type, urban or rural). The geoprocessing tool "spatial join" was utilized to spatially match the crash records with STN intersection locations. The buffer distance was set as 100 feet, a conservative threshold to help lower the possibility of mismatching. In other words, if an intersection is located within a 100-feet radius of a crash, that crash will be linked to the intersection. This spatial joining process is illustrated in Figure 5-3.

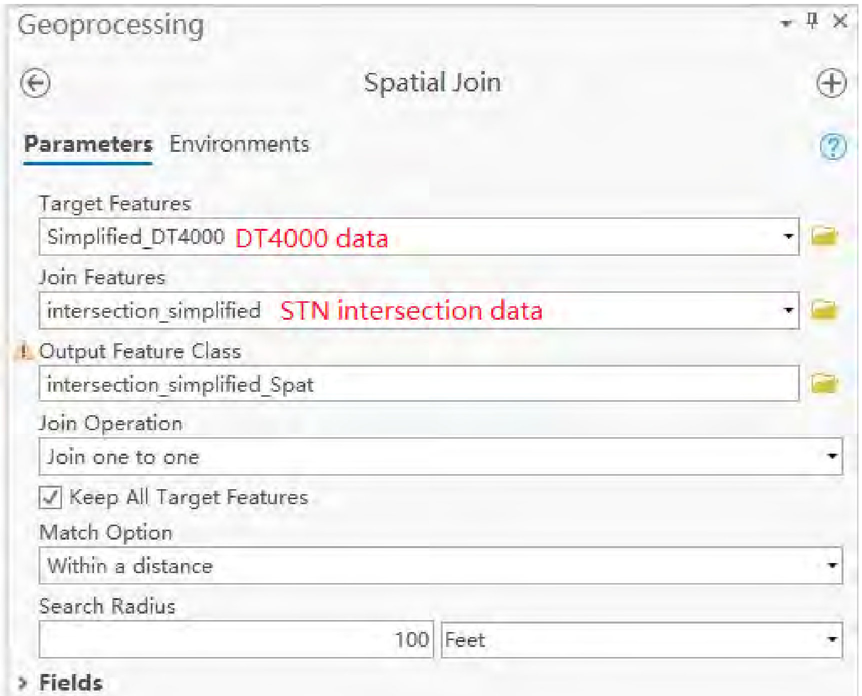


Figure 5-3: Spatial Join for Matching Crash Records with Intersection Locations

Figure 5-4 displays the distribution of 1,401 crash records along with linked intersection data. The STN intersection data is assumed to be the ground truth. The following rating criteria were created to evaluate the intersection-related data fields in DT4000:

- Highly consistent (match rate>85%)
- Consistent (match rate: 76%-85%)
- Less consistent (match rate: 51-75%)
- Inconsistent (match rate <=50%)

5.1.1. LOCTYPE

"LOCTYPE" denotes whether the crash location is an intersection (I) or not (N). All 1,401 filtered crash records are considered to be "I" because they are within 100 feet of an STN intersection; however, the results show 1,129 records with an "I" location for the data field LOCTYPE, while the remaining 272 (or 19.4%) crash records were identified as "N". For instance, in Figure 5-5, four crashes are linked to the same intersection, but three are "I" and one is "N". Aside from the inconsistencies with LOCTYPE, discrepancies also appear in other data fields in Figure 5-5 (i.e., INTTYPE, TRFCWAY, TOTLANES, TRFCCNTL). Based on the rating criteria, "LOCTYPE" is rated as "***consistent***".

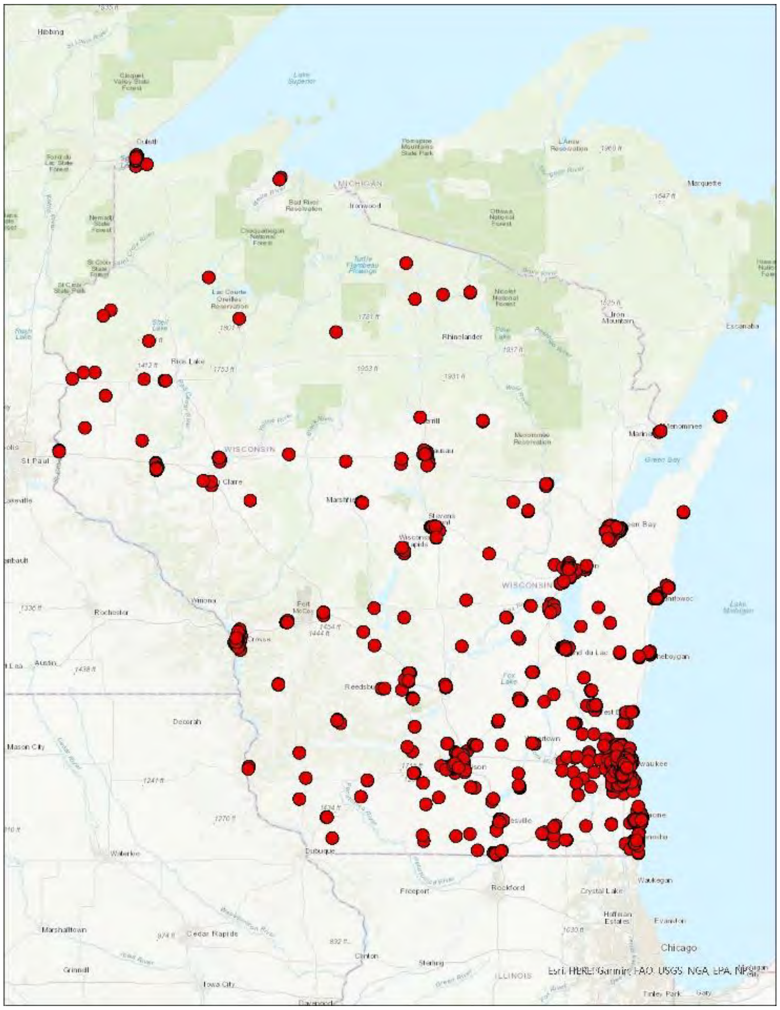


Figure 5-4: Spatial Distribution of the Matched Crashes Records

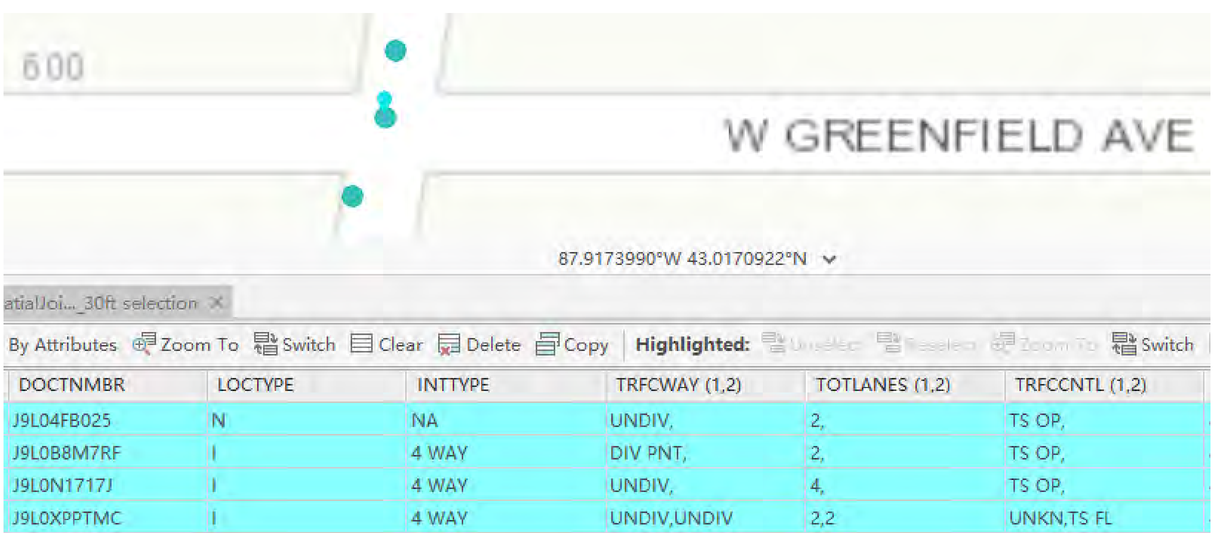


Figure 5-5: Illustrations of Crash Records with Different Recorded Data Fields

5.1.2. INTTYPE vs. IX_CONFIG

Table 5-1 shows the results of comparing INTTYPE and IX_CONFIG. The **bold and gray shaded** numbers represent the consistently matched record counts that correspond to each category in the DT4000 and in the STN data. Note that there are more than 20 “three-way intersection” types in the STN data; for simplicity, all 20 are classified as a “three-way intersection” in Table 5-1. Overall, 996 out of 1129 (88.22%) records in DT4000 match information provided in the STN data. Based on the rating criteria, INTTYPE is rated as “***consistent***”. Please note that records with “NA” or “UNKN” were not used in the evaluation; this criterion was applied to other data fields in this section.

Table 5-1: Comparison between INTTYPE and IX_CONFIG

DT4000: INTTYPE	STN: IX_CONFIG					Total	Match Rate
	4 LEG	4+DRIVEWAY	5 LEG	6 LEG	Three-Way Intersection Subtotal		
4 WAY	817	3	8	4	65	897	91.42%
5	5		6	6		17	70.59%
L					2	2	0.00%
RAB	12		1			13	0.00%
T	14	1			159	174	91.38%
Y	3				5	8	62.50%
Three-Way Intersection Subtotal	17	1			164	182	90.11%
OTHR	15			1	2	18	0.00%
NA	187	1	3	2	79	272	-
Total	1,053	5	18	13	312	1,401	-
Total (NA excluded)	866	4	15	11	233	1,129	88.22%
Match Rate	94.34%	75.00%	40.00%	54.55%	70.39%	88.22%	

A data mismatch can result from databases having different coding schemas. For instance, “RAB (roundabout)” is coded as INTTYPE in DT4000, while in STN it is coded as CONTROL. Integrating STN intersection data into the crash recording system is a possibility (i.e., intersection information could be imported into the crash database for crashes occurring at a location with STN information) and could help mitigate this issue, but the specificity of the STN classifications of IX_CONFIG (e.g., 20+ types of three-way intersections) may present an issue. Therefore, it would be necessary to evaluate tradeoffs between data needs and collection methods (e.g., crash analysis, traffic engineering studies) when considering future system integration or crash database improvements.

5.1.3. TRFCCNTL [1,2] vs. CONTROL

Table 5-2 shows the comparison results between TRFCCNTL [1,2] and CONTROL with selected attributes (of TRFCCNTL) that represent the correctly recorded records in DT4000. The **bold and gray shaded** numbers represent the consistently matched record counts. Note that "YIELD" signs could be placed either in a signalized intersection with a channelized right turn lane or in a roundabout. Table 5-2 illustrates that when the intersection is coded as "SIGNAL" or "RAB" in STN, the crash records with " , YIELD", "YIELD,", and "YIELD, YIELD" are considered consistent. "NONE" and "UNKN/OTHR" in DT4000 could be referred to as "OTHER" in the STN dataset. It is worth noting that signalized intersections and all-way stop control intersections are highly consistent between the two data sources, while two-way stop control intersections are not. Overall, 828 out of 1,365 (60.66%) records in DT4000 were matched with the information provided in STN, rating this data field as ***"less consistent"***.

Table 5-2: Comparison between TRFCCNTL [1,2] and CONTROL[2]

DT4000: TRFCCNTL [1,2]	**STN: CONTROL**						
	AWSC	TWSC	RAB	SIGNAL	OTHER	**Total**	**Match Rate**
, NONE		5		2		7	0.00%
NONE,		158		27	4	189	2.12%
NONE, NONE		89	2	12	1	104	0.96%
NONE Subtotal		252	2	41	5	300	1.67%
, STOP		3				3	100.00%
STOP,	3	60		2	4	69	91.30%
STOP, STOP	3	36				39	100.00%
STOP Subtotal	6	99		2	4	111	94.59%
, TS OP		1		21		22	95.45%
TS OP,		3		418	1	422	99.05%
TS OP, TS OP		2		267	1	270	98.89%
TS OP Subtotal		6		706	2	714	98.88%
OTHR,		9	1	1	1	12	8.33%
OTHR, OTHR		2				2	0.00%
OTHR Subtotal		11	1	1	1	14	7.14%
, YIELD					1	1	0.00%
YIELD,		1	2	2		5	80.00%
YIELD, YIELD			5	2		7	100.00%
YIELD Subtotal		1	7	4	1	13	84.62%
SCHOOL,		3				3	0.00%
SCHOOL, SCHOOL		1				1	0.00%
SCHOOL Subtotal		4				4	0.00%
TS FL,				4		4	0.00%
TS FL, TS FL				2		2	0.00%
TS FL Subtotal				6		6	0.00%
WS FL,		7			1	8	0.00%

2. Acronyms: "AWSC" – All Way Stop Control; "TWSC" – Two Way Stop Control; "TS OP" – Traffic Signal Operation; TS FL – Traffic Signal Flash; WS/WS FL – Warning Sign/ Warning Sign with Flash.

WS,		1				1	0.00%
WS Subtotal		8			1	9	0.00%
Internal Inconsistent Records	1	146	4	34	9	194	0.00%
UNKN	1	11		24		36	-
Total	8	538	14	818	23	1401	-
Total (UNKN excluded)	7	527	14	794	23	1365	60.66%
Match Rate	85.71%	18.79%	50.00%	89.42%	26.09%	60.66%	

The TRFCCNTL [1,2] data field includes information from the first two units involved in the crash. The two-unit (Unit 1, Unit 2) element may be beneficial in that it collects a greater number of combinations without having to include them in an exhaustive attribute list; however, the need to collect information for each unit means more work for the police officer. Furthermore, analysts might be confused when different attributes are associated with units in the same location, and this could lead to data errors. One possible solution is to have the intersection automatically added from another reliable source such as the STN intersection inventory, assuming the information is available.

"RAB (roundabout)" is coded as INTTYPE in DT4000, while in STN it is considered as CONTROL. By examining both INTTYPE in DT4000 and CONTROL in the STN data for "RAB" and manually checking the corresponding locations in the Google Maps, 15 records were identified as locations that are actual roundabouts. The results are shown in Table 5-3. 14 out of 15 were recorded correctly in the STN dataset (i.e., 1 is coded as "OTHER" in the data but is actually "RAB"), while 13 out of 15 were recorded correctly in DT4000 (i.e., 2 recorded as "NA"). Moreover, 4 out of 15 in DT4000 indicate the traffic control as "NONE" when it should be "YIELD". The results indicate the need to ensure data fields meet existing traffic engineering practices to further improve the recording accuracy and consistency to the related safety analysis.

Table 5-3: "RAB" in both data

DOCTNMBR	DT4000		STN	
	INTTYPE	TRFCCNTL [1,2]	CONTROL	IX_CONFIG
04L0Q0GSGF	RAB	YIELD, YIELD	RAB	4 LEGS
16L08CTJRN	RAB	YIELD,	RAB	4 LEGS
2JL04BTWSV	RAB	OTHR,	RAB	4 LEGS
3NL0Z7RB1J	NA	YIELD,	RAB	4 LEGS
5NL00MQKX5	RAB	YIELD, NONE	RAB	4 LEGS
5NL00RFPL8	RAB	UNKN, NONE	RAB	4 LEGS
5NL01JWD9D	NA	YIELD, NONE	RAB	4 LEGS
5NL01JWDHT	RAB	NONE, NONE	RAB	4 LEGS
DGL068VN1B	RAB	YIELD, YIELD	RAB	4 LEGS
5NL007D704	RAB	NONE, NONE	RAB	4 LEGS
6NL097RB25	RAB	YIELD, YIELD	RAB	4 LEGS
2JL08M7RB1	RAB	YIELD, UNKN	RAB	4 LEGS
2QL021PTJT	RAB	YIELD, YIELD	RAB	4 LEGS
5NL17GNQ8K	RAB	YIELD, YIELD	RAB	4 LEGS
0BL096J9J3	RAB	, YIELD	OTHER	5 LEGS

5.1.4. TOTLANES [1,2] vs. MAJ_LNS

Table 5-4 shows the comparison results between TOTLANES [1,2] and MAJ_LNS with selected attributes (of TOTLANES) that represent the correctly recorded records in DT4000. The **bold and gray shaded** numbers represent the consistently matched record counts corresponding to each category. TOTLANES in DT4000 contains information in pairs for the first two units involved in the crash (e.g., “2,4” denotes “2 lanes in the roadway on which unit 1 was traveling” and “4 lanes in the roadway on which unit 2 was traveling”). It is assumed that the larger value in the pair represents the total lanes of the major road. It is assumed that doubling the values of “MAJ_LNS” in the STN intersection file leads to the correct values for DT4000, according to the description of TOTLANES in the *Wisconsin DT4000 Crash Data User Guide*:

> “***TOTLANES [1,2]*** *- Total number of lanes in the roadway on which this motor vehicle was traveling. For undivided highways - total through lanes in both directions, excluding designated turn lanes. For divided highways - total through lanes for roadway the motor vehicle under consideration was traveling.*”

Overall, 708 out of 1,401 (50.54%) records in DT4000 matched with the information provided in the STN data. Hence, this data field could be rated as ***“less consistent”***.

Table 5-4: Comparison between TOTLANES [1,2] and MAJ_LNS

DT4000: TOTLANES [1,2]	STN: MAJ_LNS								
	1	1.5	2	2.5	3	3.5	4	Total	Match Rate
1 Lane Subtotal	8	1	25		2		1	37	0.00%
2 Lane Subtotal	288	7	347	8	46		4	700	41.14%
3 Lane Subtotal	17	1	44	4	47	1		114	0.88%
4 Lane Subtotal	29	8	375	6	34			452	82.96%
5 Lane Subtotal	3		26	1	2			32	3.13%
6 Lane Subtotal			11	5	43	1	1	61	70.49%
7 Lane Subtotal					2			2	0.00%
8 Lanes Subtotal	1				2			3	0.00%
Total	346	17	828	24	178	2	6	1401	50.54%
Match rate	83.24%	5.88%	45.29%	4.17%	24.16%	0.00%	0.00%	50.54%	

5.1.5. TRFCWAY [1,2] vs. MEDIAN_TYP

TRFWAY [1,2] records information from the first two units involved in the crash, denoting “whether or not the trafficway for this unit is divided and whether it serves one-way or two-way traffic”. The information could be different for each unit when both travel perpendicularly (i.e., on different roadways). Furthermore, unlike the information in STN, there is no description of which roadway is the “major road”. Hence, when referring to TOTLANES, the “major road” is assumed to be the one with more lanes, and this information will be compared with “major road” in TRFWAY. Table 5-5 shows the comparison results between TRFCWAY [1,2] and MEDIAN_TYP with selected attributes (of TRFCWAY [1,2]) that represent the correctly recorded records in DT4000.

The **bold and gray shaded** numbers represent the consistently matched record counts. The two data fields have very different coding schemas. For convenience purposes, we classified all descriptions related to "divided roadway" in DT4000 as "DIVIDED" and then linked them to the classifications of "CH", "CH+TL", "DITCH", "DIVIDED", and "RAISED" in the STN data. Overall, 940 out of 1,401 (69.37%) records in DT4000 matched with the information in STN. Hence, this data field is rated as ***"less consistent"***.

Table 5-5: Comparison between TRFCWAY [1,2] and MEDIAN_TYP[3]

DT4000: TRFCWAY [1,2]	STN: MEDIAN_TYP								Total	Match Rate
	CH	CH+TL	DITCH	DIVIDED	PCR	RAISED	TWLTL	UNDIVIDED		
DIV BAR						71		3	74	95.95%
DIV MBR						48		1	49	97.96%
DIV NO		2	4	3		247	1	14	271	94.46%
DIV PNT		1				36		15	52	71.15%
DIVIDED Subtotal		3	4	3		402	1	33	446	92.38%
OW						18	1	44	63	0.00%
RAMP						17		2	19	0.00%
TWLTL						12	4	4	20	20.00%
UNDIV	7	21	1	1		229	24	524	807	64.93%
UNKN		1			1	23		21	46	-
Total	**7**	25	5	4	1	701	30	628	1401	-
Total (UNKN excluded)	**7**	24	5	4	0	678	30	607	1355	69.37%
Match Rate	**0.00%**	12.50%	80.00%	75.00%	0.00%	59.29%	13.33%	86.33%	69.37%	

5.1.6. URBRURAL vs. ARTYP_FED

Table 5-6 shows the comparison results between URBRURAL and ARTYP_FED. The **bold and gray shaded** numbers represent the consistently matched record counts. By observing the statistics in **Table 5-6**, 1,312 out of 1401 (93.65%) records for URBRUAL in DT4000 are matched with the information provided in STN. Hence, "URBRURAL" is rated as **"*highly consistent*"**. However, it is concerning to see that more than half of the records that are classified as rural in DT4000 do not match the STN data. Since URBRURAL is a "derived" field[4], the quality of the external data source directly affects the quality of the crash data for any "derived" data elements. However, no description has been found to explain the origin of this data field.

[3] Acronyms: CH – Channelized; CH+TL – Channelized Turn Lane; PCR – Pedestrian Crossing; DIV NO – Divided Hwy W/O Traffic Barrier; DIV PNT – Two-Way, Divided, Unprotected (Painted > 4 Feet) Median; DIV BAR – Divided Hwy W/Traffic Barrier; DIV MBR – Divided Hwy Median W/Barrier; OW – One-Way Traffic.

[4] A "derived" field means the data are important from an external source, not directly collected by the law enforcement.

Table 5-6: Comparison between URBRURAL and ARTYP_FED

DT4000: URBRURAL	STN: ARTYP_FED			
	RURAL	URBAN	**Total**	**Match Rate**
R LT 5000	62	67	129	48.06%
R TOWN	15	18	33	45.45%
Rural Subtotal	77	85	162	47.53%
U GT 5000	4	1217	1221	99.67%
U LT 5000		18	18	100.00%
Urban Subtotal	4	1235	1239	99.68%
Total	81	1320	1401	93.65%
Match Rate	95.06%	93.56%	93.65%	

5.2 Summary

Adding details to the existing data fields and creating new data fields in DT4000 (assuming the new data stream maintains good quality and integrity) enhances the crash analysis by providing more complete information and saving time and effort on the part of the safety analysts. In this section, the intersection-related information recorded in DT4000 is compared with the STN intersection information prepared by WisDOT traffic engineers. The consistency of each examined data field is summarized in Table 5-7. The internal inconsistencies of data fields in DT4000 among different crash records for the same location, as well as external inconsistencies of the same data fields between DT4000 and STN data, are observed.

Table 5-7: Summary of Consistencies of the Intersection Related Data Fields in DT4000

Data Field	Consistency
LOCTYPE	Consistent
INTTYPE	Consistent
TRFCCNTL	Less consistent
TOTLANES	Less consistent
TRFWAY	Less consistent
URBRURAL	Highly consistent

One factor that contributes to this inconsistent information is the different coding schemas used by the data fields (compared to the standards of traffic engineering practices). Another plausible reason for inconsistencies is that data entry is happening at the unit level. While collecting site characteristics at the unit (e.g., Unit 1, Unit 2) helps to produce a greater number of combinations without needing to include them in an exhaustive attribute list, the practice may create extra work for the data collector and could confuse analysts when conflicting attribute values are associated with each unit for the same location. The first problem can be mitigated by leveraging existing highway inventory data to include more standard traffic and highway engineering typology and classifications. The second issue may be solved by improving the data entry interface of Badger TraCs and/or automatically filling in the information from an external source such as the STN highway inventory. Finally, continuous crash data quality improvements cannot be achieved without better training and better data quality assurance.

6. EXPLORATORY DATA ANALYSIS

In this section, the patterns, trends, and characteristics of relevant crash data fields were explored using the Univariate and Multi-variate analyses. For brevity, variables with the suffix of “-MV” and “-DT” represent the variables that are coded in MV4000 and DT4000, respectively.

6.1 Univariate and Multivariate Analysis

A comprehensive comparison was conducted for a list of selected data fields between MV4000 and DT4000 crash forms based on 3,885 pedestrian- and 2,652 bicycle-related crashes in 2017-2020. These data fields are considered to be useful for pedestrian/bicycle safety. The analysis is conducted through descriptive statistics of individual attribute values; and the cross-classification table of combined values from two or more attributes. For definition of data fields and their attributes, please refer to Appendices A-C.

6.1.1. Analysis of Individual Data Fields

The univariate analysis is focused on single variables/data fields which are highly relevant to pedestrian and bicycle related crashes. For a new data field in the DT4000, descriptive statistics are calculated; for a data field that exists in both the MV4000 and DT4000 crash forms but has different attributes, a conversion is first performed and then, a contingency table is generated with rows being MV4000 attributes and columns being DT4000, or vice versa. In general, the data fields are categorized into seven types: roadway, environment, driver, pedestrian, bicyclist, crash, and vehicle related. For example, Figure 6-1 shows the weather condition (i.e., WTCOND [A,B] in DT4000) of a crash. As can be seen, the statistics of attribute value rain (i.e., RAIN) are slightly different in two forms, such as the total number where DT4000 is 459 and MV4000 is 445. Moreover, it should be noted that DT4000 might be not better if worse scenario is considered. In this case, you can easily pick up another 120 cases from "CLDY, RAIN" (i.e., 26% more compared to MV4000) and exclude 6 cases from “RAIN, SNOW”. Other examples include 1) freezing rain (i.e., FRZ RN in DT4000), which is classified as sleet in MV4000 but is not; 2) snow, when worse scenario is considered.

WTCOND [A,B] - DT	WTHRCOND - MV										Grand Total
	BLNK	CLDY	CLR	FOG	OTHR	RAIN	SLET	SNOW	UNKN	WIND	
,	1										1
B SNOW,										1	1
CLDY,		1544									1544
CLDY,FOG		4									4
CLDY,RAIN		120									120
CLDY,SNOW		13									13
CLEAR,			4241								4241
FOG,				11							11
FRZ RN,							7				7
OTHR,					4						4
RAIN,						445					445
RAIN,FOG						6					6
RAIN,SLEET						1					1
RAIN,SNOW						6					6
RAIN,WIND						1					1
SLEET,							3				3
SLEET,WIND							1				1
SNOW,								69			69
SNOW,B SNOW								1			1
SNOW,FRZ RN								1			1
SNOW,SLEET								7			7
SNOW,WIND								1			1
UNKN,									49		49
Grand Total	**1**	**1681**	**4241**	**11**	**4**	**459**	**11**	**79**	**49**	**1**	**6537**

Figure 6-1: Illustration of Different Distributions and Patterns of Data Fields

Given the large number of data fields analyzed, several findings are mentioned here after large disparities are observed between the two forms (the statistics of these crash variables below are based on information from the DT4000):

- For road surface condition, 12.93% of the crashes occurred in wet roadway surface conditions.
- 55.13% of crashes occurred at intersections, whereas 44.87% of them occurred at non-intersection/midblock locations.
- Taking into account the intersection type in which the crash occurred, 44.78% of the crashes occurred at 4-way stop intersections and 11.53% at T intersections.
- Driver under the influence of medication/drugs/alcohol (UI MDA) when a crash occurred lead to the highest proportion of severer injuries (i.e., 37.80% = 6.75% for fatal injury + 30.95% for incapacitating) among all abnormal driver condition, which is higher than the overall K+A percentage (i.e., 20.73% = 3.69% for fatal injury+ 17.07% for incapacitating injury).
- The factor of pedestrian under the influence of medication/drugs/alcohol (UI MDA) when a crash occurred and the proportions fatal injury (i.e., 20.51%) and incapacitating

injury (i.e., 42.31%) severity crashes are much higher than the overall situation (i.e., 5.28% for fatal injury and 21.31% for incapacitating injury); male pedestrians tend to sustain severer injurie than female pedestrians.

- Bicyclists wearing reflective clothes (Jacket, Backpack, etc.) or lighting equipment and bicyclists wearing helmet result in higher proportions of both fatal and incapacitating injuries, which might be counterintuitive; female bicyclist tends to have higher proportion of fatal injuries (i.e., 1.52%) than male (i.e., 1.31%).
- Compared to young (age <30) and aged 30-64 VRUs, old VRUs (age ≥65) are prone to severer injuries.
- Concerning the horizontal curve of a roadway, the factor of curve left shows the highest proportion of incapacitating injury crashes (i.e., 22.89%) and the factor of curve right shows the highest proportion of fatal injury crashes (i.e., 9.47%).
- 65.64% of the crashes occurred involved the private vehicle; however, sport utility vehicle, utility truck/pickup truck, and passenger van would lead to higher severer injury proportions other than the private vehicles within their own categories.

Besides, following facts are also observed associated with several important roadway and intersection related data fields. However, the results in Chapter 5 indicate that these data fields are "less consistent" with the information collected by WisDOT traffic engineers and therefore, they are listed here for references only:

- Viewing the type of trafficway division, 70.35%, and 10.60% of the crashes occurred when the motorists travelled in two-way undivided highways (UNDIV), and divided '' highways without a traffic barrier (DIV NO), respectively.
- Concerning the total number of lanes in a roadway where a crash took place, roadways with two and four total number of lanes contribute together to 78.63% of the total number of crashes.
- For the traffic control device (TCD) in effect at the time of crash, 1.33% of the crashes are reported as lacking a TCD (NONE), which results from excluding number of the non-intersection locations (N) (44.87%) from the total number of locations lacking a TCD (NONE) (46.20%). 26.36%, and 9.53% of the crashes occurred at traffic signal controlled (TS OP) and at stop sign controlled (STOP/SS FL) locations, respectively.

6.1.2. Analysis of Combined Data Fields

Informed by the univariate analysis, the multivariate analysis (MVA), also known as the correspondence modeling, is used to detect the presence of significant association between two or more categorical data fields. This type of analysis can also be used to determine whether a new "combined" data field is more meaningful than two or more separate ones. Selected attributes of each data field are listed as rows and columns with the count as the value in the joint cell. Table 1 to Table 6-20 present the potential new relationships and circumstances associated with motor vehicle crashes involving pedestrians and bicyclists, in particular: action-location; roadway design-traffic control characteristics; driver actions-roadway characteristics; pedestrian/bicyclist location-roadway characteristics; driver actions-pedestrian/bicyclist actions; and environmental conditions-roadway characteristics.

6.1.2.1. Action-Location

Action-Location means the relationships between actions of involved road users (i.e., driver movements and VRUs' actions/prior actions) and VRUs' locations. This combination is important for ped/bike safety analysis because the injury severity of a VRU in a motor vehicle crash depends largely on the vehicles' speed, trajectory and interaction between the two (e.g., precrash vehicle movement, body orientation (and locations) of VRU when crash occurred). The VRU's location might affect the decision-making processes of the driver and the VRU, which in return influences the drivers' action to the precrash movement of the vehicle and the reaction of the VRU. According to literatures, many researchers studied VRUs' locations and driver actions separately to test if a certain VRU location accompanied with a certain driver action increases the odds of a more severely injured non-motorist involved in a vehicle crash (*69*, *82*, *83*). One research studied drivers' behaviors and proposed more intensive driver education and restrictive traffic regulations targeting at middle-aged male drivers (*6*). In the same study, after examining pedestrian behaviors and location, the authors highlighted the value of improving pedestrian designated areas for travel, as a result of recognizing that a high percentage of crashes occur at marked and unmarked crosswalks. However, few research have considered the combined action-location effect for the traffic safety analysis. Therefore, this subsection attempt to provide some new insights by examining a series of the combined data fields of action-location.

Table 6-1 to Table 6-6 presents the statistical results of the following combined data fields: "Driver Movement and Pedestrian Location", "Driver Movement and Bicyclist Location", "Pedestrian Action and Pedestrian Location", "Bicyclist Action and Bicyclist Location", "Pedestrian Prior Action and Pedestrian Location", and "Bicyclist Prior Action and Bicyclist Location", respectively.

a. Driver Movement and Pedestrian Location

The "driver movement (i.e., DRVRDO in MV4000, DRVRDOIN in DT4000)" here is described as "*what the driver of unit was doing at the time of the crash*" in MV4000, and "*the controlled maneuver for this motor vehicle prior to the beginning of the sequence of events*" in DT4000, respectively. The "pedestrian location (i.e., NMTLOC)" is referred to "*the location of the non-motorist with respect to the roadway at the time of the crash*" in DT4000, and this data field cannot be found in WisTransportal Crash Retrieval Facility for MV4000, which however could be obtained by converting "NMTLOC [1,2]-PED-DT" in DT4000 via using the SAS code translation Excel file provided through the WisTransportal website.

Figure 6-2 provides the relationships of different data attributes between MV4000 and DT4000 for both driver movement (i.e., DRVRDO and DRVRDOIN) and pedestrian's location (i.e., NMTLOC). For driver movement, it can be seen that DT4000 further details "other driver movements (OTHR)" in MV4000 by providing additional data attributes (i.e., ACCEL, ENT LN, LVG LN, STARTING, and LV PRK). The newly added attribute values are more specific, more accurate and mutually exclusive. Specific information offers important and accurate details to crash analysis; and mutually exclusive describes a situation where the occurrence of outcome supersedes the other; or two or more events cannot happen simultaneously. Moreover, new patterns might be observed, such as there were 46 crashes occurred when driver accelerated in road (ACCEL). For pedestrian's location, despite the "on sidewalk" in MV4000, "in crosswalk", "in roadway", and "not in roadway" have been expanded with many new data attributes in DT4000 as shown in Figure 6-1. Such expansions now denote specific roadway facility features, such as the presence of intersection and crosswalk mark. According to the State of Wisconsin's law (*84*), the driver(s) must yield the right-of-way (ROW) to the pedestrian(s) who already started crossing an intersection on a "walk" signal or a green light if there is no walk signal. Moreover, the driver(s) must also yield the ROW to the pedestrian(s) who started crossing within a marked/unmarked crosswalk at an intersection where there are no traffic lights or traffic control signals. Thus, the enhanced information might have impacts on the in-depth analysis regarding to the safety of pedestrian, such as the analysis of at-fault party at specific locations. For instance, observed from Table 6-1, statistics from MV4000 show that 991 crashes (25.51%) occurred while the driver was going straight, and the pedestrian was located in the roadway/at a midblock. However, the DT4000 dataset shows that 757 (19.49%) of these crashes that involved pedestrians located on the roadway not in a marked crosswalk (NAI NX) while the driver was going straight. According to the statistics in DT4000, left turn by drivers (556, 14.31%) is more common to pedestrian at an intersection with marked crosswalk (ATI MX).

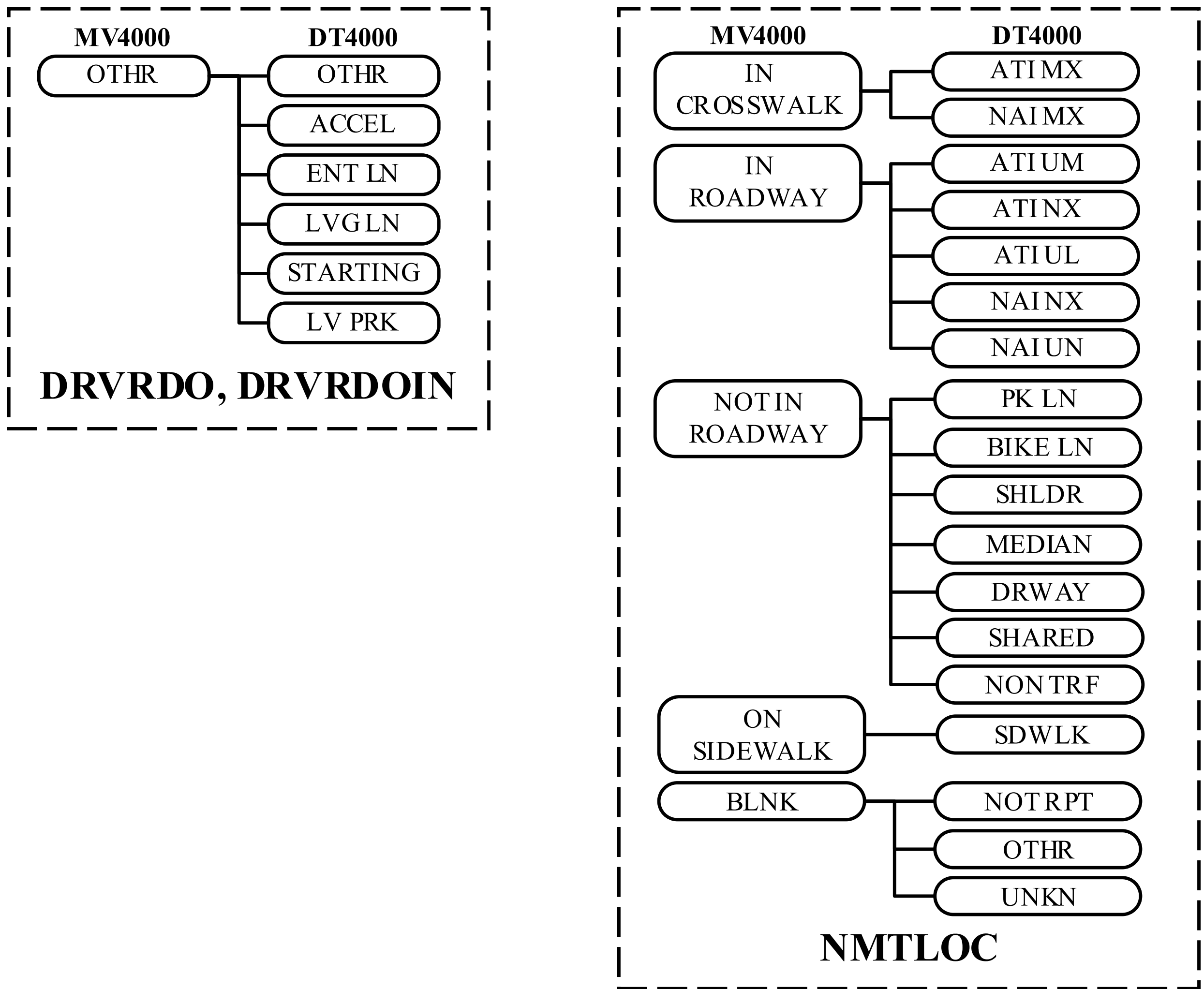


Figure 6-2: Code Conversions between MV4000 and DT4000 for Driver Movement (i.e., DRVRDO and DRVRDOIN) and VRU's Location (i.e., NMTLOC)

Table 6-1: Driver Movement and Pedestrian Location.

DRVRDO [1, 2]-MV	NMTLOC [1, 2]-PED-MV											
	blank		in crosswalk		in roadway		not in roadway		on sidewalk		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	27	0.69%	392	10.09%	991	25.51%	119	3.06%	21	0.54%	1,550	39.90%
BLNK	25	0.64%	330	8.49%	413	10.63%	78	2.01%	17	0.44%	863	22.21%
LT TRN	3	0.08%	562	14.47%	141	3.63%	11	0.28%	6	0.15%	723	18.61%
RT TRN	0	0.00%	265	6.82%	69	1.78%	11	0.28%	5	0.13%	350	9.01%
OTHR	7	0.18%	17	0.44%	60	1.54%	29	0.75%	11	0.28%	124	3.19%
BACKING	4	0.10%	5	0.13%	63	1.62%	31	0.80%	11	0.28%	114	2.93%
SL/ST	0	0.00%	10	0.26%	28	0.72%	3	0.08%	1	0.03%	42	1.08%
NEGCRV	1	0.03%	11	0.28%	16	0.41%	11	0.28%	3	0.08%	42	1.08%
OVT LT	2	0.05%	2	0.05%	11	0.28%	1	0.03%	0	0.00%	16	0.41%
OVT RT	0	0.00%	5	0.13%	5	0.13%	2	0.05%	0	0.00%	12	0.31%
CHG LN	0	0.00%	3	0.08%	7	0.18%	2	0.05%	0	0.00%	12	0.31%
RTOR	0	0.00%	10	0.26%	0	0.00%	0	0.00%	0	0.00%	10	0.26%
U TURN	0	0.00%	1	0.03%	5	0.13%	1	0.03%	0	0.00%	7	0.18%
PARKNG	1	0.03%	0	0.00%	1	0.03%	4	0.10%	0	0.00%	6	0.15%
STOPED	0	0.00%	2	0.05%	2	0.05%	2	0.05%	0	0.00%	6	0.15%
MERGNG	0	0.00%	0	0.00%	3	0.08%	1	0.03%	0	0.00%	4	0.10%
LG PRK	0	0.00%	0	0.00%	0	0.00%	3	0.08%	0	0.00%	3	0.08%
NPASZN	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	1	0.03%
IL PRK	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Total	70	1.80%	1,616	41.60%	1,815	46.72%	309	7.95%	75	1.93%	3,885	100.00%

DRVRDOIN [1, 2]-DT	NMTLOC [1, 2]-PED-DT																							
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		SDWLK		SHLDR		OTHR		Other bicyclist's locations (< 1.00%, i.e., DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF)		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	355	9.14%	130	3.35%	9	0.23%	80	2.06%	37	0.95%	757	19.49%	15	0.39%	21	0.54%	81	2.08%	20	0.51%	45	1.16%	1,550	39.90%
LT TRN	556	14.31%	33	0.85%	6	0.15%	68	1.75%	6	0.15%	32	0.82%	2	0.05%	6	0.15%	2	0.05%	2	0.05%	10	0.26%	723	18.61%
blank	193	4.97%	35	0.90%	6	0.15%	40	1.03%	4	0.10%	123	3.17%	3	0.08%	9	0.23%	18	0.46%	3	0.08%	17	0.44%	451	11.61%
UNKN[5]	123	3.17%	25	0.64%	15	0.39%	33	0.85%	10	0.26%	130	3.35%	3	0.08%	8	0.21%	30	0.77%	9	0.23%	26	0.67%	412	10.60%
RT TRN	263	6.77%	14	0.36%	6	0.15%	36	0.93%	2	0.05%	13	0.33%	0	0.00%	5	0.13%	5	0.13%	0	0.00%	6	0.15%	350	9.01%
BACKING	4	0.10%	5	0.13%	0	0.00%	2	0.05%	1	0.03%	54	1.39%	2	0.05%	11	0.28%	5	0.13%	3	0.08%	27	0.69%	114	2.93%
ACCEL	11	0.28%	2	0.05%	0	0.00%	2	0.05%	1	0.03%	21	0.54%	2	0.05%	0	0.00%	3	0.08%	3	0.08%	1	0.03%	46	1.18%
SLOWNG	9	0.23%	5	0.13%	1	0.03%	3	0.08%	1	0.03%	19	0.49%	0	0.00%	1	0.03%	1	0.03%	0	0.00%	2	0.05%	42	1.08%
NEGCRV	8	0.21%	1	0.03%	1	0.03%	0	0.00%	3	0.08%	13	0.33%	1	0.03%	3	0.08%	10	0.26%	0	0.00%	2	0.05%	42	1.08%
OTHR	1	0.03%	0	0.00%	0	0.00%	1	0.03%	1	0.03%	9	0.23%	0	0.00%	3	0.08%	5	0.13%	3	0.08%	1	0.03%	24	0.62%
ENT LN	1	0.03%	2	0.05%	0	0.00%	1	0.03%	0	0.00%	6	0.15%	0	0.00%	4	0.10%	1	0.03%	0	0.00%	6	0.15%	21	0.54%
LV PRK[6]	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	8	0.21%	0	0.00%	3	0.08%	4	0.10%	0	0.00%	3	0.08%	19	0.49%
OVT LT	2	0.05%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	10	0.26%	0	0.00%	0	0.00%	0	0.00%	2	0.05%	1	0.03%	16	0.41%
CHG LN	3	0.08%	2	0.05%	1	0.03%	0	0.00%	0	0.00%	4	0.10%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	12	0.31%
OVT RT	5	0.13%	1	0.03%	0	0.00%	2	0.05%	0	0.00%	2	0.05%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	12	0.31%
RTOR	10	0.26%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	10	0.26%
LVG LN	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	4	0.10%	1	0.03%	1	0.03%	9	0.23%
U TRN	1	0.03%	0	0.00%	0	0.00%	3	0.08%	0	0.00%	2	0.05%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	7	0.18%
STOPED	2	0.05%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.05%	6	0.15%
ARKNG[7]	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	1	0.03%	1	0.03%	0	0.00%	6	0.15%
STARTNG	2	0.05%	0	0.00%	0	0.00%	3	0.08%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	5	0.13%
MERGING	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	4	0.10%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	4	0.10%
LG PRK	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.08%	3	0.08%
NO PASS	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%
Total	1,550	39.90%	258	6.64%	45	1.16%	275	7.08%	66	1.70%	1,209	31.12%	28	0.72%	75	1.93%	172	4.43%	47	1.21%	160	4.12%	3,885	100.00%

[5] "UNKN" is not found or used in DT4000 according to the "Wisconsin DT4000 Crash Data User Guide", but here in the data retrieved from "WisTransportal Crash Retrieval Facility", it has been used. There might be some data compiling error.

[6] No data attribute of "LV PRK" has been found and used in DT4000.

[7] In "Wisconsin DT4000 Crash Data User Guide", this data attribute should be "PARKNG", but here in the data retrieved from "WisTransportal Crash Retrieval Facility", it is coded as "ARKNG".

b. Driver Movement and Bicyclist Location

The “driver movement (i.e., DRVRDO in MV4000, DRVRDOIN in DT4000)” here is described as “*What the driver of unit was doing at the time of the crash*” in MV4000, and “*the controlled maneuver for this motor vehicle prior to the beginning of the sequence of events*” in DT4000, respectively. The “bicyclist location (i.e., NMTLOC)” is referred to “*The location of the non-motorist with respect to the roadway at the time of the crash*” in DT4000, and this data field cannot be found in WisTransportal Crash Retrieval Facility for MV4000, which however could be obtained by converting “NMTLOC [1,2]-BIKE-DT” in DT4000 via using the SAS code translation Excel file provided through the WisTransportal website. The relationships of different data attributes between MV4000 and DT4000 for both driver movement (i.e., DRVRDO and DRVRDOIN) and bicyclist’s location (i.e., NMTLOC) can be referred to Figure 6-2.

Similar to pedestrians, more data attributes are available for bicyclists in the DT4000 regarding the location features (i.e., crosswalk marking associated with the intersection). For instance, in Table 6-2, MV4000 shows 293 (11.05%) crashes occurred while drivers were going straight (GO STR), and the bicyclist is in a crosswalk regardless of the crosswalk status. Whereas statistics from DT4000 further denote those 259 (9.77%) crashes occurred while the bicyclist was located at an intersection and in a marked crosswalk (ATI MX). For another example, information from MV4000 shows that 631 (23.79%) crashes occurred while the driver was going straight (GO STR), and the bicyclist was crossing the roadway where there is no crosswalk. Whereas, according to the DT4000, 237 (8.94%) crashes occurred while the bicyclist was not located in an intersection and was not in a marked crosswalk (NAI NX). Moreover, an examining of the DT4000 data shows that, right turn (RT TRN with 314 crashes, 11.84% of the total) and going straight (GO STR with 259 crashes, 9.77%) are the most common driver movements associated with bicyclist crashes at intersection when the bicyclist is traveling within a marked crosswalk (ATI MX). Driver going straight (237 crashes, 8.94%) is the most common movement involved with bicycle crashes that occur when the bicyclist is on the roadway, not at an intersection and not in a marked (NAI NX). Again, such information collected by DT4000 could offer a better chance for enhanced analyses in details, such as the analysis of at-fault party at specific locations.

Table 6-2: Driver Movement and Bicyclist Location

DRVRDO [1, 2]-MV	NMTLOC [1, 2]-BIKE-MV											
	blank		in crosswalk		in roadway		not in roadway		on sidewalk		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	16	0.60%	293	11.05%	631	23.79%	91	3.43%	35	1.32%	1,066	40.20%
RT TRN	0	0.00%	320	12.07%	134	5.05%	41	1.55%	23	0.87%	518	19.53%
BLNK	5	0.19%	118	4.45%	183	6.90%	57	2.15%	16	0.60%	379	14.29%
LT TRN	4	0.15%	116	4.37%	156	5.88%	57	2.15%	5	0.19%	338	12.75%
OTHR	1	0.04%	33	1.24%	25	0.94%	14	0.53%	25	0.94%	98	3.70%
SL/ST	0	0.00%	14	0.53%	24	0.90%	4	0.15%	2	0.08%	44	1.66%
BACKING	0	0.00%	0	0.00%	11	0.41%	17	0.64%	6	0.23%	34	1.28%
NEGCRV	0	0.00%	12	0.45%	16	0.60%	3	0.11%	0	0.00%	31	1.17%
OVT LT	1	0.04%	3	0.11%	11	0.41%	6	0.23%	0	0.00%	21	0.79%
STOPED	0	0.00%	7	0.26%	9	0.34%	2	0.08%	2	0.08%	20	0.75%
CHG LN	1	0.04%	4	0.15%	5	0.19%	0	0.00%	0	0.00%	10	0.38%
RTOR	0	0.00%	8	0.30%	1	0.04%	0	0.00%	0	0.00%	9	0.34%
U TURN	0	0.00%	0	0.00%	6	0.23%	2	0.08%	0	0.00%	8	0.30%
OVT RT	0	0.00%	2	0.08%	2	0.08%	3	0.11%	0	0.00%	7	0.26%
LG PRK	0	0.00%	0	0.00%	1	0.04%	6	0.23%	0	0.00%	7	0.26%
MERGNG	0	0.00%	1	0.04%	5	0.19%	0	0.00%	0	0.00%	6	0.23%
PARKNG	0	0.00%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	2	0.08%
IL PRK	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	1	0.04%
Other driver movements combinations (e.g., [RT TRN, GO STR])	0	0.00%	17	0.64%	17	0.64%	17	0.64%	2	0.08%	53	2.00%
Total	28	1.06%	948	35.75%	1,239	46.72%	321	12.10%	116	4.37%	2,652	100.00%

DRVRDOIN [1, 2]-DT	NMTLOC [1, 2]-BIKE-DT																									
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		BIKE LN		SDWLK		SHLDR		OTHR		Other pedestrian's locations (< 1.00%, i.e., DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF)		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	259	9.77%	266	10.03%	27	1.02%	91	3.43%	27	1.02%	237	8.94%	5	0.19%	22	0.83%	35	1.32%	43	1.62%	11	0.41%	30	1.13%	1,053	39.71%
RT TRN	314	11.84%	51	1.92%	12	0.45%	57	2.15%	2	0.08%	14	0.53%	0	0.00%	18	0.68%	23	0.87%	9	0.34%	0	0.00%	14	0.53%	514	19.38%
LT TRN	116	4.37%	84	3.17%	9	0.34%	36	1.36%	0	0.00%	27	1.02%	0	0.00%	30	1.13%	5	0.19%	13	0.49%	4	0.15%	14	0.53%	338	12.75%
blank	67	2.53%	44	1.66%	1	0.04%	16	0.60%	4	0.15%	33	1.24%	1	0.04%	9	0.34%	15	0.57%	7	0.26%	0	0.00%	11	0.41%	208	7.84%
UNKN	45	1.70%	27	1.02%	4	0.15%	23	0.87%	2	0.08%	33	1.24%	1	0.04%	13	0.49%	1	0.04%	14	0.53%	2	0.08%	6	0.23%	171	6.45%
SLOWNG	14	0.53%	3	0.11%	0	0.00%	10	0.38%	0	0.00%	9	0.34%	0	0.00%	1	0.04%	2	0.08%	1	0.04%	0	0.00%	2	0.08%	42	1.58%
ENT LN	5	0.19%	2	0.08%	0	0.00%	3	0.11%	0	0.00%	5	0.19%	0	0.00%	3	0.11%	15	0.57%	1	0.04%	1	0.04%	2	0.08%	37	1.40%
BACKING	0	0.00%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	8	0.30%	1	0.04%	4	0.15%	6	0.23%	5	0.19%	0	0.00%	8	0.30%	34	1.28%
NEGCRV	11	0.41%	8	0.30%	0	0.00%	0	0.00%	1	0.04%	7	0.26%	0	0.00%	0	0.00%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	30	1.13%
OVT LT	2	0.08%	1	0.04%	0	0.00%	1	0.04%	1	0.04%	8	0.30%	0	0.00%	2	0.08%	0	0.00%	4	0.15%	1	0.04%	1	0.04%	21	0.79%
STOPED	7	0.26%	4	0.15%	0	0.00%	4	0.15%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	2	0.08%	20	0.75%
ACCEL	14	0.53%	1	0.04%	1	0.04%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	20	0.75%
STARTNG	10	0.38%	3	0.11%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	2	0.08%	0	0.00%	0	0.00%	1	0.04%	19	0.72%
OTHR	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	2	0.08%	0	0.00%	1	0.04%	5	0.19%	0	0.00%	0	0.00%	2	0.08%	11	0.41%
CHG LN	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	3	0.11%	0	0.00%	3	0.11%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	9	0.34%
RTOR	8	0.30%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	9	0.34%
U TRN	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	4	0.15%	0	0.00%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	8	0.30%
OVT RT	2	0.08%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	7	0.26%
LG PRK	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	2	0.08%	0	0.00%	3	0.11%	7	0.26%
MERGING	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	6	0.23%
LVG LN	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	3	0.11%
LV PRK	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	3	0.11%
ARKNG	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.08%
IL PRK[8]	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%
Other driver movements combinations (e.g., [RT TRN, GO STR])	36	1.36%	10	0.38%	2	0.08%	6	0.23%	0	0.00%	12	0.45%	0	0.00%	5	0.19%	2	0.08%	5	0.19%	1	0.04%	0	0.00%	79	2.98%
Total	910	34.31%	507	19.12%	57	2.15%	255	9.62%	38	1.43%	412	15.54%	8	0.30%	118	4.45%	116	4.37%	111	4.19%	21	0.79%	99	3.73%	2,652	100.00%

[8] According to both "Wisconsin DT4000 Crash Data User Guide" and "Crash Data User Guide" for MV4000, data attribute of "IL PRK" is only used in MV4000 but not in DT4000, there might be some error while compiling data between MV4000 and DT4000 formats.

c. Pedestrian Action and Pedestrian Location

In DT4000, pedestrian action is described as "*the actions/circumstances of the non-motorist (e.g., jaywalking, disregarded signal, walking not facing traffic) that may have contributed to the crash* (i.e., NMTACT)", and pedestrian location refers to "*the location of the non-motorist with respect to the roadway at the time of the crash* (*e.g., at intersection-in marked crosswalk, not at intersection-in marked crosswalk*) (i.e., NMTLOC)". Linking action with location can help better assess the risk of a pedestrian in specific location. Similar to pedestrian location, the data field of pedestrian action also cannot be found in WisTransportal Crash Retrieval Facility for MV4000, which however could be obtained by converting "NMTACT [1,2]-PED-DT" in DT4000 via using the SAS code translation Excel file provided through the WisTransportal website.

Figure 6-3 provides the relationships of different data attributes between MV4000 and DT4000 for pedestrian's action (i.e., NMTACT). As shown in Figure 6-3, many new data attributes have been created for the NMTACT [1,2][A,B]-PED (i.e., pedestrian's action) variable in DT4000 to have an expansion on "OTHER" in MV4000.

Based on Table 6-3, most of the crashes could not be clearly identified as any specific categories if the information is extracted from the MV4000, since they are classified as "other actions". DT4000 provides an option for no improper action by the pedestrian (NO IMPR with 1,260 pedestrian crashes, 32.43%), which helps separate such no-fault action of a VRU from the blank/other field in the MV4000. As denoted previously, linking action with location can help better assess the risk of a pedestrian in specific location. According to the Table 6-3, the information from the DT4000 shows that crashes involving pedestrians making a sudden movement into the traffic are more common on the roadway (Not at Intersection-On Roadway, Not in Marked Crosswalk, NAI NX) (308, 7.93% of total crashes) than at an intersection location in a marked crosswalk (ATI MX) (71, 1.83% of total crashes). This information has been aggregated into "in roadway" in MV4000, while again additional mutually exclusive data attributes are provided in DT4000 for achieving a higher data resolution. Additionally, it should be noted that "wearing dark clothes" is neither an action nor against the law.

According to "Wisconsin DT4000 Crash Data User Guide", "*[1,2] Denotes unit level information, where a unit is any vehicle, bicycle, pedestrian, or equipment involved in a crash*", and *"[A,B] Denotes elements that take on multiple values*". Hence, information recorded in "pedestrian action (NMTACT)" includes statement/descriptions from both the driver and pedestrian, which could be inconsistent in some cases. Such inconsistence led to many actions' combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING]), which can be observed from both the MV4000 dataset and DT4000 dataset. This phenomenon can also apply to other data fields that include multi-valued elements, such as driver contributing action (i.e., DRVRPC), type of traffic control device (TCD) (i.e., TRFCNTL, TRFCCNTL).

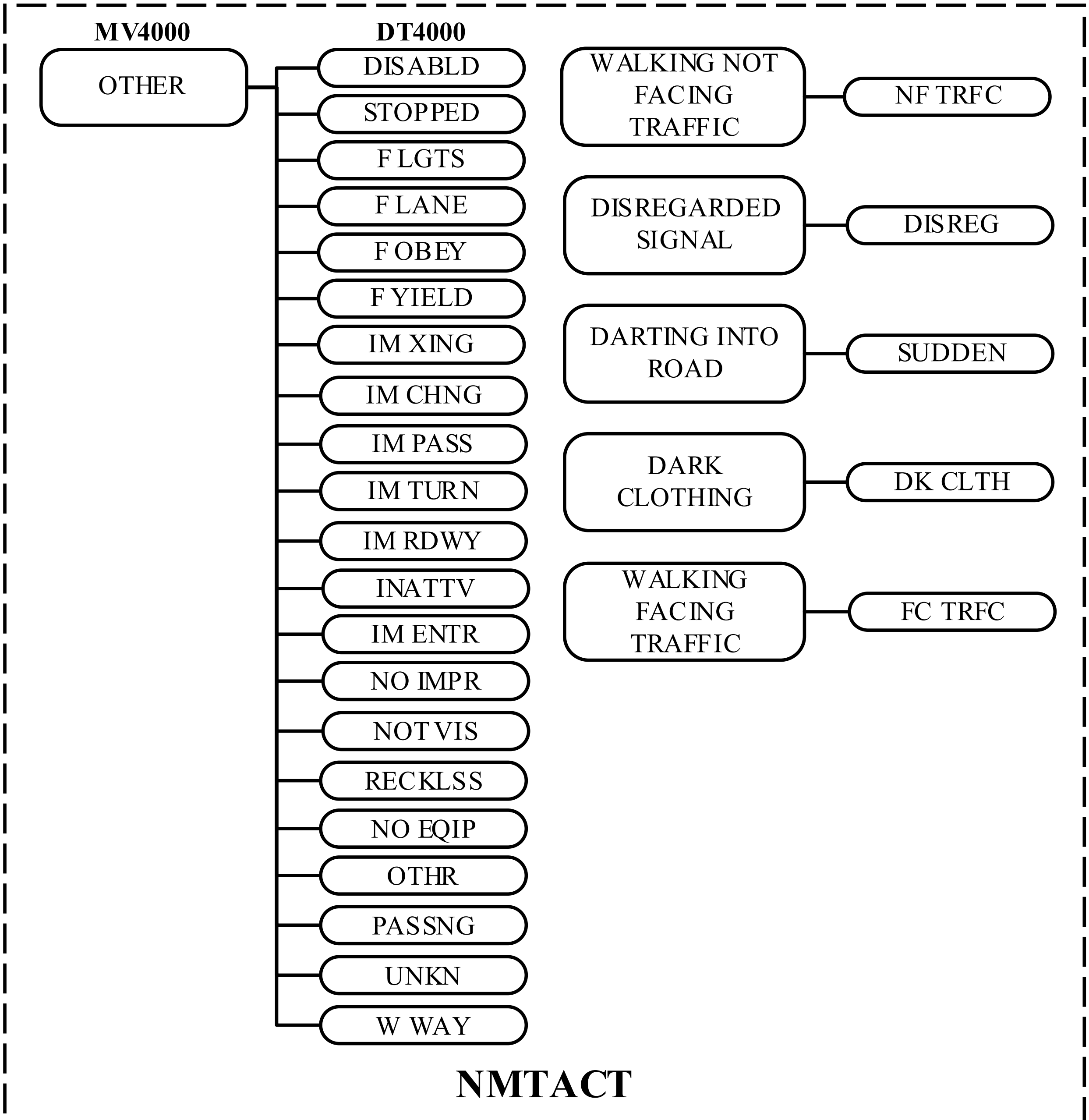


Figure 6-3: Code Conversions between MV4000 and DT4000 for VRU's Action (i.e., NMTACT) for "OTHER" Data Attribute

Table 6-3: Pedestrian Action and Pedestrian Location

NMTACT [1, 2]-PED-MV	NMTLOC [1, 2]-PED-MV											
	blank		in crosswalk		in roadway		not in roadway		on sidewalk		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
OTHER	55	1.42%	1026	26.41%	858	22.08%	211	5.43%	64	1.65%	2214	56.99%
DARTING INTO ROAD	5	0.13%	83	2.14%	389	10.01%	9	0.23%	0	0.00%	486	12.51%
WALKING NOT FACING TRAFFIC	3	0.08%	142	3.66%	100	2.57%	36	0.93%	4	0.10%	285	7.34%
WALKING FACING TRAFFIC	0	0.00%	67	1.72%	41	1.06%	14	0.36%	2	0.05%	124	3.19%
DARK CLOTHING	0	0.00%	63	1.62%	32	0.82%	2	0.05%	1	0.03%	98	2.52%
DISREGARDED SIGNAL	0	0.00%	77	1.98%	11	0.28%	0	0.00%	0	0.00%	88	2.27%
Other pedestrian's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])	7	0.18%	158	4.07%	384	9.88%	37	0.95%	4	0.10%	590	15.19%
Total	70	1.80%	1,616	41.60%	1,815	46.72%	309	7.95%	75	1.93%	3,885	100.00%

NMTACT [1, 2] [A,B]-PED-DT	NMTLOC [1, 2]-PED-DT																							
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		SDWLK		SHLDR		OTHR		Other bicyclist's locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF)		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NO IMPR	782	20.13%	39	1.00%	7	0.18%	122	3.14%	27	0.69%	93	2.39%	1	0.03%	52	1.34%	50	1.29%	18	0.46%	69	1.78%	1260	32.43%
SUDDEN	71	1.83%	48	1.24%	2	0.05%	26	0.67%	12	0.31%	308	7.93%	5	0.13%	0	0.00%	4	0.10%	5	0.13%	5	0.13%	486	12.51%
UNKN	130	3.35%	15	0.39%	19	0.49%	38	0.98%	6	0.15%	76	1.96%	1	0.03%	6	0.15%	13	0.33%	7	0.18%	21	0.54%	332	8.55%
NF TRFC	133	3.42%	15	0.39%	3	0.08%	18	0.46%	9	0.23%	59	1.52%	5	0.13%	4	0.10%	25	0.64%	2	0.05%	12	0.31%	285	7.34%
IM XING	3	0.08%	28	0.72%	0	0.00%	2	0.05%	0	0.00%	121	3.11%	3	0.08%	0	0.00%	2	0.05%	0	0.00%	1	0.03%	160	4.12%
OTHR	30	0.77%	6	0.15%	0	0.00%	5	0.13%	1	0.03%	58	1.49%	5	0.13%	4	0.10%	8	0.21%	9	0.23%	21	0.54%	147	3.78%
FC TRFC	66	1.70%	3	0.08%	1	0.03%	11	0.28%	1	0.03%	26	0.67%	0	0.00%	2	0.05%	12	0.31%	0	0.00%	2	0.05%	124	3.19%
DK CLTH	61	1.57%	7	0.18%	1	0.03%	11	0.28%	2	0.05%	13	0.33%	0	0.00%	1	0.03%	2	0.05%	0	0.00%	0	0.00%	98	2.52%

IM RDWY	1	0.03%	8	0.21%	3	0.08%	4	0.10%	0	0.00%	62	1.60%	1	0.03%	0	0.00%	7	0.18%	0	0.00%	4	0.10%	90	2.32%
DISREG	76	1.96%	8	0.21%	0	0.00%	3	0.08%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	88	2.27%
STOPPED	0	0.00%	2	0.05%	0	0.00%	0	0.00%	0	0.00%	19	0.49%	0	0.00%	0	0.00%	6	0.15%	0	0.00%	7	0.18%	34	0.88%
INATTV	13	0.33%	3	0.08%	0	0.00%	1	0.03%	1	0.03%	8	0.21%	0	0.00%	1	0.03%	3	0.08%	1	0.03%	2	0.05%	33	0.85%
F YIELD	4	0.10%	3	0.08%	0	0.00%	4	0.10%	0	0.00%	15	0.39%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	27	0.69%
NOT VIS	9	0.23%	1	0.03%	0	0.00%	1	0.03%	1	0.03%	7	0.18%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	21	0.54%
F OBEY	6	0.15%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	9	0.23%
DISABLD	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	5	0.13%	0	0.00%	0	0.00%	8	0.21%
RECKLSS	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	4	0.10%	0	0.00%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	5	0.13%
W WAY	0	0.00%	3	0.08%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	4	0.10%
IM ENTR	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%	2	0.05%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.08%
PASSNG	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.03%
Other pedestrian's actions combinations (e.g., [IM XING, F YIELD])	164	4.22%	67	1.72%	9	0.23%	27	0.69%	4	0.10%	336	8.65%	7	0.18%	5	0.13%	33	0.85%	5	0.13%	13	0.33%	670	17.25%
Total	1,550	39.90%	258	6.64%	45	1.16%	275	7.08%	66	1.70%	1,209	31.12%	28	0.72%	75	1.93%	172	4.43%	47	1.21%	160	4.12%	3,885	100.00%

d. Bicyclist Action and Bicyclist Location

In DT4000, bicyclist action is described as "*the actions/circumstances of the non-motorist (e.g., jaywalking, disregarded signal, walking not facing traffic) that may have contributed to the crash* (i.e., NMTACT)", and bicyclist location refers to "*the location of the non-motorist with respect to the roadway at the time of the crash* (*e.g., at intersection-in marked crosswalk, not at intersection-in marked crosswalk*) (i.e., NMTLOC)". Similar to pedestrian action-location combination, examining action and location together can help better assess the risk of a bicyclist in specific location. This data field of bicyclist action also cannot be found in WisTransportal Crash Retrieval Facility for MV4000, which however could be obtained by converting "NMTACT [1,2]-BIKE-DT" in DT4000 via using the SAS code translation Excel file provided through the WisTransportal website. The relationships of different data attributes between MV4000 and DT4000 for bicyclist action (i.e., NMTACT) can be referred to Figure 6-3.

Once again, in DT4000, attribute values are more specific, more accurate and mutually exclusive. Specific information offers important and accurate details to crash analysis; and mutually exclusive describes a situation where the occurrence of outcome supersedes the other; or two or more events cannot happen simultaneously. For example, in DT4000, NAI MX, NAI NX, NAI UN are mutually exclusive; in contrast, "in crosswalk" and "in roadway" in MV4000 are not because you can be on roadway and in crosswalk the same time. If following MV4000, it will not be able to know how many crashes occurred on roadway and in marked crosswalk while a bicyclist had no improper action, but in DT4000, the number is 127. As shown in Table 6-4, MV4000 presents that there were 84.80% of the crashes involved bicyclists that acted with improper actions other than darting into road or disregarding signal. Such actions involve but are not limited to wearing dark clothes (DK CLTH), crossing improperly (IM XING), failed to yield (F YIELD), and passing improperly (IM PASS). Again, DT4000 offering "NO IMPR" further details the no-fault action of a bicyclist from blank/other field in the old form. Also, statistics from both forms show that 279 (10.52%) crashes involved bicyclists who darted in the roadway (i.e., a bicyclist who is with sudden movement in DT4000), which is the most common action with clear definition by a bicyclist. Furthermore, among these 279 crashes, 107 happened in a crosswalk (i.e., "ATI MX" in DT4000, At Intersection In Marked Crosswalk). Moreover, MV4000 indicates that most crashes associated with such action happened in roadway (154 bicyclist crashes, 5.81%), while such conclusion might be too rough as the location data fields have been enhanced with more details in DT4000. Though not many obvious patterns have been identified for this combination, such extension with many more attributes added to the variable might lead to a more comprehensive analysis on the traffic crashes when more data are available in the future.

Table 6-4: Bicyclist Action and Bicyclist Location

NMTACT [1, 2]-BIKE-MV	NMTLOC [1, 2]-BIKE-MV											
	blank		in crosswalk		in roadway		not in roadway		on sidewalk		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
OTHER	20	0.75%	633	23.87%	844	31.83%	296	11.16%	108	4.07%	1,901	71.68%
DARTING INTO ROAD	2	0.08%	109	4.11%	154	5.81%	10	0.38%	4	0.15%	279	10.52%
DISREGARDED SIGNAL	0	0.00%	70	2.64%	50	1.89%	2	0.08%	2	0.08%	124	4.68%
DARK CLOTHING	1	0.04%	13	0.49%	14	0.53%	3	0.11%	0	0.00%	31	1.17%
WALKING NOT FACING TRAFFIC	0	0.00%	3	0.11%	3	0.11%	0	0.00%	0	0.00%	6	0.23%
WALKING FACING TRAFFIC	0	0.00%	4	0.15%	1	0.04%	0	0.00%	0	0.00%	5	0.19%
Other bicyclist's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])	5	0.19%	116	4.37%	173	6.52%	10	0.38%	2	0.08%	306	11.54%
Total	28	1.06%	948	35.75%	1,239	46.72%	321	12.10%	116	4.37%	2,652	100.00%

NMTACT [1, 2] [A,B]-BIKE-DT	NMTLOC [1, 2]-BIKE-DT																									
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		BIKE LN		SDWLK		SHLDR		OTHR		Other bicyclist locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF) and other pedestrian's locations combinations		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NO IMPR	383	14.44%	130	4.90%	7	0.26%	99	3.73%	19	0.72%	127	4.79%	2	0.08%	88	3.32%	57	2.15%	59	2.22%	9	0.34%	40	1.51%	1020	38.46%
SUDDEN	107	4.03%	34	1.28%	4	0.15%	35	1.32%	2	0.08%	79	2.98%	2	0.08%	2	0.08%	4	0.15%	1	0.04%	1	0.04%	8	0.30%	279	10.52%
UNKN	83	3.13%	42	1.58%	15	0.57%	21	0.79%	1	0.04%	40	1.51%	2	0.08%	5	0.19%	9	0.34%	21	0.79%	2	0.08%	12	0.45%	253	9.54%
DISREG	70	2.64%	30	1.13%	8	0.30%	9	0.34%	0	0.00%	3	0.11%	0	0.00%	2	0.08%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	124	4.68%
OTHR	33	1.24%	17	0.64%	1	0.04%	10	0.38%	3	0.11%	14	0.53%	2	0.08%	5	0.19%	22	0.83%	6	0.23%	1	0.04%	7	0.26%	121	4.56%
F YIELD	16	0.60%	37	1.40%	4	0.15%	15	0.57%	1	0.04%	15	0.57%	0	0.00%	2	0.08%	2	0.08%	0	0.00%	0	0.00%	5	0.19%	97	3.66%
F OBEY	12	0.45%	42	1.58%	1	0.04%	6	0.23%	2	0.08%	3	0.11%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	1	0.04%	2	0.08%	72	2.71%
W WAY	20	0.75%	15	0.57%	1	0.04%	9	0.34%	1	0.04%	10	0.38%	0	0.00%	2	0.08%	3	0.11%	5	0.19%	0	0.00%	1	0.04%	67	2.53%
DK CLTH	12	0.45%	7	0.26%	1	0.04%	2	0.08%	1	0.04%	4	0.15%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	1	0.04%	2	0.08%	31	1.17%

IM ENTR	10	0.38%	2	0.08%	1	0.04%	5	0.19%	1	0.04%	8	0.30%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.11%	30	1.13%
NOT VIS	5	0.19%	7	0.26%	1	0.04%	3	0.11%	0	0.00%	6	0.23%	0	0.00%	1	0.04%	0	0.00%	5	0.19%	0	0.00%	0	0.00%	28	1.06%
INATTV	1	0.04%	2	0.08%	0	0.00%	2	0.08%	1	0.04%	5	0.19%	0	0.00%	1	0.04%	5	0.19%	1	0.04%	0	0.00%	4	0.15%	22	0.83%
IM XING	4	0.15%	4	0.15%	0	0.00%	0	0.00%	0	0.00%	6	0.23%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	16	0.60%
F LGTS	5	0.19%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	1	0.04%	2	0.08%	0	0.00%	0	0.00%	1	0.04%	13	0.49%
IM TURN	0	0.00%	4	0.15%	3	0.11%	0	0.00%	0	0.00%	5	0.19%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	13	0.49%
F LANE	3	0.11%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	8	0.30%
IM RDWY	1	0.04%	1	0.04%	0	0.00%	0	0.00%	1	0.04%	2	0.08%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	0	0.00%	1	0.04%	8	0.30%
IM CHNG	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	4	0.15%	0	0.00%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	6	0.23%
RECKLSS	2	0.08%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	6	0.23%
PASSNG	0	0.00%	1	0.04%	1	0.04%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	6	0.23%
NF TRFC	3	0.11%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	6	0.23%
FC TRFC	4	0.15%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	5	0.19%
NO EQIP	2	0.08%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.08%
STOPPED	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	1	0.04%
IM PASS	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%
Other bicyclist's actions combinations (e.g., [IM XING, F YIELD])	134	5.05%	128	4.83%	9	0.34%	34	1.28%	5	0.19%	72	2.71%	0	0.00%	3	0.11%	7	0.26%	9	0.34%	5	0.19%	11	0.41%	417	15.72%
Total	910	34.31%	507	19.12%	57	2.15%	255	9.62%	38	1.43%	412	15.54%	8	0.30%	118	4.45%	116	4.37%	111	4.19%	21	0.79%	99	3.73%	2,652	100.00%

e. Pedestrian Prior Action and Pedestrian Location

For achieving a complete picture of a crash, both during-crash and precrash actions should be included. Hence, the new form has a data field of "Pedestrian Prior Action (NMTPRIOR [1, 2]-PED)", which is described as "*the action of a non-motorist immediately prior to a crash*" in DT4000. Furthermore, the prior action and the location of a pedestrian involved in the crash has been linked together to examine the combined effects.

It can be observed from Table 6-5 that 1305 crashes (33.59% of total) happened when the pedestrian was crossing the roadway (XING) while located at an intersection with a marked crosswalk (ATI MX). Whereas 606 crashes (15.60% of total) happened when the pedestrian was crossing the roadway (XING) not at an intersection and not in a marked crosswalk (NAI NX). In addition to these two most common situations, the third most common situation is crashes involved pedestrians in roadway not in a marked crosswalk (RDWY OT-NAI NX).

Table 6-5: Pedestrian Prior Action and Pedestrian Location

NMTPRIOR [1, 2]-PED-DT	NMTLOC [1, 2]-PED-DT																							
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		SDWLK		SHLDR		OTHR		Other pedestrian locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF) and other bicyclist's locations combinations		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
XING	1305	33.59%	154	3.96%	30	0.77%	221	5.69%	50	1.29%	606	15.60%	14	0.36%	1	0.03%	7	0.18%	4	0.10%	16	0.41%	2408	61.98%
RDWY OT	11	0.28%	35	0.90%	7	0.18%	8	0.21%	1	0.03%	246	6.33%	9	0.23%	2	0.05%	23	0.59%	7	0.18%	30	0.77%	379	9.76%
WAITING	136	3.50%	9	0.23%	2	0.05%	22	0.57%	6	0.15%	24	0.62%	1	0.03%	3	0.08%	2	0.05%	0	0.00%	2	0.05%	207	5.33%
OTHR	5	0.13%	10	0.26%	0	0.00%	1	0.03%	2	0.05%	51	1.31%	0	0.00%	8	0.21%	15	0.39%	20	0.51%	29	0.75%	141	3.63%
JOGGING	35	0.90%	7	0.18%	1	0.03%	9	0.23%	0	0.00%	58	1.49%	0	0.00%	1	0.03%	11	0.28%	0	0.00%	2	0.05%	124	3.19%
W TRFC	7	0.18%	9	0.23%	0	0.00%	3	0.08%	2	0.05%	56	1.44%	2	0.05%	1	0.03%	29	0.75%	1	0.03%	13	0.33%	123	3.17%
ADJACNT	5	0.13%	3	0.08%	0	0.00%	0	0.00%	2	0.05%	28	0.72%	1	0.03%	3	0.08%	45	1.16%	1	0.03%	15	0.39%	103	2.65%
SIDE WK	27	0.69%	2	0.05%	0	0.00%	7	0.18%	1	0.03%	13	0.33%	0	0.00%	43	1.11%	0	0.00%	0	0.00%	10	0.26%	103	2.65%
STOPPED	2	0.05%	4	0.10%	0	0.00%	0	0.00%	0	0.00%	46	1.18%	0	0.00%	0	0.00%	7	0.18%	3	0.08%	21	0.54%	83	2.14%
UNKN	5	0.13%	7	0.18%	4	0.10%	3	0.08%	2	0.05%	30	0.77%	0	0.00%	2	0.05%	6	0.15%	3	0.08%	14	0.36%	76	1.96%
A TRFC	6	0.15%	8	0.21%	0	0.00%	0	0.00%	0	0.00%	31	0.80%	1	0.03%	0	0.00%	10	0.26%	2	0.05%	2	0.05%	60	1.54%
NONE	5	0.13%	2	0.05%	0	0.00%	0	0.00%	0	0.00%	4	0.10%	0	0.00%	11	0.28%	5	0.13%	2	0.05%	5	0.13%	34	0.88%
WORKING	0	0.00%	7	0.18%	1	0.03%	0	0.00%	0	0.00%	10	0.26%	0	0.00%	0	0.00%	4	0.10%	4	0.10%	1	0.03%	27	0.69%
DISABLD	1	0.03%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	6	0.15%	0	0.00%	0	0.00%	8	0.21%	0	0.00%	0	0.00%	17	0.44%
Total	1,550	39.90%	258	6.64%	45	1.16%	275	7.08%	66	1.70%	1,209	31.12%	28	0.72%	75	1.93%	172	4.43%	47	1.21%	160	4.12%	3,885	100.00%

f. Bicyclist Prior Action and Bicyclist Location

Similarly, the data field of "Bicyclist Prior Action (NMTPRIOR [1, 2]-BIKE)" is described as "*the action of a non-motorist immediately prior to a crash*" in DT4000. It is worth mentioning again that such enhanced information might help reveal the effects of VRU behaviors that possibly contribute to the crash outcome for achieve a better analysis.

Regarding bicyclist's locations and actions prior to the crash displayed in Table 6-6, 910 crashes involved bicyclists located at intersections in marked crosswalks (ATI MX), among which 582 were crossing the roadway (XING). This was the most common bicyclist action and location combination in the dataset. Then the second most common situation for a crash is when a bicyclist cycling on sidewalk (SIDE WK) approaching an intersection with marked crosswalk (ATI MX). In a sense that both of the combinations of "Pedestrian Prior Action and Pedestrian Location" and "Bicyclist Prior Action and Bicyclist Location" could have potential for detecting the pre-crash event chain for crashes.

Table 6-6: Bicyclist Prior Action and Bicyclist Location

NMTPRIOR [1, 2]-BIKE-DT	NMTLOC [1, 2]-BIKE-DT																									
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		BIKE LN		SDWLK		SHLDR		OTHR		Other bicyclist's locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF) and other pedestrian's locations combinations		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
XING	582	21.95%	190	7.16%	28	1.06%	139	5.24%	23	0.87%	104	3.92%	3	0.11%	9	0.34%	9	0.34%	4	0.15%	3	0.11%	17	0.64%	1111	41.89%
W TRFC	34	1.28%	152	5.73%	12	0.45%	29	1.09%	1	0.04%	149	5.62%	1	0.04%	64	2.41%	0	0.00%	55	2.07%	5	0.19%	28	1.06%	530	19.98%
SIDE WK	210	7.92%	22	0.83%	3	0.11%	53	2.00%	7	0.26%	14	0.53%	0	0.00%	2	0.08%	91	3.43%	0	0.00%	0	0.00%	20	0.75%	422	15.91%
RDWY OT	12	0.45%	88	3.32%	6	0.23%	14	0.53%	1	0.04%	79	2.98%	2	0.08%	17	0.64%	0	0.00%	23	0.87%	9	0.34%	16	0.60%	267	10.07%
A TRFC	15	0.57%	30	1.13%	0	0.00%	9	0.34%	0	0.00%	32	1.21%	0	0.00%	13	0.49%	3	0.11%	5	0.19%	0	0.00%	1	0.04%	108	4.07%
WAITING	41	1.55%	9	0.34%	1	0.04%	6	0.23%	3	0.11%	7	0.26%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	69	2.60%
OTHR	7	0.26%	7	0.26%	1	0.04%	2	0.08%	3	0.11%	9	0.34%	1	0.04%	1	0.04%	8	0.30%	2	0.08%	3	0.11%	6	0.23%	50	1.89%
ADJACNT	1	0.04%	2	0.08%	1	0.04%	2	0.08%	0	0.00%	7	0.26%	0	0.00%	3	0.11%	1	0.04%	15	0.57%	0	0.00%	3	0.11%	35	1.32%
UNKN	7	0.26%	6	0.23%	5	0.19%	1	0.04%	0	0.00%	5	0.19%	1	0.04%	1	0.04%	0	0.00%	2	0.08%	0	0.00%	4	0.15%	32	1.21%
NONE	1	0.04%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	4	0.15%	0	0.00%	7	0.26%	4	0.15%	5	0.19%	1	0.04%	3	0.11%	26	0.98%
WORKING	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.08%
Total	910	34.31%	507	19.12%	57	2.15%	255	9.62%	38	1.43%	412	15.54%	8	0.30%	118	4.45%	116	4.37%	111	4.19%	21	0.79%	99	3.73%	2,652	100.00%

After examining different combinations of actions and locations between drivers and pedestrians/bicyclists and comparing the differences of information completeness between the MV4000 and DT4000 data, both the enhanced data fields and new data field in DT4000 offer a better opportunity to enable a more comprehensive traffic safety analysis with providing more complete information. However, due to the relatively small sample size of VRU crashes at the current period of time, more data accumulation is needed for identifying critical crash prone patterns with more detailed and disaggregated data fields and attributes. Other than that, information from both forms regarding all action-location relationships nearly matches each other.

Below is a brief summary of several critical, common crash patterns that the DT4000 provides more detail than the MV4000 to examine action-location relationships:

i. Driver Movement and Pedestrian Location:
   a. Going straight by drivers and pedestrians in roadway not in marked crosswalk
   b. Left turning by drivers and pedestrian at intersection in marked crosswalk

ii. Driver Movement and Bicyclist Location
   a. **Going straight by drivers** and bicyclists at an intersection with marked crosswalk, at an intersection without marked crosswalk, or in roadway not in marked crosswalk
   b. Turning right by drivers and bicyclists at an intersection with marked crosswalk

iii. Pedestrian Action and Pedestrian Location
   a. Pedestrians located in roadway not in marked crosswalk with sudden movement

iv. Bicyclist Action and Bicyclist Location
   a. Bicyclists at intersection in marked crosswalk with **sudden movement**

v. Pedestrian Prior Action and Pedestrian Location
   a. **Pedestrian crossing the roadway** while located at intersection in marked crosswalk, or in roadway not in marked crosswalk

vi. Bicyclist Prior Action and Bicyclist Location
   a. Bicyclists crossing the roadway while located at intersection in marked crosswalk

6.1.2.2. Driver Actions-Roadway Characteristics Relationships

Drive actions mean the actions by the driver that may have contributed to the crash such as exceed speed limit, following too close, failed to yield right-of-way, looked but did not see, often referring to a negative action or behavior related to driver's errors, violations or lapses. Researchers have attempted to relate drivers' actions/behavior at signalized crosswalks with roadway design characteristics (*85*, *86*) in order to find ways to modify driver's behavior for good. Hence, it is important to examine how driver actions may be affected by different roadway characteristics. Table 6-7 to Table 6-8 show drivers' contributing actions associated with crashes occurred within and at intersections and types of traffic control devise (TCD). Roadway characteristics can be a source of information for studying drivers' actions at the time of crash.

a. Driver Contributing Actions and Intersection Type

The "driver contributing action (i.e., DRVRPC)" is described as "*the possible driver contributing circumstances (Driver Factors) in a collision*" in MV4000 and "*The actions by the driver that may have contributed to the crash*" in DT4000. The data field of "intersection type" is a newly added data field in DT4000 and has a description of "*The type of intersection in which a crash occurred*".

It should be noted that the data field of driver contributing actions in MV4000 doesn't provide the option of "No Contributing Action (NO)", which has been improved in DT4000. As denoted previously, the data field of intersection type is also newly added in DT4000. From the overall data, although attributes of the driver contributing circumstances have been enhanced in the DT4000 form such as the direction of the improper overtaking, the data showed for the most common two driver circumstances were consistent between MV4000 and DT4000 forms while considering driver contributing actions alone (i.e., no contributing action and fail to yield right-of-way (ROW)). In addition, "looked but did not see" is newly added in DT4000, which presents 203 (3.11% of total) crashes, which is an immediate improvement compared to MV4000.

From Table 6-7, 1412 crashes (21.60% of total) involved a driver who failed to yield the ROW (FTY). Within this category, 513 (7.85% of total) crashes happened at 4-way intersections (4 WAY), which is the most common situation among all possible driver-at-fault scenarios within an intersection. Generally, a driver coming to a 4-way stop without traffic signal control, must yield the ROW to the person on the right. In addition, there are 234 (3.58% of total) crashes happened at T-intersections (T) with driver failing to yield. Besides, 4-way and T-intersections are the intersection types with most crashes (2666 and 754, respectively).

Table 6-7: Driver Contributing Actions and Intersection Type

DRVRPC [1, 2] [A, B, C, D]-DT	INTTYPE-DT																	
	≥ 5 WAY		4 WAY		T		Y		L		RAB		OTHR		NA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NO	15	0.23%	911	13.94%	238	3.64%	11	0.17%	6	0.09%	13	0.20%	20	0.31%	1250	19.12%	2,464	37.69%
FTY	10	0.15%	513	7.85%	234	3.58%	3	0.05%	2	0.03%	20	0.31%	21	0.32%	309	4.73%	1412	21.60%
UNKN	9	0.14%	412	6.30%	90	1.38%	4	0.06%	2	0.03%	4	0.06%	8	0.12%	571	8.73%	1,100	16.83%
NOT SEE	0	0.00%	90	1.38%	29	0.44%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	84	1.28%	203	3.11%
ID	0	0.00%	65	0.99%	24	0.37%	2	0.03%	0	0.00%	0	0.00%	0	0.00%	100	1.53%	191	2.92%
OTR	0	0.00%	44	0.67%	12	0.18%	0	0.00%	1	0.02%	0	0.00%	0	0.00%	94	1.44%	151	2.31%
UB	0	0.00%	4	0.06%	3	0.05%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	58	0.89%	65	0.99%
FVC	1	0.02%	6	0.09%	5	0.08%	1	0.02%	0	0.00%	0	0.00%	1	0.02%	44	0.67%	58	0.89%
AR	0	0.00%	4	0.06%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	1	0.02%	34	0.52%	40	0.61%
IT	0	0.00%	13	0.20%	8	0.12%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	6	0.09%	27	0.41%
TFC	0	0.00%	6	0.09%	2	0.03%	0	0.00%	0	0.00%	0	0.00%	1	0.02%	18	0.28%	27	0.41%
DTC	0	0.00%	12	0.18%	3	0.05%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	6	0.09%	21	0.32%
IOL	0	0.00%	1	0.02%	1	0.02%	0	0.00%	1	0.02%	1	0.02%	0	0.00%	17	0.26%	21	0.32%
FDL	0	0.00%	2	0.03%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	17	0.26%	20	0.31%
SPD	0	0.00%	3	0.05%	2	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	15	0.23%	20	0.31%
DSS	0	0.00%	12	0.18%	4	0.06%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.05%	19	0.29%
DRED	1	0.02%	14	0.21%	2	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	17	0.26%
IC	0	0.00%	1	0.02%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	6	0.09%	8	0.12%
WW	0	0.00%	2	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	5	0.08%	7	0.11%
FTC	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	5	0.08%	5	0.08%
DRM	0	0.00%	2	0.03%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.02%	4	0.06%
IOR	0	0.00%	2	0.03%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.05%
ROR	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.03%	2	0.03%
OVR	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.02%	1	0.02%
Other drivers contributing factors combinations (e.g., [FTY, NOT SEE])	3	0.05%	547	8.37%	92	1.41%	5	0.08%	1	0.02%	7	0.11%	9	0.14%	287	4.39%	651	9.96%
Total	39	0.60%	2666	40.78%	754	11.53%	26	0.40%	13	0.20%	45	0.69%	61	0.93%	2,933	44.87%	6,537	100.00%

b. Driver Contributing Actions and the Type of TCD

For the completion of the analysis, the type of TCD has been included, even though it is "inconsistent in Chapter 5 by comparing with the STN data. The data field of "type of TCD (TRFCNTL, TRFCCNTL)" is described as "*the traffic controls in effect at the time of a crash*" in MV4000 and "*the type of traffic control device (TCD) applicable to this motor vehicle at the crash location*" in DT4000. TCD is normally deployed to regulate drivers' risky behavior. By relating type of TCD with driver contributing action, it could help with examining the effect of different TCDs that has been installed to modify driver's behavior for good.

In DT4000, two more data attributes have been added for type of TCD, which are "School Zone Sign/ Device (SCHOOL)" and "Unknown (UNKN)". According to Table 6-8, driver failing to yield (FTY) with a traffic signal (TS OP) in control is the most common driver-at-fault situation for crashes to happen, which shows 627 (9.59% of total) crashes in MV4000 and 577 (8.83% of total) crashes in DT4000. However, it might worth noting that the deployment of specific TCD is highly based on both traffic volume and different road users' exposure. Therefore, further studies might still need to explore the true effects of different TCDs in different locations. Besides, the data field of driver contributing actions in MV4000 again doesn't provide the option of "No Contributing Action (NO)", which has been provided in DT4000 and helps separate no-fault action of a driver in a crash.

Table 6-8: Driver Contributing Actions and the Type of TCD

TRFCNTL [1, 2]-MV	DRVRPC [1, 2] [A, B, C, D]-MV															
	blank		FTY		OTHR		ID		FVC		DTC		Other drivers contributing actions (UB, FTC, IO, IT, SPD, TFC) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NONE	1942	29.71%	416	6.36%	155	2.37%	119	1.82%	70	1.07%	13	0.20%	354	5.42%	3069	46.95%
TS OP	884	13.52%	627	9.59%	28	0.43%	45	0.69%	11	0.17%	28	0.43%	119	1.82%	1742	26.65%
SS	270	4.13%	248	3.79%	14	0.21%	20	0.31%	2	0.03%	15	0.23%	45	0.69%	614	9.39%
BLNK[9]	185	2.83%	6	0.09%	1	0.02%	2	0.03%	0	0.00%	0	0.00%	5	0.08%	199	3.04%
YIELD	14	0.21%	24	0.37%	0	0.00%	1	0.02%	1	0.02%	0	0.00%	3	0.05%	43	0.66%
OTHR	18	0.28%	10	0.15%	1	0.02%	1	0.02%	1	0.02%	1	0.02%	18	0.28%	50	0.76%
TS FL	21	0.32%	10	0.15%	1	0.02%	0	0.00%	0	0.00%	1	0.02%	1	0.02%	34	0.52%
TC PR	5	0.08%	1	0.02%	2	0.03%	3	0.05%	0	0.00%	7	0.11%	8	0.12%	26	0.40%
WS FL	4	0.06%	9	0.14%	1	0.02%	1	0.02%	0	0.00%	2	0.03%	8	0.12%	25	0.38%
SS FL	3	0.05%	3	0.05%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	2	0.03%	9	0.14%
WS	4	0.06%	4	0.06%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.05%	11	0.17%
RRSIG	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.02%	1	0.02%	2	0.03%
Other TCD types combinations (e.g., [NONE, TS OP])	453	6.93%	193	2.95%	19	0.29%	15	0.23%	1	0.02%	13	0.20%	19	0.29%	713	10.91%
Total	3,803	58.18%	1551	23.73%	223	3.41%	207	3.17%	86	1.32%	81	1.24%	586	8.96%	6,537	100.00%

[9] No "BLNK" has been found or used in "Crash Data User Guide" for MV4000, but here in the data retrieved from "WisTransportal Crash Retrieval Facility", it is coded as "BLNK"

TRFCNTL [1, 2]-MV	DRVRPC [1, 2] [A, B, C, D]-MV															
	NO		FTY		UNKN		NOT SEE		ID		OTR		Other drivers contributing actions (< 1.00%, i.e., FTC, IO, IT, SPD, TFC) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NONE	1336	20.44%	375	5.74%	464	7.10%	80	1.22%	109	1.67%	100	1.53%	556	8.51%	3020	46.20%
TS OP	586	8.96%	577	8.83%	212	3.24%	56	0.86%	43	0.66%	19	0.29%	230	3.52%	1723	26.36%
STOP	158	2.42%	228	3.49%	80	1.22%	28	0.43%	19	0.29%	12	0.18%	89	1.36%	614	9.39%
UNKN	0	0.00%	3	0.05%	183	2.80%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	186	2.85%
YIELD	8	0.12%	20	0.31%	4	0.06%	0	0.00%	1	0.02%	0	0.00%	8	0.12%	41	0.63%
OTHR	3	0.05%	7	0.11%	5	0.08%	0	0.00%	0	0.00%	1	0.02%	15	0.23%	31	0.47%
TS FL	13	0.20%	9	0.14%	7	0.11%	0	0.00%	0	0.00%	1	0.02%	3	0.05%	33	0.50%
TC PR	2	0.03%	1	0.02%	2	0.03%	1	0.02%	3	0.05%	1	0.02%	16	0.24%	26	0.40%
WS FL	1	0.02%	8	0.12%	3	0.05%	0	0.00%	1	0.02%	1	0.02%	11	0.17%	25	0.38%
SS FL	2	0.03%	2	0.03%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	4	0.06%	9	0.14%
WS	3	0.05%	3	0.05%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	4	0.06%	11	0.17%
SCHOOL	7	0.11%	3	0.05%	2	0.03%	0	0.00%	1	0.02%	0	0.00%	6	0.09%	19	0.29%
RRSIG	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.03%	2	0.03%
Other TCD types combinations (e.g., [NONE, TS OP])	345	5.28%	176	2.69%	136	2.08%	38	0.58%	14	0.21%	16	0.24%	72	1.10%	797	12.19%
Total	2,464	37.69%	1412	21.60%	1100	16.83%	203	3.11%	191	2.92%	151	2.31%	1016	15.54%	6,537	100.00%

By exploring possible relationship combinations between driver actions and roadway characteristics, the most common driver action observed in VRU at intersections or in an intersection-related area is “fail to yield the ROW (FTY)”. The results of this analysis should be compared to findings from. For example, a very strong inverse correlation, with low yield rates on high-speed roadways suggests that drivers, tend not to give pedestrians’ right-of-way on marked crosswalks (*87*). In contrast, advance yield markings are associated with significant increase in the frequency of looking for pedestrians when they encountered advance yield markings (*88*). Thus, the newly added data fields reviewed in this section provide enhanced information for understanding VRU crash circumstances.

6.1.2.3. Roadway Characteristics Relationships

Roadway (e.g., interstate, junction, and roadway profile) and environmental characteristics (e.g., light condition and weather condition) often act together on the occurrence of a crash. Moreover, factors in both categories have significant effects on the injury severities of VRU involved crashes (*89*). However, studying their separate effects are common among researchers (*18*; *19*), which fails to disclose the real impact. Our analyses focus on studying the effect of a combination of roadway and environmental characteristics, which may enhance the knowledge about the crash circumstances. Unlike the previous sections, the following analyses of roadway characteristics are done on a combined dataset that includes both pedestrian and bicyclist crashes together.

Table 6-9 to Table 6-11 presents the statistical results of the following combined data fields: “Whether a Crash Occurred Within an Interchange/Junction Area and the Specific Location”, “Type of TCD and Intersection Type & Total Number of Lanes”, and “Roadway Curvature and Grade in the Direction of Vehicle Travel”.

a. Interchange/Junction Area and the Specific Location

Both “if a crash occurred within the Interchange area” (RLTNJNIC) and “specific location in a junction or interchange” (RLTNJNLC) are newly added in the DT4000.

Based on the statistics in Table 6-9, the first harmful event leading to crashes occurring at non-interchange areas-or not interchange related- add up to 88.31%, where 36.45% and 39.65% of these crashes are located at intersections and at non-junction locations. A non-interchange-related crash means that the location of the crash was not next to an interchange and did not result from an action related to the movement of traffic units through an interchange. With respect to “RLTNJNLC”, definitions of some attributes are not very clearly defined. For instance, “INR which refers to intersection-related locations, but no more descriptions have been provided in the guideline for explaining what locations should be identified as intersection-related location.

Table 6-9: Whether a Crash Occurred Within an Interchange/Junction Area and the Specific Location

RLTNJNLC-DT	RLTNJNIC-DT							
	N		Y		Unknown and blank values for if the crash occurred in an interchange area		TOTAL	
	N	%	N	%	N	%	N	%
INR	597	9.13%	105	1.61%	3	0.05%	705	10.78%
INT	2,383	36.45%	516	7.89%	26	0.40%	2,925	44.75%
NJ	2,592	39.65%	36	0.55%	13	0.20%	2,641	40.40%
DRRL	71	1.09%	0	0.00%	0	0.00%	71	1.09%
DRWY	59	0.90%	3	0.05%	0	0.00%	62	0.95%
OTHR	9	0.14%	4	0.06%	0	0.00%	13	0.20%
UNKN	6	0.09%	0	0.00%	4	0.06%	10	0.15%
Other junction /interchange locations (ACCEL, ENRP, ENRPR, EXRP, EXRPR, PATH, RR, THRU, XOVOR)	201	3.07%	38	0.58%	27	0.41%	651	9.96%
TOTAL	5,773	88.31%	695	10.63%	69	1.06%	6,537	100.00%

b. Type of TCD, Intersection Type, and Total of Lanes

Intersection configuration and traffic control are integral parts of intersection design; therefore, should be considered together. In crash data, intersection configuration is described by intersection type and the total number of lanes (on the major approach); and traffic control means the traffic control devices on all intersecting roads. Therefore, investigating the number of lanes with the intersection type, in conjunction with the type of TCD available at the intersection offers extra information about the intersection environment.

Built upon the analysis of "driver contributing actions and the type of TCD", Table 6-10 only shows "NONE", "STOP", and "TS OP" for the type of TCDs, since the number of crashes associated with other TCDs are relatively too small and don't exhibit any specific patterns. The relationship indicates that 9.06% of crashes occurred at 4-way, two-lane, traffic signal-controlled intersections, which can be seen from Table 6-10 and is also the most common situation for a VRU crash to happen. The second most common situation is that crashes occurred at 4-way, four-lane, traffic signal-controlled intersections, with 6.01% of the total VRU crashes.

Table 6-10: Type of TCD and Intersection Type & Total Number of Lanes

TRFCCNTL [1, 2]-DT	INTTYPE-DT, TOTLANES [1, 2]-DT									
	4 WAY, 2		4 WAY, 4		T, 2		Other intersection type and total lane combinations		Total	
	N	%	N	%	N	%	N	%	N	%
NONE	264	4.04%	83	1.27%	194	2.97%	2,479	37.92%	3,020	46.20%
STOP	306	4.68%	21	0.32%	123	1.88%	164	2.51%	614	9.39%

TS OP	592	9.06%	393	6.01%	35	0.54%	703	10.75%	1,723	26.36%
Other TCD types and TCD types combinations	339	5.19%	51	0.78%	131	2.00%	659	10.08%	1,180	18.05%
Total	1,501	22.96%	548	8.38%	483	7.39%	4,005	61.27%	6,537	100.00%

c. Roadway Curvature and Grade in the Direction of Vehicle Travel

While most previous research within the literature study these two factors separately, it makes more sense to explore the combined effects of them to the traffic crash between vehicle and non-motorist. Both data fields in DT4000 extend non-straight curvature attribute (i.e., hill crest [CST], uphill [UP], downhill [DN], sag/bottom [SAG]) and non-level grade attribute (i.e., curve left [LT], curve right [RT], curve-unknown direction [CU]) into more categories.

It is not hard to see from Table 6-11, DT4000 form data fields show that the vast majority (83.08%) of crashes occurred on straight (ST) and level (LVL) roads in the travel direction of the vehicle involved in the crash, while the corresponding statistics in MV4000 is 88.74%. Also, the rest of the crashes occurring on straight roadways (ST) were almost equally distributed between uphill/upgrade (UP) and downhill/downgrade (DN); 1.88% and 2.72%, respectively. Crashes on curves comprised slightly more than 5% (all crashes excluding crashes on straight roadway curvature (ST)) of all crashes. Clearly, the new attributes enhance the knowledge about the type of curvature and grade. However, due to the extremely small sample size of the data, such disaggregated information should be expected to be more helpful in the future with more data accumulation.

Table 6-11: Roadway Curvature and Grade in the Direction of Vehicle Travel

ROADVERT-MV	ROADHOR-MV					
	C		(blank)		Total	
	N	%	N	%	N	%
H			473	7.24%	532	8.14%
(blank)	204	3.12%	5,801	88.74%	6,005	91.86%
Total	263	4.02%	6,274	95.98%	6,537	100.00%

ROADVERT [1,2] -DT	ROADHOR [1,2] -DT													
	ST		RT		LT		CU		UNKN		Other horizontal road terrains combinations (e.g., [LT, ST])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
LVL	5431	83.08%	69	1.06%	66	1.01%	5	0.08%	8	0.12%	68	1.04%	5,647	86.39%
DN	178	2.72%	14	0.21%	7	0.11%	0	0.00%	0	0.00%	2	0.03%	201	3.07%
UP	127	1.94%	6	0.09%	7	0.11%	0	0.00%	0	0.00%	2	0.03%	142	2.17%
CST	42	0.64%	4	0.06%	1	0.02%	0	0.00%	0	0.00%	0	0.00%	47	0.72%
SAG	9	0.14%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	9	0.14%

UNKN	6	0.09%	0	0.00%	0	0.00%	0	0.00%	180	2.75%	1	0.02%	187	2.86%
Other vertical road terrains combinations (e.g., [CST, LVL])	186	2.85%	2	0.03%	2	0.03%	0	0.00%	1	0.02%	113	1.73%	304	4.65%
Total	5979	91.46%	95	1.45%	83	1.27%	5	0.08%	189	2.89%	186	2.85%	6,537	100.00%

In summary, Table 6-9 to Table 6-11 show multiple studied combinations of roadway characteristics, which help in recommending different actions to help minimize crashes. For instance, findings linked to poor roadway lighting provide an opportunity to suggest different roadway visibility enhancement actions or installing tools that provide drivers with better vision that help in recognizing pedestrians and bicyclists at different roadway locations. The most interesting critical crash prone patterns that have been identified in this subsection is the 4-way intersection with traffic control associated with both 2-lanes and 4-lanes roads. Other than that, crashes occurred at 4-way intersection without traffic control (TRFCCNTL [1,2]: NONE) would also need more attentions.

6.1.2.4. Relationships between Driver Actions and VRU Actions

An analysis of driver and pedestrian actions in pedestrian crashes also found that the most prevalent combination of driver and pedestrian maneuvers in both fatal and injury crashes is Driving Straight Ahead (driver action) and Crossing Not at Intersection (pedestrian action). Furthermore, making a Left Turn (driver action) and Crossing at the Intersection (pedestrian action) were the second most common combination of driver and pedestrian action (*91*, *92*). Hence, these findings support the need to study driver-non-motorist actions related to the crash. Besides, analyses for each combination are split for pedestrian and bicyclist, respectively.

Table 6-12 to Table 6-15 presents the statistical results of the following combined data fields: “Driver Contributing Action and Pedestrian Action”, “Driver Contributing Action and Bicyclist Action”, “Driver Movement and Pedestrian Action”, and “Driver Movement and Bicyclist Action”. All data fields in this section have been previously introduced and examined individually, and hereby this section will focus on presenting the critical scenarios/patterns for each combination.

a. Driver Contributing Action and Pedestrian Action

It should be noted that more than half of the data field “DRVRPC” (i.e., contributing driver action) in MV4000 are not blanks. However, no description has been found to clarify that a “BLANK” coding means no contributing driver action, especially crash number of this coding does not match the one of “NO” in DT4000. While a crash occurred with no contributing driver action presenting, the most common pedestrians’ action is darting into road (i.e., sudden movement in DT4000) with 383 crashes (9.86% of total). Driver failed to yield to ROW (FTY) is concerning as the most common contributing driver action, accounting for 888 crashes in MV4000 while the number is 802 in DT4000.

Table 6-12: Driver Contributing Action and Pedestrian Action

NMTACT [1, 2]-PED-MV	**DRVRPC [1, 2] [A, B, C, D]-MV**																	
	blank		FTY		OTHR		ID		FVC		UB		DTC		Other drivers contributing actions (< 1.00%, i.e., FTC, IO, IT, SPD, TFC) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
OTHER	974	25.07%	658	16.94%	108	2.78%	81	2.08%	54	1.39%	48	1.24%	33	0.85%	258	6.64%	2214	56.99%
DARTING INTO ROAD	436	11.22%	13	0.33%	9	0.23%	10	0.26%	3	0.08%	0	0.00%	2	0.05%	13	0.33%	486	12.51%
WALKING NOT FACING TRAFFIC	145	3.73%	86	2.21%	9	0.23%	14	0.36%	5	0.13%	4	0.10%	3	0.08%	19	0.49%	285	7.34%
WALKING FACING TRAFFIC	51	1.31%	44	1.13%	7	0.18%	3	0.08%	3	0.08%	3	0.08%	2	0.05%	11	0.28%	124	3.19%
DARK CLOTHING	50	1.29%	36	0.93%	1	0.03%	1	0.03%	1	0.03%	0	0.00%	0	0.00%	9	0.23%	98	2.52%
DISREGARDED SIGNAL	76	1.96%	5	0.13%	3	0.08%	1	0.03%	0	0.00%	0	0.00%	1	0.03%	2	0.05%	88	2.27%
Other pedestrian's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])	479	12.33%	46	1.18%	14	0.36%	13	0.33%	3	0.08%	4	0.10%	1	0.03%	30	0.77%	590	15.19%
Total	2,211	56.91%	888	22.86%	151	3.89%	123	3.17%	69	1.78%	59	1.52%	42	1.08%	342	8.80%	3,885	100.00%

NMTACT [1, 2][A,B]]-PED-DT	DRVRPC [1, 2] [A, B, C, D]-DT															
	NO		FTY		UNKN		NOT SEE		ID		OTR		Other drivers contributing actions (< 1.00%, i.e., UB, FVC, AR, IT, TFC, DTC, IOL, FDL, SPD, DSS, DRED, IC, WW, FTC, DRM, IOR, ROR, OVR) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
NO IMPR	89	2.29%	508	13.08%	213	5.48%	38	0.98%	47	1.21%	23	0.59%	342	8.80%	1260	32.43%
SUDDEN	383	9.86%	12	0.31%	38	0.98%	11	0.28%	10	0.26%	4	0.10%	28	0.72%	486	12.51%
UNKN	51	1.31%	45	1.16%	159	4.09%	15	0.39%	8	0.21%	5	0.13%	49	1.26%	332	8.55%
NF TRFC	56	1.44%	81	2.08%	78	2.01%	11	0.28%	12	0.31%	8	0.21%	39	1.00%	285	7.34%
IM XING	78	2.01%	1	0.03%	49	1.26%	4	0.10%	3	0.08%	1	0.03%	24	0.62%	160	4.12%
OTHR	35	0.90%	16	0.41%	24	0.62%	6	0.15%	4	0.10%	15	0.39%	47	1.21%	147	3.78%
FC TRFC	19	0.49%	41	1.06%	28	0.72%	3	0.08%	3	0.08%	4	0.10%	26	0.67%	124	3.19%
DK CLTH	21	0.54%	33	0.85%	22	0.57%	6	0.15%	1	0.03%	1	0.03%	14	0.36%	98	2.52%
IM RDWY	28	0.72%	1	0.03%	30	0.77%	1	0.03%	3	0.08%	4	0.10%	23	0.59%	90	2.32%
DISREG	65	1.67%	4	0.10%	10	0.26%	1	0.03%	1	0.03%	3	0.08%	4	0.10%	88	2.27%
Other pedestrian's actions (< 1.00%, i.e., STOPPED, INATTV, F YIELD, NOT VIS, F OBEY, DISABLD, RECKLSS, W WAY, IM ENTR, PASSNG) and combinations (e.g., [IM XING, F YIELD])	479	12.33%	60	1.54%	119	3.06%	17	0.44%	29	0.75%	20	0.51%	91	2.34%	815	20.98%
Total	1,304	33.56%	802	20.64%	770	19.82%	113	2.91%	121	3.11%	88	2.27%	687	17.68%	3,885	100.00%

b. Driver Contributing Action and Bicyclist Action

Compared to the previous "driver contributing action and pedestrian action" combination, for the bicycle-vehicle crashes, similar conclusions could be made according to Table 6-13, in terms of most common situations. As mentioned previously, driver failed to yield to ROW (FTY) is concerned as the most common contributing driver action (other than the situations with no driver action noted). Within this category, MV4000 shows the most frequent bicyclist's action is "OTHER (606 crashes)"; while in DT4000, the most frequent bicyclist's action is "NO IMPR (453 crashes)", which helps separate no-fault action of a bicyclist. When a crash occurred with no driver action noted, the most common bicyclists' action is darting into road (i.e., sudden movement in DT4000). Moreover, statistics in MV4000 shows 238 crashes for such situation, while DT4000 shows 202 crashes.

Table 6-13: Driver Contributing Action and Bicyclist Action

NMTACT [1, 2]-BIKE-MV	DRVRPC [1, 2] [A, B, C, D]-MV													
	blank		FTY		OTHR		ID		DTC		Other drivers contributing actions (< 1.00%, i.e., IO, IT, TFC, FTC, FVC, SPD, UB) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
OTHER	943	35.56%	606	22.85%	64	2.41%	74	2.79%	33	1.24%	181	6.83%	1901	71.68%
DARTING INTO ROAD	238	8.97%	23	0.87%	3	0.11%	4	0.15%	2	0.08%	9	0.34%	279	10.52%
DISREGARDED SIGNAL	116	4.37%	3	0.11%	2	0.08%	1	0.04%	0	0.00%	2	0.08%	124	4.68%
DARK CLOTHING	12	0.45%	13	0.49%	1	0.04%	0	0.00%	0	0.00%	5	0.19%	31	1.17%
WALKING NOT FACING TRAFFIC	1	0.04%	3	0.11%	0	0.00%	1	0.04%	0	0.00%	1	0.04%	6	0.23%
WALKING FACING TRAFFIC	4	0.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	5	0.19%
Other bicyclist's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])	278	10.48%	15	0.57%	4	0.15%	4	0.15%	4	0.15%	1	0.04%	306	11.54%
Total	1,592	60.03%	663	25.00%	74	2.79%	84	3.17%	39	1.47%	200	7.54%	2,652	100.00%

NMTACT [1, 2][A,B]-BIKE-DT	DRVRPC [1, 2] [A, B, C, D]-DT															
	NO		FTY		UNKN		NOT SEE		ID		OTR		Other drivers contributing actions (< 1.00%, i.e., UB, FVC, AR, IT, TFC, DTC, IOL, FDL, SPD, DSS, DRED, IC, WW, FTC, DRM, IOR, ROR, OVR) and combinations (e.g., [FTY, NOT SEE])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
DISREG	109	4.11%	3	0.11%	5	0.19%	1	0.04%	1	0.04%	2	0.08%	3	0.11%	124	4.68%
DK CLTH	4	0.15%	13	0.49%	5	0.19%	3	0.11%	0	0.00%	1	0.04%	5	0.19%	31	1.17%
F OBEY	62	2.34%	2	0.08%	3	0.11%	0	0.00%	0	0.00%	1	0.04%	4	0.15%	72	2.71%
F YIELD	84	3.17%	5	0.19%	5	0.19%	0	0.00%	1	0.04%	0	0.00%	2	0.08%	97	3.66%
IM ENTR	17	0.64%	5	0.19%	4	0.15%	1	0.04%	1	0.04%	2	0.08%	0	0.00%	30	1.13%
NO IMPR	114	4.30%	453	17.08%	126	4.75%	35	1.32%	47	1.77%	30	1.13%	215	8.11%	1020	38.46%
NOT VIS	9	0.34%	8	0.30%	4	0.15%	4	0.15%	0	0.00%	0	0.00%	3	0.11%	28	1.06%
OTHR	57	2.15%	25	0.94%	14	0.53%	3	0.11%	4	0.15%	6	0.23%	12	0.45%	121	4.56%
SUDDEN	202	7.62%	23	0.87%	21	0.79%	12	0.45%	4	0.15%	3	0.11%	14	0.53%	279	10.52%
UNKN	72	2.71%	32	1.21%	94	3.54%	12	0.45%	7	0.26%	8	0.30%	28	1.06%	253	9.54%
W WAY	32	1.21%	12	0.45%	4	0.15%	7	0.26%	3	0.11%	3	0.11%	6	0.23%	67	2.53%
Other bicyclist's actions (< 1.00%, i.e., INATTV, IM XING, F LGTS, IM TURN, F LANE, IM RDWY, IM CHNG, RECKLSS, PASSNG, NF TRFC, FC TRFC, NO EQIP, STOPPED, IM PASS) and combinations (e.g., [IM XING, F YIELD])	398	15.01%	29	1.09%	45	1.70%	12	0.45%	11	0.41%	7	0.26%	28	1.06%	530	19.98%
Total	1,160	43.74%	610	23.00%	330	12.44%	90	3.39%	79	2.98%	63	2.38%	320	12.07%	2,652	100.00%

c. Driver Movement and Pedestrian Action

Actions of pedestrian together with the driver's maneuver prior the beginning of the sequence of crash events, are studied and summarized in Table 6-14. It should be noted that pedestrians who did not act in any improper actions at the time of crash have been clearly recorded in DT4000, while such information has been included in "other actions" in MV4000. Statistics from DT4000 shows that more than 30% of the total pedestrian crashes (1260 crashes) with no improper action by the pedestrian, among which there were 392 crashes (10.09% of total) occurred while a driver turned left. From both forms, the most common action by a pedestrian is darting into road (i.e., sudden movement in DT4000), among which the association with driver going straight is the most common situation for a crash to happen, accounting for 356 crashes in both forms.

Table 6-14: Driver Movement and Pedestrian Action

DRVRDO [1, 2]-MV	NMTACT [1, 2] [A, B]-PED-MV															
	OTHER		DARTING INTO ROAD		WALKING NOT FACING TRAFFIC		WALKING FACING TRAFFIC		DARK CLOTHING		DISREGARDED SIGNAL		Other pedestrian's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	632	16.27%	356	9.16%	96	2.47%	26	0.67%	34	0.88%	38	0.98%	368	9.47%	1,550	39.90%
BLNK	534	13.75%	77	1.98%	91	2.34%	32	0.82%	21	0.54%	15	0.39%	93	2.39%	863	22.21%
LT TRN	491	12.64%	21	0.54%	64	1.65%	41	1.06%	27	0.69%	22	0.57%	57	1.47%	723	18.61%
RT TRN	254	6.54%	9	0.23%	19	0.49%	16	0.41%	12	0.31%	11	0.28%	29	0.75%	350	9.01%
OTHR	98	2.52%	7	0.18%	3	0.08%	2	0.05%	0	0.00%	1	0.03%	13	0.33%	124	3.19%
BACKING	99	2.55%	1	0.03%	6	0.15%	3	0.08%	1	0.03%	0	0.00%	4	0.10%	114	2.93%
SL/ST	19	0.49%	7	0.18%	0	0.00%	2	0.05%	1	0.03%	1	0.03%	12	0.31%	42	1.08%
NEGCRV	24	0.62%	5	0.13%	4	0.10%	1	0.03%	1	0.03%	0	0.00%	7	0.18%	42	1.08%
Other driver movements (< 1.00%, i.e., OVT LT, OVT RT, CHG LN, RTOR, U TURN, PARKNG, STOPED, MERGNG, LG PRK, NPASZN, IL PRK)	63	1.62%	3	0.08%	2	0.05%	1	0.03%	1	0.03%	0	0.00%	7	0.18%	77	1.98%
Total	2214	56.99%	486	12.51%	285	7.34%	124	3.19%	98	2.52%	88	2.27%	590	15.19%	3,885	100.00%

DRVRDO [1, 2]-DT	NMTACT [1, 2] [A, B]-BIKE-DT																							
	NO IMPR		SUDDEN		UNKN		NF TRFC		IM XING		OTHR		FC TRFC		DK CLTH		IM RDWY		DISREG		Other pedestrian's actions (< 1.00%, i.e., STOPPED, INATTV, F YIELD, NOT VIS, F OBEY, DISABLD, RECKLSS, W WAY, IM ENTR, PASSNG) and actions combinations (e.g., [IM XING, NF TRFC])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	242	6.23%	356	9.16%	90	2.32%	96	2.47%	84	2.16%	60	1.54%	26	0.67%	34	0.88%	40	1.03%	38	0.98%	484	12.46%	1,550	39.90%
LT TRN	392	10.09%	21	0.54%	55	1.42%	64	1.65%	9	0.23%	8	0.21%	41	1.06%	27	0.69%	2	0.05%	22	0.57%	82	2.11%	723	18.61%
blank	144	3.71%	65	1.67%	37	0.95%	45	1.16%	14	0.36%	17	0.44%	18	0.46%	10	0.26%	12	0.31%	11	0.28%	78	2.01%	451	11.61%
UNKN	139	3.58%	12	0.31%	83	2.14%	46	1.18%	22	0.57%	16	0.41%	14	0.36%	11	0.28%	14	0.36%	4	0.10%	51	1.31%	412	10.60%
RT TRN	186	4.79%	9	0.23%	36	0.93%	19	0.49%	7	0.18%	11	0.28%	16	0.41%	12	0.31%	1	0.03%	11	0.28%	42	1.08%	350	9.01%
BACKING	45	1.16%	1	0.03%	10	0.26%	6	0.15%	13	0.33%	15	0.39%	3	0.08%	1	0.03%	8	0.21%	0	0.00%	12	0.31%	114	2.93%
ACCEL	18	0.46%	2	0.05%	3	0.08%	1	0.03%	2	0.05%	7	0.18%	0	0.00%	0	0.00%	3	0.08%	1	0.03%	9	0.23%	46	1.18%
SLOWNG	12	0.31%	7	0.18%	1	0.03%	0	0.00%	2	0.05%	1	0.03%	2	0.05%	1	0.03%	1	0.03%	1	0.03%	14	0.36%	42	1.08%
NEGCRV	12	0.31%	5	0.13%	7	0.18%	4	0.10%	1	0.03%	0	0.00%	1	0.03%	1	0.03%	2	0.05%	0	0.00%	9	0.23%	42	1.08%
Other driver movements (< 1.00%, i.e., OVT LT, OVT RT, CHG LN, RTOR, U TURN, PARKNG, STOPED, MERGNG, LG PRK, NPASZN, IL PRK)	70	1.80%	8	0.21%	10	0.26%	4	0.10%	6	0.15%	12	0.31%	3	0.08%	1	0.03%	7	0.18%	0	0.00%	34	0.88%	155	3.99%
Total	1260	32.43%	486	12.51%	332	8.55%	285	7.34%	160	4.12%	147	3.78%	124	3.19%	98	2.52%	90	2.32%	88	2.27%	815	20.98%	3,885	100.00%

d. Driver Movement and Bicyclist Action

According to Table6-15, information from both MV4000 and DT4000 are nearly the same. However, again, bicyclists who did not act in any improper actions at the time of crash have been clearly recorded in DT4000, while such information has been included in “other actions” in MV4000. Additionally, not too many patterns have been observed from this combination in terms of driver’s movement by utilizing the current dataset. But it is still worth mentioning that with more data gathering in the future, such combination would help to identify the at-fault party.

Table 6-15: Driver Movement and Bicyclist Action

DRVRDO [1, 2]-MV	NMTACT [1, 2] [A, B]-PED-MV															
	OTHER		DARTING INTO ROAD		DISREGARDED SIGNAL		DARK CLOTHING		WALKING FACING TRAFFIC		WALKING NOT FACING TRAFFIC		Other bicyclist's actions combinations (e.g., [DARTING INTO ROAD, DARK CLOTHING])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	633	23.87%	147	5.54%	87	3.28%	12	0.45%	2	0.08%	4	0.15%	181	6.83%	1,066	40.20%
RT TRN	392	14.78%	65	2.45%	13	0.49%	4	0.15%	2	0.08%	0	0.00%	42	1.58%	518	19.53%
BLNK	307	11.58%	26	0.98%	8	0.30%	5	0.19%	0	0.00%	2	0.08%	31	1.17%	379	14.29%
LT TRN	285	10.75%	14	0.53%	10	0.38%	7	0.26%	1	0.04%	0	0.00%	21	0.79%	338	12.75%
OTHR	79	2.98%	5	0.19%	1	0.04%	2	0.08%	0	0.00%	0	0.00%	11	0.41%	98	3.70%
SL/ST	26	0.98%	10	0.38%	2	0.08%	0	0.00%	0	0.00%	0	0.00%	6	0.23%	44	1.66%
BACKING	26	0.98%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	8	0.30%	34	1.28%
NEGCRV	24	0.90%	1	0.04%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	5	0.19%	31	1.17%
Other driver movements (< 1.00%, i.e., OVT LT, STOPED, CHG LN, RTOR, U TURN, OVT RT, LG PRK, MERGNG, PARKNG, IL PRK)	129	4.86%	11	0.41%	2	0.08%	1	0.04%	0	0.00%	0	0.00%	1	0.04%	144	5.43%
Total	1901	71.68%	279	10.52%	124	4.68%	31	1.17%	5	0.19%	6	0.23%	306	11.54%	2,652	100.00%

DRVRDO [1, 2]-DT	NMTACT [1, 2] [A, B]-PED-DT																											
	NO IMPR		SUDDEN		UNKN		DISREG		OTHR		F YIELD		F OBEY		W WAY		DK CLTH		IM ENTR		NOT VIS		Other bicyclist's actions (< 1.00%, i.e., INATTV, IM XING, F LGTS, IM TURN, F LANE, IM RDWY, IM CHNG, RECKLSS, PASSNG, NF TRFC, FC TRFC, NO EQIP, STOPPED, IM PASS) and actions combinations (e.g., [IM XING, NF TRFC])		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GO STR	261	9.84%	145	5.47%	82	3.09%	86	3.24%	39	1.47%	61	2.30%	56	2.11%	10	0.38%	12	0.45%	14	0.53%	10	0.38%	277	10.44%	1,053	39.71%
RT TRN	227	8.56%	65	2.45%	45	1.70%	13	0.49%	29	1.09%	11	0.41%	3	0.11%	34	1.28%	4	0.15%	6	0.23%	2	0.08%	75	2.83%	514	19.38%
LT TRN	198	7.47%	14	0.53%	25	0.94%	10	0.38%	14	0.53%	7	0.26%	3	0.11%	8	0.30%	7	0.26%	0	0.00%	10	0.38%	42	1.58%	338	12.75%
blank	86	3.24%	19	0.72%	23	0.87%	8	0.30%	6	0.23%	5	0.19%	5	0.19%	8	0.30%	2	0.08%	3	0.11%	2	0.08%	41	1.55%	208	7.84%
UNKN	90	3.39%	7	0.26%	38	1.43%	0	0.00%	6	0.23%	3	0.11%	1	0.04%	1	0.04%	3	0.11%	2	0.08%	2	0.08%	18	0.68%	171	6.45%
SLOWNG	11	0.41%	9	0.34%	2	0.08%	2	0.08%	4	0.15%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	11	0.41%	42	1.58%
ENT LN	15	0.57%	2	0.08%	2	0.08%	1	0.04%	1	0.04%	1	0.04%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	14	0.53%	37	1.40%
BACKING	22	0.83%	0	0.00%	5	0.19%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	4	0.15%	34	1.28%
NEGCRV	7	0.26%	1	0.04%	10	0.38%	1	0.04%	1	0.04%	2	0.08%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	7	0.26%	30	1.13%
OTHR	7	0.26%	0	0.00%	0	0.00%	0	0.00%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	11	0.41%
Other driver movements (< 1.00%, i.e., OVT LT, STOPED, ACCEL, STARTNG, CHG LN, RTOR, U TRN, OVT RT, LG PRK, MERGING, LVG LN, LV PRK, ARKNG, IL PRK)	96	3.62%	17	0.64%	21	0.79%	3	0.11%	17	0.64%	3	0.11%	4	0.15%	4	0.15%	3	0.11%	5	0.19%	1	0.04%	40	1.51%	214	8.07%
Total	1020	38.46%	279	10.52%	253	9.54%	124	4.68%	121	4.56%	97	3.66%	72	2.71%	67	2.53%	31	1.17%	30	1.13%	28	1.06%	530	19.98%	2,652	100.00%

In summary, Table 6-12 to Table 6-15 show the relationship between driver actions and pedestrian/bicyclist actions. Drivers have a tendency to slow down when pedestrians are not looking at the approaching drivers, also drivers were also found to stop more often when approach velocity was low (*93*). Drivers' behavior in proximity of pedestrians is likely to be statistically significantly less aggressive when the approach velocity is lower, curb-side parking is not allowed, when a crosswalk exists, and when the street involves a higher number of pedestrians crossing (*94*). Hence, the aim is to study the driver-pedestrian/bicyclist interaction with an intention to propose and evaluate safety measures and traffic calming techniques.

6.1.2.5. VRU Location-Roadway Characteristics Relationships

Roadway characteristics and their association with pedestrian/bicycle-vehicle crashes has long been studied by researchers (*95–98*). The use of knowledge of the VRU location in relation to roadway characteristics at the time of crash may enrich the investigation of pedestrian/bicycle-vehicle crashes.

Table 6-16 to Table 6-17 presents the statistical results of the following combined data fields: "Pedestrian Location and Intersection Type" and "Bicyclist Location and Intersection Type". All data fields in this section have been previously introduced and examined individually, and hereby this section will focus on presenting the critical scenarios/patterns for each combination.

a. Pedestrian Location and Intersection Type

Following conclusions could be made based on the statistics in Table 6-16: the DT4000 form shows that the greatest percentage of crashes occurring at 4-way intersections (4 WAY), reported that the pedestrian was at an intersection, in a marked crosswalk (4-WAY-ATI MX, 1101 crashes, 28.34% of the total). On the other hand, more crashes happened on road not at intersection and not in marked crosswalk (NA-NAI NX, 1151 crashes, 29.63% of total). Again, this is also an example of where exposure is very important context to understand, which implies that not because these specific locations are more dangerous than others, but more pedestrian exposures and more traffic are expected within these locations.

Table 6-16: Pedestrian Location and Intersection Type

	NMTLOC [1, 2]-PED-DT																							
INTTYPE-DT	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		SDWLK		SHLDR		OTHR		Other pedestrian's locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF) and locations combinations		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
≥ 5 WAY	20	0.51%	2	0.05%	1	0.03%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	24	0.62%
4 WAY	1101	28.34%	137	3.53%	30	0.77%	166	4.27%	4	0.10%	39	1.00%	0	0.00%	5	0.13%	4	0.10%	2	0.05%	13	0.33%	1501	38.64%
T	194	4.99%	51	1.31%	4	0.10%	68	1.75%	2	0.05%	16	0.41%	2	0.05%	1	0.03%	3	0.08%	1	0.03%	4	0.10%	346	8.91%
Y	5	0.13%	4	0.10%	0	0.00%	2	0.05%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	13	0.33%
L	3	0.08%	2	0.05%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	8	0.21%
RAB	6	0.15%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	7	0.18%
OTHR	21	0.54%	2	0.05%	0	0.00%	2	0.05%	0	0.00%	1	0.03%	0	0.00%	1	0.03%	0	0.00%	0	0.00%	0	0.00%	27	0.69%
NA	200	5.15%	59	1.52%	10	0.26%	35	0.90%	60	1.54%	1151	29.63%	26	0.67%	66	1.70%	165	4.25%	44	1.13%	143	3.68%	1959	50.42%
Total	1,550	39.90%	258	6.64%	45	1.16%	275	7.08%	66	1.70%	1,209	31.12%	28	0.72%	75	1.93%	172	4.43%	47	1.21%	160	4.12%	3,885	100.00%

b. Bicyclist Location and Intersection Type

From Table 6-17, bicyclists showed the same trend as pedestrians in terms of their location in a 4-way intersection, at the time of crash. From DT4000, there were 582 vehicle-bicyclist crashes (21.95% of total) where the bicyclist was located at an intersection in a marked crosswalk (4-WAY-ATI MX). Furthermore, 321 out of these 582 4-way intersection crashes were not in the crosswalk (4-WAY-ATI NX). Similar to "pedestrian location and intersection type" combination, the facts observed for specific locations should be further examined in association with bicyclist exposures and traffic volumes to assess the risk of bicyclist.

Table 6-17: Bicyclist Location and Intersection Type

INTTYPE-DT	NMTLOC [1, 2]-BIKE-DT																									
	ATI MX		ATI NX		ATI UL		ATI UM		NAI MX		NAI NX		NAI UN		BIKE LN		SDWLK		SHLDR		OTHR		Other pedestrian's locations (DRWAY, MEDIAN, PK LN, BIKE LN, SHARED, UNKN, NOT RPT, NON TRF) and other pedestrian's locations combinations		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
≥ 5 WAY	8	0.30%	4	0.15%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	1	0.04%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	15	0.57%
4 WAY	582	21.95%	321	12.10%	36	1.36%	137	5.17%	1	0.04%	28	1.06%	0	0.00%	32	1.21%	7	0.26%	8	0.30%	4	0.15%	9	0.34%	1165	43.93%
T	160	6.03%	97	3.66%	16	0.60%	78	2.94%	0	0.00%	12	0.45%	0	0.00%	23	0.87%	4	0.15%	10	0.38%	2	0.08%	6	0.23%	408	15.38%
Y	10	0.38%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	13	0.49%
L	2	0.08%	3	0.11%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	5	0.19%
RAB	15	0.57%	18	0.68%	1	0.04%	0	0.00%	0	0.00%	3	0.11%	0	0.00%	1	0.04%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	38	1.43%
OTHR	12	0.45%	11	0.41%	0	0.00%	2	0.08%	1	0.04%	3	0.11%	0	0.00%	2	0.08%	2	0.08%	0	0.00%	0	0.00%	1	0.04%	34	1.28%
NA	121	4.56%	50	1.89%	4	0.15%	37	1.40%	36	1.36%	366	13.80%	8	0.30%	59	2.22%	102	3.85%	93	3.51%	15	0.57%	83	3.13%	974	36.73%
Total	910	34.31%	507	19.12%	57	2.15%	255	9.62%	38	1.43%	412	15.54%	8	0.30%	118	4.45%	116	4.37%	111	4.19%	21	0.79%	99	3.73%	2,652	100.00%

In summary, Table 6-16 and Table 6-17 examine pedestrian and bicyclist locations at different types of intersections. Engineering decisions can be informed by the non-motorist location. For instance, if crashes occurred not at crosswalk locations at a 4-way intersection, road markings and signs could be added at that location to reduce crash risk at the intersection and encourage pedestrians to cross in the crosswalks. Also, education messages to motorists, pedestrians, and bicyclists can emphasize looking for pedestrians located in the minor road at an intersection before making a left turn. Other education messages to motorists, can be focused on yielding the ROW when located in the minor road of a 4-way intersection.

6.1.2.6. Environmental Conditions - Roadway Characteristics Relationships

Fountas and colleagues concluded that the effect of lighting characteristics on driving behavior depends on other environmental factors, in particular weather conditions. Also, the authors stated that it should be noted that the most pronounced effect of the pedestrian involvement indicator on serious and fatal injuries is identified in the model reflecting darkness and poor weather on unlighted roadways, whereas the least pronounced effect is observed in the model reflecting daylight and poor weather (*99*).

Per the collected data, a non-negligible percentage of pedestrian/bicycle crashes occurred under certain weather and light conditions (roadway-related condition). In addition, previous research studied the relationship between crashes and environmental conditions associated with specific roadway characteristics.

For instance, the effect of road shoulder and weather conditions on crashes was studied by (*100*). Table 6-18 to Table 6-20 show multiple relationships, including: “Prevailing Atmospheric Conditions and Type/Level of Light”, “Prevailing Atmospheric Conditions-Trafficway Division”, and “Road Surface Type and Condition”. Discovering that bicyclist crashes are more likely to occur in rainy weather conditions on undivided roadways can lead to roadway division modifications.

a. Prevailing Atmospheric Conditions and Type/Level of Light

Studying the effect of adverse weather conditions accompanied with poor light conditions, other factors such as driver’s cautiousness and non-motorists obeying traffic signs, signals and police officers appear to be the reason behind noticing less crashes with such circumstances. It is clear from examining the relationship between adverse weather conditions accompanied with poor light conditions in Table 6-18 that in the DT4000 form, 44.41% of crashes occurred during the daylight, were associated with clear weather conditions existing at the time of crash (DAY-CLEAR). The information is considered consistent in the MV4000 form, as 44.65% of crashes occurred during the daylight, and were associated with clear weather conditions existing at the time of crash (blank-CLR). It should be noted that just because more crashes occurred during the daytime does not mean that daytime is riskier than night for pedestrians. This is an example of where exposure is very important context to understand. Additionally, in both crash forms, the attributes consistently describe the weather and light conditions in the roadway were the crash occurred, i.e., 13.78% of crashes occurred in dark/lighted roadways (LIGT/LITE) and during clear (CLR/CLEAR) weather conditions.

Table 6-18: Prevailing Atmospheric Conditions and Type/Level of Light

WTHRCOND -MV	LGTCOND-MV													
	DARK		LIGT		DAWN		DUSK		(blank)		Other light conditions		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
CLDY	119	1.82%	365	5.58%	46	0.70%	51	0.78%	1,099	16.81%	1	0.02%	1,681	25.72%
CLR	187	2.86%	901	13.78%	96	1.47%	135	2.07%	2,919	44.65%	3	0.05%	4,241	64.88%
RAIN	25	0.38%	242	3.70%	11	0.17%	11	0.17%	170	2.60%	0	0.00%	459	7.02%
Other weather conditions	15	0.23%	61	0.93%	4	0.06%	6	0.09%	63	0.96%	7	0.11%	156	2.39%
Total	346	5.29%	1,569	24.00%	157	2.40%	203	3.11%	4,251	65.03%	11	0.17%	6,537	100.00%

WTCOND [A, B]-DT	LGTCOND-DT													
	DARK		LITE		DAWN		DUSK		DAY		Other light conditions		Total, including other light condition combinations	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
CLDY	107	1.64%	314	4.80%	39	0.60%	46	0.70%	1,033	15.80%	5	0.08%	1,544	23.62%
CLEAR	187	2.86%	901	13.78%	96	1.47%	135	2.07%	2,903	44.41%	19	0.29%	4,241	64.88%
RAIN	24	0.37%	233	3.56%	11	0.17%	11	0.17%	165	2.52%	1	0.02%	445	6.81%
Other weather conditions	28	0.43%	121	1.85%	11	0.17%	11	0.17%	124	1.90%	12	0.18%	307	4.70%
Total	346	5.29%	1,569	24.00%	157	2.40%	203	3.11%	4,225	64.63%	37	0.57%	6,537	100.00%

b. Trafficway Divided/Undivided with Type of Division and Prevailing Atmospheric Conditions

By examining Table 6-19, both crash forms show nearly consistent information. For instance, undivided roadway sections show to be more crash prone (about 70%) than other divided roadway sections (UNDIV/ND). Whereas, more than half of the crashes (about 45%) occurred at clear atmospheric conditions (CLEAR). The DT4000 form provides an information, showing that 15.71% of crashes occurred under cloudy atmospheric conditions (CLOUDY-UNDIV), while such number in MV4000 is 18.22%.

Table 6-19: Trafficway Divided/Undivided with Type of Division and Prevailing Atmospheric Conditions

TRFCWAY -MV	WTHRCOND -MV									
	CLOUDY		CLEAR		RAIN		Other weather conditions		Total	
	N	%	N	%	N	%	N	%	N	%
D/WO	213	3.26%	429	6.56%	48	0.73%	7	0.11%	697	10.66%
ND	1,191	18.22%	3,047	46.61%	309	4.73%	110	1.68%	4,657	71.24%
D/B	120	1.84%	302	4.62%	51	0.78%	15	0.23%	488	7.47%
OW	72	1.10%	186	2.85%	19	0.29%	9	0.14%	286	4.38%
Other values describing trafficway division	85	1.30%	277	4.24%	32	0.49%	15	0.23%	409	6.26%
Total	1,681	25.72%	4,241	64.88%	459	7.02%	156	2.39%	6,537	100.00%

TRFCWAY [1, 2]_DRVR-DT	WTCOND [A, B]-DT									
	CLDY		CLEAR		RAIN		Other weather conditions		Total	
	N	%	N	%	N	%	N	%	N	%
DIV NO	187	2.86%	384	5.87%	36	0.55%	26	0.40%	633	9.68%
UNDIV	1,027	15.71%	2,921	44.68%	291	4.45%	213	3.26%	4,452	68.10%
DIV BAR	29	0.44%	92	1.41%	18	0.28%	9	0.14%	148	2.26%
DIV MBR	29	0.44%	83	1.27%	10	0.15%	7	0.11%	129	1.97%
DIV PNT	32	0.49%	91	1.39%	18	0.28%	9	0.14%	150	2.29%
OW	55	0.84%	149	2.28%	16	0.24%	11	0.17%	231	3.53%
Other values describing trafficway division	185	2.83%	521	7.97%	56	0.86%	32	0.49%	794	12.15%
Total	1,544	23.62%	4,241	64.88%	445	6.81%	307	4.70%	6,537	100.00%

c. Road Surface Type and Condition

The data field of roadway surface type (SURFTYPE) is a new addition in DT4000. Table 6-20 shows that 49.37% of crashes that took place on dry (DRY) roadway surface conditions (83.60%), and more occurred on bituminous road surfaces (BLACK) than concrete surfaces (CONC). This result is very likely due to the amount of traffic and pedestrian exposure because there is more bituminous road space around the state in places where pedestrians walk, so we would expect to see more pedestrian crashes on bituminous surface types.

Table 6-20: Road Surface Type and Condition

SURFTYPE [1, 2]	RDCOND [A, B, C]							
	DRY		WET		Other roadway surface conditions		Total	
	N	%	N	%	N	%	N	%
BLACK	3,227	49.37%	499	7.63%	136	2.08%	3,862	59.08%
CONC	1,874	28.67%	297	4.54%	71	1.09%	2,242	34.30%
Other roadway surface types	364	5.57%	49	0.75%	20	0.31%	433	6.62%
Total	5,465	83.60%	845	12.93%	227	3.47%	6,537	100.00%

6.2 Injury Severity Distribution by Crash Characteristics

Following is a summary of potential crash variables distributed by injury severity level in Table 6-21 to Table 6-25. All statistics are based on the information provided by DT4000 due to the more detailed features of the new form, which has been demonstrated in the previous sections in this chapter. One thing needs to be mentioned is that the row percentages are used here to compare which factors have the highest percentages of K or K+A severity crashes.

6.2.1. Descriptive Statistics of the Potential Contributing Driver-Related Crash Variables

According to the Table 6-21, there are 1,412 out of 6,537 crashes happened when a driver failed to yield the ROW (FTY). However, by examining the row percentage of this factor, the percentages of K (i.e., 0.85%) or K+A (i.e., 12.18%) severity crashes are lower than the overall values (i.e., 3.69% and 17.07%). On the other hand, though the number of crashes with inattentive driving (ID) is relatively small (i.e., 191 out of 6,537), it has the highest percentage of K+A severity crashes (i.e., 21.46% = 4.71% + 16.75%, higher than overall situation). Regarding the driver movement, drivers involved in crashes were going straight (GO STR) is the most common situation and has the highest K (i.e., 6.19%) and A severity (i.e., 23.36%) crashes in both numbers and row percentages. In terms of row percentages of K and A severity crashes, higher percentages have been observed for drivers backing vehicle (BACKING) than both drivers taking left turn (LT TRN) and right turn (RT TRN), based on Table 6-21. For the factor of restraint equipment in use at the time of the crash by a driver, though the most common situation is that drivers used Shoulder & lap belt (i.e., 4,587 out of 6,537), it should be noted that crashes with no restraint equipment by drivers result in the highest percentages of both K (i.e., 4.73%) and A (i.e., 20.95%) severity crashes, which are even higher than the overall statistics.

Table 6-21: Descriptive Statistics of the Potential Contributing Driver-Related Crash Variables

Variable	Indication	Injury severity									
		K		A		B		C		Subtotal	
		N	%	N	%	N	%	N	%	N	%
		241	3.69%	1,116	17.07%	3,502	53.57%	1,678	25.67%	6,537	100.00%
DRVRPC [1, 2] [A, B]	**The actions by the driver that may have contributed to the crash, based on the judgment of the law enforcement officer investigating the crash**										
	FTY	12	0.85%	172	12.18%	828	58.64%	400	28.33%	1,412	100.00%
	NO	105	4.26%	429	17.41%	1,334	54.14%	596	24.19%	2,464	100.00%
	ID	9	4.71%	32	16.75%	98	51.31%	52	27.23%	191	100.00%
	NOT SEE	6	2.96%	26	12.81%	107	52.71%	64	31.53%	203	100.00%
	Other values	109	4.81%	457	20.16%	1,135	50.07%	566	24.97%	2,267	100.00%
DRVRDOIN [1, 2]	**The controlled maneuver for this motor vehicle prior to the beginning of the sequence of events**										
	GO STR	**161**	6.19%	**608**	23.36%	1,311	50.36%	523	20.09%	2,603	100.00%
	LT TRN	7	0.66%	135	12.72%	611	57.59%	308	29.03%	1,061	100.00%
	RT TRN	8	0.93%	55	6.37%	495	57.29%	306	35.42%	864	100.00%
	BACKING	5	3.38%	21	14.19%	78	52.70%	44	29.73%	148	100.00%
	Other values	60	3.22%	297	15.96%	1,007	54.11%	497	26.71%	1,861	100.00%
	659 (10.08%) blank values										

6.2.2. Descriptive Statistics of the Potential Contributing Pedestrian-Related Crash Variables

Regarding the pedestrian's locations, "Not at Intersection-On Roadway, Not in Marked Crosswalk (NAI NX)" could be identified as the factor associated with most severe crashes, which has the highest percentages of both K (i.e., 9.02%) and A (i.e., 26.88%) severity crashes. The number of pedestrian crashes happening at this location also ranks the 2nd highest with 1,209. When examining the pedestrians' actions, the factor of improper crossing of roadway (jaywalking) by the pedestrians has the highest K+A severity crashes (i.e., 29.38% = 4.38 + 25.00%). On the other hand, crashes with pedestrians wearing dark clothes (DK CLTH) would lead to the highest percentage of K severity crashes (i.e., 7.14%) and again, it should be noted that "wearing dark clothes" is neither an action nor against the law but do require more attention. Besides, the factors of pedestrians disregarding signals (DISREG) and pedestrians with sudden movement into traffic (SUDDEN) also have higher percentages of A (i.e., 23.86% and 22.22%) severity crashes than the overall statistics (i.e., 21.31%).

Table 6-22: Descriptive Statistics of the Potential Contributing Pedestrian-Related Crash Variables

Variable	Indication	Injury severity									
		K		A		B		C		Subtotal	
		N	%	N	%	N	%	N	%	N	%
		205	5.28%	828	21.31%	1,864	47.98%	988	25.43%	3,885	100.00%
NMTLOC [1, 2]	**The location of the non-motorist with respect to the roadway at the time of the crash.**										
	ATI MX	28	1.81%	250	16.13%	786	50.71%	486	31.35%	1550	100.00%
	ATI NX	11	4.26%	61	23.64%	119	46.12%	67	25.97%	258	100.00%
	ATI UM	10	3.64%	52	18.91%	124	45.09%	89	32.36%	275	100.00%
	NAI NX	109	9.02%	325	26.88%	566	46.82%	209	17.29%	1209	100.00%
	SHLDR	21	12.21%	42	24.42%	75	43.60%	34	19.77%	172	100.00%
	Other values	65	2.92%	409	18.35%	1099	49.30%	656	29.43%	2229	100.00%
NMTACT [1, 2]	**The actions/circumstances of the non-motorist that may have contributed to the crash, based on the judgement of the law enforcement officer investigating the crash.**										
	NF TRFC	12	4.21%	49	17.19%	133	46.67%	91	31.93%	285	100.00%
	DISREG	3	3.41%	21	23.86%	43	48.86%	21	23.86%	88	100.00%
	DK CLTH	7	7.14%	20	20.41%	45	45.92%	26	26.53%	98	100.00%
	FC TRFC	6	4.84%	22	17.74%	57	45.97%	39	31.45%	124	100.00%
	IM XING	7	4.38%	40	25.00%	79	49.38%	34	21.25%	160	100.00%
	NO IMPR	35	2.78%	211	16.75%	656	52.06%	358	28.41%	1260	100.00%
	SUDDEN	18	3.70%	108	22.22%	234	48.15%	126	25.93%	486	100.00%
	Other values	117	8.45%	357	25.79%	617	44.58%	293	21.17%	1384	100.00%
NMTPRIOR [1, 2]	**The action of a non-motorist immediately prior to a crash.**										
	JOGGING	1	0.81%	26	20.97%	62	50.00%	35	28.23%	124	100.00%
	RDWY OT	28	7.39%	107	28.23%	162	42.74%	82	21.64%	379	100.00%
	WAITING	3	1.45%	39	18.84%	107	51.69%	58	28.02%	207	100.00%
	XING	106	4.40%	467	19.39%	1188	49.34%	647	26.87%	2408	100.00%
	Other values	67	8.74%	189	24.64%	345	44.98%	166	21.64%	767	100.00%

* DT4000 mistakenly reported 23 observations, showing that the pedestrian used a helmet as a safety equipment (HLMT).

6.2.3. Descriptive Statistics of the Potential Contributing Bicyclist-Related Crash Variables

Regarding bicyclists' locations, Table 6-23 shows that factors of "Not at Intersection-On Roadway, Not in Marked Crosswalk (NAI NX)" and "Shoulder / Roadside (SHLDR)" have the highest percentages of K (i.e., 4.13% and 4.50%, respectively) and K+A (i.e., 17.72% = 4.13% + 13.59% and 19.82% = 4.50% + 15.32%, respectively) severity crashes, which are much higher than the overall situation. For the prior actions of the bicyclists, highest percentages of K and A severity crashes could be observed for "Cycling Along Roadway with Traffic (In or Adjacent to Travel Lane) (W TRFC)" (i.e., 2.08% and 17.74%, respectively, higher than the overall situation mentioned above). The percentage of K severity crashes ranks 1st for the factor of bicyclists disregarding signals (DISREG) with 1.61%, and then comes the factor of bicyclist with sudden movement into traffic (SUDDEN).

Table 6-23: Descriptive Statistics of the Potential Contributing Bicyclist-Related Crash Variables

Variable	Indication	Injury severity									
		K		A		B		C		Subtotal	
		N	%	N	%	N	%	N	%	N	%
		36	1.36%	288	10.86%	1,638	61.76%	690	26.02%	2,652	100.00%
NMTLOC [1, 2]	**The location of the non-motorist with respect to the roadway at the time of the crash.**										
	ATI MX	**5**	0.55%	**60**	6.59%	559	61.43%	286	31.43%	910	100.00%
	ATI NX	**4**	0.79%	**83**	16.37%	312	61.54%	108	21.30%	507	100.00%
	ATI UM	**1**	0.39%	**23**	9.02%	160	62.75%	71	27.84%	255	100.00%
	BIKE LN	0	0.00%	12	10.17%	75	63.56%	31	26.27%	118	100.00%
	NAI NX	17	4.13%	56	13.59%	256	62.14%	83	20.15%	412	100.00%
	SHLDR	5	4.50%	17	15.32%	66	59.46%	23	20.72%	111	100.00%
	Other values	4	1.18%	37	10.91%	210	61.95%	88	25.96%	339	100.00%
NMTPRIOR [1, 2]	**The action of a non-motorist immediately prior to a crash.**										
	A TRFC	0	0.00%	13	12.04%	70	64.81%	25	23.15%	108	100.00%
	RDWY OT	10	3.75%	31	11.61%	159	59.55%	67	25.09%	267	100.00%
	SIDE WK	1	0.24%	28	6.64%	264	62.56%	129	30.57%	422	100.00%
	W TRFC	11	2.08%	94	17.74%	334	63.02%	91	17.17%	530	100.00%
	XING	10	0.90%	97	8.73%	681	61.30%	323	29.07%	1,111	100.00%
	Other values	4	1.87%	25	11.68%	130	60.75%	55	25.70%	214	100.00%

	The actions/circumstances of the non-motorist that may have contributed to the crash, based on the judgement of the law enforcement officer investigating the crash.										
NMTACT [1, 2]	DISREG	2	1.61%	13	10.48%	83	66.94%	26	20.97%	124	100.00%
	NO IMPR	7	0.69%	93	9.12%	652	63.92%	268	26.27%	1,020	100.00%
	SUDDEN	4	1.43%	33	11.83%	165	59.14%	77	27.60%	279	100.00%
	Other values	23	1.87%	149	12.12%	738	60.05%	319	25.96%	1,229	100.00%

6.2.4. *Descriptive Statistics of the Potential Contributing Roadway-Related Crash Variables*

Though crashes happening at two-way-not divided (UNDIV) trafficways result in the most number of crashes (i.e., 4,452 out of 6,537), compared to all displayed divided trafficways in the Table 6-24 (i.e., divided highway without traffic barrier (DIV NO), two-way, divided, unprotected (painted > 4 feet) median (DIV PNT), divided highway with traffic barrier (DIV BAR), and divided highway median with barrier (DIV MBR)), two-way-not divided (UNDIV) trafficways have relatively lower percentage of K severity crashes (i.e., 3.21%). Besides, statistics of most factors in this category show that the results meet the common expectations. For instance, regarding the total number of lanes, it could be observed that more lanes means higher percentage of K+A severity crashes. Moreover, compared to crashes occurred on dry roadway surface, crashes occurred on wet roadway surface led to a slightly higher percentages of K and A severity crashes.

Table 6-24: Descriptive Statistics of the Potential Contributing Roadway-Related Crash Variables

Variable	**Indication**	**Injury severity**									
		K		**A**		**B**		**C**		**Subtotal**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
		241	3.69%	1,116	17.07%	3,502	53.57%	1,678	25.67%	6,537	100.00%
	Indication of whether or not the trafficway for this vehicle is divided and whether it serves one-way or two-way traffic.										
TRFCWAY [1, 2]	UNDIV	143	3.21%	769	17.27%	2,425	54.47%	1,115	25.04%	4,452	100.00%
	DIV NO	52	8.21%	116	18.33%	326	51.50%	139	21.96%	633	100.00%
	OW	3	1.30%	32	13.85%	137	59.31%	59	25.54%	231	100.00%
	DIV BAR	15	10.14%	37	25.00%	47	31.76%	49	33.11%	148	100.00%
	DIV MBR	8	6.20%	31	24.03%	46	35.66%	44	34.11%	129	100.00%
	DIV PNT	10	6.67%	25	16.67%	80	53.33%	35	23.33%	150	100.00%
	Other values	10	1.26%	106	13.35%	441	55.54%	237	29.85%	794	100.00%

TOTLANES [1, 2]	1 Lane	7	2.52%	31	11.15%	163	58.63%	77	27.70%	278	100.00%
	2 Lanes	137	3.39%	744	18.40%	2,158	53.36%	1,005	24.85%	4,044	100.00%
	3 Lanes	18	6.62%	49	18.01%	143	52.57%	62	22.79%	272	100.00%
	>3 Lanes	75	5.89%	242	19.01%	631	49.57%	325	25.53%	1,273	100.00%
	Other values	4	0.60%	50	7.46%	407	60.75%	209	31.19%	670	100.00%
RDCOND [A, B, C]	**The roadway surface condition at the time and place of a crash.**										
	DRY	194	3.55%	912	16.69%	2,973	54.40%	1,386	25.36%	5,465	100.00%
	WET	35	4.14%	153	18.11%	423	50.06%	234	27.69%	845	100.00%
	Other values	12	5.29%	51	22.47%	106	46.70%	58	25.55%	227	100.00%
RLTNRDWY	**The location of the first harmful event as it relates to its position within or outside the trafficway.**										
	ON	218	3.54%	1,050	17.07%	3,293	53.54%	1,590	25.85%	6,151	100.00%
	R SIDE	9	5.26%	23	13.45%	101	59.06%	38	22.22%	171	100.00%
	LTSH/RTSH	10	10.10%	22	22.22%	49	49.49%	18	18.18%	99	100.00%
	Other values	4	3.45%	21	18.10%	59	50.86%	32	27.59%	116	100.00%
RLTNJNLC	**The location of the first harmful event of the crash. It identifies the crash's location with respect to presence in a junction or proximity to components typically in a junction or an interchange area. This field identifies the specific location in a junction or interchange.**										
	INR	12	1.70%	115	16.31%	402	57.02%	176	24.96%	705	100.00%
	INT	51	1.74%	414	14.15%	1,596	54.56%	864	29.54%	2,925	100.00%
	NJ	173	6.55%	556	21.05%	1,337	50.62%	575	21.77%	2,641	100.00%
	Other values	5	1.88%	31	11.65%	167	62.78%	63	23.68%	266	100.00%
RLTNJNIC	**The location of the first harmful event of the crash. It identifies the crash's location with respect to the presence in a junction or proximity to components typically in a junction or an interchange area. This field identifies if a crash occurred within the Interchange area. (Y/N/UNKN).**										
	N	229	3.97%	1,001	17.34%	3,081	53.37%	1,462	25.32%	5,773	100.00%
	UNKN	0	0.00%	9	19.57%	25	54.35%	12	26.09%	46	100.00%
	Y	12	1.73%	104	14.96%	384	55.25%	195	28.06%	695	100.00%
	blank	0	0.00%	2	8.70%	12	52.17%	9	39.13%	23	100.00%
ROADHOR [1, 2]	**The horizontal road terrain at the point of impact.**										
	LT	5	6.02%	19	22.89%	48	57.83%	11	13.25%	83	100.00%
	RT	9	9.47%	18	18.95%	49	51.58%	19	20.00%	95	100.00%
	ST	222	3.71%	1,023	17.11%	3,194	53.42%	1,540	25.76%	5,979	100.00%
	Other values	5	1.32%	56	14.74%	211	55.53%	108	28.42%	380	100.00%

	The vertical road terrain at the point of impact.										
	DN	18	8.96%	46	22.89%	104	51.74%	33	16.42%	201	100.00%
	CST	2	4.26%	10	21.28%	31	65.96%	4	8.51%	47	100.00%
ROADVERT [1, 2]	LVL	202	3.58%	951	16.84%	3,004	53.20%	1,490	26.39%	5,647	100.00%
	SAG	1	11.11%	3	33.33%	4	44.44%	1	11.11%	9	100.00%
	UP	10	7.04%	37	26.06%	76	53.52%	19	13.38%	142	100.00%
	Other values	8	1.63%	69	14.05%	283	57.64%	131	26.68%	491	100.00%
	The type of intersection in which a crash occurred. An intersection consists of two or more roadways that intersect at the same level.										
	5	1	2.56%	3	7.69%	18	46.15%	17	43.59%	39	100.00%
	4 WAY	45	1.69%	397	14.89%	1,454	54.54%	770	28.88%	2,666	100.00%
	L	0	0.00%	1	7.69%	8	61.54%	4	30.77%	13	100.00%
INTTYPE	RAB	0	0.00%	8	17.78%	28	62.22%	9	20.00%	45	100.00%
	T	15	1.99%	96	12.73%	429	56.90%	214	28.38%	754	100.00%
	Y	0	0.00%	7	26.92%	13	50.00%	6	23.08%	26	100.00%
	Other values	180	6.01%	604	20.17%	1,552	51.84%	658	21.98%	2,994	100.00%
	NA	2933 (43.67%)									
	The type of traffic control device (TCD) applicable to this motor vehicle at the crash location.										
	NONE	183	6.06%	665	22.02%	1,561	51.69%	611	20.23%	3,020	100.00%
TRFCCNTL [1, 2]	STOP	5	0.81%	62	10.10%	333	54.23%	214	34.85%	614	100.00%
	TS OP	32	1.86%	237	13.76%	916	53.16%	538	31.22%	1,723	100.00%
	Other values	21	1.78%	152	12.88%	692	58.64%	315	26.69%	1,180	100.00%
	The type of location at which a crash occurred.										
LOCTYPE	I	62	1.72%	522	14.48%	1,986	55.11%	1,034	28.69%	3,604	100.00%
	N	179	6.10%	594	20.25%	1,516	51.69%	644	21.96%	2,933	100.00%
	CONC	75	3.35%	365	16.28%	1,180	52.63%	622	27.74%	2,242	100.00%
SURFTYPE	BLACK	160	4.14%	685	17.74%	2,084	53.96%	933	24.16%	3,862	100.00%
	Other values	2	2.78%	11	15.28%	42	58.33%	17	23.61%	72	100.00%

6.2.5. Descriptive Statistics of the Potential Contributing Environmental Condition-Related Crash Variables

Table 6-25 shows the descriptive analysis of environmental condition related crash variables. Similar to the previous category of "Roadway-Related Crash Variables", statistics for most environmental condition related crash variables meet common expectations, hence no more explanations will be provided here.

Table 6-25: Descriptive Statistics of the Potential Contributing Environmental Condition-Related Crash Variables

Variable	Indication	Injury severity									
		K		A		B		C		Subtotal	
		N	%	N	%	N	%	N	%	N	%
		241	3.69%	1,116	17.07%	3,502	53.57%	1,678	25.67%	6,537	100.00%
WTCOND [A, B]	**The prevailing atmospheric conditions that existed at the time of the crash.**										
	CLDY	69	4.47%	260	16.84%	828	53.63%	387	25.06%	1,544	100.00%
	CLEAR	146	3.44%	714	16.84%	2,298	54.19%	1,083	25.54%	4,241	100.00%
	RAIN	14	3.15%	80	17.98%	227	51.01%	127	28.54%	445	100.00%
	Other values	12	3.91%	62	20.20%	149	48.53%	81	26.38%	307	100.00%
LGTCOND	**The type/level of light that existed at the time of the motor vehicle crash.**										
	DARK	66	19.08%	99	28.61%	137	39.60%	44	12.72%	346	100.00%
	DAWN	8	5.10%	23	14.65%	89	56.69%	37	23.57%	157	100.00%
	DAY	86	2.04%	556	13.16%	2,424	57.37%	1,159	27.43%	4,225	100.00%
	DUSK	8	3.94%	31	15.27%	119	58.62%	45	22.17%	203	100.00%
	LITE	72	4.59%	400	25.49%	715	45.57%	382	24.35%	1,569	100.00%
	Other Values	1	2.70%	7	18.92%	18	48.65%	11	29.73%	37	100.00%

7. STATISTICAL TESTS OF INJURY SEVERITY PROPORTION

The purposeful selection process begins by a univariate analysis of each variable. Any variable having a significant univariate test at a predetermined level of significance is selected as a candidate for the multivariate analysis. We based this on the Wald test from logistic regression and p-value cut-off point of 0.25 because more traditional levels such as 0.05 can fail to identify variables known to be important.

As introduced in the Section of METHODOLOGY, Z-test is selected concerning injury severity proportion for each new variable created from a multi-variable analysis. Results of this analysis can be found in Table 7-1 to Table 7-4. These results show the proportion of fatal injury, severe injury, and non-severe injury including evident and possible injury crashes by variable and identify the crash variables that have a significantly different proportion of fatal injury and severe injury crashes versus non-severe injury crashes. A $(++)$ symbol implies crash variables with significantly higher proportion of fatalities and severe injuries at a 95% confidence level, and a $(-)$ symbol implies crash variables with significantly lower proportion of fatalities injuries at a 95% confidence level.

7.1 Pedestrian Crash Variables Using MV4000 Dataset

7.1.1. Roadway-Environmental-Related

As demonstrated in Table 7-1, most common roadway environmental-related variable that yielded severe and fatal pedestrian crashes was when crashes occur on curve (not straight) and hill (not level) road terrain (ROADHOR_C- ROADVERT_H; 1.36%). The next most common crash variable within this group that yielded higher severe and fatal pedestrian crashes proportions than non-severe crashes proportion was when streetlight is available at time of crash in a divided trafficway without a traffic barrier (LGTCOND_LIGT-TRFCWAY_D_WO; 6.10%). The last two variables in this group that produced higher sever and fatal injury crashes proportions were both associated with roadways with available light (dark), but one is under clear weather (LGTCOND_DARK-WTHRCOND_CLR; 7.65%) and another is under cloudy weather (LGTCOND_DARK-WTHRCOND_CLDY; 5.61). No difference has been found for variable of "LGTCOND_LIGT-TRFCWAY_ND" (streetlight is available at time of crash in undivided trafficway) between proportions of severe/fatal injury crashes and non-severe injury crashes.

Table 7-1: Summary of the Z-test for Proportion Results for the Newly Created Pedestrian Crash Variables.

Variable Symbol	Variable Indication	Fatal Injury Crash (K)	Severe Injury Crash (A)	Fatal and Severe Injury Crash (K+A)	Evident and Possible Injury Crash (B+C)	Sig. Result of the Z-Test (K+A vs. B+C)
Roadway-Environmental-Related						
LGTCOND_LIGT-TRFCWAY_D_WO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier	7.32%	5.80%	6.10%	3.23%	+ +
LGTCOND_LIGT-TRFCWAY_ND	Streetlight is available at time of crash in undivided trafficway	19.51%	28.02%	26.33%	19.46%	
LGTCOND_DARK-WTHRCOND_CLDY	No light (dark) is available at time of crash under cloudy weather	12.20%	3.99%	5.61%	1.82%	+ +
LGTCOND_DARK-WTHRCOND_CLR	No light (dark) is available at time of crash under clear weather	15.12%	5.80%	7.65%	2.28%	+ +
ROADHOR_C- ROADVERT_H	Curve (not straight) and hill (not level) road terrain	0.98%	1.45%	1.36%	0.49%	+ +
Driver- Environmental Related						
LGTCOND_LIGT-DRVRDO_GO_STR	Streetlight is available at time of crash and driver going straight	20.98%	24.76%	24.01%	9.54%	+ +
LGTCOND_DARK-DRVRDO_GO_STR	No light (dark) is available at time of crash and driver going straight	21.46%	7.13%	9.97%	2.14%	+ +
Pedestrian- Environmental Related						
LGTCOND_DARK-NMTLOC_2	No light (dark) is available at time of crash and pedestrian located in roadway	21.46%	7.49%	10.26%	3.12%	+ +

WTHRCOND_CLDY-NMTLOC_2	Crash occurred under cloudy weather and pedestrian located in roadway	19.02%	15.22%	15.97%	10.27%	+ +
Pedestrian-Driver Related						
DRVRDO_GO_STR-NMTACT_1	Driver going straight and pedestrian walking not facing traffic	3.41%	2.78%	2.90%	2.31%	
DRVRDO_GO_STR-NMTLOC_2	Driver going straight and pedestrian located in roadway	45.85%	35.51%	37.56%	21.14%	+ +
DRVRDO_LT_TRN-NMTLOC_1	Driver left turn and pedestrian located in crosswalk	1.95%	9.54%	8.03%	16.58%	−
Total Cashes (N=3,885)		**205**	**828**	**1,033**	**2,852**	

Note: The significant value (Sig. Result of the Z-Test) is a result of the Z-test of the Difference Between Two Proportions; the proportion of crashes resulting in a fatal (K) versus the proportion of crashes resulting in an evident (B) and possible (C) injury for each new variable resulting from a multi-variable analysis, where; − = proportion of crashes resulting in a fatal (K) is significantly lower at 95% confidence level, + + = proportion of crashes resulting in a fatal (K) and sever (A) injury is significantly higher at 95% confidence level.

7.1.2. Driver-Environmental Related

Both driver weather-related variables yielded higher severe and fatal injury crashes proportions in this group, which were when drivers go straight while streetlight is available (LGTCOND_LIGT-DRVRDO_GO_STR) and when drivers go straight without available streetlight (LGTCOND_DARK-DRVRDO_GO_STR), associated with 37.56%, and 24.01% fatal and severe pedestrian crashes, respectively. Such results indicate that the availability of streetlight does not change the effect of driver going straight towards the severe and fatal bicyclist crashes. The results for these two variables are consistent across all datasets in this chapter.

7.1.3. Pedestrian- Environmental Related

In this group, crashes occurred under cloudy weather while pedestrians were located in roadway (WTHRCOND_CLDY-NMTLOC_2), and crashes occurred on roadways with no available light (dark) while pedestrians were located in roadway (LGTCOND_DARK-NMTLOC_2), were two most common pedestrian weather-related variables that were responsible for 15.97%, and 10.26% of fatal and severe injury pedestrian crashes, respectively.

7.1.4. Pedestrian-Driver Related

One variable in this group that produced higher sever and fatal injury crashes was driver going straight while pedestrian were located in roadway (DRVRDO_GO_STR-NMTLOC_2), which is responsible for 37.56% of sever and fatal injury crashes. On the contrary, left turning by drivers while pedestrians were located in crosswalk produced less sever and fatal injury crashes proportions, associated with 8.03% of sever and fatal injury crashes (vs. non-severe injury crashes 16.58%). No difference has been found for variable of "DRVRDO_GO_STR-NMTACT_1" (drivers going straight while pedestrians were walking not facing traffic) between proportions of severe/fatal injury crashes and non-severe injury crashes.

7.2 Pedestrian Crash Variables Using DT4000 Dataset

Same variables were also examined using the DT4000 dataset, basically since many variables related to roadway, weather, environment, vehicle, crash, and person involved in the crash have been recategorized and some have different meanings. Results are shown in Table 7-2.

Table 7-2: Summary of the Z-test for Proportion Results for the Newly Created Pedestrian Crash Variables.

Variable Symbol	Variable Indication	Fatal Injury Crash (K)	Severe Injury Crash (A)	Fatal and Severe Injury Crash (K+A)	Evident and Possible Injury Crash (B+C)	Sig. Result of the Z-Test (K+A vs. B+C)
Roadway-Environmental-Related						
LGTCOND_LITE-TRFCWAY_DIV_NO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier	7.32%	5.80%	6.10%	3.23%	+ +
LGTCOND_LITE-TRFCWAY_UNDIV	Streetlight is available at time of crash in undivided trafficway	18.54%	27.05%	25.36%	18.97%	+ +
LGTCOND_DARK-WTCOND_CLDY	No light (dark) is available at time of crash under cloudy weather	11.22%	3.62%	5.13%	1.65%	+ +
LGTCOND_DARK-WTCOND_CLEAR	No light (dark) is available at time of crash under clear weather	15.12%	5.80%	7.65%	2.28%	+ +
ROADHOR_LT_RT_CU-ROADVERT_CST_UP_DN_SAG	Curve (not straight) and hill (not level) road terrain	2.44%	5.68%	5.03%	5.47%	
Driver- Environmental Related						
LGTCOND_LITE-DRVRDOIN_GO_STR	Streetlight is available at time of crash and driver going straight	20.98%	24.76%	24.01%	9.54%	+ +
LGTCOND_DARK-DRVRDOIN_GO_STR	No light (dark) is available at time of crash and driver going straight	23.41%	7.13%	10.36%	2.14%	+ +
Pedestrian- Environmental Related						
LGTCOND_DARK-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	No light (dark) is available at time of crash and pedestrian located in roadway	26.34%	9.30%	12.68%	3.89%	+ +

WTCOND_CLDY-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	Crash occurred under cloudy weather and pedestrian located in roadway	21.95%	15.10%	16.46%	9.61%	+ +
Pedestrian-Driver Related						
DRVRDOIN_GO_STR-NMTACT_NF_TRFC	Driver going straight and pedestrian walking not facing traffic	3.41%	2.78%	2.90%	2.31%	
DRVRDOIN_GO_STR-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	Driver going straight and pedestrian located in roadway	49.76%	38.65%	40.85%	22.72%	+ +
DRVRDOIN_LT_TRN-NMTLOC_ATI_MX-NAI_MX	Driver left turn and pedestrian located in crosswalk	1.95%	9.54%	8.03%	16.58%	−
Total Cashes (N=3,885)		**205**	**828**	**1,033**	**2,852**	

Note: The significant value (Sig. Result of the Z-Test) is a result of the Z-test of the Difference Between Two Proportions; the proportion of crashes resulting in a fatal (K) versus the proportion of crashes resulting in an evident (B) and possible (C) injury for each new variable resulting from a multi-variable analysis, where; − = proportion of crashes resulting in a fatal (K) is significantly lower at 95% confidence level, + + = proportion of crashes resulting in a fatal (K) and sever (A) injury is significantly higher at 95% confidence level.

7.2.1. Roadway-Environmental-Related

According to Table 7-2, the variable of "ROADHOR_LT_RT_CU-ROADVERT_CST_UP_DN_SAG" (crashes occurred on curve (not straight) and hill (not level) road terrain) was the only variable for that no difference has been found between the proportions of severe/fatal injury crashes and non-severe injury crashes. With that being said, variables of "LGTCOND_LITE-TRFCWAY_DIV_NO" (streetlight is available at time of crash in a divided trafficway without a traffic barrier), "LGTCOND_LITE-TRFCWAY_UNDIV" (streetlight is available at time of crash in undivided trafficway), "LGTCOND_DARK-WTCOND_CLDY", (no light (dark) is available at time of crash under cloudy weather), and "LGTCOND_DARK-WTCOND_CLEAR" (no light (dark) is available at time of crash under clear weather) were found to produce higher severe and fatal injury crashes proportions, associated with 6.10%, 25.36%, 5.13%, and 7.65% of severe and fatal injury crashes, respectively.

7.2.2. Driver- Environmental Related

Both driver weather-related variables yielded higher severe and fatal injury crashes proportions in this group, which were when drivers go straight while streetlight is available (LGTCOND_LIGT-DRVRDO_GO_STR) and when drivers go straight without available streetlight (LGTCOND_DARK-DRVRDO_GO_STR), associated with 24.01%, and 10.36% fatal and severe pedestrian crashes, respectively.

7.2.3. Pedestrian - Environmental Related

Crashes occurred under clear weather while pedestrians were located in roadway (WTCOND_CLDY- NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR), and crashes occurred on roadways with no available light (dark) and while pedestrians were located in roadway (LGTCOND_DARK- NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR), were two most common pedestrian weather-related variables that were responsible for 16.46%, and 12.68% fatal and severe injury pedestrian crashes, respectively.

7.2.4. Pedestrian -Driver Related

Drivers going straight while pedestrians were acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway at time of crash (DRVRDOIN_GO_STR-NMTACT_OTHER_NF_TRFC-DISREG-SUDDEN-DK_CLTH-FC_TRFC), were responsible for 27.98% of the fatal and severe pedestrian crashes, which produced higher severe and fatal injury crashes proportions. Crashes occurred at the time when drivers turn left with pedestrians being located in crosswalk was a variable that yielded significant less severe and fatal injury crashes proportions (8.03% vs. non-severe injury crashes with 16.58%).

7.3 Bicyclist Crash Variables Using MV4000 Dataset

7.3.1. Roadway-Environmental-Related

The most common roadway environmental-related variable that yielded higher severe fatal and severe bicyclist crashes proportions were associated with no available light (dark) in roadways at time of crash under cloudy weather conditions (LGTCOND_DARK-WTHRCOND_CLDY; 1.23%). Another most common variable in this group that produced higher severe and fatal injury crashes proportions was "LGTCOND_LIGT-TRFCWAY_D_WO" (streetlight is available at time of crash in a divided trafficway without a traffic barrier), responsible for 2.47% of severe and fatal injury crashes. For the other three variables within this group, no difference has been found between the proportions of severe/fatal injury crashes and non-severe injury crashes.

7.3.2. Driver- Environmental Related

Driver going straight while no streetlight (dark) is available at the time of crash (LGTCOND_DARK-DRVRDO_GO_STR), and while streetlight is available at time of crash (LGTCOND_LIGT-DRVRDO_GO_STR) were the most common driver-weather related variables that yielded higher severe and fatal injury crashes proportions, associated with 3.40% and 8.64% of sever and fatal injury crashes, respectively.

7.3.3. Bicyclist - Environmental Related

Concerning bicyclist weather-related variables, no differences have been found for any newly created variables in this group between the proportions of severe/fatal injury crashes and non-severe injury crashes.

7.3.4. Bicyclist -Driver Related

Similar to pedestrian crashes, drivers going straight while bicyclists were located in roadway (DRVRDOIN_GO_STR-NMTLOC_2), were responsible for 39.81% of fatal and severe bicyclist crashes, which also yielded higher severe and fatal injury crashes proportions. On the other hand, crashes occurred when pedestrians were located in the roadway with left turning by drivers (DRVRDOIN_LT_TRN-NMTLOC_1) produced less sever and fatal injury crashes associated with 2.47% of sever and fatal injury crashes (vs. non-severe injury crashes 4.64%).

Table 7-3: Summary of the Z-test for Proportion Results for the Newly Created Bicyclist Crash Variables.

Variable Symbol	Variable Indication	Fatal Injury Crash (K)	Severe Injury Crash (A)	Fatal and Severe Injury Crash (K+A)	Evident and Possible Injury Crash (B+C)	Sig. Result of the Z-Test (K+A vs. B+C)
Roadway-Environmental-Related						
LGTCOND_LIGT-TRFCWAY_D_WO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier	5.56%	2.08%	2.47%	1.03%	+ +
LGTCOND_LIGT-TRFCWAY_ND	Streetlight is available at time of crash in undivided trafficway	5.56%	10.42%	9.88%	7.43%	
LGTCOND_DARK-WTHRCOND_CLDY	No light (dark) is available at time of crash under cloudy weather	8.33%	0.35%	1.23%	0.21%	+ +
LGTCOND_DARK-WTHRCOND_CLR	No light (dark) is available at time of crash under clear weather	8.33%	2.08%	2.78%	1.46%	
ROADHOR_C- ROADVERT _H	Curve (not straight) and hill (not level) road terrain	5.56%	1.04%	1.54%	1.12%	
Driver- Environmental Related						
LGTCOND_LIGT-DRVRDO_GO_STR	Streetlight is available at time of crash and driver going straight	8.33%	8.68%	8.64%	4.21%	+ +
LGTCOND_DARK-DRVRDO_GO_STR	No light (dark) is available at time of crash and driver going straight	11.11%	2.43%	3.40%	0.77%	+ +
Bicyclist - Environmental Related						
LGTCOND_DARK-NMTLOC_2	No light (dark) is available at time of crash and bicyclist located in roadway	8.33%	1.39%	2.16%	0.99%	

WTHRCOND_CLOUDY-NMTLOC_2	Crash occurred under clear weather and bicyclist located in roadway	11.11%	13.54%	13.27%	10.18%	
Bicyclist -Driver Related						
DRVRDO_GO_STR-NMTACT_1	Driver going straight and bicyclist walking not facing traffic	0.00%	0.35%	0.31%	0.13%	
DRVRDOIN_LT_TRN-NMTLOC_1	Driver left turn and bicyclist located in crosswalk	0.00%	2.78%	2.47%	4.64%	−
DRVRDOIN_GO_STR-NMTLOC_2	Driver going straight and bicyclist located in roadway	58.33%	37.50%	39.81%	21.56%	+ +
Total Cashes (N=2,652)		**36**	**288**	**324**	**2,328**	

Note: The significant value (Sig. Result of the Z-Test) is a result of the Z-test of the Difference Between Two Proportions; the proportion of crashes resulting in a fatal (K) versus the proportion of crashes resulting in an evident (B) and possible (C) injury for each new variable resulting from a multi-variable analysis, where; − = proportion of crashes resulting in a fatal (K) is significantly lower at 95% confidence level, + + = proportion of crashes resulting in a fatal (K) and sever (A) injury is significantly higher at 95% confidence level.

7.4 Bicyclist Crash Variables Using DT4000 Dataset

Same variables were also examined using the DT4000 dataset, basically since many variables related to roadway, weather, environment, vehicle, crash, and person involved in the crash have been recategorized and some have different meanings. Results are shown in Table 7-4.

7.4.1. Roadway-Environmental-Related

According to Table 7-4, the only variable that has been tested to show significant difference between proportions of severe and fatal injury crashes and non-severe injury crashes was "LGTCOND_DARK-WTCOND_CLDY" (no light (dark) is available at time of crash under cloudy weather), which yielded higher severe and fatal injury crashes proportions (1.23% vs. non-severe injury crashes proportion with 0.13%).

7.4.2. Driver- Environmental Related

As mentioned previously, the results for the two variables in this group (i.e., "LGTCOND_LITE-DRVRDOIN_GO_STR" and "LGTCOND_DARK-DRVRDOIN_GO_STR") are consistent across all datasets in this chapter, associated with 8.64% and 3.40% of severe and fatal injury crashes, respectively.

7.4.3. Bicyclist - Environmental Related

Crashes occurred under clear weather while bicyclists were located in roadway (WTCOND_CLDY- NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR), and crashes occurred on roadways with no available light (dark) and while bicyclists were located in roadway (LGTCOND_DARK- NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR), were two most common bicyclist-weather related variables that were responsible for 3.70%, and 16.98% fatal and severe injury pedestrian crashes, respectively. It should be noted that these two corresponding variables in MV4000 dataset does not show any significant difference between the proportions of severe/fatal injury crashes and non-severe injury crashes. Such difference relies on the detail attributes of non-motorist's location.

7.4.4. Bicyclist -Driver Related

Drivers going straight while bicyclists were acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway at time of crash (DRVRDOIN_GO_STR-NMTACT_OTHER_NF_TRFC-DISREG-SUDDEN-DK_CLTH-FC_TRFC), were responsible for 22.22% of the fatal and severe bicyclist crashes, which produced higher severe and fatal injury crashes proportions. Crashes occurred at the time when drivers turn left with bicyclists being located in crosswalk (DRVRDOIN_LT_TRN-NMTLOC__ATI_MX-NAI_MX) was a variable that yielded significant less severe and fatal injury crashes proportions (2.47% vs. non-severe injury crashes with 4.64%).

Table 7-4: Summary of the Z-test for Proportion Results for the Newly Created Bicyclist Crash Variables.

Variable Symbol	Variable Indication	Fatal Injury Crash (K)	Severe Injury Crash (A)	Fatal and Severe Injury Crash (K+A)	Evident and Possible Injury Crash (B+C)	Sig. Result of the Z-Test (K+A vs. B+C)
Roadway-Environmental-Related						
LGTCOND_LITE-TRFCWAY_DIV_NO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier	2.78%	1.39%	1.54%	0.77%	
LGTCOND_LITE-TRFCWAY_UNDIV	Streetlight is available at time of crash in undivided trafficway	5.56%	10.07%	9.57%	6.96%	
LGTCOND_DARK-WTCOND_CLDY	No light (dark) is available at time of crash under cloudy weather	8.33%	0.35%	1.23%	0.13%	++
LGTCOND_DARK-WTCOND_CLEAR	No light (dark) is available at time of crash under clear weather	8.33%	2.08%	2.78%	1.46%	
ROADHOR_LT_RT_CU-ROADVERT_CST_UP_DN_SAG	Curve (not straight) and hill (not level) road terrain	8.33%	3.82%	4.32%	5.15%	
Driver- Environmental Related						
LGTCOND_LITE-DRVRDOIN_GO_STR	Streetlight is available at time of crash and driver going straight	8.33%	8.68%	8.64%	3.99%	++
LGTCOND_DARK-DRVRDOIN_GO_STR	No light (dark) is available at time of crash and driver going straight	11.11%	2.43%	3.40%	0.77%	++
Bicyclist - Environmental Related						
LGTCOND_DARK-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	No light (dark) is available at time of crash and bicyclist located in roadway	13.89%	2.43%	3.70%	1.16%	++

WTCOND_CLDY-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	Crash occurred under CLDY weather and bicyclist located in roadway	13.89%	17.36%	16.98%	9.84%	++
Bicyclist -Driver Related						
DRVRDOIN_GO_STR-NMTACT_NF_TRFC	Driver going straight and bicyclist walking not facing traffic	0.00%	0.35%	0.31%	0.13%	
DRVRDOIN_GO_STR-NMTLOC_ATI_NX-ATI_UL-NAI_NX-NAI_UN-PK_LN-BIKE_LN-SHLDR-SHARED-OTHR	Driver going straight and bicyclist located in roadway	69.44%	38.89%	42.28%	21.91%	++
DRVRDOIN_LT_TRN-NMTLOC__ATI_MX-NAI_MX	Driver left turn and bicyclist located in crosswalk	0.00%	2.78%	2.47%	4.64%	-
Total Cashes (N=2,652)		**36**	**288**	**324**	**2,328**	

Note: The significant value (Sig. Result of the Z-Test) is a result of the Z-test of the Difference Between Two Proportions; the proportion of crashes resulting in a fatal (K) versus the proportion of crashes resulting in an evident (B) and possible (C) injury for each new variable resulting from a multi-variable analysis, where; − = proportion of crashes resulting in a fatal (K) is significantly lower at 95% confidence level, + + = proportion of crashes resulting in a fatal (K) and sever (A) injury is significantly higher at 95% confidence level.

8. SELECT CRASH VARIABLE USING CHAID

This section shows results of the CHAID analysis applied on vehicle crashes involving pedestrians and bicyclists for both MV4000 and DT4000. In order to achieve a relatively reliable result, each data is further split into training (70%) and testing subsets (30%) for the modeling.

8.1 Input Variables

In Table 8-1 and Table 8-2, variables used by the CHAID decision tree technique for analyzing VRU crashes recorded in MV4000 and DT4000 are shown, respectively. The independent variables include those that have been created and tested in the previous chapter.

Table 8-1: Dependent and Independent Variables Used to Create the CHAID Decision Tree Models Using MV4000 Dataset.

Dependent Variable (Abbreviation)	Attributes
Crash injury severity (INJSVR)	Fatality (K)
	Severe Injury (A)
	Evident and Possible (B+C)
Independent Variables	
ACCDLOC	The type of location at which a crash occurred (I/N)
ALCFLAG	Alcohol Involvement
CONSZONE	Construction zone related crash (Y/N)
DRUGFLAG	Drug Involvement
DRVRAGE	Driver age
DRVRDO [1,2]	Controlled Maneuver by The Driver
DRVRPC [1,2]	Driver contributing actions/circumstances
DRVRSEX	Driver gender
HITRUN	Hit and run
LGTCOND	Light condition
NMTACT [1,2] [A,B]	VRU's actions/circumstances contributing to the crash
NMTAGE	VRU's age
NMTLOC [1,2]	VRU's location with respect to the roadway
NMTSEX	VRU's gender
RLTNRDWY	Location of first harmful event
ROADCOND	Road surface condition
ROADHOR	Horizontal road terrain
ROADVERT	Vertical road terrain
SAFETY [1,2]	The type of safety equipment, if any, that was used by a driver, bicyclist or pedestrian involved in a crash
SPEEDFLAG	Speeding Involvement
TRFCNTL [1,2]	Traffic control device (TCD) in effect
TRFCWAY	Trafficway description
VEHTYPE [1,2]	Vehicle type involved in the crash
WTHRCOND	Prevailing atmospheric conditions
LGTCOND_LIGT_TRFCWAY_D_WO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier

LGTCOND_LIGT_TRFCWAY_ND	Streetlight is available at time of crash in undivided trafficway
LGTCOND_DARK_WTHRCOND_CLDY	No light (dark) is available at time of crash under cloudy weather
LGTCOND_DARK_WTHRCOND_CLR	No light (dark) is available at time of crash under clear weather
ROADHOR_C_ROADVERT_H	Curve (not straight) and hill (not level) road terrain
LGTCOND_LIGT_DRVRDO_GO_STR	Streetlight is available at time of crash and driver going straight
DRVRDO_GO_STR_NMTLOC_2	Driver going straight and VRU located in roadway
DRVRDO_LT_TRN_NMTLOC_1	Driver left turn and VRU located in crosswalk
LGTCOND_DARK_DRVRDO_GO_STR	No light (dark) is available at time of crash and driver going straight
LGTCOND_DARK_NMTLOC_2	No light (dark) is available at time of crash and VRU located in roadway
WTHRCOND_CLDY_NMTLOC_2	Crash occurred under cloudy weather and VRU located in roadway
DRVRDO_GO_STR_NMTACT_1	Driver going straight and VRU walking (or biking) not facing traffic

Table 8-2: Dependent and Independent Variables Used to Create the CHAID Decision Tree Models Using DT4000 Dataset

Dependent Variable (Abbreviation)	**Attributes**
Crash injury severity (INJSVR)	Fatality (K)
	Severe Injury (A)
	Evident and Possible (B+C)
Independent Variables	
ALCFLAG	Alcohol Involvement
CONSZONE	Construction zone related crash (Y/N)
DISTFLAG	
DNMFTR [1,2] [A,B] _DRVR	Driver condition relevant to the crash
DNMFTR [1,2] [A,B] _NMT	VRU's condition relevant to the crash
DRUGFLAG	Drug Involvement
DRVRAGE	Driver age
DRVRDOIN [1,2]	Controlled Maneuver by The Driver
DRVRPC [1,2] [A,B,C,D]	Driver contributing actions/circumstances
DRVRRACE	Driver race
DRVRSEX	Driver gender
ENVPC [A,B,C]	Apparent environmental conditions which may have contributed to the crash
HITRUN	Hit and run
INTTYPE	Intersection type where the crash occurred
LGTCOND	Light conditions
LOCTYPE	The type of location at which a crash occurred (I/N)
NMTACT [1,2] [A,B]	VRU's actions/circumstances contributing to the crash
NMTAGE	VRU's age
NMTLOC [1,2]	VRU's location with respect to the roadway

NMTPRIOR [1,2]	VRU's actions immediately prior to the crash
NMTSEX	VRU's gender
NMTSFQ [1,2] [A,B]	Safety equipment used by the VRU
RDCOND [A,B,C]	Road surface condition
RDWYPC [A, B, C]	Apparent factors of the road/ highway
RLTNRDWY	Location of first harmful event
RLTNTRWY	Crash location with respect to trafficway
ROADHOR [1,2]	Horizontal road terrain
ROADVERT [1,2]	Vertical road terrain
SFTYEQP [1,2]	The restraint equipment in use at the time of the crash
SPEEDFLAG	Vehicle speeding status
SURFTYPE [1,2]	Road surface type
TEENDRVR	Teen driver
TOTLANES [1,2]	Total number of lanes
TRFCCNTL [1,2]	Traffic control device (TCD) in effect
TRFCINOP [1,2]	Status of the TCD
TRFCWAY [1,2]	Trafficway description
VEHTYPE [1,2]	Vehicle type involved in the crash
WTCOND [A, B]	Prevailing atmospheric conditions
LGTCOND_LITE_TRFCWAY_DIV_NO	Streetlight is available at time of crash in a divided trafficway without a traffic barrier
LGTCOND_LITE_TRFCWAY_UNDIV	Streetlight is available at time of crash in undivided trafficway
LGTCOND_DARK_WTCOND_CLDY	No light (dark) is available at time of crash under cloudy weather
LGTCOND_DARK_WTCOND_CLEAR	No light (dark) is available at time of crash under clear weather
ROADHOR_LT_RT_CU_ROADVERT_CST_UP_DN_SAG	Curve (not straight) and hill (not level) road terrain
LGTCOND_LITE_DRVRDOIN_GO_STR	Streetlight is available at time of crash and driver going straight
DRVRDOIN_GO_STR_NMTLOC_NOT_ATI_MX_NAI_MX	Driver going straight and VRU located in roadway
DRVRDOIN_LT_TRN_NMTLOC_ATI_MX_NAI_MX	Driver left turn and VRU located in crosswalk
LGTCOND_DARK_DRVRDOIN_GO_STR	No light (dark) is available at time of crash and driver going straight
LGTCOND_DARK_NMTLOC_NOT_ATI_MX_NAI_MX	No light (dark) is available at time of crash and VRU located in roadway
WTCOND_CLDY_NMTLOC_NOT_ATI_MX_NAI_MX	Crash occurred under cloudy weather and VRU located in roadway
DRVRDOIN_GO_STR_NMTACT_NF_TRFC	Driver going straight and VRU walking (or biking) not facing traffic

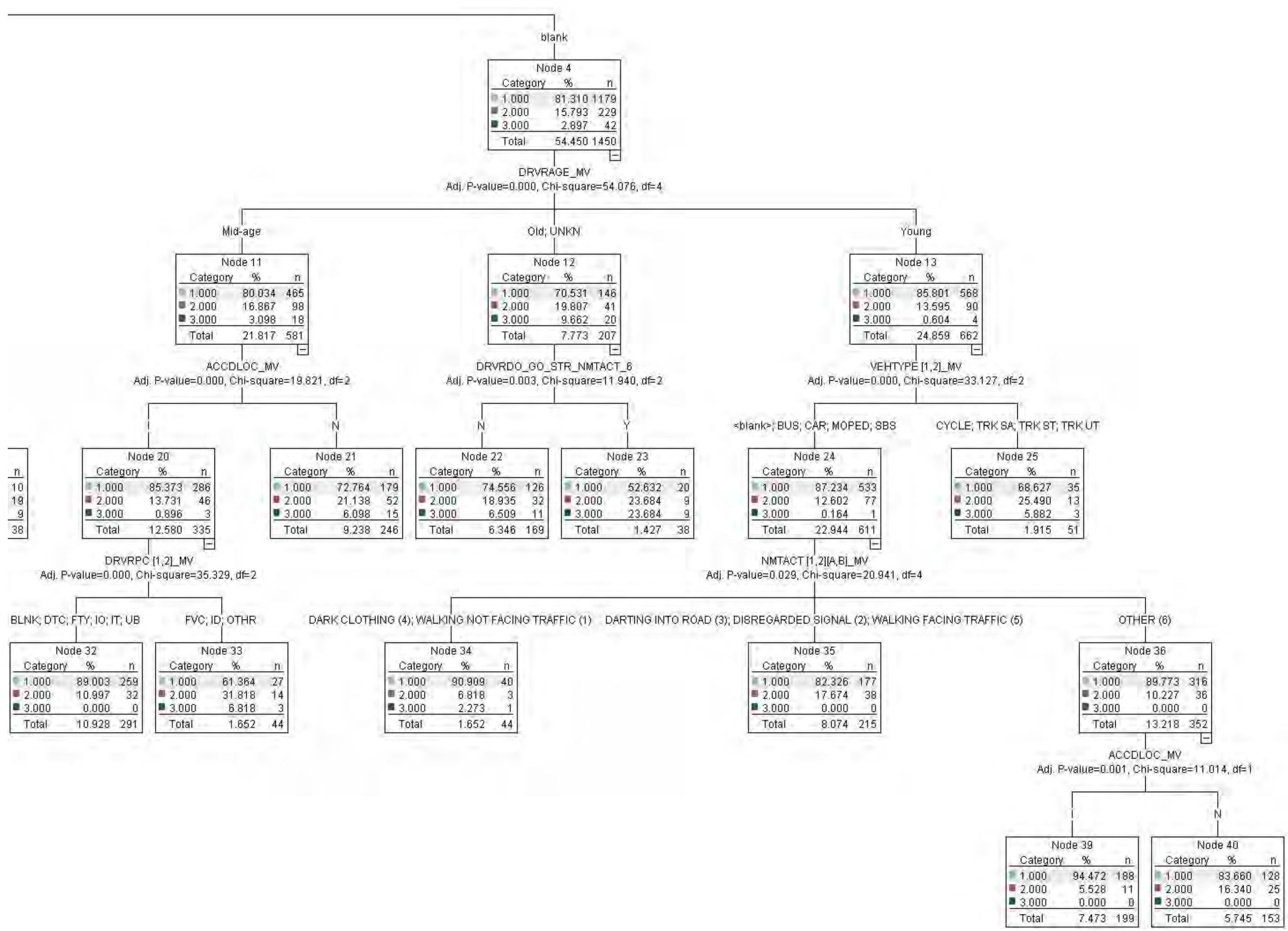
8.2 CHAID Decision Trees of Pedestrian Crashes Datasets

The CHAID decision trees for pedestrian crashes recorded by using the MV4000 divide the dataset into 40 nodes, and 23 terminal nodes based on 14 splitting variables. For the DT4000 pedestrian crashes, the CHAID decision trees divide the dataset into 48 nodes, and 29 terminal nodes with 14 splitting variables. CHAID trees of pedestrian crashes are presented in Figure 8-1 and Figure 8-2, respectively. In addition, the predictor importance rankings for both tree models and the comparison results between the predictors in both models are illustrated in Figure 8-3. The highlighted items are not significant in the new DT4000 crash form; "NEW" means a new variable in the new DT4000 crash form; "UP" means rank of a variable goes up in the new DT4000 crash form; and "DOWN" means rank of a variable goes down in the new DT4000 crash form.

As mentioned previously, there are 22 terminal nodes in the CHAID decision tree associated with the MV4000 dataset, which can be treated as 22 unique scenarios with different sets of conditions being met. For example, the scenario, which has prediction results of 18.92% non-severe injuries, 24.32% severe injuries, and 56.76% fatalities, meets the following conditions when a crash occurs: the light condition is either dark without streetlight (DARK), or unknown (UNKN); and the trafficway division type is either divided highway with traffic barrier (D/B), or divided highway without traffic barrier (D/WO). It should also be noted that this specific scenario (i.e., terminal node) has both the greatest number of fatalities and the highest percentage of fatalities predicted than other scenarios (i.e., terminal node).

For the CHAID tree model by using the DT4000 dataset, 29 unique scenarios could be observed. The node has the highest fatality proportion with 63.64% meets the following conditions: driver's condition is either using cane or crutches, asleep or fatigued, under the influence of medication/drugs/alcohol, none, or other; roadway without streetlight (DARK); and mid-age driver. Compared to the CHAID model by using the MV4000 pedestrian crash dataset, one another different phenomenon is that there are many nodes in the tree model by using the DT4000 data have much higher severe injury crashes predicted.

Regarding the variable importance, it should be noted that the conditions of involved parties, especially drivers (i.e., DNMFTR [1,2][A,B]_DRVR) with top rank show significant impact to the pedestrian crashes. Another notable fact is that "ALCFLAG" is not significant at all in the model by using the DT4000 dataset.


blank
Node 4
Category % n
1.000 81.310 1179
2.000 15.793 229
3.000 2.897 42
Total 54.450 1450
DRVRAGE_MV
Adj. P-value=0.000, Chi-square=54.076, df=4
Mid-age
Old; UNKN
Young
Node 11
Category % n
1.000 80.034 465
2.000 16.867 98
3.000 3.098 18
Total 21.817 581
Node 12
Category % n
1.000 70.531 146
2.000 19.807 41
3.000 9.662 20
Total 7.773 207
Node 13
Category % n
1.000 85.801 568
2.000 13.595 90
3.000 0.604 4
Total 24.859 662
ACCDLOC_MV
Adj. P-value=0.000, Chi-square=19.821, df=2
DRVRDO_GO_STR_NMTACT_6
Adj. P-value=0.003, Chi-square=11.940, df=2
VEHTYPE [1,2]_MV
Adj. P-value=0.000, Chi-square=33.127, df=2
I
N
N
Y
<blank>; BUS; CAR; MOPED; SBS
CYCLE; TRK SA; TRK ST; TRK UT
n
10
19
9
38
Node 20
Category % n
1.000 85.373 286
2.000 13.731 46
3.000 0.896 3
Total 12.580 335
Node 21
Category % n
1.000 72.764 179
2.000 21.138 52
3.000 6.098 15
Total 9.238 246
Node 22
Category % n
1.000 74.556 126
2.000 18.935 32
3.000 6.509 11
Total 6.346 169
Node 23
Category % n
1.000 52.632 20
2.000 23.684 9
3.000 23.684 9
Total 1.427 38
Node 24
Category % n
1.000 87.234 533
2.000 12.602 77
3.000 0.164 1
Total 22.944 611
Node 25
Category % n
1.000 68.627 35
2.000 25.490 13
3.000 5.882 3
Total 1.915 51
DRVRPC [1,2]_MV
Adj. P-value=0.000, Chi-square=35.329, df=2
NMTACT [1,2][A,B]_MV
Adj. P-value=0.029, Chi-square=20.941, df=4
BLNK; DTC; FTY; IO; IT; UB
FVC; ID; OTHR
DARK CLOTHING (4); WALKING NOT FACING TRAFFIC (1)
DARTING INTO ROAD (3); DISREGARDED SIGNAL (2); WALKING FACING TRAFFIC (5)
OTHER (6)
Node 32
Category % n
1.000 89.003 259
2.000 10.997 32
3.000 0.000 0
Total 10.928 291
Node 33
Category % n
1.000 61.364 27
2.000 31.818 14
3.000 6.818 3
Total 1.652 44
Node 34
Category % n
1.000 90.909 40
2.000 6.818 3
3.000 2.273 1
Total 1.652 44
Node 35
Category % n
1.000 82.326 177
2.000 17.674 38
3.000 0.000 0
Total 8.074 215
Node 36
Category % n
1.000 89.773 316
2.000 10.227 36
3.000 0.000 0
Total 13.218 352
ACCDLOC_MV
Adj. P-value=0.001, Chi-square=11.014, df=1
I
N
Node 39
Category % n
1.000 94.472 188
2.000 5.528 11
3.000 0.000 0
Total 7.473 199
Node 40
Category % n
1.000 83.660 128
2.000 16.340 25
3.000 0.000 0
Total 5.745 153

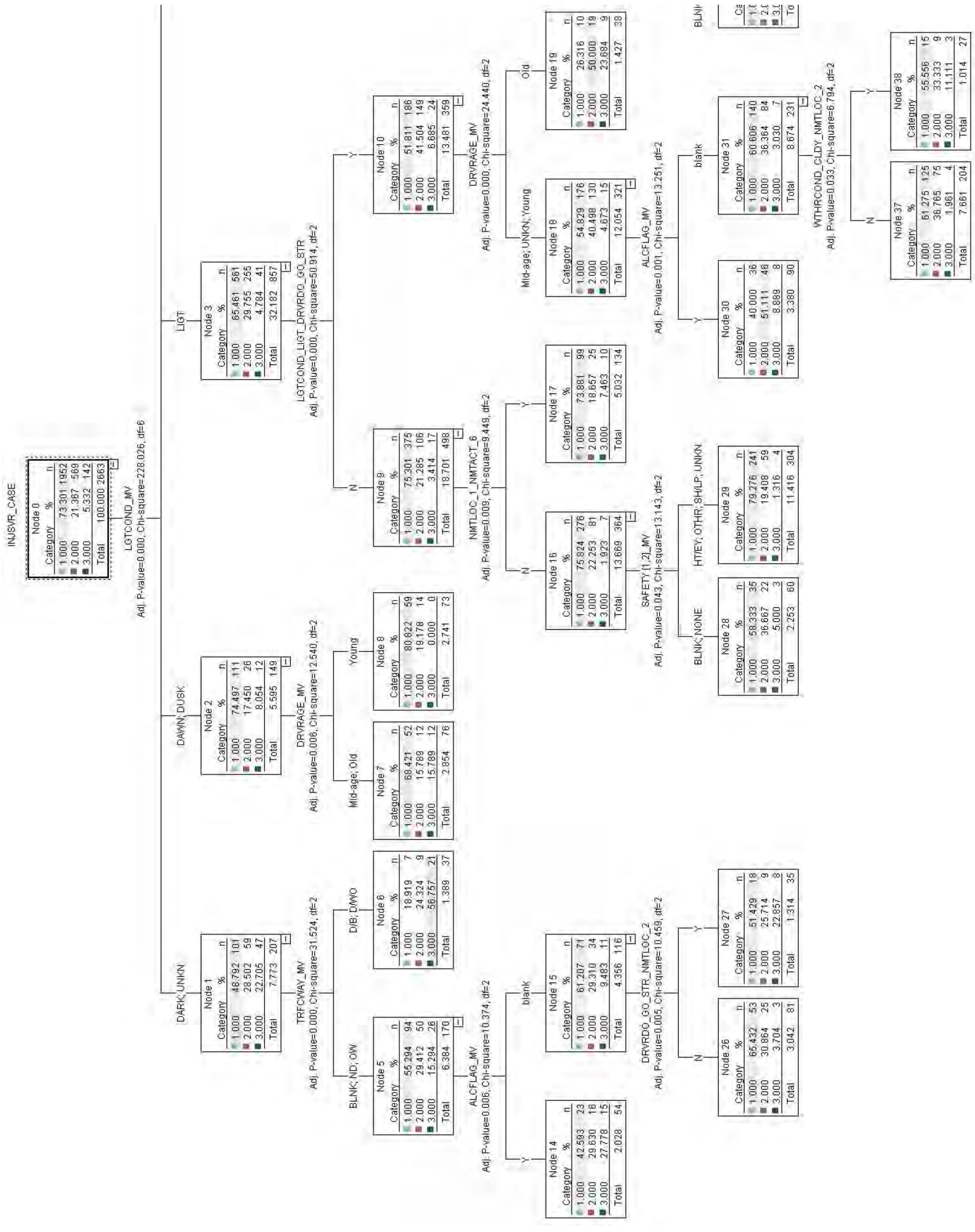
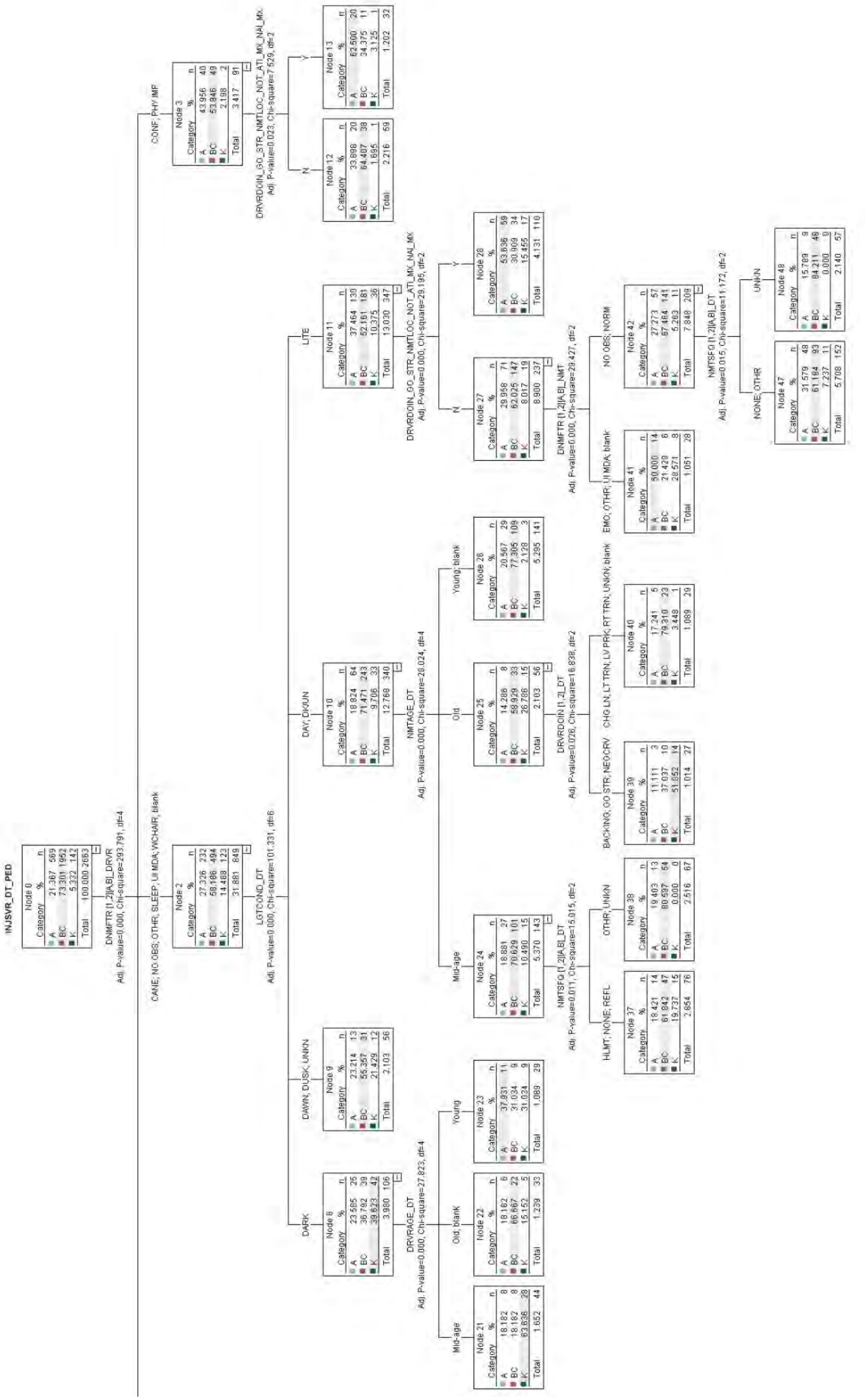


Figure 8-1: CHAID Analysis to Determine Variables that Affect Pedestrians Crash Severity Level Using MV4000 Dataset


INJSVR_DT_PED
Node 0: A 21.367 569; BC 73.301 1952; K 5.332 142; Total 100.000 2663
DNMFTR [1,2][A,B]_DRVR
Adj. P-value=0.000, Chi-square=293.791, df=4
CANE; NO OBS; OTHR; SLEEP; UI MDA; WCHAIR; blank
CONF; PHY IMP
Node 2: A 27.326 232; BC 58.186 494; K 14.488 123; Total 31.881 849
LGTCOND_DT
Adj. P-value=0.000, Chi-square=101.331, df=6
Node 3: A 43.956 40; BC 53.846 49; K 2.198 2; Total 3.417 91
DRVRDOIN_GO_STR_NMTLOC_NOT_ATI_MX_NAI_MX
Adj. P-value=0.023, Chi-square=7.529, df=2
N
Node 12: A 33.898 20; BC 64.407 38; K 1.695 1; Total 2.216 59
Y
Node 13: A 62.500 20; BC 34.375 11; K 3.125 1; Total 1.202 32
DARK
Node 8: A 23.585 25; BC 36.792 39; K 39.623 42; Total 3.980 106
DAWN; DUSK; UNKN
Node 9: A 23.214 13; BC 55.357 31; K 21.429 12; Total 2.103 56
DAY; DK/UN
Node 10: A 18.824 64; BC 71.471 243; K 9.706 33; Total 12.768 340
LITE
Node 11: A 37.464 130; BC 52.161 181; K 10.375 36; Total 13.030 347
DRVRAGE_DT
Adj. P-value=0.000, Chi-square=27.823, df=4
Mid-age
Node 21: A 18.182 8; BC 18.182 8; K 63.636 28; Total 1.652 44
Old; blank
Node 22: A 18.182 6; BC 66.667 22; K 15.152 5; Total 1.239 33
Young
Node 23: A 37.931 11; BC 31.034 9; K 31.034 9; Total 1.089 29
NMTAGE_DT
Adj. P-value=0.000, Chi-square=28.024, df=4
Mid-age
Node 24: A 18.881 27; BC 70.629 101; K 10.490 15; Total 5.370 143
Old
Node 25: A 14.286 8; BC 58.929 33; K 26.786 15; Total 2.103 56
Young; blank
Node 26: A 20.567 29; BC 77.305 109; K 2.128 3; Total 5.295 141
DRVRDOIN_GO_STR_NMTLOC_NOT_ATI_MX_NAI_MX
Adj. P-value=0.000, Chi-square=29.195, df=2
N
Node 27: A 29.958 71; BC 62.025 147; K 8.017 19; Total 8.900 237
Y
Node 28: A 53.636 59; BC 30.909 34; K 15.455 17; Total 4.131 110
NMTSFQ [1,2][A,B]_DT
Adj. P-value=0.011, Chi-square=15.015, df=2
HLMT; NONE; REFL
Node 37: A 18.421 14; BC 61.842 47; K 19.737 15; Total 2.854 76
OTHR; UNKN
Node 38: A 19.403 13; BC 80.597 54; K 0.000 0; Total 2.516 67
DRVRDOIN [1,2]_DT
Adj. P-value=0.026, Chi-square=16.838, df=2
BACKING; GO STR; NEGCRV
Node 39: A 11.111 3; BC 37.037 10; K 51.852 14; Total 1.014 27
CHG LN; LT TRN; LV PRK; RT TRN; UNKN; blank
Node 40: A 17.241 5; BC 79.310 23; K 3.448 1; Total 1.089 29
DNMFTR [1,2][A,B]_NMT
Adj. P-value=0.000, Chi-square=29.427, df=2
EMO; OTHR; UI MDA; blank
Node 41: A 50.000 14; BC 21.429 6; K 28.571 8; Total 1.051 28
NO OBS; NORM
Node 42: A 27.273 57; BC 67.464 141; K 5.263 11; Total 7.848 209
NMTSFQ [1,2][A,B]_DT
Adj. P-value=0.015, Chi-square=11.172, df=2
NONE; OTHR
Node 47: A 31.579 48; BC 61.184 93; K 7.237 11; Total 5.708 152
UNKN
Node 48: A 15.789 9; BC 84.211 48; K 0.000 0; Total 2.140 57

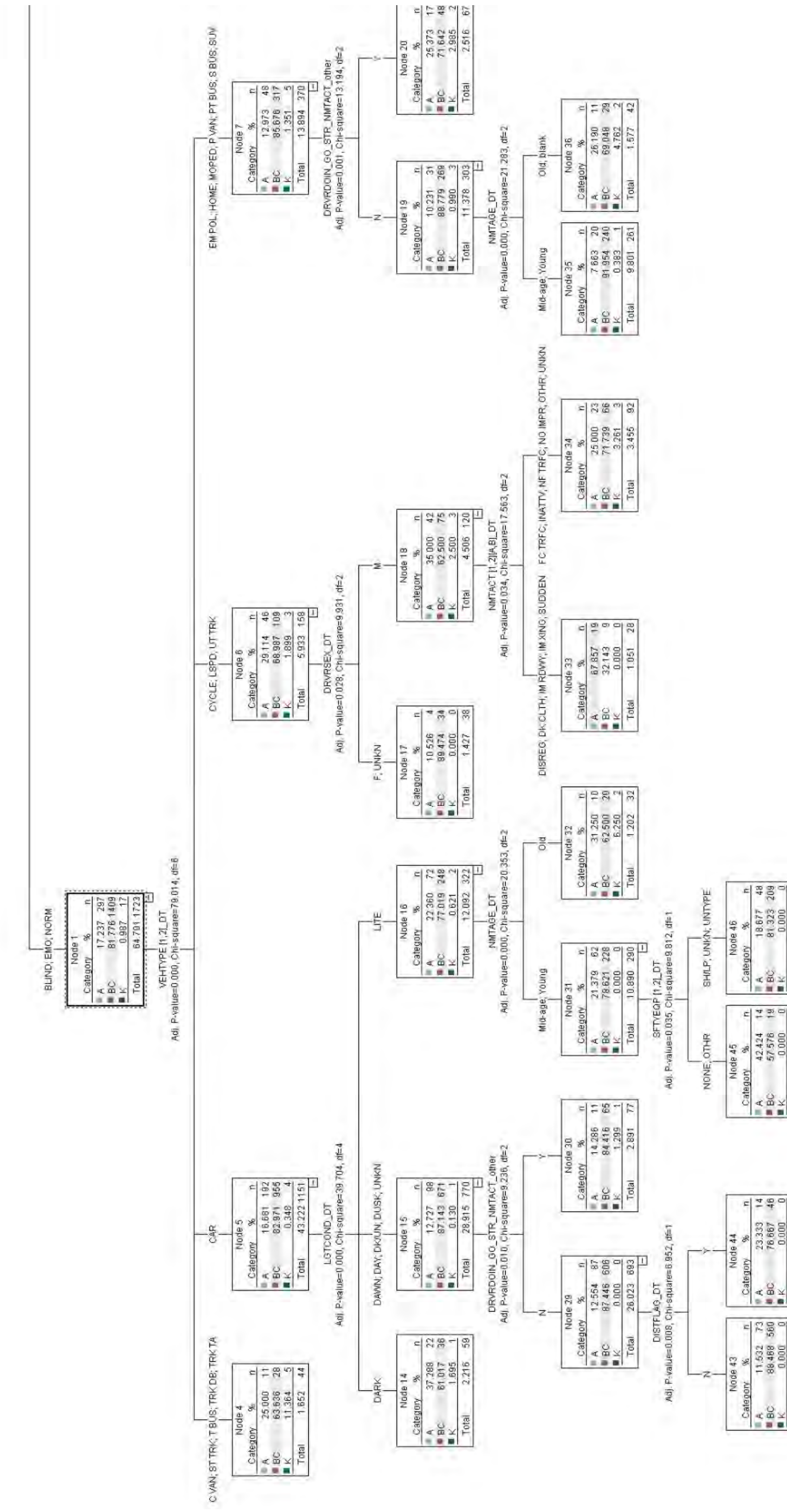
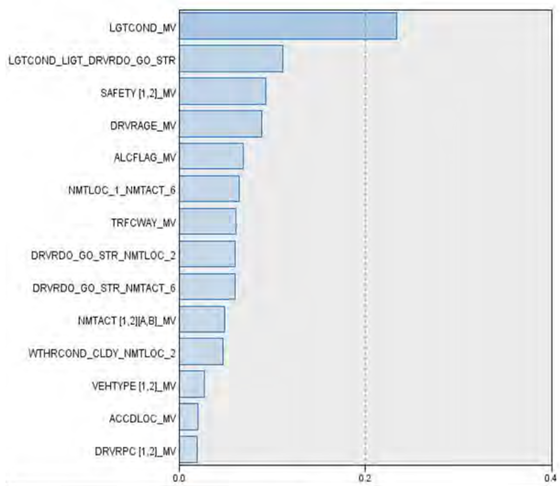
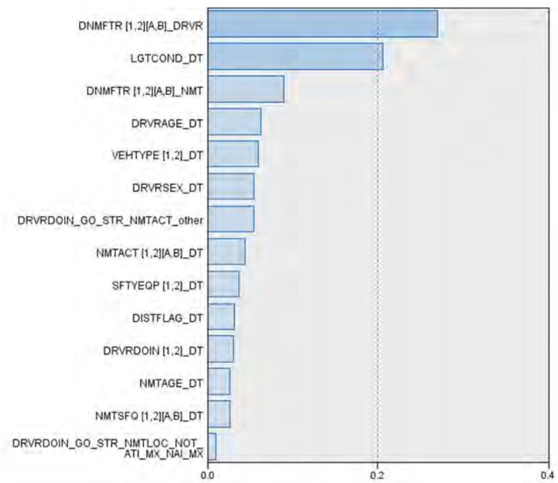


Figure 8-2: CHAID Analysis to Determine Variables that Affect Pedestrians Crash Severity Level Using DT4000 Dataset





MV4000	
Nodes	**Indications**
LGTCOND_MV	Light condition
LGTCOND_LIGT_DRVRDO_GO_STR	Streetlight is available at time of crash and driver going straight
SAFETY [1,2]_MV	The type of safety equipment
DRVRAGE_MV	Driver's age
ALCFLAG_MV	Alcohol involvement
NMTLOC_1_NMTACT_6	Pedestrian located in the roadway and acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway
TRFCWAY_MV	Trafficway division type
DRVRDO_GO_STR_NMTLOC_2	Driver going straight with the pedestrian in the roadway
DRVRDO_GO_STR_NMTACT_6	Driver going straight and pedestrian acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway.
NMTACT [1,2][A,B]_MV	Pedestrian's action
WTHRCOND_CLDY_NMTLOC_2	Crash occurred under cloudy weather and pedestrian located in roadway
VEHTYPE [1,2]_MV	Vehicle type
ACCDLOC_MV	The location of crash
DRVRPC [1,2]_MV	Contributing driver factor

VS.

DT4000		**Change from MV4000 to DT4000**
Nodes	**Indications**	
DNMFTR [1,2][A,B]_DRVR	Driver's condition	**NEW**
LGTCOND_DT	Light condition	**DOWN**
DNMFTR [1,2][A,B]_NMT	Pedestrian's condition	**NEW**
DRVRAGE_DT	Driver's age	-
VEHTYPE [1,2]_DT	Vehicle type	**UP**
DRVRSEX_DT	Driver's gender	**Not significant in MV400**
DRVRDOIN_GO_STR_NMTACT_other	Driver going straight and pedestrian acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway	**UP**
NMTACT [1,2][A,B]_DT	Pedestrian's action contributing to the crash	**UP**
SFTYEQP [1,2]_DT	The restraint equipment in use at the time of the crash	**DOWN**
DISTFLAG_DT	Distractive driving involved	**NEW**
DRVRDOIN [1,2]_DT	The controlled maneuver for the vehicle by the driver	**Not significant in MV400**
NMTAGE_DT	Pedestrian's age	**Not significant in MV400**
NMTSFQ [1,2][A,B]_DT	The safety equipment in use by the pedestrian	**NEW**
DRVRDOIN_GO_STR_NMTLOC_NOT_ATI_MX_NAI_MX	Driver going straight and bicyclist located in roadway	**DOWN**

Figure 8-3 Predictor Importance Rankings of CHAID Decision Trees for Pedestrian Crash Dataset

8.3 CHAID Decision Trees of Bicyclist Crashes Datasets

In the CHAID decision tree for bicyclist crashes in the MV4000, the dataset was divided into 22 nodes, and 13 terminal nodes. Moreover, there are 8 splitting variables in the model. While, in the DT4000, the tree divides the dataset into 28 nodes, and 17 terminal nodes with 10 splitting variables. CHAID trees of bicyclist crashes are presented in Figure 8-4 and Figure 8-5, respectively. Moreover, the predictor importance rankings for both tree models and the comparison results between the predictors in both models are illustrated in Figure 8-6. The highlighted items are not significant in the new DT4000 crash form; "NEW" means a new variable in the new DT4000 crash form; "UP" means rank of a variable goes up in the new DT4000 crash form; and "DOWN" means rank of a variable goes down in the new DT4000 crash form.

For the CHAID model with the MV4000 dataset, the most common scenario that will lead to a crash regardless of the injury severity meets the following conditions: alcohol not involved; bicyclist darting into road/disregarding signal/with other actions; young or unknown age driver; driver not going straight; bicyclist not located in the roadway; and with traffic control device (i.e., not NONE). For the CHAID model by using the DT4000 dataset, the most common scenario (conditions: at intersection with marked crosswalk, no alcohol involvement, cloudy weather, driver going straight, and driver conditions being emotional/normal/sick/sleep/not recorded) that will lead to crash in the model is with 504 crashes predicted, but no fatality in this scenario. Other than that, there are not too many obvious patterns could be seen via the models.

Similar to the result of pedestrian crashes, the newly added data field, the condition of the driver (i.e., DNMFTR[1,2][A,B]_DRVR), is found to affect the crash outcomes in the DT4000 dataset. Moreover, it is also very interesting to see that "ALCFLAG" is no longer the top variable in the tree model by using the DT4000 dataset. Besides, one splitting variable in the CHAID decision tree of the DT4000 bicyclist crash dataset is the action of a bicyclist immediately prior to a crash (i.e., NMTPRIOR [1,2]_DT), which implies that the necessity of collecting such information for a crash.

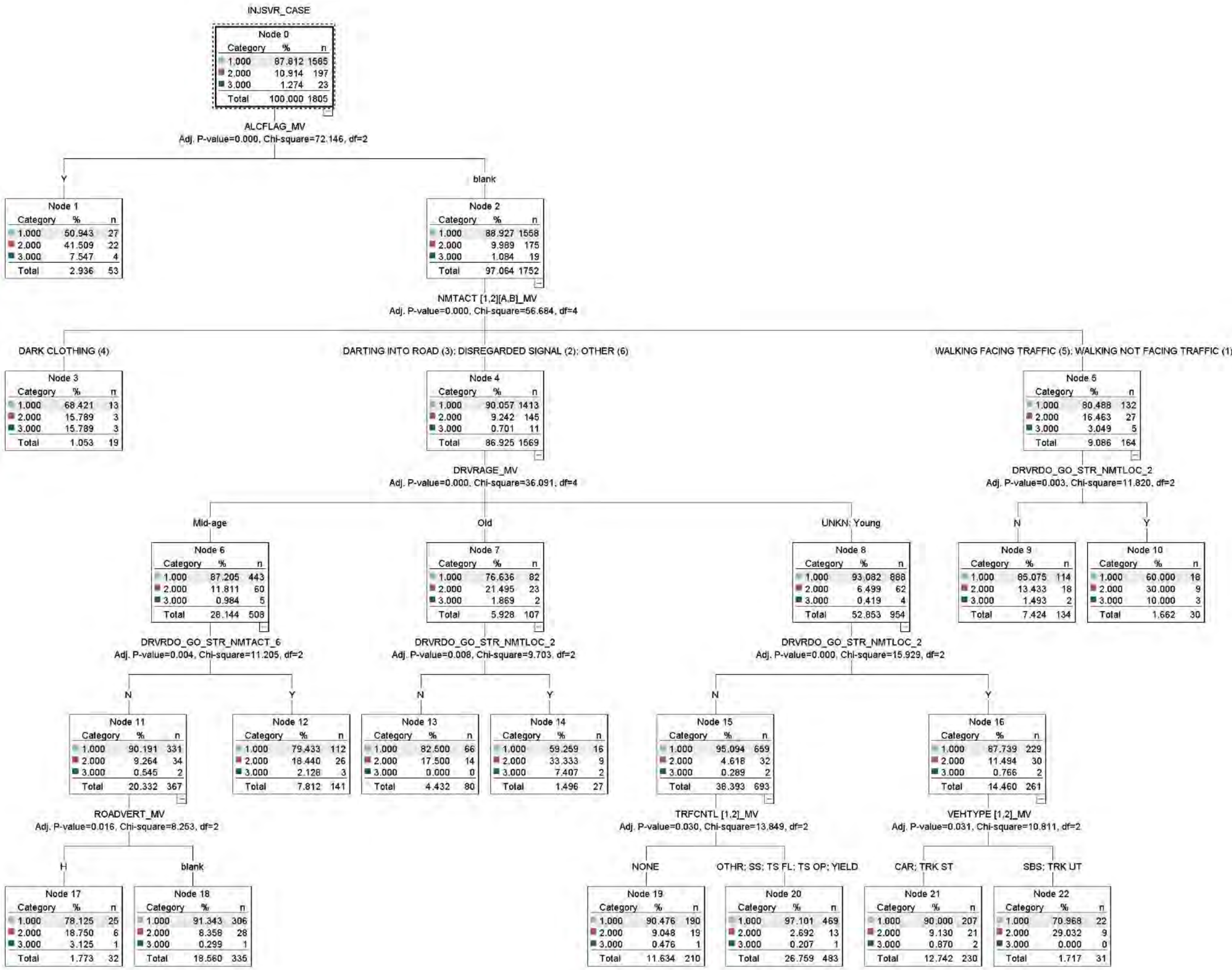


Figure 8-4: CHAID Analysis to Determine Variables that Affect Bicyclists Crash Severity Level Using MV4000 Dataset

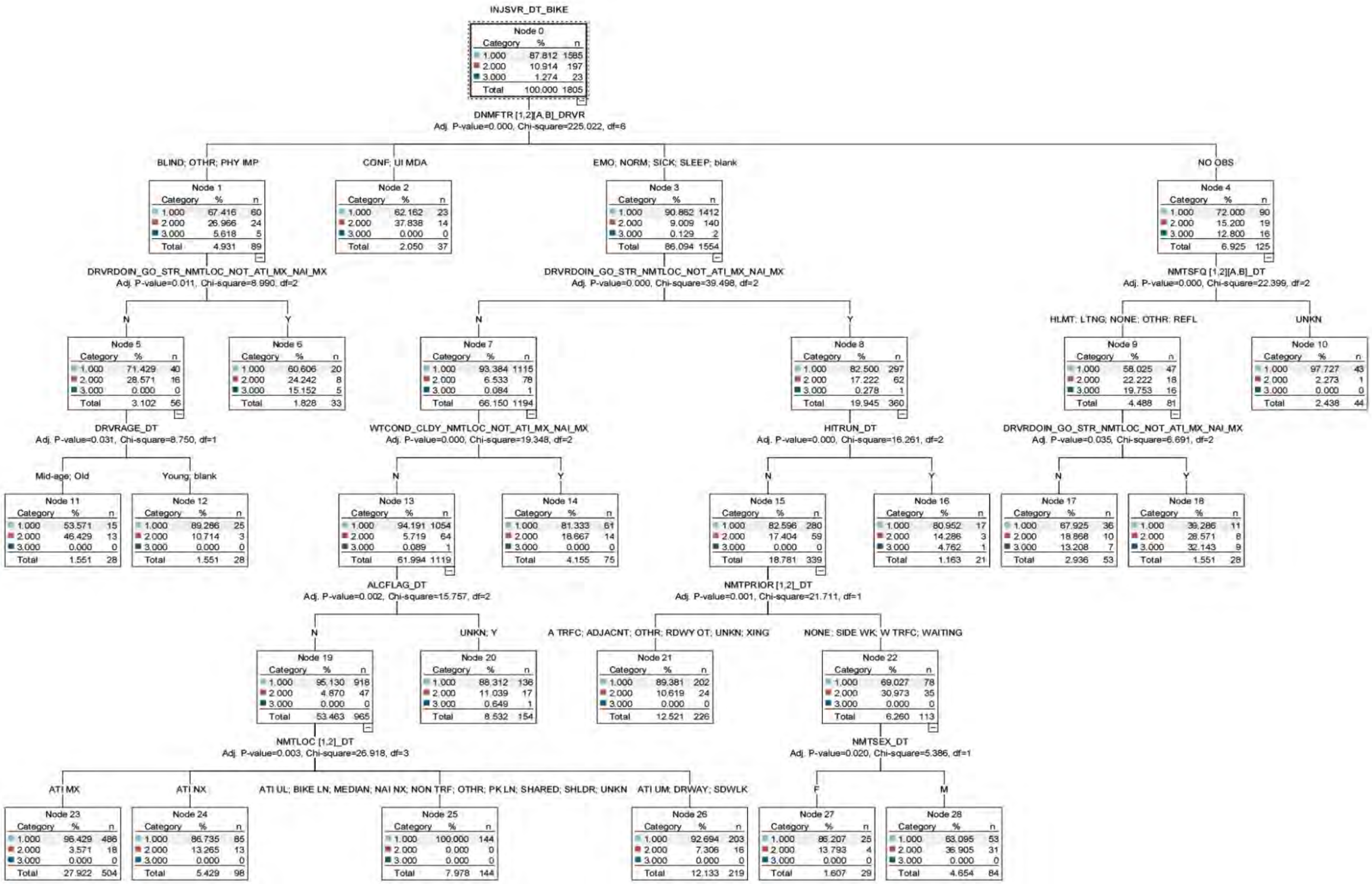
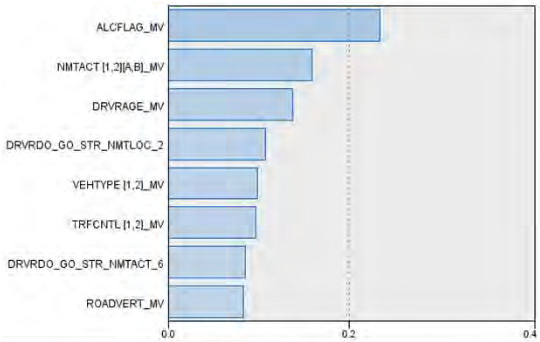
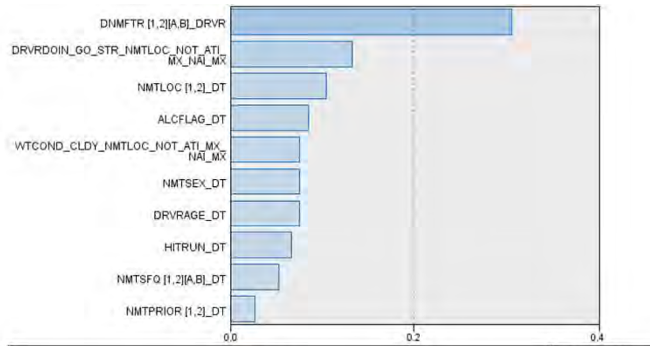


Figure 8-5: CHAID Analysis to Determine Variables that Affect Bicyclist Crash Severity Level Using DT4000 Dataset





MV4000	
Nodes	**Indications**
ALCFLAG_MV	Alcohol involvement
DRVRAGE_MV	Driver's age
NMTACT [1,2][A,B]_MV	Bicyclist's action contributing to the crash
DRVRDO_GO_STR_NMTLOC_2	Driver going straight while bicyclist located in roadway
ROADVERT_MV	The vertical road terrain at the point of impact
DRVRPC [1,2]_MV	Contributing driver factor
DRVRDO_GO_STR_NMTACT_6	Driver going straight and bicyclist acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway
NMTLOC_1_NMTACT_6	Bicyclist located in the roadway and acting other than disregarding signal, walking not facing traffic, wearing dark clothes, and darting into roadway

VS.

DT4000		**Change from MV4000 to DT4000**
Nodes	**Indications**	
DNMFTR [1,2][A,B]_DRVR	Driver's condition	**NEW**
DRVRDOIN_GO_STR_NMTLOC_NOT_ATI_MX_NAI_MX	Driver going straight and bicyclist acting other than disregarding signal, walking facing traffic, walking not facing traffic, wearing dark clothes, and darting into roadway	**UP**
NMTLOC [1,2]_DT	Bicyclist's location	
ALCFLAG_DT	Alcohol involvement	**DOWN**
WTCOND_CLDY_NMTLOC_NOT_ATI_MX_NAI_MX	Crash occurred under CLDY weather and bicyclist located in roadway	**Not significant in MV4000**
NMTSEX_DT	Bicyclist's gender	**Not significant in MV4000**
DRVRAGE_DT	Driver's age	**DOWN**
HITRUN_DT	Hit-and-run involvement	**Not significant in MV4000**
NMTSFQ [1,2][A,B]_DT	Driver's condition	**NEW**
NMTPRIOR [1,2]_DT	The action of a bicyclist immediately prior to a crash	**NEW**

Figure 8-6 Predictor Importance of CHAID Decision Trees for Bicyclist Crash Dataset

8.4 Discussion of Variable Selection

Results from all CHAID decision tree analyses show that driver's age is one of the critical variables that has impact on the crash outcomes, though not obvious patterns have been observed. Similarly, it has also been found that going straight by drivers while pedestrians were located in roadway is one of the common factors that affect the crash outcomes. These results are consistent with some other previous research (*101*, *102*).

Additionally, for pedestrian-vehicle crashes, the results are in line with previous studies (*103–105*) revealed that light condition of the roadway at time of crash is one of the most important predictors of the severity of pedestrian crashes. Relating this fact to the previous exploratory analysis that majority of the fatalities and severely injured crashes occurred within the nighttime, one reason if that lower visibility level and drivers' failure to yield could be an explanation for this specific type of crashes (*103*). It should be noted that several newly added data field in DT4000 dataset have been found to have the impact on determining the crash injury severity, such as the conditions of both drivers and pedestrians (i.e., DNMFTR [1,2][A,B]) and the distractive driving involvement (i.e., DISTFLAG). It indicates that the conditions and circumstances of involved parties in the crash might have heavily contributed to the crash.

For bicyclist-vehicle crashes, other than the two variables mentioned at the beginning (i.e., driver's age and going straight by drivers while pedestrians were located in roadway), one common variable shared by the results from both MV4000 and DT4000 dataset is the alcohol involvement, and this variable seems not dominant the outcomes of pedestrian crashes. Other than that, no other similarities have been found. Similar to the result of pedestrian crash, the newly added data field, the condition of the driver (i.e., DNMFTR [1,2][A,B]_DRVR), is found to affect the crash outcomes in DT4000 dataset. Besides, the top splitting variable in CHAID decision tree of DT4000 bicyclist crash dataset is the action of a bicyclist immediately prior to a crash (i.e., NMTPRIOR [1,2]_DT), which implies that the necessity of collecting such information for a crash.

Overall, the results of the employed CHAID decision tree, were steady and found to be consistent with previous research that used other statistical techniques. This implies that the use of this technique in crash severity analysis is valid. Unlike regression models, the personal judgement has no influence on the model specification, which is an advantage of using the CHAID technique. Additionally, the technique is not confined to binary splits, which yields a wider decision tree in comparison to the other decision tree and helps to show the non-linear relation between dependent variables and crashes (*106*).

CHAID representation is easy to comprehend, and able to distinguish between a complex structure of many severity factors. Therefore, it is beneficial to be implemented in studying pedestrian and bicyclist crash severity factors. A drawback of CHAID, is the instability issue; the random procedure of choosing training and test samples which depends on the seed number, produce different trees. Yet, in this study the tree variation was trivial, and the common important predictors presented resulted were presented.

9. RANK CRASH VARIABLE USING RANDOM FORESTS

In this study, the four datasets (MV4000 and DT4000, pedestrian crashes and bicyclist crashes) with a total of 91 predictor variables were imported for variable importance analysis (36 in MV4000 and 50 in DT4000). The important explanatory variables in the crash model were determined by a RF model, starting with fitting a RF to the data. At that point, the OOB is recorded for each data point. This error is then averaged over the forest. To measure the importance score of importance of a variable after training, the values are permuted among the training dataset and the OOB error is recorded. Then, the difference in before and after permutation OOB error is averaged among all trees, showing the importance score of the variable. Afterwards, the standard deviation of the difference values is used to normalize the importance score.

Variables with higher importance score values are ranked as more important than other variables (*77*). In this study, the RF technique is constructed in the RStudio (V 4.1.0) “randomForest” package, and “mtry” is used as tuning model parameter. Regarding the number of trees in the forest (ntree), 500 trees were run for each model to obtain relatively consistent variable importance measures. Concerning the importance, the OOB error was used, but for variable impurity two indices were used: the Mean Decrease Accuracy (MDA) and the Mean Decrease Gini (MDG) indices.

The two indices, MDA and MDG are used to evaluate the importance of each variable since the Gini index is suitable for classification, both indices are default output of the RF procedure, and using both indices is more robust than using one index (*72*). As the MDA value gets larger, the variable importance increase. Whereas MDG shows the total decrease in node impurities averaged for all trees.

Figure 9-1 to Figure 9-4 show RF variable importance ranking for pedestrian and bicyclist-related variables using MV4000 and DT4000 datasets, correspondingly. The importance score of variables in the prediction of pedestrian and bicyclist’s injury severity was carried out using the Random Forests method for each dataset; MV4000 and DT4000 crash forms. The method was implemented with 500 trees, using a training dataset of 70% of the crash observations, and using “mtry” of ($\sqrt{p}$) where p is the number of studied variables. Also, the newly created variables from the DT4000 dataset were included in the importance ranking process for variables adopted from the DT4000 crash form dataset. Note that common pedestrian and bicyclist variables in MV4000 and DT4000 datasets are used as well as the newly created variables showed in Table 8-1 and Table 8-2 for a more consistent comparison.

9.1 Pedestrian Crash Variables

Generally, many variables showed strong effects on injury severity of pedestrians involved in vehicle crashes. The results are shown in both Figure 9-1 and Figure 9-2.

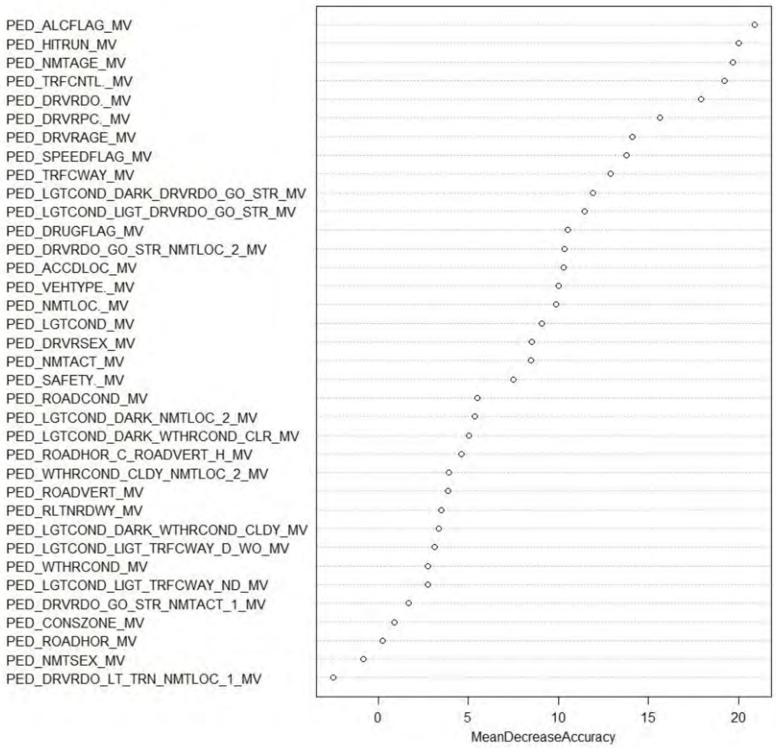


Figure 9-1: RF for MV4000 Crash Form Variable Importance Ranking for Pedestrian Crashes

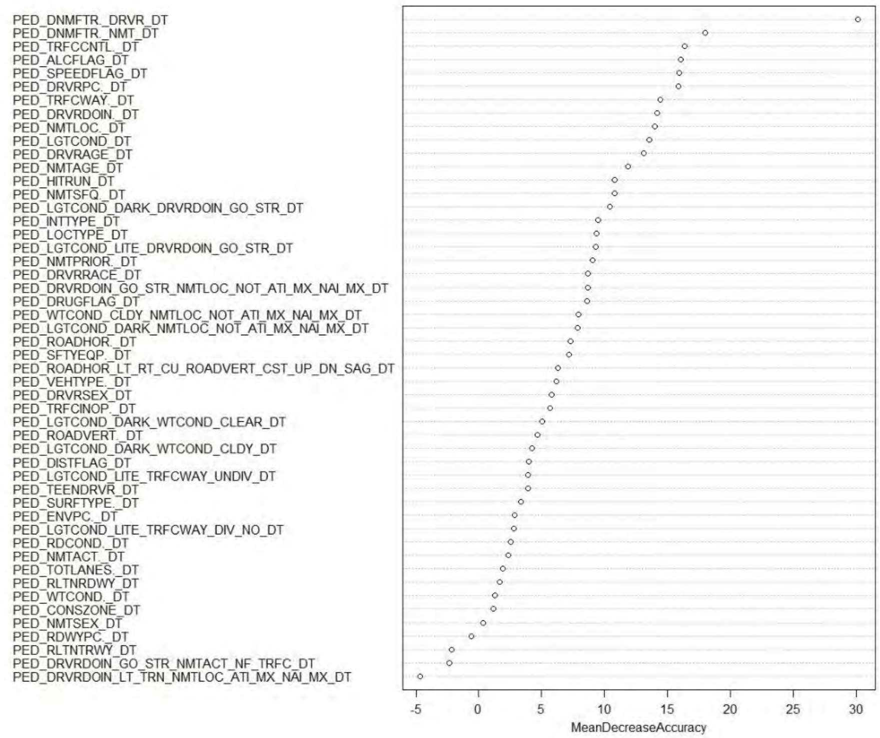


Figure 9-2: RF for DT4000 Crash Form Variable Importance Ranking for Pedestrian Crashes

9.1.1. Pedestrian Crashes-MV4000

The rankings of all input variables for pedestrian crashes by using MV4000 dataset can be seen from Figure 9-1. The top three important variables in MV4000 are common variable, which are "PED_ALCFLAG_MV" (i.e., the involvement of alcohol in the crashes), "PED_HITRUN_MV" (i.e., hit-and-run involvement in the crashes), and "PED_NMTAGE_MV" (i.e., pedestrian age). Other than the common variables, it has been observed that two newly created variables show strong effects in terms of MDA and rank within top 15 important variables, which are PED_LGTCOND_DARK_DRVRDO_GO_STR_MV which refers to dark without streetlight crash location with the driver going straight, PED_LGTCOND_LIGT_DRVRDO_GO_STR_MV which refers to dark with streetlight crash location with the driver going straight, and PED_DRVRDO_GO_STR_NMTLOC_2_MV which refers to crashes involving the driver going straight with pedestrians in the roadway.

9.1.2. Pedestrian Crashes-DT4000

Unlike the patterns shown in MV4000 pedestrian crash dataset, the variable ranks first is "PED_DNMFTR_DRVR_DT" (i.e., driver condition at the time when crash occurred). The following two variables within the top three most important variables are "PED_DRVRPC_DT" (i.e., contributing driver factor in the crash) and "PED_DNMFRT_NMT_DT" (i.e., pedestrian condition at the time when crash occurred). These two results are consistent with the results from CHAID decision tree. There also one newly variable rank within top 15, which is PED_LGTCOND_DARK_DRVRDO_GO_STR_DT which refers to dark without streetlight crash location with the driver going straight. Compared to the rankings by using the MV4000 pedestrian crash dataset, hit-and-run involvement (i.e., PED_HITRUN_DT) ranks relatively low and so does drug involvement. On the other hand, pedestrian's location (PED_NMTLOC_DT) shows strong effect here than the one result from using the MV4000 pedestrian crash dataset. The other important variables with relatively similar rankings in both models include alcohol involvement, driver's contributing factor, trafficway division type, traffic control in effect, driver's age, and driver's action.

9.2 DT4000 Crash Variables

More variables showed strong effects on injury severity of bicyclists involved in vehicle crashes using both datasets of MV4000 and DT4000 as well. The results are shown in both Figure 9--3 and Figure 9-4.

9.2.1. Bicyclist Crashes-MV4000

As for bicyclist crashes, the results display in Figure 9-2, which have quite different pattern compared to pedestrian crashes. The top three important variables in MV4000 are "BIKE_DRVRPC_MV" (i.e., contributing driver factor), newly created variable "BIKE_DRVRDO_GO_STR_NMTOC_2_MV" (i.e., driver going straight, and bicyclist located in roadway), and "BIKE_HITRUN_MV" (i.e., hit and run involvement). Compared to

“BIKE_DRVRDO_GO_STR_NMTOC_2_MV”, other newly created variables don’t show strong impacts and rank relatively low.

It is observed from the results shown in Figure 9-1 and Figure 9-3 that some common variables tend to be significant in previous studies but rank low or even not important, such as weather condition at time of crash (PED_WTHRCOND_MV and BIKE_ WTHRCOND_MV). Additionally, some variables rank totally different in two datasets. For example, it is noted that trafficway division type and level had a higher importance ranking for pedestrian crashes than bicyclist crashes. This is an interesting finding, which is opposite to expectation, since usually a bicycle is considered a vehicle and mainly follows traffic rules and have an interaction with the roadway geometry more than a pedestrian. Compared to the pedestrian’s location in the crash (i.e., PED_NMTLOC_MV), bicyclist’s location (i.e., BIKE_NMTLOC_MV) has more effect to the crash in terms of the ranking among all 36 variables. Other variables in common for both pedestrian and bicyclist crashes that show strong effects to the crash include hit-and-run involvement (i.e., HITRUN_MV), traffic control in effect (i.e., TRFCNTL_MV), driver’s action (i.e., DRVRDO_MV), and driver’s age (i.e., DRVRAGE_MV).

9.2.2. Bicyclist Crashes-DT4000

Whereas, for bicyclist injury severity, it is observed in Figure 9-4 that the first ranked variable (i.e., “BIKE_DNMFTR_DRVR_DT”, which refers to driver condition at the time when crash occurred) is the same as “PED_DNMFTR_DRVR_DT” in the pedestrian crash DT4000 dataset. This result is consistent with the result from CHAID decision tree. Then, the following two top three variables are related to drug and alcohol involvement in the crash. One newly created variable ranks within top 15 most important variables in bicyclist crash DT4000 dataset, which is “BIKE_DRVRDOIN_GO_STR-NMTLOC_NOT_ATI_MX_NAI_MX_DT” (i.e., driver going straight, and bicyclist located in roadway). Drug involvement (i.e., BIKE_DRUGFLAG_DT) here ranks pretty high with showing strong effect to the crash, but it seems to be not that critical by using the MV4000 bicyclist crash dataset.

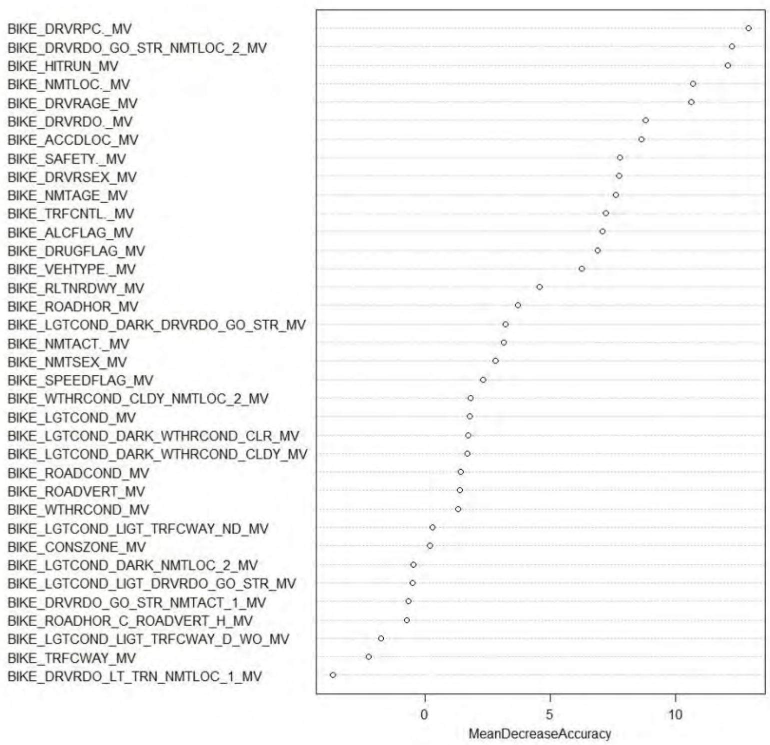


Figure 9-3: RF for MV4000 Crash Form Variable Importance Ranking for Bicyclist Crashes

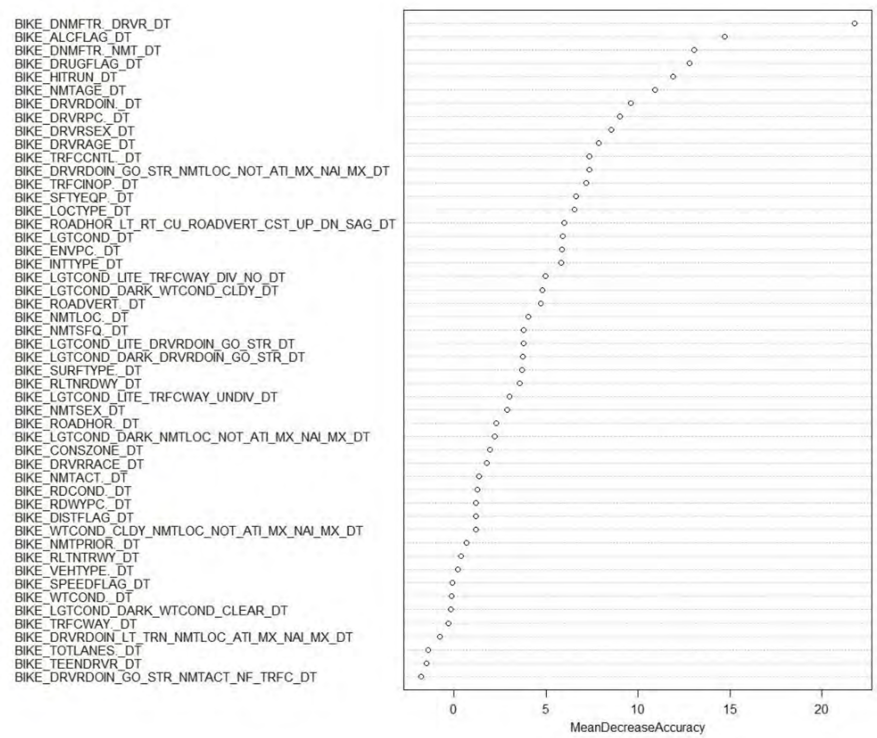


Figure 9-4: RF for DT4000 Crash Form Variable Importance Ranking for Bicyclist Crashes

9.3 Discussion of Variable Ranking

Some common variables, such as weather condition at time of crash (WTCOND_MV and WTCOND_MV), rank pretty low or even the lowest. Moreover, it is observed that the trafficway division type and level had a higher importance ranking for pedestrian crashes than bicyclist crashes for both MV4000 and DT4000 datasets. Though not consistent results obtained across the four datasets, one of the most common variables influencing pedestrian and bicyclist injury severity in vehicle crashes is pedestrian and bicyclist location with respect to the roadway (i.e., PED_NMTLOC_DT and BIKE_NMTLOC_MV). Previous studies have also presented that crashes involving vulnerable road users (VRUs) at signalized intersections are less severe than crashes occurred elsewhere (*9*, *107*, *108*).

Besides, several newly added data field in DT4000, which are conditions of both drivers and non-motorists relevant to crash (i.e., DNMFRT_DT), rank relatively high and show strong effects to the crash outcomes. It indicates again that the conditions and circumstances of involved parties in the crash have heavily contributed to the crash. Despite the conditions of involved parties in the crash, the action of pedestrian prior to the crash (i.e., PED_NMTPRIOR_DT), another newly added data field, ranks 13 among all 50 variables while there is not strong effect of the same variable (i.e., BIKE_NMTPRIOR_DT) in bicyclist crash. Some other newly added data fields in DT4000 somewhat show their effects towards crash, but not as critical as the forementioned ones, which are intersection type (i.e., INTTYPE). Besides, compared to the abovementioned noticeable variables, other newly added data fields in DT4000 datasets tend to be not that important with respect to their rankings, such as distractive driving involvement (i.e., DISTFLAG_DT), total lanes of the roadway (i.e., TOTLANES), and the location of a crash with respect it's relation to a trafficway (i.e., RLTNTRWY).

Even though the RF method is capable to detect variable's importance score, obtaining the knowledge about whether a change in the value or category of specific variable will increase or decrease the pedestrian or bicyclist's injury severity is deemed challenging.

10.STATISTICAL ANALYSIS USING THE LOGIT MODEL

The MNL model was implemented using "mlogit" package in RStudio. Also, variable correlation was tested by "GoodmanKruskal" package in R (*109*) using the "GKtauMatrix" function. No pair of variables with correlation coefficient larger than 0.65 have been identified, which means no strong correlations have been found for input variables. Many variables from the MV4000 and DT4000 datasets are selected in the MNL model development. However, based on the results obtained by implementing the MNL using RStudio, the p-values of some of the variables are larger than 0.1, which means that these variables are found to be insignificant and hence are removed from the list of significant variables.

10.1 MNL Model Results for Pedestrian -Vehicle Crash

Table 10-1 shows the estimated coefficients of each variable involved in the MNL model using both the MV4000 and DT4000 datasets for pedestrian crashes, respectively. The marginal effect analysis could help evaluate how the significant variables estimated in the MNL model impact the pedestrian injury outcome probabilities (*110*). Marginal effects of each significant factor on the likelihood of each injury-severity class are reported in Table 10-2 for both the MV4000 and DT4000 MNL models regarding the pedestrian models, correspondingly.

10.1.1. MNL Model for Pedestrian Crashes-MV4000

The analysis of the MV4000 dataset for pedestrian crashes in Table 10-1 shows that 23 variables tested by the MNL model are found to be significant in the MNL model.

With respect to the involvements of drug, hit-and-run, speeding, and alcohol, the results show the effects of them all tend to increase the chance of pedestrians suffering severer injuries, which is in line with most previous studies.

Two environmental related variable, dark roadway with and without streetlight, have been found to be significant in the MNL model. In addition, according to the marginal effects in Table 10-2, pedestrians are more likely to be involved in severe and fatal injury crashes if the crash occurred in dark roadways regardless of the availability of the streetlight. Many research has highlighted the effect of wearing reflective clothes in decreasing the likelihood of being involved in a vehicle crash in dark roadways (*111*, *112*).

Concerning the roadway related factors, trafficway (divided highway with and without traffic barrier) and the newly created variables curve (not straight) and hill (not level) road terrain have been found to be significant. The former one tends to increase the probability of pedestrians sustaining severe and fatal injuries, which is in line with the previous research (*113*). Additionally, the curve (not straight) and hill (not level) road terrain increase the likelihood of pedestrian sustaining severe and fatal injury. Moreover, it should be noted that this factor represents the interaction effect of two factors, while those two factors are not found to be significant in the model.

Table 10-1: Estimated Coefficients of Variables Included in the Pedestrian Injury Severity Models

MV4000

Variable	Severe Injury (A) Crash		Fatal (K) Crash	
	Coef.	P-value	Coef.	P-value
Intercept	-1.86	0	-3.56	0
Alcohol involvement (Y) [base: N]	0.54	0	0.86	0
Drug involvement (Y) [base: N]	0.47	0.07	1.25	0
Speeding (Y) [base: N]	0.93	0	1.29	0
Hit and run involvement (Y) [base: N]	0.26	0.04	0.72	0
Light condition (dark) [base: daylight]	0.78	0	1.63	0
Light condition (dark with streetlight) [base: daylight]	0.6	0	0.4	0.04
Drive gender (female) [base: male]	-0.22	0.03	-0.41	0.04
Pedestrian age (below 30) [base: ≥ 65]	0.42	0	0.91	0
Pedestrian age (30-64) [base: ≥ 65]	0.29	0.02	1.04	0
Driver age (below 30) [base: ≥ 65]	-0.81	0	-2.7	0
Driver age (30-64) [base: ≥ 65]	-0.45	0	-1.47	0
-				
Vehicle type (straight truck (insert truck)) [base: passenger car]	-	-	2.06	0
Vehicle type (truck tractor (semi attached)) [base: passenger car]	-	-	2.98	0
-				
Vehicle type (utility truck) [base: passenger car]	0.58	0	0.52	0.05
Driver movement (going straight) [base: turning left]	0.72	0	1.02	0
Traffic control (stop sign) [base: none]	-0.58	0	-1.16	0.02

DT4000

Variable	Severe Injury (A) Crash		Fatal (K) Crash	
	Coef.	P-value	Coef.	P-value
Intercept	-1.89	0	-4.48	0
Alcohol involvement (Y) [base: N]	0.61	0	0.7	0.01
Drug involvement (Y) [base: N]	0.51	0.05	1.35	0
Speeding involvement (Y) [base: N]	0.94	0	1.25	0
Hit and run (Y) [base: N]	1	0	2.12	0
Light condition (dark) [base: daylight]	0.7	0	1.61	0
Light condition (dark with streetlight) [base: daylight]	0.56	0	0.4	0.06
Drive gender (female) [base: male]	-0.24	0.02	-0.47	0.03
Pedestrian age (below 30) [base: ≥ 65]	-0.71	0	-2.59	0
Pedestrian age (30-64) [base: ≥ 65]	-0.37	0.01	-1.46	0
Driver age (below 30) [base: ≥ 65]	0.38	0	0.7	0.02
Driver age (30-64) [base: ≥ 65]	0.26	0.04	0.89	0
Vehicle type (cargo van (10,000lbs or less)) [base: passenger car]	-	-	2.27	0
Vehicle type (straight truck) [base: passenger car]	-	-	3.04	0
-				
Vehicle type (sport utility vehicle) [base: passenger car]	0.23	0.05	0.64	0
Vehicle type (utility truck/pickup truck) [base: passenger car]	0.63	0	0.64	0.02
Driver action (going straight) [base: turning left]	0.68	0	0.86	0
Traffic control (stop sign) [base: none]	-0.57	0	-1.3	0.01

MV4000				
Variable	Severe Injury (A) Crash		Fatal (K) Crash	
	Coef.	P-value	Coef.	P-value
Traffic control (traffic signal) [base: none]	-0.27	0.02	-0.81	0
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	0.52	0	1.23	0
Trafficway (divided highway without traffic barrier) [base: one-way traffic]	0.25	0.07	1.15	0
Pedestrian location (in roadway) [base: in crosswalk]	0.25	0.01	0.44	0.02
Contributing pedestrian action (walking facing traffic) [base: Other]	0.27	0.07	0.68	0.01
-				
Contributing driver factor (other) [base: blank]	0.52	0	0.6	0.02
-				
Curve (not straight) and hill (not level) road terrain [base: straight and level road terrain]	1.39	0	-	-

DT4000				
Variable	Severe Injury (A) Crash		Fatal (K) Crash	
	Coef.	P-value	Coef.	P-value
Traffic control (traffic signal) [base: none]	-0.33	0	-0.83	0
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	0.49	0.05	1.47	0
Trafficway (divided highway without traffic barrier) [base: one-way traffic]	-	-	1.03	0
-				
Pedestrian condition (not observed) [base: normal]	-0.89	0	-2.01	0
Driver condition (confused or disoriented (non lucid)) [base: normal]	1.41	0	-	-
Driver condition (not observed) [base: normal]	0.65	0	2.88	0
Driver condition (other) [base: normal]	0.67	0	2.83	0
Driver condition (physically impaired) [base: normal]	-	-	1.47	0.01
Driver condition (under the influence of medication/drugs/alcohol) [base: normal]	-	-	1.3	0
Contributing driver factor (other) [base: no]	0.36	0	-	-
Crash occurred under cloudy weather and pedestrian located in roadway (Y) [base: N]	0.29	0.02	0.54	0.02
-				

Table 10-2: Marginal Effects Results for Pedestrian Crash Variables

MV4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
Alcohol involvement (Y) [base: N]	0.0166	0.0825	-0.0991
Drug involvement (Y) [base: N]	0.0254	0.0691	-0.0945
Speeding (Y) [base: N]	0.0243	0.143	-0.1673
Hit and run involvement (Y) [base: N]	0.0146	0.0389	-0.0535
Light condition (dark) [base: daylight]	0.0323	0.1181	-0.1504
Light condition (dark with streetlight) [base: daylight]	0.0061	0.0949	-0.101
Drive gender (female) [base: male]	-0.0081	-0.0334	0.0414
Pedestrian age (below 30) [base: ≥ 65]	0.0183	0.0629	-0.0811
Pedestrian age (30-64) [base: ≥ 65]	0.0216	0.0419	-0.0634
Driver age (below 30) [base: ≥ 65]	-0.0557	-0.1187	0.1744
Driver age (30-64) [base: ≥ 65]	-0.0304	-0.066	0.0964
-			
Vehicle type (straight truck (insert truck)) [base: passenger car]	0.0429	0.0764	-0.1193
Vehicle type (truck tractor (semi attached)) [base: passenger car]	0.0621	0.1149	-0.1771
-			
Vehicle type (utility truck) [base: passenger car]	0.0089	0.0908	-0.0996
Driver movement (going straight) [base: turning left]	0.0193	0.1108	-0.1301
Traffic control (stop sign) [base: none]	-0.0231	-0.0873	0.1103
Traffic control (traffic signal) [base: none]	-0.0167	-0.0398	0.0565
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	0.0249	0.0773	-0.1022
Trafficway (divided highway without traffic barrier) [base: one-way traffic]	0.0242	0.0349	-0.0591

DT4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
Alcohol involvement (Y) [base: N]	0.0065	0.097	-0.1036
Drug involvement (Y) [base: N]	0.0142	0.0789	-0.0932
Speeding (Y) [base: N]	0.012	0.149	-0.161
Hit and run (Y) [base: N]	0.0219	0.1571	-0.1789
Light condition (dark) [base: daylight]	0.0167	0.1098	-0.1265
Light condition (dark with streetlight) [base: daylight]	0.0033	0.0893	-0.0926
Drive gender (female) [base: male]	-0.0048	-0.0381	0.0429
Pedestrian age (below 30) [base: ≥ 65]	-0.0279	-0.1081	0.136
Pedestrian age (30-64) [base: ≥ 65]	-0.0158	-0.0556	0.0714
Driver age (below 30) [base: ≥ 65]	0.0071	0.0597	-0.0668
Driver age (30-64) [base: ≥ 65]	0.0095	0.0398	-0.0493
Vehicle type (cargo van (10,000lbs or less)) [base: passenger car]	0.0242	0.1158	-0.1399
Vehicle type (straight truck) [base: passenger car]	0.033	0.1062	-0.1392
-			
Vehicle type (sport utility vehicle) [base: passenger car]	0.0068	0.0359	-0.0427
Vehicle type (utility truck/pickup truck) [base: passenger car]	0.0059	0.1004	-0.1063
Driver action (going straight) [base: turning left]	0.0082	0.108	-0.1162
Traffic control (stop sign) [base: none]	-0.0135	-0.089	0.1025
Traffic control (traffic signal) [base: none]	-0.0087	-0.0509	0.0596
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	0.0156	0.076	-0.0916
Trafficway (divided highway without traffic barrier) [base: one-way traffic]	0.0114	0.0225	-0.0339

MV4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
Pedestrian location (in roadway) [base: in crosswalk]	0.0086	0.0376	-0.0462
Contributing pedestrian action (walking facing traffic) [base: Other]	0.0138	0.0396	-0.0534
-			
Contributing driver factor (other) [base: blank]	0.0108	0.0805	-0.0913
Curve (not straight) and hill (not level) road terrain [base: straight and level road terrain]	0.0203	0.2184	-0.2387

DT4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
-			
Pedestrian condition (not observed) [base: normal]	-0.0209	-0.1398	0.1607
Driver condition (confused or disoriented (non lucid)) [base: normal]	0.0046	0.2266	-0.2312
Driver condition (not observed) [base: normal]	0.0314	0.0982	-0.1296
Driver condition (other) [base: normal]	0.0307	0.1019	-0.1326
Driver condition (physically impaired) [base: normal]	0.0158	0.0626	-0.0785
Driver condition (under the influence of medication/drugs/alcohol) [base: normal]	0.0149	-0.0071	-0.0079
Contributing driver factor (other) [base: no]	0.0031	0.0568	-0.0599
Crash occurred under cloudy weather and pedestrian located in roadway (Y) [base: N]	0.0055	0.0456	-0.0512
-			

Regarding age, three age groups are used in this study as previous studies divided ages (*114*). Pedestrians with age below 64 involved in the crash prone to less severe injuries while drivers with age below 64 tend to increase the likelihood of pedestrian to be severely injured or killed. This finding is supported by findings from previous research (*78*, *80*, *114*, *115*), and can be supported by the fact that older adult pedestrians, those 65 years and older, have their own limitations that make them susceptible to collisions. As adults age, gradual losses in hearing, vision, and flexibility put them at a higher risk, in addition to their need of longer reaction times while in the roadway. Furthermore, once the older adult pedestrian is struck, their co-morbid conditions and limited physical reserves contribute to a higher percentage of death and disability when compared to other pedestrian age groups (*114*). Moreover, drivers with age below 64 and female drivers tend to decrease the chance of pedestrian sustaining severer injuries.

For the vehicle type related factors, it is not surprised to see that all three significant factors in the model are trucks (i.e., truck tractor (semi attached), straight truck (insert truck), and utility truck)) with the effect of increasing the probability of pedestrian being severely injured and killed.

One factor associated with pedestrian's location that is found to significant is pedestrian in roadway and it is not surprised that it would increase the probability of pedestrian sustaining severe and fatal injuries. For contributing pedestrian factors, the factor of pedestrians walking facing traffic shows the effect to increase the chance of pedestrians sustaining severe and fatal injuries. With respect to driver's movement related factors, going straight by drivers is found to be significant in the model and this factor tends to increase the probability of pedestrian suffering severe and fatal injuries.

10.1.2. MNL Model for Pedestrian Crashes-DT4000

The analysis of the DT4000 dataset for pedestrian crashes in Table 10-1 shows that 28 variables tested by the MNL model are found to be significant. Table 10-2 shows the associated marginal effects of the 28 significant variables.

The involvements of alcohol, speeding, and hit-and-run are found to be significant by the MNL model and increase the probability of pedestrians being severely injured and killed, which meets the expectation and is consistent with MV4000 pedestrian crash MNL model. However, it should be noted that in the DT4000 MNL model, the magnitude of the marginal effect is higher for hit-and-run involvement but lower for the others while compared with MV4000 model on the probabilities of pedestrian being killed.

Regarding the light condition, regardless of the availability of streetlight, dark roadway would increase the probability of pedestrians being severely injured and killed. This is also in line with the MV4000 pedestrian crash MNL model, but only with almost half the effect towards the probability of fatalities for pedestrians. Such phenomenon could be observed for multiple significant factors in DT4000 model.

Similar to the MV4000 pedestrian crash MNL model, all age-related factors are found to be significant and have the same directions of effects towards the injury severity (i.e., pedestrians with age below 64 involved in the crash prone to less severe injuries while drivers with age below 64 drivers tend to increase the likelihood of pedestrian to be severely injured and killed). Similar to the MV4000 pedestrian crash MNL model, the factor of driver's gender (i.e., female drivers) tends to decrease the chance of pedestrian sustaining severe and fatal injuries.

While referring to vehicle type, the way DT4000 classifies the vehicle types in more details than MV4000 (38 vs. 24). Though two out of the three vehicle types that show significant effect are the same to the ones in MV4000 model (i.e., straight truck (insert truck), and utility truck), there is one new type defined in DT4000 (i.e., sport utility vehicle) has been found to be significant, which increase the chance of severe and fatal injuries for pedestrians.

Going straight by drivers is the only significant factor among all driver's actions and it is found to increase the likelihood of fatal injury pedestrian crashes, which is the same with MV4000 model.

Unlike the MV4000 pedestrian crash MNL model with one significant factor being found among pedestrian's locations, there is no significant factor has been found for this variable group in the DT4000 pedestrian crash MNL model. This might be due to the more location types in DT4000 than MV4000 with insufficient data points of each location type for model estimation and could be addressed in the future with data accumulation.

As denoted throughout the report that compared to MV4000, involved parties' conditions have been newly added to the DT4000. Thus, the results show that 6 related factors here are found to be significant, which are not observed pedestrian condition, driver being confused or disoriented (non-lucid), not observed driver condition, driver being physically impaired, driver under the influence of medication/drugs/alcohol, and other driver conditions. All driver related conditions are found to increase the chance of pedestrians being fatally injured. Except the not observed driver condition, the other 4 conditions of drivers could be treated as abnormal conditions of drivers, which make sense of increasing the probability of pedestrians sustaining severe and fatal injuries. Hence, such variables newly added in DT4000 indeed provide insights for safety analysis, and more efforts should be further made (e.g., advanced techniques, more data input, etc.) to explore the reasons behind.

Last, other than the common variables explored in the previous analysis, there is only one newly created variable in the model that is found to be significant, which is the crash occurred under cloudy weather while pedestrians were located in roadway. This factor is found to increase the likelihood of pedestrian sustaining severe and fatal injuries in the crash. It is worth mentioning that the factor of weather condition is not found to be significant in this model. Hence, this interaction variable shows its effect other than the separate components in the model and prove the way we combine some variables to examine the interactive effects.

10.2 MNL Model Results for Bicyclist-Vehicle Crash

Table 10-3 shows the estimated coefficients of each variable involved in the MNL model using both the MV4000 and DT4000 datasets for bicyclist crashes, respectively. Marginal effects of each significant factor on the likelihood of each injury-severity class are reported in Table 10-4 for the both the MV4000 and DT4000 MNL models regarding bicyclist crash, correspondingly.

10.2.1. MNL Model for Bicyclist Crashes-MV4000

The analysis of the MV4000 dataset for bicyclist crashes in Table 10-3 shows that 15 variables tested by the MNL model are found to be significant. Table 10-4 shows the associated marginal effects of the 15 significant variables.

The involvement of alcohol and hit-and-run are found to have significant effects on the bicyclist crashes with increasing the chance of bicyclists suffering severe and fatal injuries, which meets the expectation. Similarly, similar conclusion could also be applied to the factor of dark roadways without streetlights, which is the only significant environmental factor here.

Two roadway-related factors, the type of location at which a crash occurred (intersection) and the vertical road terrain at the point of impact (hill), have been found to be significant in the model of bicyclist crashes using MV4000 dataset. The factor of intersection tends to decrease the probability of bicyclists sustaining fatal injuries, but to increase the chance of them to be severely injured. One possible explanation could be concluded as the lower speed of vehicles in the intersections, which might mitigate the fatalities, but not sufficient to avoid severe injuries for bicyclists. However, for the factor of the vertical road terrain at the point of impact (hill), the marginal effects indicate that it would increase both probabilities for bicyclist. For instance, (*116*) agreed that most bicycle-motor vehicle (BMV) crashes occurred in city areas which are generally hilly, resulting in poor visibility because drivers and cyclists cannot be sure whether or not there is an oncoming vehicle hidden beyond the rise. Also, (*117*) concluded that when the automobile driver has his/her vision obscured by hill crests and are in a crash with a bicyclist, the bicyclist's severe injury and fatality risks increase by (63.4%).

Unlike the MNL model of pedestrian crashes using MV4000 dataset, drivers with age below 64 is found to decrease the chances of severe and fatal injuries for bicyclist in the crashes. Two major driver actions (i.e., go straight and turn right) are found to be significant in the model. The results show that crashes involving the driver going straight are more likely to produce severe and fatal injuries to bicyclists. For turning right by drivers, it increases the chance of bicyclists being killed but decreases the chance of bicyclist being severely injured. Most common bicycle-motor vehicle (BMV) collisions happened when the driver looks left for oncoming vehicles when they should also be looking right for cyclists. This situation creates lack of driver expectation about bicyclists' location and behavior (*118*). However, more attention might need to be put into the fatal injury, since right turn has more effects on this category of injury and decrease the probability of bicyclist being severe injured, which is in line with one other research (*119*).

Table 10-3: Estimated Coefficients of Variables Included in the Pedestrian Injury Severity Models

MV4000				
Variable	**Severe Injury (A) Crash**		**Fatal (K) Crash**	
	Coef.	P-value	Coef.	P-value
Intercept	-1.72	0	-5.56	0
Alcohol involvement (Y) [base: N]	1.03	0	-	-
-				
Hit and run (Y) [base: N]	-	-	1.23	0.01
Light condition (dark) [base: daylight]	-	-	2.17	0
-				
The type of location at which a crash occurred (intersection) [base: non-intersection]	-	-	-1.06	0.01
-				
Driver age (below 30) [base: ≥ 65]	-1.44	0	-2.07	0
Driver age (30-64) [base: ≥ 65]	-0.74	0	-0.84	0.09
Vehicle type (straight truck (insert truck)) [base: passenger car]	1.48	0	2.18	0.02
-				
The vertical road terrain at the point of impact (hill) [base: level]	0.58	0	1.39	0
Driver action (going straight) [base: turning left]	0.58	0	2.15	0
Driver action (turning right) [base: turning left]	-0.95	0	-	-
Bicyclist location (in roadway) [base: in crosswalk]	0.42	0	0.85	0.03
-				

DT4000				
Variable	**Severe Injury (A) Crash**		**Fatal (K) Crash**	
	Coef.	P-value	Coef.	P-value
Intercept	-1.24	0	-8.68	0
Alcohol involvement (Y) [base: N]	1.09	0	-	-
Drug involvement (Y) [base: N]	-	-	5.52	0
-				
Light condition (dark) [base: daylight]	-	-	2.82	0
Location of the crash relates to its position within or outside the trafficway (roadside) [base: on roadway]	-1.14	0.07	1.61	0.1
-				
Bicyclist age (below 30) [base: ≥ 65]	-1.33	0	-2.68	0
Bicyclist age (30-64) [base: ≥ 65]	-0.75	0	-	-
-				
Vehicle type (straight truck) [base: passenger car]	1.68	0	3.72	0
Roadway curvature (curve left) [base: straight]	-	-	5.6	0
-				
Driver action (going straight) [base: turning left]	0.62	0	3.61	0
Driver action (turning right) [base: turning left]	-0.86	0	1.78	0.04
Bicyclist location (at intersection-not in crosswalk) [base: at intersection-in crosswalk]	0.45	0	-	-
Bicyclist's action immediately prior to a crash (in roadway-other) [base: none]	-0.43	0.05	1.16	0.06

MV4000				
Variable	**Severe Injury (A) Crash**		**Fatal (K) Crash**	
	Coef.	P-value	Coef.	P-value
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	-	-	1.29	0.03
-				
Traffic control (other) [base: none]	-	-	0.82	0.06
-				
Contributing bicyclist action (walking facing traffic) [base: Other]	0.52	0.01	1.05	0.02
-				
Streetlight is available at time of crash in a divided trafficway without a traffic barrier (Y) [base: N]	-	-	2.74	0
-				

DT4000				
Variable	**Severe Injury (A) Crash**		**Fatal (K) Crash**	
	Coef.	P-value	Coef.	P-value
Bicyclist's action immediately prior to a crash (crossing roadway) [base: none]	-0.38	0.01	-	-
Safety equipment used by driver (shoulder & lap belt) [base: none]	-	-	-1.33	0.01
-				
Total number of lanes (>3) [base: 1 lane]	-	-	2.08	0
Traffic control (other) [base: none]	-0.29	0.07	1.27	0.01
Bicyclist condition (emotional (depressed, angry, disturbed, etc.)) [base: normal]	-	-	4.14	0
Driver condition (confused or disoriented (non lucid)) [base: normal]	2	0	-	-
Driver condition (not observed) [base: normal]	0.73	0	5.4	0
Driver condition (other) [base: normal]	0.99	0	4.35	0
-				
Contributing driver factor (other) [base: no]	0.5	0.01	-	-
Contributing environmental factor (glare) [base: none]	-	-	2.11	0.01
Weather condition (cloudy) [base: clear]	-0.69	0.02	-	-
-				
Crash occurred under cloudy weather and bicyclist located in roadway (Y) [base: N]	0.97	0	-	-

Table 10-4: Marginal Effects Results for Bicyclist Crash Variables

MV4000			
Variable	**P (Fatal (K) Crash)**	**P (Severe Injury (A) Crash)**	**P (Evident and Possible Injury (B+C) Crash)**
Alcohol involvement (Y) [base: N]	0.0027	0.0817	-0.0843
-			
Hit and run (Y) [base: N]	0.005	0.0043	-0.0093
Light condition (dark) [base: daylight]	0.0089	0.0069	-0.0157
The type of location at which a crash occurred (intersection) [base: non-intersection]	-0.0044	0.0138	-0.0094
-			
Driver age (below 30) [base: ≥ 65]	-0.008	-0.1131	0.1211
Driver age (30-64) [base: ≥ 65]	-0.0032	-0.0583	0.0614
Vehicle type (straight truck (insert truck)) [base: passenger car]	0.0084	0.1163	-0.1248
-			
The vertical road terrain at the point of impact (hill) [base: level]	0.0055	0.0457	-0.0512
Driver movement (going straight) [base: turning left]	0.0086	0.0454	-0.054
Driver movement (turning right) [base: turning left]	0.0052	-0.0755	0.0704
Bicyclist location (in roadway) [base: in crosswalk]	0.0033	0.0332	-0.0365
-			

DT4000			
Variable	**P (Fatal (K) Crash)**	**P (Severe Injury (A) Crash)**	**P (Evident and Possible Injury (B+C) Crash)**
Alcohol involvement (Y) [base: N]	0.0002	0.0807	-0.0809
Drug involvement (Y) [base: N]	0.0012	0.038	-0.0393
-			
Light condition (dark) [base: daylight]	0.0006	0.0045	-0.0052
-			
Location of the crash relates to its position within or outside the trafficway (roadside) [base: on roadway]	0.0004	-0.0841	0.0837
Bicyclist age (below 30) [base: ≥ 65]	-0.0006	-0.0981	0.0987
Bicyclist age (30-64) [base: ≥ 65]	-0.0001	-0.0554	0.0555
-			
Vehicle type (straight truck) [base: passenger car]	0.0008	0.1246	-0.1254
Roadway curvature (curve left) [base: straight]	0.0013	-0.0026	0.0014
-			
Driver movement (going straight) [base: turning left]	0.0008	0.0456	-0.0464
Driver movement (turning right) [base: turning left]	0.0004	-0.0639	0.0635
Bicyclist location (at intersection-not in crosswalk) [base: at intersection-in crosswalk]	-0.0001	0.0333	-0.0332
Bicyclist's action immediately prior to a crash (in roadway-other) [base: none]	0.0003	-0.0319	0.0316

MV4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
-			
Trafficway (divided highway with traffic barrier) [base: one-way traffic]	0.0053	0.0053	-0.0106
-			
Traffic control (other) [base: none]	0.0035	-0.0214	0.0179
-			
Contributing bicyclist action (biking facing traffic) [base: Other]	0.0041	0.0411	-0.0452
-			
Streetlight is available at time of crash in a divided trafficway without a traffic barrier (Y) [base: N]	0.0111	0.0369	-0.048
-			

DT4000			
Variable	P (Fatal (K) Crash)	P (Severe Injury (A) Crash)	P (Evident and Possible Injury (B+C) Crash)
Bicyclist's action immediately prior to a crash (crossing roadway) [base: none]	-0.0001	-0.0284	0.0285
Safety equipment used by driver (shoulder & lap belt) [base: none]	-0.0003	-0.013	0.0133
-			
Total number of lanes (>3) [base: 1 lane]	0.0005	-0.0151	0.0146
Traffic control (other) [base: none]	0.0003	-0.0214	0.0211
Bicyclist condition (emotional (depressed, angry, disturbed, etc.)) [base: normal]	0.0009	0.0244	-0.0253
Driver condition (confused or disoriented (non lucid)) [base: normal]	-0.0024	0.148	-0.1456
Driver condition (not observed) [base: normal]	0.0012	0.0538	-0.055
Driver condition (other) [base: normal]	0.001	0.0734	-0.0743
-			
Contributing driver factor (other) [base: no]	0.0001	0.0369	-0.037
Contributing environmental factor (glare) [base: none]	0.0005	0.036	-0.0365
Weather condition (cloudy) [base: clear]	0.0002	-0.0514	0.0512
-			
Crash occurred under cloudy weather and bicyclist located in roadway (Y) [base: N]	-0.0003	0.0718	-0.0715

Concerning bicyclist location at time of crash, the estimation results in Table 10-3 and Table 10-4, both showed that bicyclists located at intersections in the roadway (no specific information about the specific location of the non-motorist) are more likely to sustain severe and fatal injury when involved in motor-vehicle crashes.

One newly created variable is found to be significant in the model. Crashes happening in a divided trafficway with streetlight but without a traffic barrier could lead to more severe and fatal injuries, according to the results. This might be a little contradictory to the result that the factor of divided roadways with traffic barrier is found to be increase the probabilities of bicyclists sustaining severe injuries in the model. While relating this with the fact that bicyclist biking facing traffic has been found to increase the chance of bicyclist being severely injured, one might argue that with the presents of streetlights, when a bicyclist travel across a roadway without the traffic barrier (facing the traffic on the opposite direction), he/she might expect to be clearly noticed by the vehicles in the opposite direction and might be reckless to the situation.

One more noticeable result from marginal effects is that the probability changes of the fatal injury are quite small, even most of them are less than 1%. Compared to pedestrian crashes, the fatality rate of bicyclist in a crash in our dataset is only 1.36% (i.e., 36 out of 2,652), hence almost all of the variables would not have great impact on the chances of bicyclist being killed.

10.2.2. MNL Model for Bicyclist Crashes-DT4000

The analysis of DT4000 for bicyclist crashes in Table 10-3 shows that 24 variables are found to be statistically significant in the MNL model. Table 10-4 shows the marginal effects of these 24 variables. It is noted that having more statistically significant variables in the model with DT4000 bicyclist crash data leads to very small marginal variable effects on the probability change of fatal injuries. Therefore, our discussion is focused on the variable effects on severe injuries than fatal injuries.

Alcohol and drug involvement is found to be statistically significant in increasing the probability of severe injuries. Dark roadway without streetlight seems to slightly increase the chance of a bicyclist to be killed, but would greatly mitigate the severe injury for a bicyclist. According to the results, a crash happened at roadside is prone to non-severe injuries for a bicyclist.

The age of a bicyclist has always been considered a risk factor in injury severity studies (*120–122*). Two age related factors are found to be statistically significant in the model: bicyclist age (below 30) and bicyclist age (30-64); and a bicyclist with age below 64 is prone to non-severe injury in a crash.

It is apparent that a crash on a curved roadway especially when a vehicle turns left slightly increases the chance of a bicyclist fatality but less likely to increase the risk of a severe bicyclist injury. The marginal effect of total number of lanes (a new data field in DT4000) shows that a crash occurring on a roadway with more than 3 lanes is prone to non-severe injury for bicyclists.

With respect to driver's actions, going straight and turning right by the driver seem to slightly increase the probability of bicyclists being killed. However, the former one is more likely to increase the chance for a severe injury of a bicyclist and the latter one has the opposite effect on the severe injury of a bicyclist. A bicyclist at intersection not in crosswalk is associated with increased probability of being severely injured. A new variable in DT4000 - prior actions by bicyclists – shows the reduced risk of a severe injury when a bicyclist is crossing roadway or taking other actions but in roadway. The use of the shoulder & lap belt of a driver decreases the probability of bicyclists having severe injury. It is worth noting that in MV4000, the safety equipment used variable contains information of safety equipment used by all involved entities other than separating them as what is coded now in DT4000.

The conditions of involved parties in the crash are found to significantly impact the crash outcome such as emotional bicyclist, driver being confused or disoriented (non-lucid), not observed driver condition, and other driver condition. The emotional condition of a bicyclist increases the chance of a bicyclist to sustain severe injury in a crash. Driver being confused or disoriented (non-lucid) slightly decreases the probability of a bicyclist to be killed but greatly increases the chance of bicyclists being severely injured. This is in line with the findings in the MNL model of DT4000 pedestrian crash dataset, which shows an improvement of DT4000 by providing more useful information on the possible causes to non-motorist crashes.

Two environmental factors, glare and cloudy weather, are found to be statistically significant in the model. Glare could increases the chance of a bicyclist suffering severe injuries, and cloudy weather shows the opposite. However, it is intriguing to see when a bicyclist located in roadway under cloudy weather, the probability of him/her sustaining fatality decreases but the chance of severe injury increases. Furthermore, the factor of a bicyclist located in roadway is not even statistically significant in the model. Since the injury severity outcome of a crash is rarely dependent on a single factor, including interaction terms in the regression model helps to measure if an interaction effect exists between two or more independent variables. When the interaction term is statistically significant, it means uncertainty about the relative importance of main effects of individual factors. In this case, the importance of a bicyclist located in roadway and cloudy weather on his/her crash outcome should not be interpreted in isolation but together with the interaction effect.

11.CONCLUSIONS AND FUTURE WORK

This study investigated and reported on major upgrades to the newly designed DT4000 crash report form. The percentage of completion of the form by law enforcement was also examined. The following fields from DT4000 provide details that would not have been available with the MV4000 dataset: horizontal road terrain (ROADHOR [1,2]), vertical road terrain (ROADVERT [1,2]), road surface condition (RDCOND [A,B,C]), controlled maneuver by the driver (DRVRDOIN [1,2]), trafficway description (TRFCWAY [1, 2]), apparent factors of the road/highway (RDWYPC [A, B, C]), driver contributing actions/circumstances (DRVRPC [1,2] [A,B,C,D]), non-motorist actions/circumstances contributing to the crash (NMTACT [1,2] [A,B]), and non-motorist location with respect to the roadway (NMTLOC [1,2]). The enhanced data fields and data attributes show prominent contributions based on their sample size, which reflects the data field completion level. The new data fields are not only more specific, but they provide added information regarding the crash circumstances and help to better understand why and how a crash happened. The new data fields in DT4000 also helped fill in information that was missing from the MV4000 dataset, such as total number of lanes (TOTLANES [1,2]), status of the TCD (TRFCINOP [1,2]), individual condition relevant to the crash (DNMFTR [1,2] [A,B]), and non-motorist actions immediately prior to the crash (NMTPRIOR [1,2]).

The quality of the crash data was further assessed by comparing six new intersection-related data fields in DT4000 (i.e., LOCTYPE, INTTYPE, TRFCCNTL, TOTLANES, TRFWAY, and URBRURAL) with corresponding information from the Wisconsin State Trunk Network (STN) data (i.e., Intersection Network Screening data). The assessment uncovered inconsistencies among crash records and between data from DT4000 and STN, especially with regard to the TRFCCNTL, TOTLANES, and TRFWAY variables. Inconsistencies also exist among the data fields in DT4000, as one location may have several different descriptions. Clearly, there is a trade-off between collecting more detailed information (especially at the unit level) and imposing a larger workload on the data collector. Additionally, the coding schema of intersection related characteristics in DT4000 is not always consistent with traffic and highway engineering practices.

The information gathered from data fields in MV4000 versus DT4000 has been examined via the univariate analysis. Though the crash observations recorded in both the MV4000 and DT4000 forms are the same, and the basic information extracted from both forms should be consistent, DT4000 provides a more detailed level of information and leads to different distributions and patterns of data. Subsequently, the multivariate category analysis has been carried out using cross-classification tables. The percentage of combined values from two or more attributes in the crash data was presented, and the dependence and association between different attributes were explored for the following groups: 1) action-location relationships, 2) roadway characteristics relationships, 3) driver action-roadway characteristics relationships, 4) driver actions-VRU actions relationships, 5) VRU location-roadway characteristics relationships, and 6) environmental conditions-roadway characteristics relationships. The enhanced data fields and the newly created data fields in DT4000 offer a better opportunity to run a more comprehensive traffic safety analysis with higher data resolution. To name a few, the VRU locations (i.e., NMTLOC) data field in DT4000 adds the marking status of a crosswalk; detailed intersection-related roadway characteristics (e.g., INTTYPE, TOLANES, etc.) help reveal some critical crash prone patterns, such as 4-way intersection with traffic control. However, due to the relatively small sample size of VRU crashes, more data accumulation is needed for identifying critical crash-prone patterns with more detailed and disaggregated data fields and attributes.

Based on the multivariate analysis results, fourteen (14) new variables were created by the project team to explore the interaction effects on two or more variables. A series of Z-tests concerning injury severity proportion were employed to examine the interaction variables for pedestrian and bicycle related crashes in MV4000 and DT4000, respectively. The results indicate that most of the newly created interaction variables show a significant difference between proportions of severe and fatal injury crashes and non-severe injury crashes. Also, different patterns between the MV4000 and DT4000 datasets were observed for some variables.

The CHAID decision tree, Random Forest, and the MNL model were applied to identify any factors that significantly impacted VRU crashes. The sets of contributing factors found in the MV4000 datasets were quite different than those found in the DT4000 datasets. The following enhanced information and newly added data fields in DT4000 impacted the prediction of crash injury severity: the conditions of both drivers and VRUs (i.e., DNMFTR [1,2][A,B]), the distractive driving involvement (i.e., DISTFLAG), and the action of a bicyclist immediately prior to a crash (i.e., NMTPRIOR [1,2]_DT). This information, which was not collected in MV4000, indicates that the conditions and circumstances of the parties involved in the crash might heavily contribute to the crash.

Future studies should consider a larger sample size so that the other newly added DT4000 crash form data fields that were not statistically significant in this study's crash severity models can be evaluated further. On the other hand, more advanced analytical methods other than the ones used in this study (i.e., MNL, random forests, CHAID) would help fully understand the potential of the DT4000 data given the challenges of limited data sample size. Also, while many data fields in DT4000 provide a granular level of information due to the number of attributes, combining attributes that serve a similar purpose is believed to add more value. For example, the data field describing the actions/circumstances of the non-motorist that may have contributed to the crash (NMTACT) has several similar attributes: "sudden movement into traffic" and "improper passing"; or, "dark clothing" and "not visible (dark clothing, no lighting, etc.)". Finally, even though many road-user behavior related data fields were added to DT4000, this still presents only a portion of the potential variables that can significantly affect the likelihood of crash occurrence. Continuous efforts are needed to monitor crash data quality and identify future needs for crash data improvements.

12.REFERENCES

1. World Health Organization. *Global Status Report on Road Safety 2018*. World Health Organization, Geneva, 2018.
2. National Highway Traffic Safety Administration. *2017 Fatal Motor Vehicle Crashes: Overview*. Publication DOT HS 812 603. US Department of Transportation, Washington, DC, 2017.
3. Wisconsin DMV Official Government Site - Final Year-End Crash Statistics. https://wisconsindot.gov/Pages/about-wisdot/newsroom/statistics/final.aspx. Accessed October, 2021.
4. Qin, X., and J. N. Ivan. Estimating Pedestrian Exposure Prediction Model in Rural Areas. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1773, No. 1, 2001, pp. 89–96. https://doi.org/10.3141/1773-11.
5. Aziz, H. M. A., S. V. Ukkusuri, and S. Hasan. Exploring the Determinants of Pedestrian–Vehicle Crash Severity in New York City. *Accident Analysis & Prevention*, Vol. 50, 2013, pp. 1298–1309. https://doi.org/10.1016/j.aap.2012.09.034.
6. Lee, C., and M. Abdel-Aty. Comprehensive Analysis of Vehicle–Pedestrian Crashes at Intersections in Florida. *Accident Analysis & Prevention*, Vol. 37, No. 4, 2005, pp. 775–786. https://doi.org/10.1016/j.aap.2005.03.019.
7. M P daSilva, J. D. Smith, and W. G. Najm. *ANALYSIS OF PEDESTRIAN CRASHES*. Publication DOT-VNTSC-NHTSA-02-02. National Highway Traffic Safety Administration, 2003.
8. Fitzpatrick, K., R. Avelar, and S. Turner. Guidebook on Identification of High Pedestrian Crash Locations. 2018.
9. Haleem, K., P. Alluri, and A. Gan. Analyzing Pedestrian Crash Injury Severity at Signalized and Non-Signalized Locations. *Accident Analysis & Prevention*, Vol. 81, 2015, pp. 14–23. https://doi.org/10.1016/j.aap.2015.04.025.
10. Hamann, C., and C. Peek-Asa. On-Road Bicycle Facilities and Bicycle Crashes in Iowa, 2007–2010. *Accident Analysis & Prevention*, Vol. 56, 2013, pp. 103–109. https://doi.org/10.1016/j.aap.2012.12.031.
11. Dixon, K., K. Fitzpatrick, R. Avelar, and S. Das. Analysis of the Shoulder Widening Need on the State Highway System. https://www.researchgate.net/publication/323946139_Analysis_of_the_Shoulder_Widening_Need_on_the_State_Highway_System. Accessed Feb. 4, 2019.
12. Kim, K., P. Pant, and E. Yamashita. Accidents and Accessibility: Measuring Influences of Demographic and Land Use Variables in Honolulu, Hawaii. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2147, No. 1, 2010, pp. 9–17. https://doi.org/10.3141/2147-02.
13. Marshall, W. E., N. W. Garrick, and G. Hansen. Reassessing On-Street Parking. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2046, No. 1, 2008, pp. 45–52. https://doi.org/10.3141/2046-06.
14. McMahon, P., C. Duncan, J. Stewart, C. Zegeer, and A. Khattak. Analysis of Factors Contributing to "Walking Along Roadway" Crashes. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1674, No. 1, 1999, pp. 41–48. https://doi.org/10.3141/1674-06.

15. Miranda-Moreno, L. F., J. Strauss, and P. Morency. Disaggregate Exposure Measures and Injury Frequency Models of Cyclist Safety at Signalized Intersections. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2236, No. 1, 2011, pp. 74–82. https://doi.org/10.3141/2236-09.
16. Obaidat, M. T., H. R. Al-Masaeid, O. Al-Haji, and A. Qudah. A Knowledge- Based System for Pedestrian's Crossing Behavior through Video Cameras. *ResearchGate*. https://www.researchgate.net/publication/299136030_A_knowledge-_Based_System_for_Pedestrian's_Crossing_Behavior_through_Video_Cameras. Accessed Feb. 8, 2019.
17. Risley, J. S. Review of MOTOR VEHICLE ACCIDENT RECONSTRUCTION AND CAUSE ANALYSIS. SECOND EDITION. *Jurimetrics*, Vol. 25, No. 3, 1985, pp. 335–339.
18. Shaw, J. W., M. V. Chitturi, Y. Han, W. Bremer, and D. A. Noyce. Bicyclist and Pedestrian Safety in Work Zones: Recent Advances and Future Directions. Presented at the Transportation Research Board 95th Annual MeetingTransportation Research Board, 2016.
19. Strauss, J., L. F. Miranda-Moreno, and P. Morency. Cyclist Activity and Injury Risk Analysis at Signalized Intersections: A Bayesian Modelling Approach. *Accident Analysis & Prevention*, Vol. 59, 2013, pp. 9–17. https://doi.org/10.1016/j.aap.2013.04.037.
20. Sullivan, J. M., and M. J. Flannagan. The Role of Ambient Light Level in Fatal Crashes: Inferences from Daylight Saving Time Transitions. *Accident Analysis & Prevention*, Vol. 34, No. 4, 2002, pp. 487–498.
21. Teschke, K., M. A. Harris, C. C. O. Reynolds, M. Winters, S. Babul, M. Chipman, M. D. Cusimano, J. R. Brubacher, G. Hunte, S. M. Friedman, M. Monro, H. Shen, L. Vernich, and P. A. Cripton. Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study. *American Journal of Public Health*, Vol. 102, No. 12, 2012, pp. 2336–2343. https://doi.org/10.2105/AJPH.2012.300762.
22. Ulfarsson, G. F., S. Kim, and K. M. Booth. Analyzing Fault in Pedestrian–Motor Vehicle Crashes in North Carolina. *Accident Analysis & Prevention*, Vol. 42, No. 6, 2010, pp. 1805–1813. https://doi.org/10.1016/j.aap.2010.05.001.
23. Wang, Y., and K. M. Kockelman. A Poisson-Lognormal Conditional-Autoregressive Model for Multivariate Spatial Analysis of Pedestrian Crash Counts across Neighborhoods. *Accident Analysis & Prevention*, Vol. 60, 2013, pp. 71–84. https://doi.org/10.1016/j.aap.2013.07.030.
24. Wei, F., and G. Lovegrove. An Empirical Tool to Evaluate the Safety of Cyclists: Community Based, Macro-Level Collision Prediction Models Using Negative Binomial Regression. *Accident Analysis & Prevention*, Vol. 61, 2013, pp. 129–137. https://doi.org/10.1016/j.aap.2012.05.018.
25. Zegeer, C. V., J. Richard Stewart, H. Huang, and P. Lagerwey. Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Analysis of Pedestrian Crashes in 30 Cities. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1773, No. 1, 2001, pp. 56–68. https://doi.org/10.3141/1773-07.
26. Amoh-Gyimah, R., M. Saberi, and M. Sarvi. Macroscopic Modeling of Pedestrian and Bicycle Crashes: A Cross-Comparison of Estimation Methods. *Accident Analysis & Prevention*, Vol. 93, 2016, pp. 147–159. https://doi.org/10.1016/j.aap.2016.05.001.

27. Lee, J., M. Abdel-Aty, and X. Jiang. Multivariate Crash Modeling for Motor Vehicle and Non-Motorized Modes at the Macroscopic Level. *Accident Analysis & Prevention*, Vol. 78, 2015, pp. 146–154. https://doi.org/10.1016/j.aap.2015.03.003.
28. Narayanamoorthy, S., R. Paleti, and C. R. Bhat. On Accommodating Spatial Dependence in Bicycle and Pedestrian Injury Counts by Severity Level. *Transportation Research Part B: Methodological*, Vol. 55, 2013, pp. 245–264. https://doi.org/10.1016/j.trb.2013.07.004.
29. Siddiqui, C., M. Abdel-Aty, and K. Choi. Macroscopic Spatial Analysis of Pedestrian and Bicycle Crashes. *Accident Analysis & Prevention*, Vol. 45, 2012, pp. 382–391. https://doi.org/10.1016/j.aap.2011.08.003.
30. Ukkusuri, S., S. Hasan, and H. M. A. Aziz. Random Parameter Model Used to Explain Effects of Built-Environment Characteristics on Pedestrian Crash Frequency. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2237, No. 1, 2011, pp. 98–106. https://doi.org/10.3141/2237-11.
31. Atkins, R. M., W. H. Turner, R. B. Duthie, and B. R. Wilde. Injuries to Pedestrians in Road Traffic Accidents. *BMJ (Clinical research ed.)*, Vol. 297, No. 6661, 1988, pp. 1431–1434.
32. Das, S., and X. Sun. Factor Association with Multiple Correspondence Analysis in Vehicle–Pedestrian Crashes. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2519, No. 1, 2015, pp. 95–103. https://doi.org/10.3141/2519-11.
33. DiMaggio, C., and M. Durkin. Child Pedestrian Injury in an Urban Setting: Descriptive Epidemiology. *Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine*, Vol. 9, No. 1, 2002, pp. 54–62.
34. Ernst, M. MEAN STREETS 2004 - HOW FAR HAVE WE COME? PEDESTRIAN SAFETY, 1994-2003. 2004.
35. Huemer, A. K. Cycling under the Influence of Alcohol in Germany. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 56, 2018, pp. 408–419. https://doi.org/10.1016/j.trf.2018.05.013.
36. Luoma, J., J. Schumann, and E. C. Traube. Effects of Retroreflector Positioning on Nighttime Recognition of Pedestrians. *Accident; Analysis and Prevention*, Vol. 28, No. 3, 1996, pp. 377–383.
37. Öström, M., and A. Eriksson. Pedestrian Fatalities and Alcohol. *Accident Analysis & Prevention*, Vol. 33, No. 2, 2001, pp. 173–180. https://doi.org/10.1016/s0001-4575(00)00028-2.
38. Rodgers, G. B. Bicyclist Deaths and Fatality Risk Patterns. *Accident Analysis & Prevention*, Vol. 27, No. 2, 1995, pp. 215–223. https://doi.org/10.1016/0001-4575(94)00063-R.
39. Stoker, P., A. Garfinkel-Castro, M. Khayesi, W. Odero, M. N. Mwangi, M. Peden, and R. Ewing. Pedestrian Safety and the Built Environment: A Review of the Risk Factors. *Journal of Planning Literature*, Vol. 30, No. 4, 2015, pp. 377–392. https://doi.org/10.1177/0885412215595438.
40. Wiechel, J. F., and D. A. Guenther. Review of Pedestrian Safety Research in the United States. Presented at the SAE International Congress and Exposition, 1989.
41. Abdel-Aty, M., J. Lee, C. Siddiqui, and K. Choi. Geographical Unit Based Analysis in the Context of Transportation Safety Planning. *Transportation Research Part A: Policy and Practice*, Vol. 49, 2013, pp. 62–75. https://doi.org/10.1016/j.tra.2013.01.030.

42. Chen, P. Built Environment Factors in Explaining the Automobile-Involved Bicycle Crash Frequencies: A Spatial Statistic Approach. *Safety Science*, Vol. 79, 2015, pp. 336–343. https://doi.org/10.1016/j.ssci.2015.06.016.
43. Gladhill, K., and C. M. Monsere. Exploring Traffic Safety and Urban Form in Portland, Oregon. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2318, No. 1, 2012, pp. 63–74. https://doi.org/10.3141/2318-08.
44. Parkin, J., M. Wardman, and M. Page. Estimation of the Determinants of Bicycle Mode Share for the Journey to Work Using Census Data. *Transportation*, Vol. 35, No. 1, 2007, pp. 93–109. https://doi.org/10.1007/s11116-007-9137-5.
45. Lee, C., and M. Abdel-Aty. Comprehensive Analysis of Vehicle–Pedestrian Crashes at Intersections in Florida. *Accident Analysis & Prevention*, Vol. 37, No. 4, 2005, pp. 775–786. https://doi.org/10.1016/j.aap.2005.03.019.
46. Huemer, A. K. Motivating and Deterring Factors for Two Common Traffic-Rule Violations of Cyclists in Germany. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 54, 2018, pp. 223–235. https://doi.org/10.1016/j.trf.2018.02.012.
47. Demetriades, D. Pedestrians Injured by Automobiles: Relationship of Age to Injury Type and Severity 1. *Journal of the American College of Surgeons*, Vol. 199, No. 3, 2004, pp. 382–387. https://doi.org/10.1016/j.jamcollsurg.2004.03.027.
48. Elvik, R. The Non-Linearity of Risk and the Promotion of Environmentally Sustainable Transport. *Accident Analysis & Prevention*, Vol. 41, No. 4, 2009, pp. 849–855. https://doi.org/10.1016/j.aap.2009.04.009.
49. Jacobsen, P. L. Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling. *Injury Prevention*, Vol. 9, No. 3, 2003, pp. 205–209. https://doi.org/10.1136/ip.9.3.205.
50. Kaplan, S., and C. Giacomo Prato. A Spatial Analysis of Land Use and Network Effects on Frequency and Severity of Cyclist–Motorist Crashes in the Copenhagen Region. *Traffic Injury Prevention*, Vol. 16, No. 7, 2015, pp. 724–731. https://doi.org/10.1080/15389588.2014.1003818.
51. Loukaitou-Sideris, A., R. Liggett, and H.-G. Sung. Death on the Crosswalk: A Study of Pedestrian-Automobile Collisions in Los Angeles. *Journal of Planning Education and Research*, Vol. 26, No. 3, 2007, pp. 338–351. https://doi.org/10.1177/0739456X06297008.
52. Prato, C. G., S. Kaplan, T. K. Rasmussen, and T. Hels. Infrastructure and Spatial Effects on the Frequency of Cyclist-Motorist Collisions in the Copenhagen Region. *Journal of Transportation Safety & Security*, Vol. 8, No. 4, 2016, pp. 346–360. https://doi.org/10.1080/19439962.2015.1055414.
53. Retting, R. A. A Review of Fatal Injuries to Pedestrians Induced by Urban Truck Crashes. *Proceedings: Association for the Advancement of Automotive Medicine Annual Conference*, Vol. 37, 1993, pp. 117–128.
54. Wier, M., J. Weintraub, E. H. Humphreys, E. Seto, and R. Bhatia. An Area-Level Model of Vehicle-Pedestrian Injury Collisions with Implications for Land Use and Transportation Planning. *Accident Analysis & Prevention*, Vol. 41, No. 1, 2009, pp. 137–145. https://doi.org/10.1016/j.aap.2008.10.001.
55. Kim, K., I. M. Brunner, and E. Y. Yamashita. Influence of Land Use, Population, Employment, and Economic Activity on Accidents. *Transportation Research Record*, 1953, p. 9.

56. LaScala, E. A., D. Gerber, and P. J. Gruenewald. Demographic and Environmental Correlates of Pedestrian Injury Collisions: A Spatial Analysis. *Accident Analysis & Prevention*, Vol. 32, 2000, pp. 651–658. https://doi.org/10.1016/s0001-4575(99)00100-1.
57. Noland, R., and M. Quddus. Analysis of Pedestrian and Bicycle Casualties with Regional Panel Data. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1897, 2004, pp. 28–33.
58. Roberts, I., R. Norton, and B. Taua. Child Pedestrian Injury Rates: The Importance of "Exposure to Risk" Relating to Socioeconomic and Ethnic Differences, in Auckland, New Zealand. *Journal of Epidemiology & Community Health*, Vol. 50, No. 2, 1996, pp. 162–165. https://doi.org/10.1136/jech.50.2.162.
59. Wang, X., J. Yang, C. Lee, Z. Ji, and S. You. Macro-Level Safety Analysis of Pedestrian Crashes in Shanghai, China. *Accident Analysis & Prevention*, Vol. 96, 2016, pp. 12–21. https://doi.org/10.1016/j.aap.2016.07.028.
60. Cottrill, C. D., and P. (Vonu) Thakuriah. Evaluating Pedestrian Crashes in Areas with High Low-Income or Minority Populations. *Accident Analysis & Prevention*, Vol. 42, No. 6, 2010, pp. 1718–1728. https://doi.org/10.1016/j.aap.2010.04.012.
61. Greene-Roesel, R., M. C. Diogenes, and D. R. Ragland. ESTIMATING PEDESTRIAN ACCIDENT EXPOSURE. 2007, p. 232.
62. Noland, R. B., N. J. Klein, and N. K. Tulach. Do Lower Income Areas Have More Pedestrian Casualties? *Accident Analysis & Prevention*, Vol. 59, 2013, pp. 337–345. https://doi.org/10.1016/j.aap.2013.06.009.
63. Cai, Q., J. Lee, N. Eluru, and M. Abdel-Aty. Macro-Level Pedestrian and Bicycle Crash Analysis: Incorporating Spatial Spillover Effects in Dual State Count Models. *Accident Analysis & Prevention*, Vol. 93, 2016, pp. 14–22. https://doi.org/10.1016/j.aap.2016.04.018.
64. Dai, D., and D. Jaworski. Influence of Built Environment on Pedestrian Crashes: A Network-Based GIS Analysis. *Applied Geography*, Vol. 73, 2016, pp. 53–61. https://doi.org/10.1016/j.apgeog.2016.06.005.
65. Guo, Q., P. Xu, X. Pei, S. C. Wong, and D. Yao. The Effect of Road Network Patterns on Pedestrian Safety: A Zone-Based Bayesian Spatial Modeling Approach. *Accident Analysis & Prevention*, Vol. 99, 2017, pp. 114–124. https://doi.org/10.1016/j.aap.2016.11.002.
66. Moeinaddini, M., Z. Asadi-Shekari, and M. Zaly Shah. The Relationship between Urban Street Networks and the Number of Transport Fatalities at the City Level. *Safety Science*, Vol. 62, 2014, pp. 114–120. https://doi.org/10.1016/j.ssci.2013.08.015.
67. Pucher, J., C. Komanoff, and P. Schimek. Bicycling Renaissance in North America? *Transportation Research Part A: Policy and Practice*, Vol. 33, 1999, pp. 625–654. https://doi.org/10.1016/s0965-8564(99)00010-5.
68. Zhang, Y., J. Bigham, D. Ragland, and X. Chen. Investigating the Associations between Road Network Structure and Non-Motorist Accidents. *Journal of Transport Geography*, Vol. 42, 2015, pp. 34–47. https://doi.org/10.1016/j.jtrangeo.2014.10.010.
69. Kemnitzer, C. R., C. N. Pope, A. Nwosu, S. Zhao, L. Wei, and M. Zhu. An Investigation of Driver, Pedestrian, and Environmental Characteristics and Resulting Pedestrian Injury. *Traffic Injury Prevention*, Vol. 20, No. 5, 2019, pp. 510–514. https://doi.org/10.1080/15389588.2019.1612886.
70. Biau, G. Analysis of a Random Forests Model. 2012, p. 33.

71. Jiang, X., M. Abdel-Aty, J. Hu, and J. Lee. Investigating Macro-Level Hotzone Identification and Variable Importance Using Big Data: A Random Forest Models Approach. *Neurocomputing*, Vol. 181, 2016, pp. 53–63. https://doi.org/10.1016/j.neucom.2015.08.097.
72. Hong Han, Xiaoling Guo, and Hua Yu. Variable Selection Using Mean Decrease Accuracy and Mean Decrease Gini Based on Random Forest. Presented at the 2016 7th IEEE International Conference on Software Engineering and Service Science (ICSESS), Beijing, China, 2016.
73. Lee, J., M. Abdel-Aty, and I. Shah. Evaluation of Surrogate Measures for Pedestrian Trips at Intersections and Crash Modeling. *Accident Analysis & Prevention*, 2018. https://doi.org/10.1016/j.aap.2018.05.015.
74. Dai, S. Prioritize Winter Crash Severity Influencing Factors in US Midwestern for Autonomous Vehicle. 2020, p. 11.
75. Das, A., M. Abdel-Aty, and A. Pande. Using Conditional Inference Forests to Identify the Factors Affecting Crash Severity on Arterial Corridors. *Journal of Safety Research*, Vol. 40, No. 4, 2009, pp. 317–327. https://doi.org/10.1016/j.jsr.2009.05.003.
76. Hossain, M., and Y. Muromachi. Understanding Crash Mechanism on Urban Expressways Using High-Resolution Traffic Data. *Accident Analysis & Prevention*, Vol. 57, 2013, pp. 17–29. https://doi.org/10.1016/j.aap.2013.03.024.
77. Breiman, L. Random Forests. *Machine Learning*, Vol. 45, No. 1, 2001, pp. 5–32. https://doi.org/10.1023/A:1010933404324.
78. Chen, Z., and W. (David) Fan. A Multinomial Logit Model of Pedestrian-Vehicle Crash Severity in North Carolina. *International Journal of Transportation Science and Technology*, 2018. https://doi.org/10.1016/j.ijtst.2018.10.001.
79. Shankar, V., and F. Mannering. An Exploratory Multinomial Logit Analysis of Single-Vehicle Motorcycle Accident Severity. *Journal of Safety Research*, Vol. 27, No. 3, 1996, pp. 183–194. https://doi.org/10.1016/0022-4375(96)00010-2.
80. Tay, R., J. Choi, L. Kattan, and A. Khan. A Multinomial Logit Model of Pedestrian–Vehicle Crash Severity. *International Journal of Sustainable Transportation*, Vol. 5, No. 4, 2011, pp. 233–249. https://doi.org/10.1080/15568318.2010.497547.
81. National Highway Traffic Safety Administration. MMUCC. *NHTSA*. https://www.nhtsa.gov/mmucc-1. Accessed Apr. 21, 2020.
82. Mitman, M. F., D. R. Ragland, and C. V. Zegeer. Marked-Crosswalk Dilemma: Uncovering Some Missing Links in a 35-Year Debate. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2073, No. 1, 2008, pp. 86–93. https://doi.org/10.3141/2073-10.
83. Schneider, R. J., and J. Stefanich. Application of the Location–Movement Classification Method for Pedestrian and Bicycle Crash Typing. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2601, No. 1, 2016, pp. 72–83. https://doi.org/10.3141/2601-09.
84. Wisconsin State,. 2017−18 Wisconsin Statutes. http://docs.legis.wisconsin.gov/statutes/statutes/346.pdf. Accessed Apr. 12, 2020.
85. Hunter, W. W., R. Srinivasan, and C. A. Martell. Evaluation of Rectangular Rapid Flash Beacon at Pinellas Trail Crossing in Saint Petersburg, Florida. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2314, No. 1, 2012, pp. 7–13. https://doi.org/10.3141/2314-02.

86. Kutela, B., and H. Teng. Prediction of Drivers and Pedestrians' Behaviors at Signalized Mid-Block Danish Offset Crosswalks Using Bayesian Networks. *Journal of Safety Research*, Vol. 69, 2019, pp. 75–83. https://doi.org/10.1016/j.jsr.2019.02.008.
87. Bertulis, T., and D. M. Dulaski. Driver Approach Speed and Its Impact on Driver Yielding to Pedestrian Behavior at Unsignalized Crosswalks. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2464, No. 1, 2014, pp. 46–51. https://doi.org/10.3141/2464-06.
88. Fisher, D., and L. Garay-Vega. Advance Yield Markings and Drivers' Performance in Response to Multiple-Threat Scenarios at Mid-Block Crosswalks. *Accident Analysis & Prevention*, Vol. 44, No. 1, 2012, pp. 35–41. https://doi.org/10.1016/j.aap.2010.11.030.
89. Dong, C., A. J. Khattak, C. Shao, and K. Xie. Exploring the Factors Contribute to the Injury Severities of Vulnerable Roadway User Involved Crashes. *International Journal of Injury Control and Safety Promotion*, Vol. 26, No. 3, 2019, pp. 302–314. https://doi.org/10.1080/17457300.2019.1595665.
90. Chen, Z., and W. (David) Fan. A Multinomial Logit Model of Pedestrian-Vehicle Crash Severity in North Carolina. *International Journal of Transportation Science and Technology*, 2018. https://doi.org/10.1016/j.ijtst.2018.10.001.
91. VDOT_Pedestrians_Crash_Assessment_2014-2018.Pdf. http://www.virginiadot.org/business/resources/HSIP/VDOT_Pedestrians_Crash_Assessment_2014-2018.pdf. Accessed Apr. 26, 2020.
92. Sheykhfard, A., and F. Haghighi. Performance Analysis of Urban Drivers Encountering Pedestrian. *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 62, 2019, pp. 160–174. https://doi.org/10.1016/j.trf.2018.12.019.
93. Katz, A., D. Zaidel, and A. Elgrishi. An Experimental Study of Driver and Pedestrian Interaction during the Crossing Conflict. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 17, No. 5, 1975, pp. 514–527. https://doi.org/10.1177/001872087501700510.
94. Obeid, H., H. Abkarian, M. Abou-Zeid, and I. Kaysi. Analyzing Driver-Pedestrian Interaction in a Mixed-Street Environment Using a Driving Simulator. *Accident Analysis & Prevention*, Vol. 108, 2017, pp. 56–65. https://doi.org/10.1016/j.aap.2017.08.005.
95. Schneider, R. J., M. C. Diogenes, L. S. Arnold, V. Attaset, J. Griswold, and D. R. Ragland. Association between Roadway Intersection Characteristics and Pedestrian Crash Risk in Alameda County, California. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2198, No. 1, 2010, pp. 41–51. https://doi.org/10.3141/2198-06.
96. Schneider, R. J., O. Grembek, and M. Braughton. Pedestrian Crash Risk on Boundary Roadways: University Campus Case Study. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2393, No. 1, 2013, pp. 164–173. https://doi.org/10.3141/2393-19.
97. Kim, D. The Transportation Safety of Elderly Pedestrians: Modeling Contributing Factors to Elderly Pedestrian Collisions. *Accident Analysis & Prevention*, Vol. 131, 2019, pp. 268–274. https://doi.org/10.1016/j.aap.2019.07.009.
98. Morrison, C. N., J. Thompson, M. C. Kondo, and B. Beck. On-Road Bicycle Lane Types, Roadway Characteristics, and Risks for Bicycle Crashes. *Accident Analysis & Prevention*, Vol. 123, 2019, pp. 123–131. https://doi.org/10.1016/j.aap.2018.11.017.

99. Fountas, G., A. Fonzone, N. Gharavi, and T. Rye. The Joint Effect of Weather and Lighting Conditions on Injury Severities of Single-Vehicle Accidents. *Analytic Methods in Accident Research*, 2020, p. 100124. https://doi.org/10.1016/j.amar.2020.100124.
100. Kordani, A. A., B. Shirini, and M. Yazdani. The Effect of Road Shoulder and Weather Conditions on the Occurrence of Rollover Crashes in Two-Lane Highways. *Periodica Polytechnica Civil Engineering*, 2019. https://doi.org/10.3311/PPci.12588.
101. Johnson, M., J. Charlton, J. Oxley, and S. Newstead. Naturalistic Cycling Study: Identifying Risk Factors for On-Road Commuter Cyclists. *Annals of Advances in Automotive Medicine / Annual Scientific Conference*, Vol. 54, 2010, pp. 275–283.
102. Boufous, S., L. D. Rome, T. Senserrick, and R. Ivers. Cycling Crashes in Children, Adolescents, and Adults—A Comparative Analysis. *Traffic Injury Prevention*, Vol. 12, No. 3, 2011, pp. 244–250. https://doi.org/10.1080/15389588.2011.563333.
103. Sullivan, J. M., and M. J. Flannagan. CHARACTERISTICS OF PEDESTRIAN RISK IN DARKNESS. 2001, p. 27.
104. Gårder, P. E. The Impact of Speed and Other Variables on Pedestrian Safety in Maine. *Accident Analysis & Prevention*, Vol. 36, No. 4, 2004, pp. 533–542. https://doi.org/10.1016/S0001-4575(03)00059-9.
105. Fu, T., L. Miranda-Moreno, and N. Saunier. Pedestrian Crosswalk Safety at Nonsignalized Crossings During Nighttime: Use of Thermal Video Data and Surrogate Safety Measures. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2586, No. 1, 2016, pp. 90–99. https://doi.org/10.3141/2586-10.
106. Hezaveh, A. M., M. AzadDisfany, and C. R. Cherry. PEDESTRIAN CRASHES IN TENNESSEE; A DATA MINING APPROACH. 2017, p. 15.
107. Zegeer, C., W. Hunter, L. Staplin, F. Bents, R. Huey, and J. Barlow. Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users. 2010, p. 59.
108. Rifaat, S. M., R. Tay, and A. de Barros. Effect of Street Pattern on the Severity of Crashes Involving Vulnerable Road Users. *Accident Analysis & Prevention*, Vol. 43, No. 1, 2011, pp. 276–283. https://doi.org/10.1016/j.aap.2010.08.024.
109. Pearson R. GoodmanKruskal.Pdf. https://cran.r-project.org/web/packages/GoodmanKruskal/GoodmanKruskal.pdf. Accessed May 8, 2020.
110. Long, J. S., and J. Freese. *Regression Models for Categorical Dependent Variables Using Stata*. Stata Press, College Station, Tex, 2001.
111. Shinar, D. The Effects of Expectancy, Clothing Reflectance, and Detection Criterion on Nighttime Pedestrian Visibility. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 27, 1985, pp. 327–333. https://doi.org/10.1177/001872088502700308.
112. Tyrrell, R. A., J. M. Wood, D. A. Owens, S. W. Borzendowski, and A. S. Sewall. The Conspicuity of Pedestrians at Night: A Review. *Clinical and Experimental Optometry*, Vol. 99, No. 5, 2016, pp. 425–434. https://doi.org/10.1111/cxo.12447.
113. LaValley, J., C. S. Crandall, L. Banks, D. P. Sklar, and L. Boodlal. Rural and Urban Fatal Pedestrian Crashes Among United States American Indians and Alaskan Natives. *Annual Proceedings / Association for the Advancement of Automotive Medicine*, Vol. 47, 2003, pp. 127–143.

114. Chakravarthy, B., S. Lotfipour, and F. E. Vaca. Pedestrian Injuries: Emergency Care Considerations. *The California Journal of Emergency Medicine*, Vol. 8, No. 1, 2007, pp. 15–21.
115. Kim, J.-K., G. F. Ulfarsson, V. N. Shankar, and S. Kim. Age and Pedestrian Injury Severity in Motor-Vehicle Crashes: A Heteroskedastic Logit Analysis. *Accident Analysis & Prevention*, Vol. 40, No. 5, 2008, pp. 1695–1702. https://doi.org/10.1016/j.aap.2008.06.005.
116. Haworth, N., and A. K. Debnath. How Similar Are Two-Unit Bicycle and Motorcycle Crashes? *Accident Analysis & Prevention*, Vol. 58, 2013, pp. 15–25. https://doi.org/10.1016/j.aap.2013.04.014.
117. Robartes, E., and T. D. Chen. The Effect of Crash Characteristics on Cyclist Injuries: An Analysis of Virginia Automobile-Bicycle Crash Data. *Accident Analysis & Prevention*, Vol. 104, 2017, pp. 165–173. https://doi.org/10.1016/j.aap.2017.04.020.
118. Räsänen, M., and H. Summala. Attention and Expectation Problems in Bicycle–Car Collisions: An in-Depth Study. *Accident Analysis & Prevention*, Vol. 30, 1998, pp. 657–666. https://doi.org/10.1016/s0001-4575(98)00007-4.
119. Abdel-Aty, M., and J. Keller. Exploring the Overall and Specific Crash Severity Levels at Signalized Intersections. *Accident Analysis & Prevention*, Vol. 37, No. 3, 2005, pp. 417–425. https://doi.org/10.1016/j.aap.2004.11.002.
120. Kaplan, S., and C. Giacomo Prato. A Spatial Analysis of Land Use and Network Effects on Frequency and Severity of Cyclist–Motorist Crashes in the Copenhagen Region. *Traffic Injury Prevention*, Vol. 16, No. 7, 2015, pp. 724–731. https://doi.org/10.1080/15389588.2014.1003818.
121. Behnood, A., and F. Mannering. Determinants of Bicyclist Injury Severities in Bicycle-Vehicle Crashes: A Random Parameters Approach with Heterogeneity in Means and Variances. *Analytic Methods in Accident Research*, Vol. 16, 2017, pp. 35–47. https://doi.org/10.1016/j.amar.2017.08.001.
122. Das, S., K. Jha, K. Fitzpatrick, M. Brewer, and T. H. Shimu. Pattern Identification from Older Bicyclist Fatal Crashes. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2673, No. 6, 2019, pp. 638–649. https://doi.org/10.1177/0361198119841863.

APPENDIX A: DEFINITION AND ATTRIBUTE OF DATA FIELDS

Table 0-1 Definition and Attribute of Data Fields

Variable and Attribute Codes	Variable and attribute Code Indication	
	Roadway Level	
Horizontal Road Terrain		
ROADHOR-MV	The horizontal road terrain at the point of impact. The options for this field are either straight or curve. The field will only be filled in on this summary if curve (C) was indicated.	
ROADHOR [1,2]-DT	The curvature of the roadway in the direction of travel for the vehicle.	
	ST	Straight
	LT	Curve Left
	RT	Curve Right
	CU	Curve-Unknown Direction
	UNKN	Unknown
Vertical Road Terrain		
ROADVERT-MV	The vertical road terrain at the point of impact. The options for this field are either flat or hill. The field will only be filed in on this summary if hill H was indicated.	
ROADVERT[1,2]-DT	The grade of the roadway in the direction of travel for this vehicle.	
	LVL	Level
	CST	Hillcrest
	UP	Uphill
	DN	Downhill
	SAG	Sag (Bottom)
	UNKN	Unknown
Road Surface Condition		
ROADCOND-MV	Surface condition of the road at the point of origin for the unit apparently most at fault. If blank the road condition is DRY.	
RDCOND [A,B,C]-DT	The roadway surface condition at the time and place of a crash.	
	DRY	Dry
	WET	Wet
	SNOW	Snow
	SLUSH	Slush
	ICE	Ice
	WATER	Water (Standing/Moving)
	SAND	Sand
	MUD	Mud/Dirt
	GRAVL	Gravel
	OIL	Oil
	UNKN	Unknown
Trafficway Description		
TRFCWAY-MV	Text describing areas designed for motor vehicle operation.	
	BLNK	Blank
	ND	Not physically divided
	D/WO	Divided highway without traffic barrier
	D/B	Divided highway with traffic barrier
	OW	One-way traffic
	OTHR	Parking lot or private property
TRFCWAY [1,2]-DT	Indication of whether or not the trafficway for this vehicle is divided and whether it serves one-way or two-way traffic.	
	UNDIV	Two-Way-Not Divided
	TWLTL	Two-Way, Not Divided, With A Continuous Left Turn Lane
	DIV NO	Divided Hwy W/O Traffic Barrier
	DIV PNT	Two-Way, Divided, Unprotected (Painted > 4 Feet) Median
	DIV BAR	Divided Hwy W/Traffic Barrier
	DIV MBR	Divided Hwy Median W/Barrier

	OW	One-Way Traffic
	PL/PP	Parking Lot or Private Property
	RAMP	Entrance/Exit Ramp
	UNKN	Unknown
Total Number of Lanes		
TOTLANES [1,2]-DT	Total number of lanes in the roadway on which this motor vehicle was traveling. For undivided highways - total through lanes in both directions, excluding designated turn lanes. For divided highways - total through lanes for roadway the motor vehicle under consideration was traveling. This is a new variable suggested in the DT4000 crash form.	
Location of First Harmful Event		
RLTNRDWY-MV	Location of first harmful event in relation to a roadway.	
	GORE	Gore
	LTSH	Outside should-left
	MED	Median
	OFF	Off roadway - location unknown
	ON	On roadway
	PLOT	Private lot or private prop
	RAMP	On ramp
	RTSH	Outside shoulder-right
	SHLD	Shoulder
RLTNRDWY-DT	The location of the first harmful event as it relates to its position within or outside the trafficway	
	ON	On Roadway
	LTSH	Shoulder Left
	RTSH	Shoulder Right
	MED B	Median Barrier
	R SIDE	Roadside
	GORE	Gore
	SEP	Separator
	PARK	In Parking Lane or Zone
	OFF	Off Roadway, Location Unknown
	O ROW	Outside Right-Of-Way (Trafficway)
	CTLT	Continuous Left Turn Lane
Crash Location with Respect to Trafficway		
RLTNTRWY-DT	Identifies the location of a crash with respect it's relation to a trafficway. This is a new variable included in the DT4000 crash form.	
	ON	Trafficway - On Road
	OFF	Trafficway - Not On Road
	P LOT	Non Trafficway - Parking Lot
	OTHR	Non Trafficway-Other
Crash Location Type		
ACCDLOC-MV	The type of location at which a crash occurred. Types I and N are public roadway crashes.	
	I	Intersection related
	N	Non intersection related
	PL	Parking lot
	PP	Private property
LOCTYPE-DT	The location type of a crash.	
	I	Intersection (public roadway),
	N	Non-intersection (public roadway)
	PL	Parking lot
	PP	Private Property
Intersection Type		
INTTYPE-DT	The type of intersection in which a crash occurred. An intersection consists of two or more roadways that intersect at the same level. This is a new variable included in the DT4000 crash form.	
	NA	Not At Intersection
	4 WAY	Four-Way Intersection,
	T	T-Intersection
	L	L-Intersection

	RAB	Roundabout
	5	Five-Point or More
Status of the TCD		
TRFCINOP [1,2]-DT	Indicates whether a traffic control device was inoperable or missing at the time of the crash (Y/N/UNKN). This is a new variable included in the DT4000 crash form.	
Crash Occurrence Within an Interchange Area		
RLTNJNIC-DT	The coding of this data element is based on the location of the first harmful event of the crash. It identifies the crash's location with respect to presence in a junction or proximity to components typically in junction or interchange areas. This field identifies if a crash occurred within the Interchange area. (Y/N/UNKN). This is a new variable included in the DT4000 crash form.	
	Environmental Level	
Prevailing Atmospheric Conditions		
WTHRCOND-MV	A code which identifies the weather condition at the time of a crash.	
	BLNK	Blank
	CLR	Clear
	CLDY	Cloudy
	RAIN	Rain
	RAIN	Rain
	SNOW	Snow
	FOG	Fog / smog / smoke
	SLET	Sleet / hail
	WIND	Blowing sand / dirt / snow
	XWIND	Severe crosswinds
WTCOND[A,B]-DT	The prevailing atmospheric conditions that existed at the time of the crash.	
	CLEAR	Clear
	CLDY	Cloudy
	RAIN	Rain
	SNOW	Snow
	SLEET	Sleet/Hail
	WIND	Severe Winds
	FRZ RN	Freezing Rain or Freezing Drizzle
	FOG	Fog
	B SNOW	Blowing Snow
	SMOG	Smog/Smoke
	B DIRT	Blowing Sand, Soil, Dirt
Light Conditions		
LGTCOND-MV	Light condition at time of crash. If blank the light condition is DAY.	
	DARK	Nighttime-Unlit
	LIGT	Nighttime–Street Lights
LGTCOND-DT	The type/level of light that existed at the time of the motor vehicle crash.	
	DAY	Daylight
	DAWN	Dawn
	DUSK	Dusk
	LITE	Dark/Lighted
	DARK	Dark/Unlit
	DK/UN	Dark-Unknown Lighting
Contributing environmental Conditions		
ENVPC [A,B,C]-DT	Apparent environmental conditions which may have contributed to the crash. This is a new variable included in the DT4000 crash form.	
	NONE	None
	WTHR	Weather Conditions
	OBSTR	Visual Obstruction(s)
	GLARE	Glare
	ANML	Animal(s) In Roadway
	Driver Level	
The Driver Condition Relevant to the Crash		
DNMFTR [1,2] [A,B]-DRVR-DT	Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash.	
	NORM	Appeared Normal

	PHY IMP	Physically Impaired
	EMO	Emotional (Depressed, Angry, Disturbed, Etc.)
	SICK	Ill (Sick)- Fainted
	SLEEP	Asleep or Fatigued
	UI MDA	Under the Influence of Medication/Drugs/Alcohol
	WCHAIR	Paraplegic or Restricted to Wheelchair
	CONF	Confused or Disoriented (Non-Lucid)
	BLIND	Blind
	CANE	Using Cane or Crutches
	NO OBS	Not Observed
Distraction/Inattentive Driving		
DISTFLAG-DT	Flag indicating whether a crash involved distracting or inattentive driving.	
Driver Contributing Actions/Circumstances		
DRVRPC [1,2]-MV	Lists the possible driver contributing circumstances (driver factors) in a collision.	
	DC	Driver condition
	DIS	Physically disabled
	DTC	Disregard traffic control
	FTC	Following too close
	FTY	Failure to yield
	FVC	Failure to keep vehicle under control
	IC	In conflict
	ID	Inattentive driving
	IO	Improper overtake
	IT	Improper turn
	LOC	Left of center
	OTR	Other
	SPD	Exceed speed limit
	TFC	Too fast for conditions
	UB	Unsafe backing
DRVRPC[1,2][A,B,C,D]-DT	The actions by the driver that may have contributed to the crash, based on the judgment of the law enforcement officer investigating the crash.	
	SPD	Exceed Speed Limit
	TFC	Speed Too Fast/Cond
	FTY	Failed To Yield Right-Of-Way
	FTC	Following Too Close
	IT	Improper Turn
	UB	Unsafe Backing
	FVC	Failure To Control
	ROR	Ran Off Roadway
	DRED	Disregarded Red Light
	DSS	Disregarded Stop Sign
	DTC	Disregarded Other Traffic Control
	DRM	Disregarded Other Road Markings
	IOR	Improper Overtaking / Passing Right
	IOL	Improper Overtaking / Passing Left
	WW	Wrong Side or Wrong Way
	FDL	Failed To Keep In Designated Lane
	AR	Operated Motor Vehicle In Aggressive/Reckless Manner
	ID	Operated Motor Vehicle In Inattentive, Careless or Erratic Manner
	IC	Swerved or Avoided Due To Wind, Slippery Surface, Motor Vehicle, Object, Non-Motorist In Roadway, etc.
	OVR	Over-Correcting/Over-Steering
	RAC	Racing
	NO	No Contributing Action
	NOT SEE	Looked But Did Not See
Controlled Maneuver by the Driver		
DRVRDO [1,2]-MV	What the driver of unit was doing at the time of the crash.	
	BACKING	Backing up
	CHG LN	Changing lanes

	GO STR	Going straight
	IL PRK	Illegally parked
	LG PRK	Legally parked
	LT TRN	Making left turn
	MERGING	Merging into traffic
	NEGCRV	Negotiating curve
	NPASZN	Violate no pass zone
	OVT LT	Overtaking on the left
	OVT RT	Overtaking on right
	PARKNG	Parking maneuver
	RT TRN	Right turn
	RTOR	Right turn on red
	SL/ST	Slowing or stopped
	STOPED	Stopped in traffic
	UTURN	U turn
DRVRDOIN [1,2]-DT	The controlled maneuver for this motor vehicle prior to the beginning of the sequence of events.	
	GO STR	Going Straight
	NEGCRV	Negotiating Curve
	BACKING	Backing
	CHG LN	Changing Lanes
	OVT RT	Overtake Right
	OVT LT	Overtake Left
	RT TRN	Right Turn
	LT TRN	Left Turn
	UTRN	U Turn
	LVG LN	Leaving Traffic Lane
	ENT LN	Entering Traffic Lane
	SLOWNG	Slow/Stopping
	LG PRK	Legally Parked
	STOPED	Stop in Traffic
	NO PASS	Viol No Pass Zn
	PARKNG	Park Maneuver
	RTOR	Turn on Red
	MERGING	Merging
	ACCEL	Accelerating in Road
	STARTNG	Starting in Road
Safety Equipment Used by the Driver		
SAFETY [1,2]-DR-MV	The type of safety equipment, if any, that was used by a driver, bicyclist or pedestrian involved in a crash.	
	SH/LP	Shoulder & lap belt
	LAP	Lap belt only
	SHLD	Shoulder belt only
	CHILD	Child safety seat
	HT/EY	Helmet & eye protection
	EYE	No helmet / eye protection only
	NA	Not applicable-non-motorist
	HLMT	Helmet
SFTYWQP [1, 2]-DR-DT	The restraint equipment in use at the time of the crash (excluding motorcyclists).	
	SH/LP	Shoulder & Lap Belt
	LAP	Lap Belt Only
	SHLD	Shoulder Belt Only
	UNTYPE	Restraint Used - Type Unknown
	CH/FF	Child Restraint System - Forward Facing
	CH/RF	Child Restraint System - Rear Facing
	BOOST	Booster Seat
	CH/UN	Child Restraint - Type Unknown
Driver Race		
RACE [1,2]-DT	The race of the driver per the Wisconsin Uniform Traffic Citation. This is a new variable included in the DT4000 crash form.	

	A	Asian
	B	Black
	I	Indian
	H	Hispanic
	W	White
Teen Drivers		
TEENDRVR-DT	Flag indicating whether a crash involved a driver between the age of 16 and 19. This is a new variable included in the DT4000 crash form.	
Pedestrian Level		
The Pedestrian Condition Relevant to the Crash		
DNMFTR[1,2][A,B]-PED-DT	Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash.	
	NORM	Appeared Normal
	PHY IMP	Physically Impaired
	EMO	Emotional (Depressed, Angry, Disturbed, Etc.)
	SICK - Ill	Ill (Sick), Fainted
	SLEEP	Asleep or Fatigued
	UI MDA	Under the Influence of Medication/Drugs/Alcohol
	CONF	Confused or Disoriented (Non-Lucid)
	WCHAIR	Paraplegic or Restricted to Wheelchair
	BLIND	Blind
	CANE	Using Cane or Crutches
	NO OBS	Not Observed
Pedestrian Actions/Circumstances Contributing to the Crash		
NMTACT[1,2][A,B]-PED-MV	This data field was retrieved from "NMTACT[1,2][A,B]" in the DT4000 crash from using the SAS code translation Excel file provided through the WisTransportal website.	
	0	BLANK
	1	WALKING NOT FACING TRAFFIC
	2	DISREGARDED SIGNAL
	3	DARTING INTO ROAD
	4	DARK CLOTHING
	5	WALKING FACING TRAFFIC
	6	Other actions
NMTACT[1,2][A,B]-PED-DT	The actions/circumstances of the non-motorist that may have contributed to the crash, based on the judgement of the law enforcement officer investigating the crash.	
	NF TRFC	Walking Not Facing Traffic
	DISREG	Disregarded Signal
	SUDDEN	Sudden, Movement into Traffic
	DK CLTH	Dark Clothing
	FC TRFC	Walking Facing Traffic
	NO IMPR	No Improper Action
	IM XING	Improper Crossing of Roadway (Jaywalking)
	F YIELD	Failure to Yield Right-Of-Way
	F OBEY	Failure to Obey Traffic Signs, Signals, or Officer
	IM RDWY	In Roadway Improperly (Standing, Lying, Working, Playing)
	DISABLD	Disabled Vehicle Related (Working On, Pushing, Leaving/Approaching)
	STOPPED	Entering/Exiting Parked/Standing Vehicle
	INATTV	Inattentive (Talking, Eating, Etc.)
	NOT VIS	Not Visible (Dark Clothing, No Lighting, Etc.)
	IM TURN	Improper Turn/Merge
	IM PASS	Improper Passing
	W WAY	Wrong-Way Riding or Walking
	F LGTS	Failing to Have Lights on When Required (Bicycling)
	NO EQIP	Operation Without Required Equipment (Bicycle Reflectors)
	IM CHNG	Improper or Erratic Lane Changing
	F LANE	Failure to Keep in Proper Lane or Running Off Road
	IM ENTR	Making Improper Entry to or Exit from Trafficway
	RECKLSS	Operating in Other Erratic, Reckless or Careless Manner

	PASSNG	Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
Pedestrian Actions Immediately Prior to the Crash		
NMTPRIOR [1,2]-PED-DT	The action of a non-motorist immediately prior to a crash. No such data field in MV4000 crash form. This is a new variable included in the DT4000 crash form.	
	XING	Crossing Roadway
	WAITING	Waiting to Cross Roadway
	W TRFC	Walking / Cycling Along Roadway with Traffic (In or Adjacent to Travel Lane)
	A TRFC	Walking / Cycling Along Roadway Against Traffic (In or Adjacent to Travel Lane)
	SIDE WK	Walking / Cycling on Sidewalk
	RDWY OT	In Roadway - Other
	ADJACNT	Adjacent to Roadway (E.G., Shoulder, Median)
	NONE	None
	JOGGING	Jogging / Running
	STOPPED	Entering/Exiting Parked or Stopped Motor Vehicle
	DISABLD	Disabled Vehicle Related
Pedestrian Location with Respect to the Roadway		
NMTLOC [1,2]-PED-MV	This data field was retrieved from “NMTLOC [1,2]-PED-DT“ in the DT4000 crash from using the SAS code translation Excel file provided through the WisTransportal website.	
	0	BLANK
	1	IN CROSSWALK
	2	IN ROADWAY
	3	NOT IN ROADWAY
	4	ON SIDEWALK
NMTLOC [1,2]-PED-DT	The location of the non-motorist with respect to the roadway at the time of the crash.	
	ATI MX	At Intersection-In Marked Crosswalk
	ATI UM	At Intersection-Unmarked / Unknown If Marked Crosswalk
	ATI NX	At Intersection-Not in Crosswalk
	ATI UL	At Intersection-Unknown Location
	NAI MX	Not at Intersection-In Marked Crosswalk
	NAI NX	Not at Intersection-On Roadway, Not in Marked Crosswalk
	NAI UN	Not at Intersection-On Roadway, Crosswalk Availability Unknown
	PK LN	Parking Lane/Zone
	BIKE LN	Bicycle Lane
	SHLDR	Shoulder / Roadside
	SDWLK	Sidewalk
	MEDIAN	Median / Crossing Island
	DRWAY	Driveway Access
	SHARED	Shared-Use Path
	NON TRF	Non-Trafficway Area
	NOT RPT	Not Reported
Safety Equipment Used by the Pedestrian		
NMTSFQ[1,2][A,B]-PED-DT	The safety equipment in use by the operator non-motorist at the time of the crash (excluding motorcyclists). Note that the SAFETY [1, 2] data field in the MV4000 crash dataset indicates that the field shows the type of safety equipment that was used by a driver, bicyclist or pedestrian involved in the crash, while the data. did not show that this field was filled for pedestrians nor bicyclists. Hence, the NMTSFQ data field is a new filed included in the DT4000 crash form.	
	NONE	None
	HLMT	Helmet
	PADS	Protective Pads Used (Elbow, Knees, Shin, etc.)
	REFL	Reflective Clothing (Jacket, Backpack, etc.)
	LTNG	Lighting
Bicyclist Level		
The bicyclist condition relevant to the crash		
DNMFTR [1,2] [A,B]-BIKE-DT	Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash.	
	NORM	Appeared Normal

	PHY IMP	Physically Impaired
	EMO	Emotional (Depressed, Angry, Disturbed, Etc.)
	SICK	Ill (Sick), Fainted
	SLEEP	Asleep or Fatigued
	UI MDA	Under the Influence of Medication/Drugs/Alcohol
	CONF	Confused or Disoriented (Non-Lucid)
	WCHAIR	Paraplegic or Restricted to Wheelchair
	BLIND	Blind
	CANE	Using Cane or Crutches
	NO OBS	Not Observed
Bicyclist Actions/Circumstances Contributing to the Crash		
NMTACT [1,2] [A,B]-BIKE-MV	This data field was retrieved from “NMTACT[1,2][A,B]” in the DT4000 crash from using the SAS code translation Excel file provided through the WisTransportal website. Attribute “6” was created to combine other actions and was named “OTHR”.	
	0	BLANK
	1	WALKING NOT FACING TRAFFIC
	2	DISREGARDED SIGNAL
	3	DARTING INTO ROAD
	4	DARK CLOTHING
	5	WALKING FACING TRAFFIC
NMTACT [1,2] [A,B]-BIKE-DT	The actions/circumstances of the non-motorist that may have contributed to the crash, based on the judgement of the law enforcement officer investigating the crash.	
	NF TRFC	Walking Not Facing Traffic
	DISREG	Disregarded Signal
	SUDDEN	Sudden, Movement into Traffic
	DK CLTH	Dark Clothing
	FC TRFC	Walking Facing Traffic
	NO IMPR	No Improper Action
	IM XING	Improper Crossing of Roadway (Jaywalking)
	F YIELD	Failure to Yield Right-Of-Way
	F OBEY	Failure to Obey Traffic Signs, Signals, or Officer
	IM RDWY	In Roadway Improperly (Standing, Lying, Working, Playing)
	DISABLD	Disabled Vehicle Related (Working On, Pushing, Leaving/Approaching)
	STOPPED	Entering/Exiting Parked/Standing Vehicle
	INATTV	Inattentive (Talking, Eating, Etc.)
	NOT VIS	Not Visible (Dark Clothing, No Lighting, Etc.)
	IM TURN	Improper Turn/Merge
	IM PASS	Improper Passing
	W WAY	Wrong-Way Riding or Walking
	F LGTS	Failing to Have Lights on When Required (Bicycling)
	NO EQIP	Operation Without Required Equipment (Bicycle Reflectors)
	IM CHNG	Improper or Erratic Lane Changing
	F LANE	Failure to Keep in Proper Lane or Running Off Road
	IM ENTR	Making Improper Entry to or Exit from Trafficway
	RECKLSS	Operating in Other Erratic, Reckless or Careless Manner
	PASSNG	Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
Bicyclist Actions Immediately Prior to the Crash		
NMTPRIOR[1,2]-BIKE-DT	The action of a non-motorist immediately prior to a crash. No such data field in MV4000 crash form. This is a new variable included in the DT4000 crash form.	
	XING	Crossing Roadway
	WAITING	Waiting to Cross Roadway
	W TRFC	Walking/Cycling Along Roadway with Traffic (In or Adjacent to Travel Lane)
	A TRFC	Walking/Cycling Along Roadway Against Traffic (In or Adjacent to Travel Lane)
	SIDE WK	Walking/Cycling on Sidewalk
	RDWY OT	In Roadway - Other
	ADJACNT	Adjacent to Roadway (E.G., Shoulder, Median)
	WORKING	Working in Trafficway (Incident Response)

	NONE	None
	JOGGING	Jogging/Running
	STOPPED	Entering/Exiting Parked or Stopped Motor Vehicle
	DISABLD	Disabled Vehicle Related
Bicyclist Location with Respect to the Roadway		
NMTLOC [1,2]-BIKE-MV	This data field was retrieved from "NMTLOC[1,2]- BIKE -DT" in the DT4000 crash from using the SAS code translation Excel file provided through the WisTransportal website.	
	0	BLANK
	1	IN CROSSWALK
	2	IN ROADWAY
	3	NOT IN ROADWAY
	4	ON SIDEWALK
NMTLOC[1,2]- BIKE -DT	The location of the non-motorist with respect to the roadway at the time of the crash.	
	ATI MX	At Intersection-In Marked Crosswalk
	ATI UM	At Intersection-Unmarked / Unknown If Marked Crosswalk
	ATI NX	At Intersection-Not in Crosswalk
	ATI UL	At Intersection-Unknown Location
	NAI MX	Not at Intersection-In Marked Crosswalk
	NAI NX	Not at Intersection-On Roadway, Not in Marked Crosswalk
	NAI UN	Not at Intersection-On Roadway, Crosswalk Availability Unknown
	PK LN	Parking Lane/Zone
	BIKE LN	Bicycle Lane
	SHLDR	Shoulder / Roadside
	SDWLK	Sidewalk
	MEDIAN	Median / Crossing Island
	DRWAY	Driveway Access
	SHARED	Shared-Use Path
	NON TRF	Non-Trafficway Area
	NOT RPT	Not Reported
	Safety Equipment Used by the Bicyclist	
NMTSFQ[1,2][A,B]-BIKE-DT	The safety equipment in use by the operator non-motorist at the time of the crash (excluding motorcyclists). Note that the SAFETY [1, 2] data field in the MV4000 crash dataset indicates that the field shows the type of safety equipment that was used by a driver, bicyclist or pedestrian involved in the crash, while the data. did not show that this field was filled for pedestrians nor bicyclists. Hence, the NMTSFQ data field is a new filed included in the DT4000 crash form.	
	NONE	None
	HLMT	Helmet
	PADS	Protective Pads Used (Elbow, Knees, Shin, etc.)
	REFL	Reflective Clothing (Jacket, Backpack, etc.)
	LTNG	Lighting
Crash Level		
Events Resulting in the Most Severe Injury		
ACCDTYPE-MV	Description of type of crash based on the first harmful event. ***MVIT** - Motor Vehicle in Transit involves moving vehicles. This field appears blank.	
	ATTEN	Impact attenuator
	BIKE	Bicycle
	BRP AR	Bridge parapet
	BRPIER	Bridge/pier/abutment
	BRRAIL	Bridge rail
	CULVRT	Culvert
	CURB	Curb
	DEER	Deer
	DITCH	Ditch
	EMBKMT	Embankment
	FENCE	Fence
	FIRE	Fire / Explosion
	GR END	Guardrail end
	GR FAC	Guardrail face

	IMMER	Immersion
	JKNIF	Jackknife
	LTPOLE	Lum light support
	MAILBOX	Mailbox
	MED B	Median barrier
	MVIT*	Vehicle in transit
	OBNFX	Object not fixed
	SIGN	Overhead signpost
	OTH FX	Other object fixed
	OTH NC	Other non-collision
	OT ANL	Other animal
	OT RDY	Veh trans other rdwy
	OT PST	Other post
	OVRTRN	Overturned vehicle
	PED	Pedestrian
	PKVEH	Parked vehicle
	TFSIGN	Traffic sign
	TF SIG	Traffic signal
	TRAIN	Train
	TREE	Tree
	UT PL	Utility Pole
MOSTHARM[1,2]-DT	Event that resulted in the most severe injury or, if no injury, the greatest property damage involving this motor vehicle.	
	MVIT	Motor Vehicle in Transport
	PKVEH	Parked Motor Vehicle
	BIKE	Pedal cycle
	PED	Pedestrian
	TRAIN	Railway Vehicle (Train, Engine)
	Vehicle Level	
Vehicle Type Involved in the Crash		
VEHTYPE [1,2]-MV	The type of vehicle that was involved in a crash.	
	ATV	Snowmobile
	ATV, BIKE	Bicycle
	BLNK	Blank
	BUS	Passenger bus
	CAR	Passenger car
	CYCLE	Motorcycle
	EM AMB	Ambulance on emergency
	EM FIRE	Fire truck / fire fighter on emergency
	EM POL	Police on emergency
	FARM	Farm tractor / self-propelled
	HOME	Motor home
	HRSDRWN*	Horse drawn implement (carriage, wagon, buggy)
	MISC	Miscellaneous
	MOPED	Moped
	OTHR	Other working machine
	PED	Pedestrian
	PLOW	Snowplow
	SBS	School bus / pupil transport
	TRAIN	Railway train
	TRK DB	Truck tractor (double bottom)
	TRK NA	Truck tractor (not attached)
	TRK SA	Truck tractor (semi attached)
	TRK ST	Straight truck (insert truck)
	TRK UT	Utility truck
VEHTYPE [1,2]-DT	Specific category for the type of vehicle which was involved in a crash.	
	CAR	Passenger Car
	SUV	(Sport) Utility Vehicle
	P VAN	Passenger Van

	C VAN	Cargo Van (10,000 Lbs. or Less)
	UT TRK	Utility Truck/Pickup Truck
	HOME	Motor Home
	S BUS	School Bus
	PT BUS	Pupil Transportation School Bus
	T BUS	Passenger Bus/Transit Bus
	COACH	Motor Coach
	OT BUS	Other Bus
	CYCLE	Motorcycle
	MOPED	Moped
	LSPD	Low Speed Vehicle
	GOLF	Golf Cart
	ATV	ATV/UTV (Utility Terrain Vehicle)
	SNOW	Snowmobile
	EM POL	Police on Emergency
	ST TRK	Straight Truck
	TRK NA	Truck Tractor (Trailer Not Attached)
	TRK TA	Truck Tractor (Trailer Attached)
	TRK DB	Truck Tractor (More Than One Trailer)
	AMB EM	Ambulance on Emergency
	FIRE EM	Fire Truck on Emergency
	FARM	Farm Tractor/Self Propelled
	AGCMV	AgCMV (Ag Commercial Motor Vehicle)
	OTHR	Other Working Machine
	TRAIN	Railway Train
	PLOW	Snowplow
	MISC	Miscellaneous
	BIKE	Bicycle
	FIREF EM	Fire Fighter on Emergency
	TRAILER	Trailer
	HRSDRWN	Horse and Buggy
	MINI	Minibike/Dirt Bike
	ACYCLE	Autocycle
	ATV	ATV
	UTV	UTV (Utility Terrain Vehicle)
Extent of Vehicle Damage		
VEHDMG [1,2]-MV	The extent of vehicle damage.	
	BLNK	Blank
	V MNR	Very Minor
	MNR	Minor
	MOD	Moderate
	SVR	Severe
	V SVR	Very Severe
VEHDMG [1,2]-DT	Identifies the extent to which the damage affects the vehicles operability rather than the cost to repair.	
	NO	No Damage
	MINOR	Minor Damage
	FUNC	Functional Damage
	DISABL	Disabling Damage
	NAS	Not at Scene

APPENDIX B: CRASH DATA USER GUIDE FOR MV4000

APPENDIX C: WISCONSIN DT4000 CRASH DATA USER GUIDE

WISCONSIN TRAFFIC OPERATIONS & SAFETY LABORATORY
UNIVERSITY OF WISCONSIN-MADISON
Department of Civil and Environmental Engineering

2205 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

Phone: (608) 265-1882
Fax: (608) 262-5199
www.topslab.wisc.edu

Crash Data User Guide

March 23, 2014

The Traffic Operations and Safety (TOPS) Laboratory at the University of Wisconsin-Madison provides crash summary reports as a service to the Wisconsin Department of Transportation (WisDOT) Bureau of Traffic Operations (BTO). The crash database, provided by WisDOT, Division of Motor Vehicles, contains information on all police reported crashes in Wisconsin from 1994 to the current year. Information on the location of the crash, vehicles involved, and general crash attributes are available. Personal data have been removed.

A reportable crash is defined as a crash resulting in injury or death of any person, any damage to government-owned non-vehicle property to an apparent extent of $200 or more or total damage to property owned by any one person to an apparent extent of $1000 or more. (This definition went into effect 1/1/96). It is important to note, however, that not all reportable crashes are reported. In order for a crash to be in the database, an MV4000 crash report must have been completed by a police officer.

A legend for the abbreviations and data fields contained in the crash data summary is attached. Note that some data fields listed in the attachment may not be included in all summary reports. Additional information may also be obtained by consulting the narrative and diagram in the actual crash report. The TOPS Lab provides copies of crash reports on behalf of WisDOT BTO to government agencies and consultants working on WisDOT projects.

For general inquiries regarding TOPS Lab crash data, or to request copies of specific crash reports, email: crash-data@topslab.wisc.edu. A Crash Data Resources FAQ is also available at this address: http://transportal.cee.wisc.edu/services/.

For additional information, or if you need assistance in analyzing the crash data obtained, please contact Ms. Andrea Bill, Traffic Safety Research Program Manager: bill@wisc.edu or 608-890-3425.

For all other inquiries:

Dr. David A. Noyce, Director
Traffic Operations and Safety (TOPS) Laboratory
Department of Civil and Environmental Engineering
Department of Industrial and Systems Engineering
University of Wisconsin-Madison
2205 Engineering Hall
1415 Engineering Drive
Madison, WI 53706
Phone: 608-265-1882
Fax: 608-262-5199
Email: noyce@engr.wisc.edu

Section I. General Purpose Crash Data Elements

The following elements are included in the TOPS Lab general purpose crash data file.

ACCDDATE – Calendar date on which the crash occurred.

ACCDLOC – The type of location at which a crash occurred. Types **I** and **N** are public roadway crashes.

- **I** = Intersection related
- **N** = Non intersection related
- **PL** = Parking lot
- **PP** = Private property

ACCDSVR – Accident severity will list the worst level of the crash severity to life and property.

- **FAT** = Fatal accident
- **INJ** = Injury occurred
- **PD** = Property damage only

ACCDTYPE – Description of type of crash based on the first harmful event.

- **ATTEN** = Impact attenuator
- **BIKE** = Bicycle
- **BRPAR** = Bridge parapet
- **BRPIER** = Bridge/pier/abutment
- **BRRAIL** = Bridge rail
- **CULVRT** = Culvert
- **CURB** = Curb
- **DEER** = Deer
- **DITCH** = Ditch
- **EMBKMT** = Embankment
- **FENCE** = Fence
- **FIRE** = Fire / Explosion
- **GR END** = Guardrail end
- **GR FAC** = Guardrail face
- **IMMER** = Immersion
- **JKNIF** = Jackknife
- **LTPOLE** = Lum light support
- **MAILBOX** = Mailbox
- **MED B** = Median barrier
- **MVIT*** = Vehicle in transit
- **OBNFX** = Object not fixed
- **SIGN** = Overhead sign post
- **OTH FX** = Other object fixed
- **OTH NC** = Other non-collision
- **OT ANL** = Other animal
- **OT RDY** = Veh trans other rdwy
- **OT PST** = Other post
- **OVRTRN** = Overturned vehicle
- **PED** = Pedestrian
- **PKVEH** = Parked vehicle
- **TFSIGN** = Traffic sign
- **TF SIG** = Traffic signal
- **TRAIN** = Train
- **TREE** = Tree
- **UNKN** = Unknown
- **UT PL** = Utility Pole

*__MVIT__ = Motor Vehicle in Transit involves moving vehicles. This field appears blank.

AGE[1,2] – The age of a driver, bicyclist or pedestrian at the time of the crash, generated from birthdate (age=0 if birthdate unknown).

ALCFLAG – Flag to indicate whether a driver, bicyclist or pedestrian was listed on the police report as drinking alcohol before the crash.

ATHWY – Name of the intersecting or nearest highway on which the crash took place.

ATNMBR – House, fire, railroad or other number associated with the crash location.

ATSTR – Name of street which intersects with the street on which the crash took place.

BIKEFLAG – Flag which indicates if a bicycle was involved in a crash.

CONSZONE – Indicates the crash resulted from an activity, behavior or traffic control related to a construction zone, but not necessarily within it.

COUNTY – The name of the county in which a crash occurred.

CYCLFLAG – Flag which indicates if a motorcycle was involved in a crash.

DOCTNMBR – The preprinted number on an MV4000 form.

DRVRDO[1,2] – What the driver of unit was doing at the time of the crash.

- **BACKING =** Backing up
- **BLNK** = Blank
- **CHG LN** = Changing lanes
- **GO STR** = Going straight
- **IL PRK** = Illegally parked
- **LG PRK** = Legally parked
- **LT TRN** = Making left turn
- **MERGING** = Merging into traffic
- **NEGCRV** = Negotiating curve
- **NPASZN** = Violate no pass zone
- **OTHER** = Other
- **OVT LT** = Overtaking on the left
- **OVT RT** = Overtaking on right
- **PARKNG** = Parking maneuver
- **RT TRN** = Right turn
- **RTOR** = Right turn on red
- **SL/ST** = Slowing or stopped
- **STOPED** = Stopped in traffic
- **UTURN** = U turn

DRVRPC[1,2] – Lists the possible driver contributing circumstances (Driver Factors) in a collision. These flags are generated by TOPS Lab.

- **DC** = Driver condition
- **DIS** = Physically disabled
- **DTC** = Disrgd traffic cntl
- **FTC** = Following too close
- **FTY** = Failure to yield
- **FVC** = Failure to keep vehicle under control
- **IC** = In conflict
- **ID** = Inattentive driving
- **IO** = Improper overtake
- **IT** = Improper turn
- **LOC** = Left of center
- **OTR** = Other
- **SPD** = Exceed speed limit
- **TFC** = Too fast for conditions
- **UB** = Unsafe backing

DRVRPC[1,2]A - Corresponds to the first item checked on the MV4000 list of Driver Factors. This element has been deprecated in favor of DRVRPC[1,2].

HWYCLASS – A code which describes the type of road the crash took place on.

- **BLNK** = Blank
- **R CITY** = City street rural
- **R CTH** = County trunk rural
- **R IH** = Interstate highway rural
- **R STH** = State highway rural
- **R TOWN** = Town road rural
- **U CITY** = City street urban
- **U CTH** = County trunk urban
- **U IH** = Interstate highway urban
- **U STH** = State highway urban
- **OTHR** = Parking lot / other

INJSVR – Highest level injury severity for a crash, taken over all persons involved in a crash.

- **K** = Killed
- **A** = Incapacitating
- **B** = Non-incapacitating
- **C** = Possible
- **Blank** = Unreported

INJSVR[1,2] – Text describing the most severe injury to a driver, bicyclist or pedestrian involved in a crash. Same format as INJSVR.

INJTRNS – Indicator describing whether any injured persons were transported to a medical facility or not. Generated by TOPS Lab.

INTDIR – Cardinal direction of the distance of the intersecting highway which is used to identify the location of the crash.

INTDIS – Intersection Distance in hundredths of a mile from intersection location listed (1 = approx. 50 feet). If the crash occurred at the intersection, the INTDIR would be blank and INTDIS would be zero.

LGTCOND – Light condition at time of crash. If blank the light condition is **DAY**.

- **DARK =** Nighttime -- unlit
- **LIGT** = Nighttime -- street lights

MNRCOLL – Manner (first harmful event) in which participants collided in the crash.

- **ANGL =** Angle
- **HEAD** = Head On Collision
- **NO C** = No collision with another vehicle
- **REAR** = Rear End
- **RTR** = Rear to rear
- **SSO** = Sideswipe/Opposite Direction
- **SSS** = Sideswipe/Same Direction
- **UNKN** = Unknown

MUNICIPALITY – The name of the municipality in which a crash occurred.

MUNITYPE – The code which describes the municipality type

- **C** = City
- **T** = Town
- **V** = Village

NTFYHOUR – The one hour range in which the enforcement agency was notified of the crash; listed in military time.

ONHWY – The name of the highway on which the crash took place.

ONHWYDIR – The primary direction of travel on the "on" highway, used in conjunction with RPNMBR and RPDIS for the total reference point number for a State Trunk Numbered (STN) highway. If the highway is divided, the side of the highway where the crash occurred will be listed. This will always be the cardinal direction unless the highway is divided.

ONHWYRP – Three character route number for ONHWY (See: STN Roadway log).

ONSTR – The local street name on which the crash took place.

PEDFLAG – An indicator which describes whether a pedestrian was involved in a crash.

POSTSPD[1,2] – Posted speed for a vehicle unit at the location where a crash occurred.

REGION – The WisDOT region associated with a crash record CNTYCODE.

RLTNRDWY – Location of first harmful event in relation to a roadway.

- **GORE** = Gore
- **LTSH** = Outside should-left
- **MED** = Median
- **OFF** = Off roadway - location unknown
- **ON** = On roadway
- **PLOT** = Private lot or private prop
- **RAMP** = On ramp
- **RTSH** = Outside shoulder-right
- **SHLD** = Shoulder

ROADCOND – Surface condition of the road at the point of origin for the unit apparently most at fault. If blank the road condition is **DRY.**

ROADHOR – The horizontal road terrain at the point of impact. The options for this field are either straight or curve. The field will only be filled in on this summary if curve **C** was indicated.

ROADVERT – The vertical road terrain at the point of impact. The options for this field is either flat or hill. The field will only be filed in on this summary if hill **H** was indicated.

SAFETY[1,2] – The type of safety equipment, if any, that was used by a driver, bicyclist or pedestrian involved in a crash.

- **SH**/**LP** = Shoulder & lap belt
- **LAP** = Lap belt only
- **SHLD** = Shoulder belt only
- **CHILD** = Child safety seat
- **HLMT** = Helmet
- **HT**/**EY** = Helmet & eye protection
- **EYE** = No helmet / eye protection only
- **NA** = Not applicable-non-motorist
- **UNKN** = Restraint use unknown
- **NONE** = None used-vehicle occupant

SEX[1,2] – The sex of a driver, bicyclist or pedestrian involved in a crash.

STNM[1,2]1 – The state statute number corresponding to the citation issued at a crash.

STNM[1,2]2 – The state statute number corresponding to the citation issued at a crash.

TOTFATL – Total number of persons killed in a crash.

TOTINJ – Total number of persons injured in a crash.

TOTVEH – Total number of vehicles involved in a crash.

TRFCWAY – Text describing areas designed for motor vehicle operation.

- **BLNK** = Blank
- **ND** = Not physically divided
- **D/WO** = Divided highway without traffic barrier
- **D/B** = Divided highway with traffic barrier
- **OW** = One-way traffic
- **OTHR** = Parking lot or private property

TRFCNTL[1,2] – The traffic controls in effect at the time of a crash.

- **NONE** = None
- **OTHR** = Other
- **RRSIG** = RR-xing signal
- **SS** = Stop sign
- **SS FL** = Stop sign with flasher
- **TC PR** = Traffic control person
- **TS OP** = Traffic signal operation
- **TS FL** = Traffic signal flashing
- **WS** = Warning sign
- **WS FL** = Warning sign with flasher
- **YIELD** = Yield sign

TRVLDIR[1,2] – The direction of travel of a unit prior to the crash (based on primary road direction).

VEHDMG[1,2] – The extent of vehicle damage

- **BLNK** = BLANK
- **V MNR** = VERY MINOR
- **MNR** = MINOR
- **MOD** = MODERATE
- **SVR** = SEVERE
- **V SVR** = VERY SEVERE
- **UNKN** = UNKNOWN
- **NONE** = NONE

VEHTYPE[1,2] – The type of vehicle that was involved in a crash.

- **ATV** = Snowmobile / ATV
- **BIKE** = Bicycle
- **BLNK** = Blank
- **BUS** = Passenger bus
- **CAR** = Passenger car
- **CYCLE** = Motorcycle
- **EM AMB** = Ambulance on emergency
- **EM FIRE** = Fire truck / fire fighter on emergency
- **EM POL** = Police on emergency
- **FARM** = Farm tractor / self propelled
- **HOME** = Motor home
- **HRSDRWN*** = Horse drawn implement (carriage, wagon, buggy)
- **MISC** = Miscellaneous
- **MOPED** = Moped
- **OTHR** = Other working machine
- **PED** = Pedestrian
- **PLOW** = Snow plow
- **SBS** = School bus / pupil transport
- **TRAIN** = Railway train
- **TRK DB** = Truck tractor (double bottom)
- **TRK NA** = Truck tractor (not attached)
- **TRK SA** = Truck tractor (semi attached)
- **TRK ST** = Straight truck (insert truck)
- **TRK UT** = Utility truck

* HRSDRWN attribute available from 2012.

WTHRCOND – A code which identifies the weather condition at the time of a crash.

- **BLNK** = Blank
- **CLR** = Clear
- **CLDY** = Cloudy
- **RAIN** = Rain
- **SNOW** = Snow
- **FOG** = Fog / smog / smoke
- **SLET** = Sleet / hail
- **WIND** = Blowing sand / dirt / snow
- **XWIND** = Severe crosswinds
- **OTHR** = Other
- **UNKN** = Unknown

Section II. Additional Crash Data Elements

The following additional elements are available from the TOPS Lab crash database.

ACCDNMBR – Computer system generated number to uniquely identify a crash. This identifier is typically excluded from the standard data file per agreement with WisDOT DMV. DOCTNMBR should be used instead.

ATHWYTYP – Type of highway which intersects with the highway on which the crash occurred.

AUTOFLAG – Flag which indicates if a passenger car was involved in a crash.

BUSFLAG – Flag which indicates if a school bus was involved in a crash.

CITFLAG – Flag which indicates if a citation was issued in connection with a crash.

CMVFLAG – Flag which indicates if a commercial vehicle was involved in a crash.

CNTYCODE – A unique code for the county in which a crash occurred.

DAYNMBR – The day of the week on which the crash occurred.

DRUGFLAG – Flag which indicates whether a driver, bicyclist, or pedestrian was listed on the police report as using drugs before the crash.

HITRUN – Flag which indicates whether a crash involved a hit and run vehicle.

HWYPC[1,2] – Lists the possible highway contributing circumstances (Highway Factors) in a crash. These flags are generated by TOPS Lab.

- **SIW** – Snow / Ice / Wet
- **NSH** = Narrow Shoulder
- **LSH** = Low Shoulder
- **SSH** = Soft Shoulder
- **LG** = Loose Gravel
- **RP** = Rough Pavement
- **PDB** = Debris Prior to Accident
- **ODB** = Other Debris
- **SGN** = Sign Obscured / Missed
- **NB** = Narrow Bridge
- **CZ** = Construction Zone
- **VIS** = Visibility Obscured
- **SPD** = Other

LGTRKFLAG – Flag indicating whether a crash involved a large truck. Large trucks include straight (insert) trucks and truck tractors (not attached, semi attached, double bottom).

MCFLNMBR – Microfilm / image number for an MV4000 crash report. This identifier is typically excluded from the standard data file per agreement with WisDOT DMV. DOCTNMBR or ACCDNMBR are sufficient to request a copy of a crash report.

MOPFLAG – Flag which indicates if a moped was involved in a crash.

MUNICODE – A unique code for the municipality in which a crash occurred.

ONDUTY[1,2] – An indicator whether the driver of the vehicle was operating on duty.

- **P** = Police officer
- **F** = Fireman
- **E** = EMT
- **H** = Winter highway maintenance

ONHWYTYP – The type of roadway on which the crash occurred (business road, frontage road, ramp, etc.).

ROLE[1,2] – Identifies the role of the occupant: driver, passenger, pedestrian, motorcyclist, bicyclist, or moped user.

RPDIS – Reference Point Distance; Distance in miles in the cardinal direction from the RP number listed.

RPFLAG – Flag indicating whether a crash was coded to a highway reference point.

RPNMBR – Reference Point number where a crash occurred. (See: STN Roadway log)

SPEEDFLAG – Flag indicating that at least one driver involved in the crash received a citation for speeding, or was listed on the crash report as "exceeding speed limit" or "speed too fast/conditions." Generated by TOPS Lab.

TRAINFLAG – Flag indicating whether a train was involved in a crash.

TRKFLAG – Flag which indicates if a truck was involved in a crash.

TRLRFLAG – Flag which indicates if a vehicle unit was towing a trailer.

WISLR_LATDECDG – WISLR crash map crash location latitude in decimal degrees.

WISLR_LONDECDG – WISLR crash map crash location longitude in decimal degrees.

Section III. Document Revision History

The field name abbreviations for HWYCLASS, SFTYEQP, TRFCWAY, VEHDMG, and VEHTYPE changed as of 11/12/2007**.**

Wisconsin DT4000 Crash Data User Guide

Wisconsin Traffic Operations and Safety Laboratory

May 28, 2019

The Traffic Operations and Safety (TOPS) Laboratory at the University of Wisconsin-Madison provides crash summary data files as a service to the Wisconsin Department of Transportation (WisDOT) Bureau of Traffic Operations (BTO). The crash database, provided by WisDOT, Division of State Patrol, contains information on all police reported crashes in Wisconsin from 1994 to the current year. Information on the location of the crash, vehicles involved, and general crash attributes are available. Personally identifiable information (PII) data have been removed.

A reportable crash is defined as a crash resulting in injury or death of any person, any damage to government-owned non-vehicle property to an apparent extent of $200 or more or total damage to property owned by any one person to an apparent extent of $1000 or more. (This definition went into effect 1/1/96). It is important to note, however, that not all reportable crashes are reported. In order for a crash to be in the database, a crash report must have been completed by a police officer.

A legend for the abbreviations and data fields contained in the crash data summary is attached. Note that some data fields listed in the attachment may not be included in all summary reports. Additional information may also be obtained by consulting the narrative and diagram in the actual crash report. The TOPS Lab provides copies of crash reports on behalf of WisDOT BTO to government agencies and consultants working on WisDOT projects.

For general inquiries regarding TOPS Lab crash data, or to request copies of specific crash reports, email: crash-data@topslab.wisc.edu. A Crash Data Resources FAQ is also available from the TOPS Lab WisTransPortal system: http://transportal.cee.wisc.edu/services/crash-data/.

For additional information, or if you need assistance in analyzing the crash data obtained, please contact Ms. Andrea Bill, Traffic Safety Research Program Manager: bill@wisc.edu or 608-890-3425.

For all other inquiries:

Dr. David A. Noyce, Director
Traffic Operations and Safety (TOPS) Laboratory
Department of Civil and Environmental Engineering
Department of Industrial and Systems Engineering
University of Wisconsin-Madison
2205 Engineering Hall
1415 Engineering Drive
Madison, WI 53706
Phone: 608-265-1882
Email: noyce@engr.wisc.edu

Crash Data Guide Usage Notes

As of January 1, 2017, the Wisconsin DT4000 crash report has replaced the MV4000 for all police reported motor vehicle crashes in Wisconsin. The DT4000 introduced a number of important changes to the overall set of crash data elements and attributes[1], including adherence to the US DOT Model Minimum Uniform Crash Criteria (MMUCC) standard for crash data systems. Information about the DT4000 crash database modernization project is available on the TOPS Lab website: http://topslab.wisc.edu/research/cdi/.

This Data Guide provides a description of DT4000 data elements and attributes available from the WisTransPortal crash database at the TOPS Lab. Data elements are listed in alphabetical order. The definition of each element is provided, along with the corresponding list of attributes, where applicable. For multiyear queries that include crashes prior to 2017, the TOPS Lab provides a "legacy" data file that translates DT4000 crash elements into an equivalent MV4000 format. It is recommended to use the DT4000 data file whenever possible to obtain the most complete and accurate picture of the crashes listed.

The following conventions are used in Section 1, DT4000 Crash Data Elements:

- [1,2] Denotes unit level information, where a unit is any vehicle, bicycle, pedestrian, or equipment involved in a crash. Unit level element names in the data file are appended with "1" or "2", representing the first or second unit involved in the crash. For example, VEHTYPE1 describes the vehicle type of the first unit listed on the DT4000 crash report. The TOPS Lab crash data file includes information on the first two units involved in a crash along with information on the drivers or primary non-motorists for those units. Additional information may be obtained by consulting the DT4000 crash report.

- [A,B] Denotes elements that take on multiple values. Multi-valued element names in the data file are appended with "A", "B", "C", etc. For example, RDWYPC_A and RDWYPC_B describe the first two roadway factors listed on the DT4000 crash report. The TOPS Lab crash data file includes the first several attributes for multi-valued elements. The actual number of attributes provided varies by element and follows the number of subtypes recommended by the MMUCC standard, regardless of how many attributes are recorded in the database. Additional information may be obtained by consulting the DT4000 crash report.

- [1,2][A,B] Denotes combined unit level and multi-valued elements. For example, DRVRPC1A and DRVRPC1B describe the first two contributing factors listed for the driver of the first unit on the DT4000 crash report.

The DT4000 crash database is subject to change over time as new elements are added, modified, or replaced. A Document Revision History is provided in Section 2 at the end of this Guide. This Data Guide reflects the new DT4000 version of the WisTransPortal Crash Database. An MV4000 Data Guide corresponding to the "legacy" crash data is also available from the TOPS Lab.

---

[1] Elements refer to individual fields on the crash database. Attributes refer to predefined values of elements. For example *Fatality* is an attribute of the element *Injury Severity*. Many database elements do not have predefined attributes, such as the element *Crash Date*.

SECTION 1: DT4000 Crash Data Elements

ACSCNTL – The degree that access to abutting land is fully, partially, or not controlled by a public authority.

- **Full** - Full Control
- **PART** - Partial Control
- **NO** - No Control

AGCYCASE – Used by law enforcement to record their case identifier for a crash.

AGCYNAME – The name of the reporting law enforcement agency.

AGCYNMBR – The NCIC number for the reporting law enforcement agency.

AGCYTYPE – The type of law enforcement agency that reported the crash.

- **BLNK**- Blank
- **WSP** - State Patrol
- **CO SHF** - County Sheriff
- **C POL** - City Police
- **V POL** - Village Police
- **TWN POL** - Town Police
- **TRIBAL** - Tribal
- **OTHR** - Other

AGE[1,2] – The age in years of a person involved in a crash.

ALCFLAG – Indicates whether law enforcement suspected that at least one driver or non-motorist involved in the crash had used alcohol. This includes both alcohol use under the legal limit and at or over the legal limit. (Y/N/UNKN),

ALTLAT – The latitude coordinate value of a crash location in decimal degrees, manually entered during the RP crash coding process for quality control of the TraCS TLT location.

ALTLON - The longitude coordinate value of a crash location in decimal degrees, manually entered during the RP crash coding process for quality control of the TraCS TLT location.

AMENDED – Indicates whether a crash report was an amendment to a previous report.

ANMLTY[A,B] – Identifies the type of animal hit in a crash.

- **BEAR** - Bear
- **COYT** - Coyote
- **DEER** - Deer
- **OPOS** - Opossum
- **OTHR** - Other Non-Domesticated
- **RACC** - Raccoon(s)
- **TRKY** - Turkey

ARBGDLPT[1,2] – Deployment status of an air bag relative to the position of the operator of the vehicle.

- **DP FT** - Deployed-Front
- **DP SD** - Deployed-Side
- **DP CT** - Deployed-Curtain
- **DP OT** - Deployed-Other (Knee, Air Belt, etc.)
- **DP CB** - Deployed-Combination
- **NON DP** - Non Deployed

- **NDP OFF** – Non-Deployed – Switched Off
- **NDP RE** – Non-Deployed – Defective/Removed
- **SHLD** - Shoulder
- **NA** - Not Applicable
- **UNKN** - Unknown

ARDATE – The date the law enforcement officer arrived at the crash scene (YYYYMMDD).

ARTIME – The time the law enforcement officer arrived at the crash scene (HHMI).

ATCODE – A code used to identify the type of "Structure Number" associated with a crash location (i.e., house #, utility #, fire #, railroad #, other #).

- **N** - No Structure
- **H** - House/Building
- **F** - Fire
- **U** - Utility
- **R** - Railroad
- **B** - Bridge
- **O** - Other

ATHWY – The name of the intersecting highway which is used to identify the location of a crash.

ATHWYDIR – The signed direction of the intersecting highway which is used to identify the location of a crash.

- **NB** - Northbound
- **EB** - Eastbound
- **SB** - Southbound
- **WB** - Westbound

ATHWYSYS – The system type of the intersecting highway which is used to identify the location of a crash.

- **IH** - Interstate
- **USH** - US Highway
- **STH** - State Highway
- **CTH** - County Highway

ATHWYTYP – The type of intersecting highway which is used to identify the location of a crash.

- **R** - Ramp
- **F** - Frontage
- **B** - Business

ATNMBR – The structure number associated with a crash location.

ATSTR – The name of the intersecting street which is used to identify the location of a crash.

AUTOFLAG - Flag indicating whether a passenger car was involved in a crash.

BIKEFLAG - Flag indicating whether a bicycle was involved in a crash.

BUSFLAG - Indicates whether a school bus or motor vehicle functioning as a school bus for a school-related purpose is involved in the crash.

- **N** - No
- **Y/D** - Yes, School Bus Directly Involved
- **Y/I** - Yes, School Bus Indirectly Involved

CITFLAG - Flag indicating whether a crash report lists citations.

CLRDATE - The date the crash scene was cleared (YYYYMMDD).

CLRTIME – The time the crash scene was cleared (HHMI)

CLSDATE – The date a road/lane was initially closed due to a crash (YYYYMMDD).

CLSFLAG – Flag indicating whether any lanes were closed due to a crash.

CLSRSN[A,B] - Describes the reason for the road/lane closure due to a crash.

- **TOW** - Tow Truck
- **FIRE** - Fire/EMS
- **MED** - Med Flight
- **ENF** - Law Enforcement
- **WTHR** - Weather Conditions
- **SECD** - Secondary Crash
- **OTHR** - Other

CLSTIME – The time a road/lane was initially closed due to a crash (HHMI).

CLSTYPE - Describes the type of road/lane closure due to a crash.

- **FC** - Full Closure
- **1D** - Closure – One Direction
- **LC** - Lane Closure
- **OC** - Other Closure

CMAAFLAG - Flag indicating whether a crash has been geo-coded for crash mapping and analysis purposes.

CMVFLAG - Flag indicating whether a commercial motor vehicle was involved in a crash.

CNTYCODE - The code value of the county in which the crash occurred.

CNTYNAME - The name of the county in which the crash occurred.

CONSZONE - Flag indicating whether a crash occurred in a construction, maintenance, or utility work zone or was related to activity within a work zone.

CONTCPT[1,2] - The approximate contact point on this vehicle associated with this vehicles initial harmful event.

- **NON** - Non-Collision
- **1** - Right Front Corner
- **2** - Ride Side Front
- **3** - Right Side Middle
- **4** - Right Side Rear
- **5** - Right Rear Corner
- **6** - Rear
- **7** - Left Rear Corner
- **8** - Left Side Rear
- **9** - Left Side Middle
- **10** - Left Side Front
- **11** - Left Front Corner
- **12** - Front
- **TOP** - Top

- **UNDER** - Undercarriage
- **CARGO** - Cargo Loss
- **NAS** - Not at Scene
- **UNKN** - Unknown

CRSHDATE - The date on which a crash occurred (YYYYMMDD).

CRSHHOUR - The time at which a crash occurred (HHMI).

CRSHJUR - Identifies the type of jurisdiction of the land where a crash occurred.

- **NO** - No Special Jurisdiction
- **N PARK** - National Park Service
- **MILT** - Military
- **TRIBE** - Indian Reservation/Trust
- **EDU** - College/University Campus
- **FED** - Other Federal Properties
- **PRV** - Private Property
- **OTHR** - Other
- **UNKN** - Unknown

CRSHLOC - Identifies ownership of the land where a crash occurred.

- **PUB** - Public Property
- **PRV** - Private Property
- **TRIBE** - Tribal Land

CRSHMTH - The month in which a crash occurred.

CRSHNMBR - Unique identifier for a crash assigned by the database management system (format YYMMNNNNN).

CRSHSVR - A code describing the overall severity of a crash.

- **FAT** - Fatal
- **INJ** - Injury
- **PD** - Property Damage
- **NR** - Not Reportable

CRSHTIME - The time at which a crash occurred (HHMI).

CRSHTYPE - The first injury or damage-producing event that characterizes the crash type. Same as MOSTHARM.

CRSHYEAR – The year in which a crash occurred (YYYY).

CYCLFLAG - Flag indicating whether a motorcycle was involved in a crash.

DAYNMBR - The day of the week on which a crash occurred.

DEERFLAG - Flag indicating whether a crash involved a deer.

DISTFLAG - Flag indicating whether a crash involved distracting or inattentive driving.

DMGAR[1,2][A,B] - Identifies areas damaged on the vehicle as a result of the crash.

- **1** - Right Front Corner
- **2** - Ride Side Front
- **3** - Right Side Middle

- **4** - Right Side Rear
- **5** - Right Rear Corner
- **6** - Rear
- **7** - Left Rear Corner
- **8** - Left Side Rear
- **9** - Left Side Middle
- **10** - Left Side Front
- **11** - Left Front Corner
- **12** - Front
- **TOP** - Top
- **UNDER** - Undercarriage
- **ALL** - All Areas
- **NO** - No Damage
- **NAS** - Not at Scene
- **UNKN** - Unknown

DNMFTR[1,2][A,B] - Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash.

- **NORM** - Appeared Normal
- **PHY IMP** - Physically Impaired
- **EMO** - Emotional (Depressed, Angry, Disturbed, Etc.)
- **SICK** - Ill (Sick), Fainted
- **SLEEP** - Asleep or Fatigued
- **UI MDA** - Under the Influence of Medication/Drugs/Alcohol
- **CONF** - Confused or Disoriented (Non Lucid)
- **WCHAIR** - Paraplegic or Restricted to Wheelchair
- **BLIND** - Blind
- **CANE** - Using Cane or Crutches
- **NO OBS** - Not Observed
- **OTHR** - Other

DOCTNMBR - The document number printed on the initial police report submitted for this crash. For amendments, this value is taken from the Document Number Override field.

DRUGLFAG – Indicates whether law enforcement suspected that at least one driver or non-motorist involved in the crash had used drugs (Y/N/UNKN).

DRVRDOIN[1,2] - The controlled maneuver for this motor vehicle prior to the beginning of the sequence of events.

- **GO STR** - Going Straight
- **NEGCRV** - Negotiating Curve
- **BACKING** - Backing
- **CHG LN** - Changing Lanes
- **OVT RT** - Overtake Right
- **OVT LT** - Overtake Left
- **RT TRN** - Right Turn
- **LT TRN** - Left Turn
- **U TRN** - U Turn
- **LVG LN** - Leaving Traffic Lane
- **ENT LN** - Entering Traffic Lane

- **SLOWNG** - Slow/Stopping
- **LG PRK** - Legally Parked
- **STOPED** - Stop in Traffic
- **NO PASS** - Viol No Pass Zn
- **PARKNG** - Park Maneuver
- **RTOR** - Turn on Red
- **MERGING** - Merging
- **ACCEL** - Accelerating in Road
- **STARTNG** - Starting in Road

DRVRDOTR[1,2] - A description of the controlled maneuver before the crash when 'Other' is indicated.

DRVRPC[1,2][A,B,C,D] - The actions by the driver that may have contributed to the crash, based on the judgment of the law enforcement officer investigating the crash.

- **SPD** - Exceed Speed Limit
- **TFC** - Speed Too Fast/Cond
- **FTY** - Failed To Yield Right-Of-Way
- **FTC** - Following Too Close
- **IT** - Improper Turn
- **UB** - Unsafe Backing
- **FVC** - Failure To Control
- **ROR** - Ran Off Roadway
- **DRED** - Disregarded Red Light
- **DSS** - Disregarded Stop Sign
- **DTC** - Disregarded Other Traffic Control
- **DRM** - Disregarded Other Road Markings
- **IOR** - Improper Overtaking / Passing Right
- **IOL** - Improper Overtaking / Passing Left
- **WW** - Wrong Side or Wrong Way
- **FDL** - Failed To Keep In Designated Lane
- **AR** - Operated Motor Vehicle In Aggressive/Reckless Manner
- **ID** - Operated Motor Vehicle In Inattentive, Careless or Erratic Manner
- **IC** - Swerved or Avoided Due To Wind, Slippery Surface, Motor Vehicle, Object, Non-Motorist In Roadway, etc.
- **OVR** - Over-Correcting/Over-Steering
- **RAC** - Racing
- **OTR** - Other Contributing Action
- **NO** - No Contributing Action
- **NOT SEE** - Looked But Did Not See
- **UNKN** - Unknown

DRVRRS[1,2][A,B,C] - Restrictions assigned to an individual’s driver license by the license examiner.

- **NONE** - None
- **LENS** - Corrective Lenses
- **MECH** - Mechanical Devices (Special Brakes, Hand Controls, or Other Adaptive Devices)
- **PROS** - Prosthetic Aid
- **TRANS** - Automatic Transmission
- **MIRR** - Outside Mirror
- **DAY** - Limited To Daylight Only

- **EMPLY** - Limited To Employment
- **PERMIT** - Learners Permit Restrictions
- **INTERM** - Intermediated License Restrictions
- **LIMIT** - Limited-Other
- **CDL** - CDL Intrastate Only
- **W/O AIR** - Motor Vehicles Without Air Brakes
- **MILT** - Military Vehicles Only
- **BUS A** - Except Class A Bus
- **BUS AB** - Except Class A and Class B Bus
- **TRLR** - Except Tractor-Trailer
- **FARM** - Farm Waiver
- **IID** - Ignition Interlock Device (IID)
- **OTHR** - Other
- **UNKN** - Unknown

EJECT[1,2][A,B,C] - Indicates the extent to which the person was ejected from the interior of the motor vehicle as a result of the crash. This excludes motorcycles.

- **NO** – Not Ejected
- **TOTAL** – Totally Ejected
- **PARTL** – Partially Ejected
- **NA** – Not Applicable
- **UNKN** - Unknown

ENVPC[A,B,C] - Apparent environmental conditions which may have contributed to the crash.

- **NONE** - None
- **WTHR** - Weather Conditions
- **OBSTR** - Visual Obstruction(s)
- **GLARE** - Glare
- **ANML** - Animal(s) In Roadway
- **OTHR** - Other

EYEPROT[1,2] - The type of eye protection used by a motorcyclist at the time of a crash.

- **WORN** - Yes: Worn
- **SHLD** - Yes: Windshield
- **BOTH** - Yes: Worn and Windshield
- **NO** - No
- **UNKN** - Unknown

FRSTDTTM - Record Modified timestamp for initial crash report.

FIREFLAG - Flag indicating whether a crash involved a fire in a motor vehicle in transport.

FMCSARPT - Flag indicating whether a crash is required to be reported to the Federal Motor Carrier Administration (FMCSA).

GOVTPROP - Flag indicating whether a crash involved damage to government property.

HITRUN - Flag indicating whether a crash involved a hit and run vehicle.

HLMTUSE[1,2] - The type of helmet used by a motorcyclist at the time of the crash.

- **HALF** - Half
- **3Q** - Three-Quarter

- **FULL** - Full-Face
- **NO** - No
- **UNKN** - Unknown

HWYCLASS - A code which describes the type of road the crash took place on.

- **U CITY** - City Street Urban
- **R CITY** - City Street Rural
- **R TOWN** - Town Road Rural
- **U CTH** - County Trunk Urban
- **R CTH** - County Trunk Rural
- **U STH** - State Highway Urban
- **R STH** - State Highway Rural
- **U IH** - Interstate Hwy Urban
- **R IH** - Interstate Hwy Rural
- **P LOT** - Parking Lot
- **OTHR** - Other

INJSVR - The severity of a crash based on the most severe injury to any person involved in the crash.

- **K** - Fatal Injury
- **A** - Suspected Serious Injury
- **B** - Suspected Minor Injury
- **C** - Possible Injury
- **O** - No Apparent Injury

INJSVR[1,2] - The injury severity level for a person involved in a crash.

- **K** - Fatal Injury
- **A** - Suspected Serious Injury
- **B** - Suspected Minor Injury
- **C** - Possible Injury
- **O** - No Apparent Injury

INJTRNS - Flag indicating whether any person involved in a crash was transported to a medical facility.

INTDIR - The compass direction of the distance to an intersecting highway or street which is used to identify the location of a crash.

INTDIS - The distance in miles to an intersecting highway or street which is used to identify a crash location.

INTTYPE - The type of intersection in which a crash occurred. An intersection consists of two or more roadways that intersect at the same level.

- **NA** - Not At Intersection
- **4 WAY** - Four-Way Intersection
- **T** - T-Intersection
- **Y** - Y-Intersection
- **L** - L-Intersection
- **RAB** - Roundabout
- **5** - Five-Point, or More
- **OTHR** - Other

JRSDTN - Text describing the location of the reporting law enforcement agency.

LASTDTTM - Record Modified timestamp for last received report (initial or amendment).

LATDECDG - The latitude expressed in decimal degrees where the first harmful event occurred.

LGTCOND - The type/level of light that existed at the time of the motor vehicle crash.

- **DAY** - Daylight
- **DAWN** - Dawn
- **DUSK** - Dusk
- **LITE** - Dark/Lighted
- **DARK** - Dark/Unlit
- **DK/UN** - Dark-Unknown Lighting
- **UNKN** - Unknown

LGTRKFLAG – Flag indicating that a crash involved a large truck.

LNKNMBR - Used to link multiple crash reports for the same crash. References the crash document number of the primary report.

LOCTYPE – Same as MV4000 "ACCDLOC" element, indicating the location type of a crash.

- **I** – Intersection (public roadway)
- **N** – Non-intersection (public roadway)
- **PL** – Parking lot
- **PP** – Private Property

LONDECDG - The longitude expressed in decimal degrees where the first harmful event occurred.

LTLNSRC - The source of the latitude and longitude locations.

- **TLT** - TLT
- **GPS** - GPS
- **OTHR** - Other

MATLSPIL - Flag indicating whether a crash involved a material spill.

MNRCOLL - The manner in which two motor vehicles in transport initially came together without regard to the direction of force. Only where the first harmful event involves a collision between two motor vehicles in transport. Note: attribute value "Front to Side" corresponds to the MMUCC 5 "Angle" value.

- **NO** - No Collision W/Vehicle In Transport
- **FTR** - Front To Rear
- **FTF** - Front To Front
- **RTR** - Rear To Rear
- **SSS** - Sideswipe/Same Direction
- **SSO** - Sideswipe/Opposite Direction
- **RTS** - Rear To Side
- **FTS** - Front to Side
- **OTHR** - Other
- **UNKN** - Unknown

MOPFLAG - Flag indicating whether a moped was involved in a crash.

MOSTHARM[1,2] - Event that resulted in the most severe injury or, if no injury, the greatest property damage involving this motor vehicle.

- **MVIT** - Motor Vehicle In Transport
- **PKVEH** - Parked Motor Vehicle
- **BIKE** - Pedalcycle

- **PED** - Pedestrian
- **TRAIN** - Railway Vehicle (Train, Engine)
- **OT RDY** - Motor Vehicle In Transport - Other Roadway
- **OBNFX** - Other Object - Not Fixed
- **TFSIGN** - Traffic Sign Post
- **TF SIG** - Traffic Signal
- **UT PL** - Utility Pole
- **LTPOLE** - Lum Light Support
- **OT PST** - Other Post, Pole or Support
- **TREE** - Tree
- **MAILBOX** - Mailbox
- **GR FAC** - Guardrail Face
- **GR END** - Guardrail End
- **BRPAR** - Bridge Parapet End
- **BRPIER** - Bridge/Pier/Abut
- **ATTEN** - Impact Attenuator/Crash Cushion
- **SIGN** - Overhead Sign Post
- **BRRAIL** - Bridge Rail
- **CULVRT** - Culvert
- **DITCH** - Ditch
- **CURB** - Curb
- **EMBKMT** - Embankment
- **FENCE** - Fence
- **OTH FX** - Other Fixed Object
- **OVRTRN** - Overturn/Rollover
- **FIRE** - Fire/Explosion
- **IMMER** - Immersion, Full or Partial
- **JKNIF** - Jackknife
- **OTH NC** - Other Non-Collision
- **CARGO** - Cargo/Equipment Loss or Shift
- **FELL** - Fell/Jumped From Motor Vehicle
- **THRWN** - Thrown or Falling Object
- **OT NMT** - Other Non-Motorist
- **STRUCK** - Struck By Falling, Shifting Cargo or Anything Set In Motion By Motor Vehicle
- **WZ EQP** - Work Zone/Maintenance Equipment
- **BRIDGE** - Bridge Overhead Structure
- **CABL B** - Cable Barrier
- **CONC B** - Concrete Traffic Barrier
- **OTHR B** - Other Traffic Barrier
- **ANL NA** - Non Domesticated Animal (Alive)
- **ANL ND** - Non Domesticated Animal (Dead)
- **ANL DA** - Domesticated Animal - Alive
- **ANL DD** - Domesticated Animal - Dead
- **HYDRNT** - Fire Hydrant
- **UNKN** - Unknown

MUNICODE - The code value for the municipality in which a crash occurred.

MUNINAME - The name of the municipality in which a crash occurred.

MUNITYPE - The type of municipality (city, town, village) in which a crash occurred.

- **C** - City
- **V** - Village
- **T** - Town

NMTACT[1,2][A,B] - The actions/circumstances of the non-motorist that may have contributed to the crash, based on the judgement of the law enforcement officer investigating the crash.

- **NF TRFC** - Walking Not Facing Traffic
- **DISREG** - Disregarded Signal
- **SUDDEN** - Sudden Movement Into Traffic
- **DK CLTH** - Dark Clothing
- **FC TRFC** - Walking Facing Traffic
- **NO IMPR** - No Improper Action
- **IM XING** - Improper Crossing Of Roadway (Jaywalking)
- **F YIELD** - Failure To Yield Right-Of-Way
- **F OBEY** - Failure To Obey Traffic Signs, Signals, or Officer
- **IM RDWY** - In Roadway Improperly (Standing, Lying, Working, Playing)
- **DISABLD** - Disabled Vehicle Related (Working On, Pushing, Leaving/Approaching)
- **STOPPED** - Entering/Exiting Parked/Standing Vehicle
- **INATTV** - Inattentive (Talking, Eating, Etc.)
- **NOT VIS** - Not Visible (Dark Clothing, No Lighting, Etc.)
- **IM TURN** - Improper Turn/Merge
- **IM PASS** - Improper Passing
- **W WAY** - Wrong-Way Riding or Walking
- **F LGTS** - Failing To Have Lights On When Required (Bicycling)
- **NO EQIP** - Operation Without Required Equipment (Bicycle Reflectors)
- **IM CHNG** - Improper or Erratic Lane Changing
- **F LANE** - Failure To Keep In Proper Lane or Running Off Road
- **IM ENTR** - Making Improper Entry To or Exit From Trafficway
- **RECKLSS** - Operating In Other Erratic, Reckless or Careless Manner
- **PASSNG** - Passing With Insufficient Distance or Inadequate Visibility Or Failing To Yield To Overtaking Vehicle
- **OTHR - Othe**r
- **UNKN** - Unknown

NMTLOC[1,2] - The location of the non-motorist with respect to the roadway at the time of the crash.

- **ATI MX** - At Intersection-In Marked Crosswalk
- **ATI UM** - At Intersection-Unmarked / Unknown If Marked Crosswalk
- **ATI NX** - At Intersection-Not In Crosswalk
- **ATI UL** - At Intersection-Unknown Location
- **NAI MX** - Not At Intersection-In Marked Crosswalk
- **NAI NX** - Not At Intersection-On Roadway, Not In Marked Crosswalk
- **NAI UN** - Not At Intersection-On Roadway, Crosswalk Availability Unknown
- **PK LN** - Parking Lane/Zone
- **BIKE LN** - Bicycle Lane
- **SHLDR** - Shoulder / Roadside
- **SDWLK** - Sidewalk
- **MEDIAN** - Median / Crossing Island

- **DRWAY** - Driveway Access
- **SHARED** - Shared-Use Path
- **NON TRF** - Non-Trafficway Area
- **NOT RPT** - Not Reported
- **OTHR** - Other
- **UNKN** - Unknown Location

NMTPRIOR[1,2] - The action of a non-motorist immediately prior to a crash.

- **XING** - Crossing Roadway
- **WAITING** - Waiting To Cross Roadway
- **W TRFC** - Walking/Cycling Along Roadway With Traffic (In or Adjacent To Travel Lane)
- **A TRFC** - Walking/Cycling Along Roadway Against Traffic (In or Adjacent To Travel Lane)
- **SIDE WK** - Walking/Cycling On Sidewalk
- **RDWY OT** - In Roadway - Other
- **ADJACNT** - Adjacent To Roadway (E.G., Shoulder, Median)
- **WORKING** - Working In Trafficway (Incident Response)
- **NONE** - None
- **JOGGING** - Jogging/Running
- **STOPPED** - Entering/Exiting Parked or Stopped Motor Vehicle
- **DISABLD** - Disabled Vehicle Related
- **OTHR** - Other
- **UNKN** - Unknown

NMTSFQ[1,2][A,B] - The safety equipment in use by the operator non-motorist at the time of the crash (excluding motorcyclists).

- **NONE** - None
- **HLMT** - Helmet
- **PADS** - Protective Pads Used (Elbow, Knees, Shin, etc.)
- **REFL** - Reflective Clothing (Jacket, Backpack, etc.)
- **LTNG** - Lighting
- **OTHR** - Other
- **UNKN** - Unknown

NTFYDATE - The date on which law enforcement was notified of a crash.

NTFYTIME - The time at which law enforcement was notified of a crash.

ONDUTY - Flag indicating whether police, EMT/first responders, fire fighters, or winter highway maintenance were "on duty" and involved in a crash.

ONDUTY[1,2] - If police, EMT/ first responder, fire fighter or winter highway maintenance were "on duty" and involved in a crash.

- **P** - Police
- **E** - EMT First Responder
- **F** - Fire Fighter
- **H** - Winter Hwy Maintenance

ONEMER - Flag indicating whether one of the units in a crash was operating as an emergency vehicle (lights and siren are activated).

ONHWY - The name of the highway on which a crash occurred.

ONHWYDIR - The signed direction of the highway on which a crash occurred.

- **NB** - Northbound
- **EB** - Eastbound
- **SB** - Southbound
- **WB** - Westbound

ONHWYSYS - The system type of the highway on which the crash occurred (CTH, STH, USH, IH).

- **IH** - Interstate
- **USH** - US Highway
- **STH** - State Highway
- **CTH** - County Highway

ONHWYTYP - The type of highway on which a crash occurred (R=ramp, F=frontage, B=business).

ONSTR - The street name on which a crash occurred.

OPNDATE - The date a road/lane was opened after a closure due to the crash.

OPNTIME - The time a road/lane was opened after a closure due to the crash.

PEDFLAG - Flag indicating whether a pedestrian was involved in a crash.

PHOTFLAG - Flag indicating whether photos were taken at a crash.

POPCLASS - The population class of the municipality where the crash occurred.

- **2500** - 2500-4999
- **5000** - 5000-9999
- **10000** - 10000-24999
- **25000** - 25000-49999
- **50000** - 50000-99999
- **100000** - 100000-249999
- **250000** - 250000-Over
- **LT 2500** - Incorp < 2500
- **U RURAL** - Unknown Rural
- **UNKN** - Unknown

POSTSPD[1,2] - The posted/statutory speed limit for a motor vehicle at the time of the crash. A value of 77 indicates Not Applicable.

PROTGR[1,2][A,B] - The protective gear used by a motorcyclist at the time of a crash.

- **REFL** - Reflective
- **GLOVS** - Gloves
- **BOOTS** - Boots
- **JACKT** - Jacket
- **PANTS** - Long Pants
- **NONE** - None
- **UNKN** - Unknown

RACE[1,2] – The race of the driver per the Wisconsin Uniform Traffic Citation Codes.

- **A** - Asian
- **B** - Black
- **I** - Indian

- **H** - Hispanic
- **W** - White

RDCOND[A,B,C] - The roadway surface condition at the time and place of a crash.

- **DRY** - Dry
- **WET** - Wet
- **SNOW** - Snow
- **SLUSH** - Slush
- **ICE** - Ice
- **WATER** - Water (Standing/Moving)
- **SAND** - Sand
- **MUD** - Mud/Dirt
- **GRAVL** - Gravel
- **OIL** - Oil
- **OTHR** - Other
- **UNKN** - Unknown

RDWYPC[A,B,C] - Apparent factors of the road which may have contributed to the crash.

- **NONE** - None
- **BUPC** - Backup Due To Prior Crash
- **BUPI** - Backup Due To Prior Non-Recurring Incident
- **BURC** - Backup Due To Regular Congestion
- **TOL** - Toll Booth/Plaza Related
- **RSC** - Road Surface Condition (Wet, Icy, Snow, Slush, etc.)
- **DBPC** - Debris Prior To Crash
- **RUT** - Rut, Holes, Bumps
- **WZ** - Work Zone (Construction/Maintenance/Utility)
- **WTP** - Worn, Travel-Polished Surface
- **OBS** - Obstruction In Roadway
- **TCD** - Traffic Control Device Inoperative, Missing, or Obscured
- **NSH** - Narrow Shoulder
- **LSH** - Low Shoulder
- **SSH** - Soft Shoulder
- **NHW** - Non-Highway Work
- **LG** - Loose Gravel
- **RP** - Rough Pavement
- **ODB** - Other Debris
- **SGN** - Sign Obscured/Miss
- **NB** - Narrow Bridge
- **VIS** - Visibility Obscured
- **NA** - Not Applicable
- **OTHR** - Other

RECDDTTM - System timestamp associated with a crash record revision number.

RECDNMBR - Revision number for a crash record in the database management system.

RECDSTAT - Status level of a given crash record.

- **P** - Production
- **A** - Action Required

- **D** - Deleted
- **T** - Test
- **F** - Final

RECONBY - The name of the agency that conducted the crash reconstruction.

REGION - The WisDOT Division of Transportation System Development (DTSD)/Division of State Patrol (DSP) region in which a crash occurred.

REPTYPE – The type of crash report that was submitted.

- DT4000 – Police crash report for crashes occurring since 2017
- DT4002 – Driver reported crash report for crashes occurring since 2017
- MV4000 – Police crash report for crashes occurring prior to 2017

RLTNJNIC - The coding of this data element is based on the location of the first harmful event of the crash. It identifies the crash's location with respect to presence in a junction or proximity to components typically in junction or interchange areas. This field identifies if a crash occurred within the Interchange area. (Y/N/UNKN).

RLTNJNLC - The coding of this data element is based on the location of the first harmful event of the crash. It identifies the crash's location with respect to presence in a junction or proximity to components typically in junction or interchange areas. This field identifies the specific location in a junction or interchange.

- **NJ** - Non-Junction
- **INT** - Intersection
- **INR** - Intersection-Related
- **ENRP** - Entrance Ramp
- **EXRP** - Exit Ramp
- **ENRPR** - Entrance Ramp-Related
- **EXRPR** - Exit Ramp-Related
- **RR** - Railway Grade Crossing
- **XOVR** - Crossover-Related
- **DRWY** - Driveway Access
- **DRRL** - Driveway Access-Related
- **PATH** - Shared-Use Path or Trail
- **ACCEL** - Acceleration Lane
- **DECEL** - Deceleration Lane
- **THRU** - Through Roadway
- **OTHR** - Other Location Not Listed Within an Interchange Area (Median, Shoulder, and Roadside)
- **UNKN** - Unknown

RLTNRDWY - The location of the first harmful event as it relates to its position within or outside the trafficway.

- **ON** - On Roadway
- **LTSH** - Shoulder Left
- **RTSH** - Shoulder Right
- **MED B** - Median Barrier
- **R SIDE** - Roadside
- **GORE** - Gore
- **SEP** - Separator
- **PARK** - In Parking Lane or Zone
- **OFF** - Off Roadway, Location Unknown
- **O ROW** - Outside Right-Of-Way (Trafficway)

- **CTLT** - Continuous Left Turn Lane
- **UNKN** - Unknown

RLTNTRWY - Identifies the location of a crash with respect it's relation to a trafficway.

- **ON** - Trafficway - On Road
- **OFF** - Trafficway - Not On Road
- **P LOT** - Non Trafficway - Parking Lot
- **OTHR** - Non Trafficway - Other

ROADHOR[1,2] - The curvature of the roadway in the direction of travel for this vehicle.

- **ST** - Straight
- **LT** - Curve Left
- **RT** - Curve Right
- **CU** - Curve - Unknown Direction
- **UNKN** - Unknown

ROADVERT[1,2] - The grade of the roadway in the direction of travel for this vehicle.

- **LVL** - Level
- **CST** - Hillcrest
- **UP** - Uphill
- **DN** - Downhill
- **SAG** – Sag (Bottom)
- **UNKN** - Unknown

ROLE[1,2] - The type of person involved in a crash.

- **DR** - Driver
- **PA** - Passenger
- **PED** - Pedestrian
- **O PED** - Other Pedestrian
- **BIKE** - Bicyclist
- **O BIKE** - Other Cyclist
- **NT** - Occupant of Motor Vehicle Not In Transport
- **NM** - Occupant of Non-Motor Vehicle Transportation Device
- **UT** - Unknown Type of Non-Motorist
- **UNKN** - Unknown

RPCODER - Indicates whether the WisDOT RP Coder Utility was used to generate STN reference point locations for a crash (Y/N/NA).

RPDIS - The relative distance in miles in the positive direction of a crash from a State Trunk Network (STN) reference point.

RPFLAG – Flag indicating that a crash was assigned to a State Trunk Network (STN) reference point (RP) location.

RPLINK - The State Trunk Network (STN) roadway link ID for a crash location.

RPLKOT - The State Trunk Network (STN) offset in miles relative to the start of a roadway link for a crash location.

RPNMBR - The State Trunk Network (STN) reference point (RP) number where a crash occurred.

RPRTEDIR - The State Trunk Network (STN) roadway route direction, used in conjunction with RPNMBR and RPDIS for the total refer

RPRTEID - The State Trunk Network (STN) roadway route ID for the highway on which a crash occurred.

RPRTENB - The State Trunk Network (STN) roadway route number where a crash occurred.

RPRTETY - The State Trunk Network (STN) roadway route type where a crash occurred (B,X,L).

RPTBFLAG - Indicates whether a crash was required to be reported by Wisconsin law.

RPTYPE - The State Trunk Network (STN) reference point (RP) type where a crash occurred (A,C,E,F,K,R,S).

RSTRFLAG - Flag indicating whether a crash report has restricted information.

SCHZONE - Flag indicating whether a crash occurred in an active school zone.

SECDAGCY - For secondary crashes, the name of the law enforcement agency handling the prior crash.

SECDFLAG - Identifies whether a crash may have occurred because of a previous crash (e.g., gawkers, slowing, etc.)

SECDPRIM - For secondary crashes, the document number of a prior crash.

SEQEVT[1,2][A,B,C,D] - The first four events (A-D) in the sequence of events related to this motor vehicle, including both non-collision as well as collision events.

- **MVIT** - Motor Vehicle In Transport
- **PKVEH** - Parked Motor Vehicle
- **BIKE** - Pedalcycle
- **PED** - Pedestrian
- **TRAIN** - Railway Vehicle (Train, Engine)
- **OT RDY** - Motor Vehicle in Transport - Other Roadway
- **OBNFX** - Other Object - Not Fixed
- **SIN PST** - Traffic Sign Post
- **TF SIG** - Traffic Signal
- **UT PL** - Utility Pole
- **LTPOLE** - Lum Light Support
- **OT PST** - Other Post, Pole or Support
- **TREE** - Tree
- **MAILBOX** - Mailbox
- **GR FAC** - Guardrail Face
- **GR END** - Guardrail End
- **BRPAR** - Bridge Parapet End
- **BRPIER** - Bridge/Pier/Abut
- **ATTEN** - Impact Attenuator/Crash Cushion
- **OH PST** - Overhead Sign Post
- **BRRAIL** - Bridge Rail
- **CULVRT** - Culvert
- **DITCH** - Ditch
- **CURB** - Curb
- **EMBKMT** - Embankment
- **FENCE** - Fence
- **OTH FX** - Other Fixed Object
- **OVRTRN** - Overturn/Rollover

- **FIRE** - Fire/Explosion
- **IMMER** - Immersion, Full or Partial
- **JKNIF** - Jackknife
- **OTH NC** - Other Non-Collision
- **CARGO** - Cargo/Equipment Loss or Shift
- **FELL** - Fell/Jumped from Motor Vehicle
- **THRWN** - Thrown or Falling Object
- **OT NMT** - Other Non-Motorist
- **STRUCK** - Struck by Falling, Shifting Cargo or Anything Set In Motion By Motor Vehicle
- **WZ EQP** - Work Zone/Maintenance Equipment
- **BRIDGE -** Bridge Overhead Structure
- **CABL B** - Cable Barrier
- **CONC B** - Concrete Traffic Barrier
- **OTHR B** - Other Traffic Barrier
- **ANM NA** – Non-Domesticated Animal (Alive)
- **ANM ND** – Non-Domesticated Animal (Dead)
- **ANM DA** - Domesticated Animal - Alive
- **ANM DD** - Domesticated Animal - Dead
- **HYDRNT -** Fire Hydrant
- **ROR R** - Run Off Roadway Right
- **ROR L** - Run Off Roadway Left
- **CR MED** - Cross Median
- **CR CL** - Cross Centerline
- **LT TRN** - Left Turn
- **DOWN** - Downhill Runaway
- **EQP FL** - Equipment Failure (Blown Tire, Brake Failure, etc.)
- **REENTR** - Reentering Roadway
- **SEP** - Separation of Units
- **RT TRN** - Right Turn
- **UNKN** - Unknown

SEX[1,2] - The sex of a person involved in a crash.

- **M** - Male
- **F** - Female
- **UNKN** - Unknown

SFTYEQP[1,2] - The restraint equipment in use at the time of the crash (excluding motorcyclists).

- **SH/LP** - Shoulder & Lap Belt
- **LAP** - Lap Belt Only
- **SHLD** - Shoulder Belt Only
- **UNKN** - Restraint Use Unknow**n**
- **NON**E - None Used - Vehicle Occupant
- **UNTYPE** - Restraint Used - Type Unknown
- **CH/FF** - Child Restraint System - Forward Facing
- **CH/RF** - Child Restraint System - Rear Facing
- **BOOST** - Booster Seat
- **CH/UN** - Child Restraint - Type Unknown
- **NA** - Not Applicable

- **OTHR** - Other

SFTYFLAG – Flag indicating whether safety equipment was unused for any person involved in a crash.

SPEEDFLAG – Flag indicating whether speed was a factor in a crash.

STATNM[1,2][A,B,C,D] - The statute number of the violation for which a driver was cited.

SURFTYPE[1,2] - Describes the type of road surface for this vehicle at the crash location.

- **BLACK** - Blacktop (Bituminous)
- **BRICK** - Brick or Block
- **CONC** - Concrete
- **DIRT** - Dirt
- **GRAVEL** - Slag, Gravel, or Stone
- **STAMP** - Stamped Concrete
- **OTHR** - Other
- **UNKN** - Unknown

TEENDRVR – Flag indicating whether a crash involved a driver between the age of 16 and 19.

TLTFLAG - Indicates whether the TraCS Locator Tool (TLT) was used to assign the crash location.

TOTCIT[1,2] - The number of citations issued to a person involved in a crash.

TOTFATL - The total number of fatalities in a crash.

TOTINJ - The total number of persons injured in a crash (excludes fatalities).

TOTINJ_A – The total number of "A" injuries in a crash, based on the WISINJ values.

TOTINJ_B – The total number of "B" injuries in a crash, based on the WISINJ values.

TOTINJ_C – The total number of "C" injuries in a crash, based on the WISINJ values.

TOTINJ_K – The total number of "K" injuries in a crash, based on the WISINJ values.

TOTINJ_O – The total number of "O" injuries in a crash, based on the WISINJ values.

TOTLANES[1,2] - Total number of lanes in the roadway on which this motor vehicle was traveling. For undivided highways - total through lanes in both directions, excluding designated turn lanes. For divided highways - total through lanes for roadway the motor vehicle under consideration was traveling.

TOTMOT - The total number of motorists involved in a crash. Excludes occupants of legally parked vehicles.

TOTNMT - The total number of non-motorists (pedestrians, pedalcyclists, etc.) involved in a crash. Includes occupants of legally parked vehicles.

TOTUNIT - The total number of units involved in a crash.

TOTVEH - The total number of vehicles involved in a crash.

TOTWIT - The total number of witnesses who observed the crash.

TOWDFLAG[1,2] – Flag indicating whether a vehicle involved in a crash is removed from the scene due to damage incurred.

- T/D – Towed Due to Disabling Damage
- T/N – Towed But Not Due To Disabling Damage
- NT – Not Towed

TRAINFLAG – Flag indicating whether a train was involved in a crash.

TRBCODE - The numeric code for the tribal land in which a crash occurred on.

TRBNAME - The name of the tribal land in which a crash occurred.

TRFCCNTL[1,2] - The type of traffic control device (TCD) applicable to this motor vehicle at the crash location.

- **NONE** - No Control
- **TS OP** - Traffic Signal
- **TS FL** - Traffic Signal Flash
- **SCHOOL** - School Zone Sign/ Device
- **STOP** - Stop Sign
- **SS FL** - Stop Sign/Flash
- **YIELD** - Yield Sign
- **WS** - Warning Sign
- **WS FL** - Warning Sign with Flash
- **TC PR** - Traffic Control Person
- **RRSIG** - Railway Crossing
- **OTHR** - Other
- **UNKN** - Unknown

TRFCINOP[1,2] - Indicates whether a traffic control device was inoperable or missing at the time of the crash (Y/N/UNKN).

TRFCWAY[1,2] - Indication of whether or not the trafficway for this vehicle is divided and whether it serves one-way or two-way traffic.

- **UNDIV**- Two-Way, Not Divided
- **TWLTL** - Two-Way, Not Divided, With A Continuous Left Turn Lane
- **DIV NO** - Divided Hwy W/O Traffic Barrier
- **DIV PNT** - Two-Way, Divided, Unprotected (Painted > 4 Feet) Median
- **DIV BAR** - Divided Hwy W/Traffic Barrier
- **DIV MBR** - Divided Hwy Median W/Barrier
- **OW** - One-Way Traffic
- **PL/PP** - Parking Lot or Private Property
- **RAMP** - Entrance/Exit Ramp
- **UNKN** - Unknown

TRKFLAG - Flag indicating whether a truck was involved in a crash.

TRLRFLAG - Flag indicating whether one or more vehicles was pulling a trailer or towing another vehicle prior to the crash.

TRLRPNTR - Flag indicating whether a trailer was involved in a crash.

TRVLDIR[1,2] - The direction of a motor vehicle's travel on the roadway before the crash. Not a compass direction, but a direction consistent with the designated direction of the road.

- **NB** - Northbound
- **SB** - Southbound
- **EB** - Eastbound
- **WB** - Westbound
- **NR** - Not on Roadway
- **UNKN** - Unknown

UNITSTAT[1,2] - The status of a unit at the time of a crash.

- **IN TRN** - In Transit
- **ON EM** - On Emergency
- **HIT RUN EM** - Hit and Run/On Emergency
- **HIT RUN** - Hit and Run
- **LG PRK** - Legally Parked
- **NCONT** - Non-Contact
- **STOLEN** - Stolen
- **HIT RUN ST** - Stolen/Hit and Run
- **IL PRK** - Illegally Parked
- **UNKN** - Unknown

URBRURAL - Urban or rural designation for the location where the crash occurred.

- **R TOWN** - Rural Town
- **R LT 5000** - Rural < 5000
- **U LT 5000** - Urban < 5000
- **U GT 5000** - Urban > 5000

VEHDMG[1,2] - Identifies the extent to which the damage affects the vehicles operability rather than the cost to repair.

- **NO** - No Damage
- **MINOR** - Minor Damage
- **FUNC** - Functional Damage
- **DISABL** - Disabling Damage
- **NAS** - Not at Scene
- **UNKN** - Unknown

VEHPC[1,2][A,B] - Pre-existing motor vehicle defects or maintenance conditions that may have contributed to the crash.

- **BRAKE** - Brakes
- **EXHT** - Exhaust System
- **BODY** - Body, Doors
- **STEER** - Steering
- **TRANS** - Power Train
- **SUSP** - Suspension
- **TIRE** - Tires
- **WHEEL** - Wheels
- **HEAD LGT** - Head Lamps
- **TURN SIG** - Turn Signals
- **TAIL LGT** - Tail Lamps
- **BRAKE LGT** - Stop Lamps
- **WINDOW** - Windows /Wind Shield
- **MIROR** - Mirrors
- **WIPE** - Wipers
- **HITCH** - Coupling Device/Trailer Hitch/Safety Chains
- **PRE CRSH** - Disabled Due to Prior Crash
- **O DISB** - Other Disabled
- **NA** - Not Applicable
- **OTHR** - Other

- **UNKN** - Unknown

VEHTYPE[1,2] - Specific category for the type of vehicle which was involved in a crash. (The combined ATV/UTV attribute was deprecated and replaced with separate elements ATV & UTV in Fall 2018).

- **CAR** - Passenger Car
- **SUV** - (Sport) Utility Vehicle
- **P VAN** - Passenger Van
- **C VAN** - Cargo Van (10,000 Lbs or Less)
- **UT TRK** - Utility Truck/Pickup Truck
- **HOME** - Motor Home
- **S BUS** - School Bus
- **PT BUS** - Pupil Transportation School Bus
- **T BUS** - Passenger Bus/Transit Bus
- **COACH** - Motor Coach
- **OT BUS** - Other Bus
- **CYCLE** - Motorcycle
- **MOPED** - Moped
- **LSPD** - Low Speed Vehicle
- **GOLF** - Golf Cart
- **ATV** - ATV/UTV (Utility Terrain Vehicle)
- **SNOW** - Snowmobile
- **EM POL** - Police on Emergency
- **ST TRK** - Straight Truck
- **TRK NA** - Truck Tractor (Trailer Not Attached)
- **TRK TA** - Truck Tractor (Trailer Attached)
- **TRK DB** - Truck Tractor (More Than One Trailer)
- **AMB EM** - Ambulance on Emergency
- **FIRE EM** - Fire Truck on Emergency
- **FARM** - Farm Tractor/Self Propelled
- **AGCMV** - AgCMV (Ag Commercial Motor Vehicle)
- **OTHR** - Other Working Machine
- **TRAIN** - Railway Train
- **PLOW** - Snow Plow
- **MISC** - Miscellaneous
- **BIKE** - Bicycle
- **FIREF** - EM - Fire Fighter on Emergency
- **TRAILER** - Trailer
- **HRSDRWN** - Horse and Buggy
- **MINI** - Mini Bike/Dirt Bike
- **ACYCLE** - Autocycle
- **ATV** - ATV
- **UTV** - UTV (Utility Terrain Vehicle)

WISINJ[1,2] – The KABCO injury severity level for a person involved in a crash, taken as the adjusted INJSVR value depending on whether the person sustained a state reportable fatality or not.

WITFLAG - Flag indicating whether witnesses are listed on a crash report.

WSLINK - The WISLR roadway link ID for a crash location provided by TraCS TLT.

WSLKOT - The WISLR link offset in feet relative to the start of a roadway link for a crash location provided by TraCS TLT.

WSXCOORD - The WISLR X-coordinate value for a crash location provided by TraCS TLT, in UTM NAD83 Meters.

WSYCOORD - The WISLR Y-coordinate value for a crash location provided by TraCS TLT, in UTM NAD83 Meters.

WTCOND[A,B] - The prevailing atmospheric conditions that existed at the time of the crash.

- **CLEAR** - Clear
- **CLDY** - Cloudy
- **RAIN** - Rain
- **SNOW** - Snow
- **SLEET** - Sleet/Hail
- **WIND** - Severe Winds
- **FRZ RN** - Freezing Rain or Freezing Drizzle
- **FOG** - Fog
- **SMOG** - Smog/Smoke
- **B SNOW** - Blowing Snow
- **B DIRT** - Blowing Sand, Soil, Dirt
- **OTHR** - Other
- **UNKN** - Unknown

WZARSP - For work zone related crashes, identifies if the work zone speed limit was Advisory or Regulatory.

- **A** - Advisory
- **R** - Regulatory

WZENF - For work zone related crashes, identifies if law enforcement was present at time of the crash.

- **N** - No
- **O** - Officer Present
- **V** - Law Enforcement Vehicle Only Present

WZLOC - Describes the location of a crash within a work zone.

- **BFOR** - Before the First Work Zone Warning Sign
- **ADVN** - Advance Warning Area
- **TRAN** - Transition Area
- **ACTV** - Activity Area
- **TERM** - Termination Area

WZNLSP - The normal posted speed limit of the work zone in which a crash occurred.

WZOTHR - A free text description of the type of work zone in which a crash occurred, when type "Other" is indicated (see WZTYPE).

WZSPD - The speed limit of the work zone in which a crash occurred.

WZTYPE - For work zone related crashes, identifies the type of work zone in which the crash occurred.

- **CLOSE** - Lane Closure
- **SHIFT** - Lane Shift/Crossover
- **SHLDR** - Work on Shoulder or Median
- **MOVE** - Intermittent or Moving Work
- **OTHR** - Other

WZWKRS - For work zone related crashes, identifies if workers were present at time of crash (Y/N/UNKN).

SECTION 2: Document Revision History

5/28/2019: Initial version of this document.