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NASS Analysis in Support Of NHTSA's Frontal Small Overlap Program

DISCLAIMER

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List of Acronyms and Corresponding SAS Variable Names

CDC	Collision Deformation Classification
SOI	Small-Overlap Impact
CUV	Crossover Utility Vehicle
FTW	Front-Track Width
RTW	Rear-Track Width
ATW*	'Average'-Track Width
WinSMASH	Software used by NHTSA to estimate changes in velocity for passenger vehicles involved in a collision.
PDOF*	Principal Direction of Force (expressed in degrees of a circle)
DOF*	Direction of Force (expressed as an 'o'clock' direction describing an arc of 30 degrees)
OW	Overall width
UEW*	Undeformed end width;
DDW*	Direct-damage width
Field-L*	Length of direct and induced damage included in the crush-profile for a vehicle
C-measures or Cs*	Measurements of the depth of a crush-profile, taken at six points along the profile
Direct-D*	The center of direct-damage with reference to the vehicle center-line or the center of the post-crash wheelbase.
SMASH-L	The value used in WinSMASH to state the length of the base of the area under a curve described by the six crush measurements.
WB*	Wheelbase
D-rail	The specified lateral distance between the longitudinal beams providing structure to the front-end of a vehicle.
$Rail_{LOC}$	The lateral distance from the vehicle center-line to the centers of the longitudinal beams.
FTW_E	One-half of the front-track width, taken as expressing the location of either bumper 'corner'.
AOB	The area outboard the longitudinal beams and forward of the lower A-pillar.
BL	The specified longitudinal distance from the center of the front bumper to the center of the base of the windshield.
FOH	Front overhang; the specified longitudinal distance from the center of the front bumper to the center of the front 'axle'.
A_{LOC}	Estimate of the longitudinal distance from the center of the front bumper to the top of the lower A-pillar.
Axle-A	Estimate of the longitudinal distance from the center of the front 'axle' to the top of the lower A-pillar. Used to locate the A-pillar in reference to the center of the wheelbase.

SAS Variable Names Referred to Relevant to CDC Codes

DOF1	Direction of Force (columns 1 and 2)
GAD1	General Area of Damage (column 3)
SHL1	Specific Longitudinal Location (column 4)
SVL1	Specific Vertical Location (column 5)
TDD1	Type of Damage Distribution (column 6)
EXTENT1	Deformation Extent (column 7)

SAS Variable Names Referred to Relevant to Crush Profiles

DIRDAMW	Direct-damage width
DVL	Field-L length
DVD	Center of direct-damage (a.k.a. Direct D)
DVC (1 to 6)	Crush measurements C1 to C6
ORIGAVETW	Original 'average'-track width
UNDENDW	Undeformed end width
Wheelbas	Wheelbase

*Has an identity with SAS variable names in published NASS-CDS data

Executive Summary

The September, 2009 NHTSA report Fatalities in Frontal Crashes Despite Seat Belts and Air Bags Review of All CDS Cases Model and Calendar Years 2000-2007: 122 Fatalities, asked "Why are people still dying in frontal crashes despite seat belt use, air bags, and the crashworthy structures of late-model vehicles?" It concluded: "Aside from a substantial proportion of these 122 crashes that are just exceedingly severe the main reason people are still dying is because so many crashes involve poor structural engagement between the vehicle and its collision partner." A case-analysis approach was used by the review team/authors of the report. The team was drawn from different offices within NHTSA.

In databases of field data on motor vehicle crashes, such as the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS), damage to vehicles is categorized using the Collision Deformation Classification (CDC) system. The CDC system uses a width of deformed sheet metal criterion to assign a type of damage distribution code. The deformation must be deemed as being due to direct contact with the object struck or collision partner. The management of crash energy by structural elements is not considered. Statistical analysis of NASS-CDS data that queries CDC type-of-damage-distribution codes to investigate the scope of the problem of poor structural engagement in small over-lap impacts (SOI) result in the scope of the problem being understated.

The 2009 NHTSA reported that 'Crashes with limited horizontal engagement (SOI) can be identified *frequently* as having Collision Deformation Classification (CDC) designations of FLEE or FREE.' An inability to rely solely on CDC codes to identify *all* SOI in queries of NASS-CDS data indicates why the scope of the SOI problem was not reported in quantitative terms. An analysis of case histories approach is expensive. There is an impetus for establishing a method for identifying SOI in queries of NASS-CDS data.

This report presents an operational definition of SOI applicable to NASS-CDS and similar datasets. It stems from a commission the Medical College of Wisconsin CIREN center (MCW-WIC) received 2006 from NHTSA-CIREN to review crashes with FLEE and FREE designations to determine whether SOI accounted for a considerable fatalities involving restrained occupants in frontal-impacts. It uses Lindquist's 2004 definition of small-overlap impacts as those that do not engage vehicle structural longitudinal components and builds on Sullivan's 2008 SAE paper presenting a taxonomy of frontal-impacts. It recognizes deformation of front-end structural members can be inferred from crush measurement data. A set of eleven vehicle size classes that correspond to NASS size classes are used. For each size class, a generic vehicle model was developed from specifications for the vehicle makes, models and model years frequently observed in NASS-CDS data as having a CDC defined small-overlap impact to the left side of the front-end (a.k.a. a 'FLEE' impact), describing the highest rank speed change impact in NASS-CDS data. These eleven classes were used to establish crush profile criteria for defining SOI. Crush criteria presuppose the following: The crush measurements reflecting the maximum or minimum amounts of crush for a specific SOI CDC code occurs at a constant location in the profile, the relationships between those crush measurements is constant and the location of the center of direct-damage in relation to the location of structural members is indicated by the generic vehicle models.

Using 2005 to 2008 NASS-CDS data, a universe of all frontal and oblique side impacts assigned a Principal Direction of Force (PDOF1) between 320 and 40 degrees ranked as the most severe impact was constructed. Cases with lesser severity rollover events were not excluded. Queries were run on this data set. The first query had a sub-routine that examined the CDC codes for highest ranked frontal plane impacts and had CDC type of damage-distribution codes that define SOI as corner (E type) and narrow end engagement (S type) impacts. The query also had another sub-routine that employed crush data.

Next, the definition of SOI was expanded to include impacts through the front fenders. Oblique side-plane SOI are defined as impacts assigned a PDOF1 between 0/40 and 320/360 degrees. The center of the crush profile is forward of the estimated lower A-pillar location and associated with a crush profile outboard of the front-end structural members and forward of the firewall/cowl. A second query, using these criteria was run. The results were added to the results of the combined CDC/Crush query to estimate the number of overall SOI type impacts.

Relative to the overall population of all front-end plane and oblique side-plane impacts, the query utilizing CDC criteria identified 87 of the raw cases as involving a fatality or 3,683 occupants on the basis of case weights. Using crush criteria, 38 fatal raw cases were identified or 1,348 on the basis of case weights. Using oblique side-impact criteria 6 fatal raw cases were identified or 130 on the basis of case weights. A total of 44 additional fatal raw cases or 1,478 on the basis of case weights were identified using the stated operational definition.

Relative to the overall population of all front-end plane and side and oblique side-plane impacts, the query utilizing CDC criteria identified 364 of the raw cases as involving an occupant sustaining a MAIS 3-6 injury were identified or 32,135 occupants on the basis of case weights. Using crush criteria 155 raw cases as involving an occupant sustaining a MAIS 3-6 injury were identified or 9,823 on the basis of case weights. Using oblique side-impact criteria 22 raw cases as involving an occupant sustaining a MAIS 3-6 injury were identified or 1,868 on the basis of case weights. A total of 177 an additional raw cases as involving an occupant sustaining a MAIS 3-6 injury or 11691 on the basis of case weights were identified using the operation definition presented here. Note: Small numbers of raw cases do not translate well to weighted cases.

This study is organized as follows: A list of acronyms and corresponding SAS variable names; an introduction; a background section; a general description of the methodology; definition of vehicle class sizes; development of the generic models of vehicle structure; a schematic description of frontal impacts; a discussion of how vehicle width in treated by the methodology; the MCW-WIC method for locating longitudinal beams; the application of the method to an compact SUV example; variables available in published NASS-CDS data; the selection of vehicles as sources of representative dimensions; how the adequacy of the size class models was evaluated; the application of the frontal-impact component of the methodology to NASS-CDS data; an overview of the oblique side-impact to the fender component; a schematic description of side-plane impacts; the application of the oblique side-impact component of the methodology to NASS-CDS data; table of results; cited sources; an appendix (Appendix A) of the vehicle dimensions used and the SAS code developed (Appendix B).

INTRODUCTION

Frontal impacts remain the highest proportion of vehicle collisions that produce serious injuries and fatalities. A recent NHTSA report examined why people are still sustaining serious injuries in frontal vehicle crashes[1]. It reported several reasons for this despite vehicle crash testing for full frontal and partial overlap impact modes. The report indicated, apart from impacts which are exceedingly severe, that small-overlap impacts involving poor structural engagement are the main reason people are still dying in frontal crashes despite seat belt use, air bags, and the improved crashworthiness of the structures of late-model vehicles.

A difficulty with understanding the scope and seriousness of the small overlap problem is defining what a small overlap crash is with respect to the Collision Deformation Classification (CDC) coding scheme used by databases containing field data on motor vehicle crashes, NASS-CDS in the U.S. and the Co-operative Crash Injury Study in the U.K. The CDC classification scheme relies on documentation of the deformation of vehicle sheet metal and was not developed with the role structural elements play in managing crash energy or close examination of structural vehicle components in mind. The CDC system uses a width of deformed sheet metal criterion to assign a type of damage distribution code. Deformation deemed to be due to direct contact with the object struck or collision partner is what is considered. The lack of engagement of structural longitudinal components and engine block are what define SOI. Consequently, SOI cannot be uniformly captured by the CDC classification scheme. Further, some oblique side-impact scenarios may result in a SOI type damage distribution. This report presents a method for using a combination of CDC variables and the crush profile data associated with a CDC to derive information about the involvement of structural members and with this operational definition, obtain a more comprehensive subset of SOI crashes from the NASS-CDS database than a set defined in accord with CDC coding.

BACKGROUND

In 2004 Mats Lindquist et al reported that in Western Sweden small-overlap impacts (SOI) accounted for 48% of fatalities involving restrained occupants in frontal-impacts [2]. This conclusion was based on a method for assessing impact damage that characterized the role of vehicle structure in the management of crash energy. The scheme for classifying impact damage employed a single generic model of passenger car. The model was used to identify nine frontal-impact load paths that occur at locations where vehicle components are stiff enough to transmit crash energy from the components engaging the object struck to the rest of the body of the vehicle[3]. SOI were defined as those where ‘the major load paths used in the crash are outside of either the left or right longitudinal beams’. The model was based on inspection of 53 vehicles in which one or more occupants died, during a series of field studies of fatal frontal impact crashes in Sweden from October 2000 to September 2001[4].

Schematic Description of Frontal Impacts

The rules for assigning a seven character Collision Deformation Code (CDC) to classify damage to sheet metal or other exterior plastic or fiber glass surface components are laid out in the Society of Automotive Engineers (SAE) document J224 MAR 80[5]. In what follows 'sheet metal' refers to exterior surfaces regardless of the actual type of material used. These rules generally do not make reference to vehicle structure, with the exception of incrementing the direction of force codes to account for 'shifting' of both of the end structures or the roof structure.

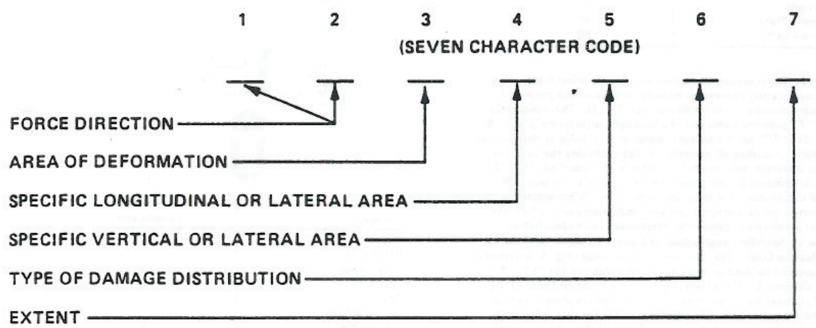

Figure 1: Seven character CDC code explanation

The first two characters of a CDC code describe the direction of the line of action the force of impact exerts on a vehicle (Figure 1). Analytically, in collisions between two vehicles, this is the resultant of the vectors each collision partner has. However, the Principal Direction of Force (PDOF) in a CDC is always determined on a subjective basis. Consequently, CDC indicates a Direction of Force (DOF) in terms of clock directions that describe arcs of 30 degrees. For example, a CDC expressing a 12 o'clock direction of force in columns one and two describes a 350, 360/0, or a 10 degree principal direction of force. The third character describes the general location of damage on a vehicle with reference to an end or side plane. The fourth character locates the damage within a segment of the damaged plane. In the context of frontal impacts, the segments are oriented on the lateral axis of the vehicle. The fifth character locates the damage on the vertical axis of the vehicle. Column seven describes the extent of damage on the longitudinal axis (vehicle front to back for frontal impacts).

CDC column six describes the damage distribution type. Most of the character codes in column six indicate the amount of engagement the vehicle sustained with the object struck, expressed as a set of width ranges. However, other codes for this column are indicative of other features of the impact. The 'S' code indexes angle of impact (see below), an extremely narrow width and a specific location when direct contact initiates on the end-plane. The 'E' code indexes a specific location where direct contact initiates on the end-plane and its width. The 'K' code indexes vehicle dynamics during impact as it indicates a transition in the width of engagement, typically from a wider width of engagement to a narrower width of engagement. The 'A' code indexes the shape of the object struck. With the exception of the 'A' code, the damage distribution type refers to the width of damage to the end-plane along the lateral axis of the vehicle, within the context of the 'width' of the vehicle. A CDC with the characters 'FLEE' in columns three to six of a code denote deformation that initiates on the front-end plane which lies within the left-third of the end-plane, extends vertically from the bottom of the bumper to the top of the door, begins on the left-front bumper corner and extends no more than 41-cm inboard from the bumper corner toward the vehicle center-line. On the basis of these rules, an absolute sameness between the FLEE CDC and SOI was posited by Lindquist.

There are 288 possible CDC code character combinations sufficient to describe a frontal SOI impact. See Table 1 for a list of CDC character codes that may describe SOI; not all combinations can result in valid impact classification codes. During the development of the operative definition, a query designed to identify fatal SOI crashes was run. Cases identified on the basis of the crush profile data which are not conventionally associated with SOI are: 12-FDEW-2, 12-FYEW-5, and 12-FREW-6.

Table 1: CDC Code Characters Theoretically Applicable to SOI

Direction of Force (DOF) – Columns 1 and 2	Area of Deformation (GAD) – Column 3	Specific Longitudinal/Lateral Location (SHL) - Column 4	Specific Vertical Location (SVL) - Column 5	Type of Damage Distribution (TDD) - Column 6
12, 11 or 01	F	L, R, Y or Z	L,M,G, H, E or A	S, E, N, W, A or K

A CDC with the characters FLES in columns three to six of a code denote deformation that initiates on the front-end plane which lies within the left-third of the end-plane, extends vertically from the bottom of the bumper to the top of the door, begins on the left-front bumper corner and extends no more than 10-cm inboard from the bumper corner toward the vehicle center-line. Both FLEE and FLES are necessarily SOI as defined by Lindquist. In Figure 2, the area encompassed by a FLES code is depicted in yellow; the area encompassed by a FLEE code is depicted in yellow and orange.

While 'FLEE' or 'FLES' impacts are necessarily small overlap impacts (SOI), the 'FLEE' and 'FLES' codes ware only sufficient descriptions of SOI. Depending on the distance from either the left or right longitudinal beams to the corresponding bumper corners, other CDC codes may describe SOI. CDC codes that may describe SOI to the left-third of the vehicle in the area depicted in yellow, orange and red inclusive in Figure 2 below are FLEN, indicating, narrow (less than 41-cm wide) damage, but not beginning on the bumper corner; FLEW indicating a wide impact resulting in more than 41-cm damage, but confined to the left third of the front-end; or FYEW indicating a wide impact with damage extending into the center-third of the of the front-end, but not involving significant longitudinal compression of the longitudinal beams (Figure 2).

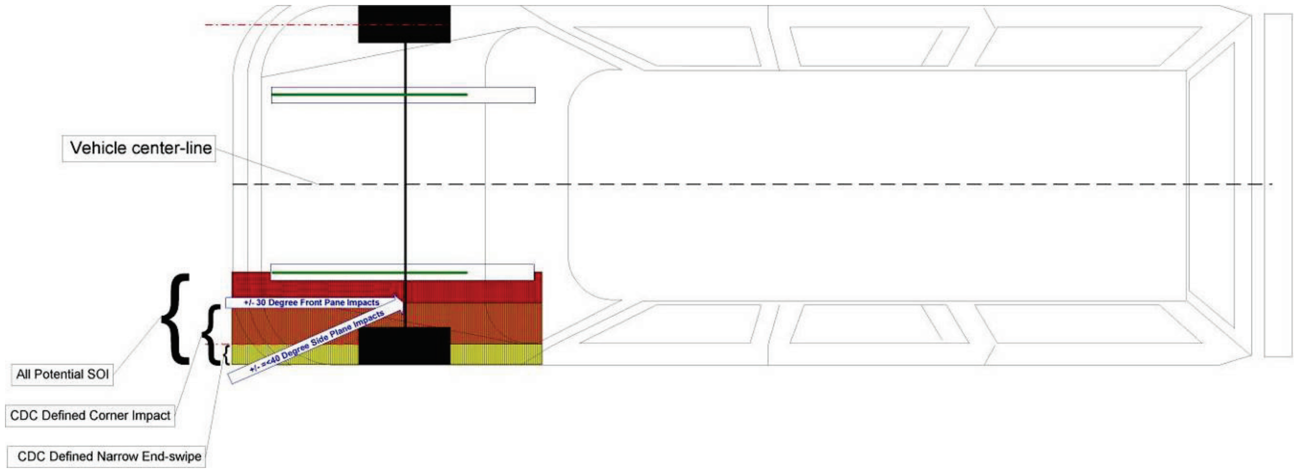

Figure 2: CDC and Structural Definitions of SOI

In 2006 NHTSA-CIREN commissioned the Medical College of Wisconsin CIREN center (MCW-WIC) to review FLEE impacts to determine whether small-overlap impacts (SOI) accounted for a significant proportion of fatalities involving restrained occupants in frontal-impacts. The results were reported by Pintar in a presentation at the SAE Industry-Government meeting in 2007, based on a query for impacts assigned 'FLEE' in National Automotive Sampling System (NASS) data for the years 2000 to 2005. Pintar reported the FLEE type impacts accounted for 4.9% of the frontal impact fatalities involving restrained occupants.

A subsequent review of CIREN cases and NASS files as case histories, suggested that SOI merited further investigation. During 2007 and 2008 a series of four crash tests were run at the Medical College of Wisconsin's Vehicle Crash Lab. These tests used cars impacting a 10-inch pole barrier to produce a FLEE damage distribution type over a range of impact speeds. Two of which featured the THOR anthropometric test device and one using a HIII instrumented with the Ribeye optical device for measuring rib deflection. These tests indicated that SOI were a potentially serious problem and the next step was to determine the scope of the SOI problem within the context of NASS-CDS data, while taking into account the limitations imposed by the CDC system's use of direct-damage measurements to 'sheet metal' as the basis for classifying impact types.

A method to account for vehicle structure in a query of NASS-CDS data was presented by Sullivan in: <u>A Frontal Impact Taxonomy for USA Field Data</u> published in 2008[6]. Sullivan presents a technique which allows for the location of longitudinal beams to be accounted for in queries of NASS-CDS data. The approach involves taking the Average Track-width (ATW) reported in NASS-CDS data and adjusting it to locate the outboard planes of the longitudinal beam relative to the vehicle center-line. The Adjusted ATW model Sullivan uses conforms to the set of vehicle classes used by NASS, with the exceptions of the small and mid-size CUV (crossover) classes which are not separate body types recognized in the NASS-CDS coding scheme.

Sullivan defined an "Adjusted ATW" as: ATW-W_T-2W_O, where W_T is the width of the tire and W_O is a tire-to-rail off-set value (Figure 3). The technique then used location of damage to define engagement of a longitudinal rail (beam). The edge of the direct-damage was found by subtracting half of the direct-damage width from the center of direct-damage. Engagement of a longitudinal beam was defined when the value for the edge of the damage was less than or equal to half of the Adjusted ATW. While there is a diagram, no detailed information on the measuring technique used to determine W_O was provided. While this method accounts for structure it does not recognize that the crush profile data can be used to infer damage to structural members. The operational definition of SOI refines the above approach using the crush profile data to infer damage to structural members and published specifications to estimate vehicle front-end structure locations.

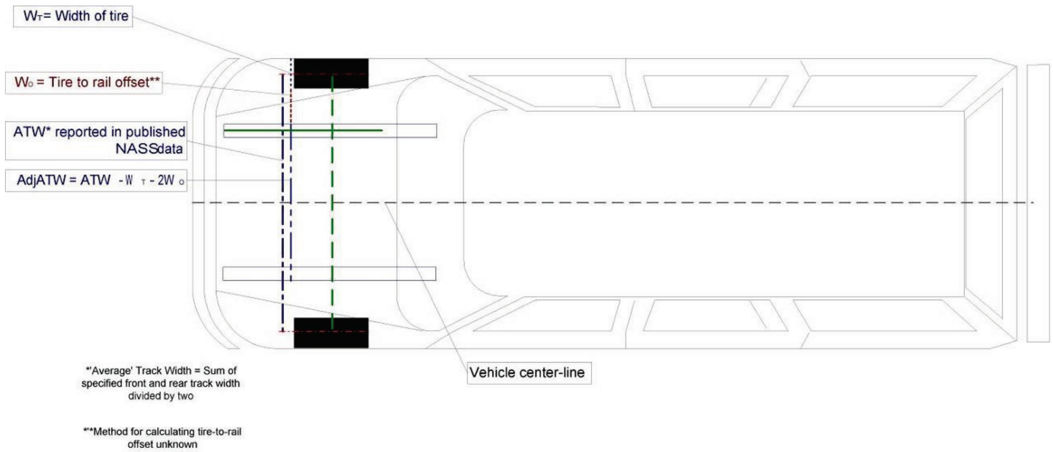

Figure 3: "Adjusted ATW" Definition of SOI

METHODOLOGY

The MCW-WIC operational definition selects crashes that have CDC codes sufficient to describe SOI. It then evaluates the direct-damage width associated with the CDC and selects cases with a direct-damage marginally wider than the area outboard of a longitudinal beam. From these crashes it selects impacts with a center of direct-damage located outside of the longitudinal beam and evaluates the relationship between the C-measurements to identify crush profiles indicating a SOI impact. The method turns on the estimated location of the longitudinal beams relative to the center-line of a vehicle. Ideally, the location of the longitudinal beams for every vehicle sold in the U.S. or included in NASS published data would be determined. However, this would be prohibitively expensive. In order to make a query of NASS-CDS data feasible, a series of generic models which meet NASS-defined Body Category and Body Type classifications was developed.

The operational definition relies on published specifications and uses NASS-CDS defined Body Category and Body Type classifications to exploits the crush profile data to evaluate damage to vehicle structure. There are two parts to the MCW-WIC methodology for a query of published NASS-CDS data to define SOI: A frontal-impact component and an oblique side-impact to the fender component of 40 degrees or less resulting in principally longitudinal loading of the vehicle structure.

The frontal-impact component involves:

1. Sorting the vehicles into vehicle size classes
2. Defining a universe of all highest speed-change impacts through the front-end plane
3. Developing generic models of the vehicle structure for each specific class

4. Developing vehicle class-specific queries of crush data and applying them to the universe of frontal-impacts to identify crush profiles that project front-left or front-right SOI impacts.
5. Querying for CDC code characters that, within the rules for their application, may identify front-left or front-right SOI impacts in the universe of frontal-impacts and noting the resulting N of raw observations (N_{CDC})
6. Merging the results of the CDC and class specific crush filter queries and removing one of any duplicate cases reported and designating the other duplicate a case selected on the basis of the CDC code and noting the N of raw observations (N_M)
7. Determine how much larger N_M is than N_{CDC}.

If N_M is greater than N_{CDC} for most vehicle classes, the utility of frontal-impact component of the method is demonstrated.

The side-impact to the fender component involves these steps:

1. Defining a universe of all highest speed-change impacts to side-plane with highest direction of force (clock) values of 11, 12 or 1.
2. Developing a query that combines CDC characters with class specific crush filter criteria; the 'LY/RY' filter and noting the N of raw observations ($N_{LY/RY}$)
3. Adding $N_{LY/RY}$ to N_M summing them to arrive at the total for raw observations of SOI (N_{SOI}).

Definition of Vehicle Class Sizes

Since the scope of the SOI problem is to be defined within the domain of NASS-CDS data, it is prudent to adhere to the classification schemes used in the collection of NASS-CDS data whenever possible. NASS employs a series of body type codes that are grouped into vehicle size classes. For passenger cars the size classification is dependent on the length of the wheelbase. For the family of non-passenger cars it is based on NASS body type codes. The MCW-WIC methodology defines a set of eleven vehicle size classes divided into a family of passenger cars and a family of non-passenger cars as follows:

For passenger cars when the body type code equals 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, or 13:

- Vehicle is Subcompact class when wheelbase is less than or equal to 253-cm
- Vehicle is Compact class when wheelbase is between 254-cm and less than or equal to 264-cm
- Vehicle is Intermediate/Medium class when wheelbase is 265-cm and less than or equal to 277-cm
- Vehicle is Full-size class when wheelbase is between 278-cm and less than or equal to 290-cm
- Vehicle is Largest-size class when wheelbase is greater than or equal to 291-cm

Note: There is no identity between NASS vehicle class codes and WinSMASH size or stiffness categories.

For the family of non-passenger cars:

- When body type code equals 14 the vehicle is Compact SUV class
- When body type code equals 15, 16 or 19 the vehicle is SUV class
- When body type code equals 20 the vehicle is Minivan class
- When body type code equals 21, 22 or 29 the vehicle is Van class
- When body type code equals 30 the vehicle is Compact Pick-up class
- When body type code equals 31, 32, 33 or 39 the vehicle is Pick-up class

Development of the Generic Models of Vehicle Structure

The generic vehicle class models use specifications taken from Canadian Vehicle Specifications (Can Specs)[7] the distance between the centers of the front longitudinal beams from Mitchell International's Mitchell Information Center (MIC)[8]. Can Specs is a NASS-approved source for vehicle body, track and wheelbase dimensions. MIC is a commercial database of manufacturer upper body and chassis specifications used by body shops to repair collision damage. The selection of the specifications used to construct generic models for each vehicle size class was dictated by the requirements for documenting a crush profile for use in the various reconstruction algorithms used by the WinSMASH program to calculate a speed change estimate from damage a vehicle sustains in a collision. Since WinSMASH assumes homogeneous stiffness across a damaged plane, the most rigid structure in the damaged plane is given emphasis when obtaining a set of crush-measurements (C-measurements or Cs). In frontal impacts this is the 'frame' or bumper-level.

Vehicle Width

There is more than one measurement of vehicle width. The most inclusive is the overall width, which specifies how wide the vehicle is at its widest point of body contour on the lateral axis. The undeformed end width (UEW) expresses how wide the vehicle end-plane is on the lateral axis, and accounts for the difference in body contour from the widest point of the body to an end. Per the 2009 NASS CDC coding manual, on an undamaged exemplar vehicle, the front UEW is determined by measuring between the apexes of the 'bumper corners'. While no written documentation could be found, the technique for locating the 'bumper corners' in the field involves projecting a tangent longitudinally along the side plane body contour from the widest point and extending to the end plane. The intersection of the projected planes is bisected by a 45 degree line back onto the undamaged end to locate the 'bumper-corners' (Figure 4). On a vehicle sustaining a SOI type impact where the plastic fascia and 'bumper' may have been sheared off during impact, locating the 'bumper-corner' in the field while documenting a crush profile becomes a more subjective process.

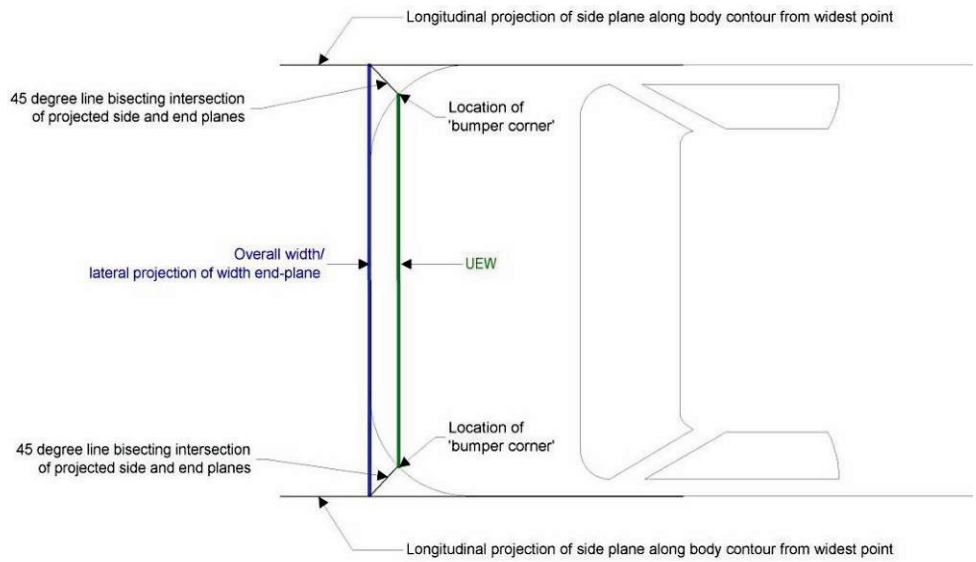

Figure 4: Determination of Undeformed End Width (UEW).

To assign the damage distribution type codes the field investigator determines the damage due to direct contact with the object struck and measures laterally along the general slope of the damaged plane to obtain the direct-damage width (DDW). The value for DDW reflects a determination of which damage was designated as characteristic of being due to direct contact with the object struck, and which damage may be classed as being remotely induced by impact forces, or perhaps due to post-crash extrication efforts. The field investigator then determines front-plane damage width due to direct contact with the object struck. The investigator also locates the pre-impact end-plane center and references the center-of-direct-damage to it. A negative sign indicates the damage is to the left of center; a positive sign indicates the damage is right of center.

Documentation of a Front-end Plane Crush Profile

It should be noted that not all front-end plane impacts will be subject to the application of a combination of CDC and crush profile criteria in a query of a data set containing the requisite variables. An impact that has a general area of deformation to the front of the vehicle can have codes indicating a highest direction of force from the 9, 10, 11, 12, 1, 2 or 3 o'clock directions. 9 and 3 o'clock impacts typically are associated with 'end-swipe' impacts. Further, an impact where the direct-damage along a side plane is more extensive than on the front-end plane is possible, provided the impacted is deemed to have initiated on the front plane. Finally, it is possible that a minor impact will cause cosmetic damage to the front of the vehicle without producing measurable residual crush.

To collect a crush profile on the front end-plane for use in the WinSMASH program, the field investigator records the 'Field-L' measurement. The 'Field-L' is generically defined as the length of direct-damage plus the induced damage for a given impact to the exterior 'sheet metal' of the vehicle. Six crush-measurements (C-measurements) are taken to describe the depth of the crush on the longitudinal axis along the lateral width of the end-plane. The length of the Field-L for a frontal impact is dependent upon the location of the 'bumper corners' as described above. C-measurement one (C1) is set on the left-front bumper corner and C-measurement six (C6) is set on the right-front bumper corner. The distance between C1 and C6 is the Field-L measurement[9]. Like Sullivan, the MCW-WIC method determines the location of C1 and C6 with certainty by assuming UEW is identical to the vehicle front-track width as specified by Can Specs.

To determine locations of the longitudinal beams, the MCW-WIC methodology assumes that the beams are parallel to each other and equidistant from the center-line of the vehicle. The MCW-WIC methodology estimates the distance between the centers of the two beams and uses a track-width value to locate the ends of the front-bumper. The use of a published specification (track-width) instead of the NASS-CDS value for Undeformed End Width (UEW) is done in order to simplify the generic model. Using front track-width (FTW) for UEW standardizes the distance from one front bumper corner to the other and this permits the location of C2 or C4 relative to the longitudinal beams to be uniformly estimated for all vehicles with a documented profile in a size class (Figure 5).

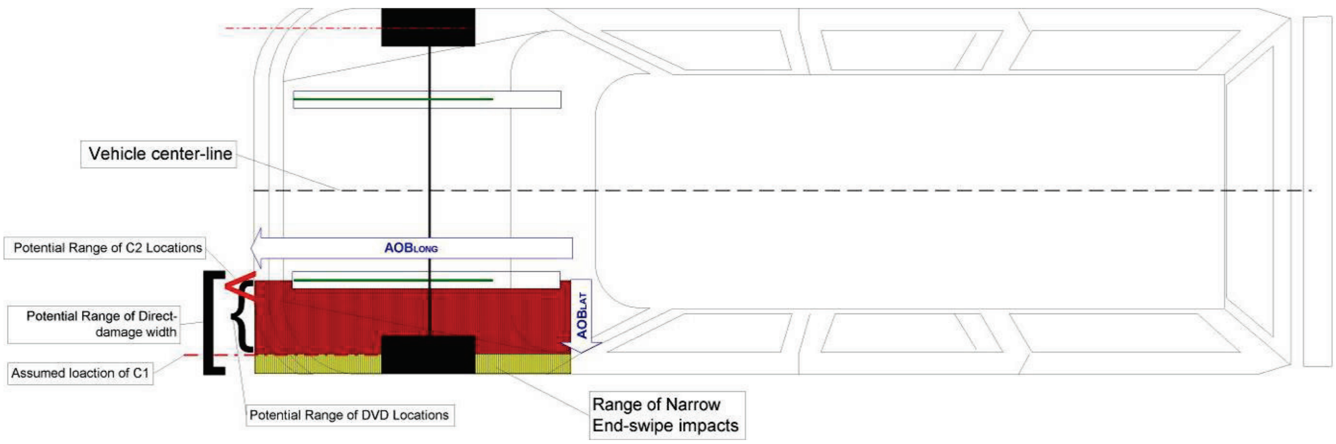

Figure 5: Locating the Longitudinal Beams

MCW-WIC Method for Locating the Longitudinal Beams

The location of the center of the longitudinal beams is estimated by dividing the distance between the beams (D-rail) and the FTW by two. $Rail_{LOC}$ (rail location) represents the distance from the vehicle center-line to the center of a beam, and FTW_E represents the distance from the vehicle center-line to a front bumper-corner. To estimate the width of the area behind the front-end components outboard of the longitudinal beams (AOB) FTW_E is subtracted from $Rail_{LOC}$. Like the center of direct-damage value reported in NASS, the beam location can be signed in accord with NASS crush measurement techniques to indicate whether the beam is left (-) or right (+) of the center-line. AOB indicates the range center of direct-damage values can have and be considered predictive of potential SOI. See the compact SUV example (and Figure 6) below. The example is based on one of the models used as a source of specifications for the generic compact SUV model.

Note: Due to body contour, the AOB extends beyond the front-track width.

Compact SUV Example

Given: PDOF >= 330 and <=360 or 0 and CDC columns three and four = 'FL'

Model

DIRDAMW = 51
FTW = 152; D-rail = 86; FTW_E = -76; $Rail_{LOC}$ = -43 (negative sign indicating damage off-set to the left).
AOB = FTW_E - $Rail_{LOC}$ = 33
When C1> C2; C1> C3; C1> C4; C1> C5; C6<= C3 AND DVD between -43 and -76 then SOI profile.

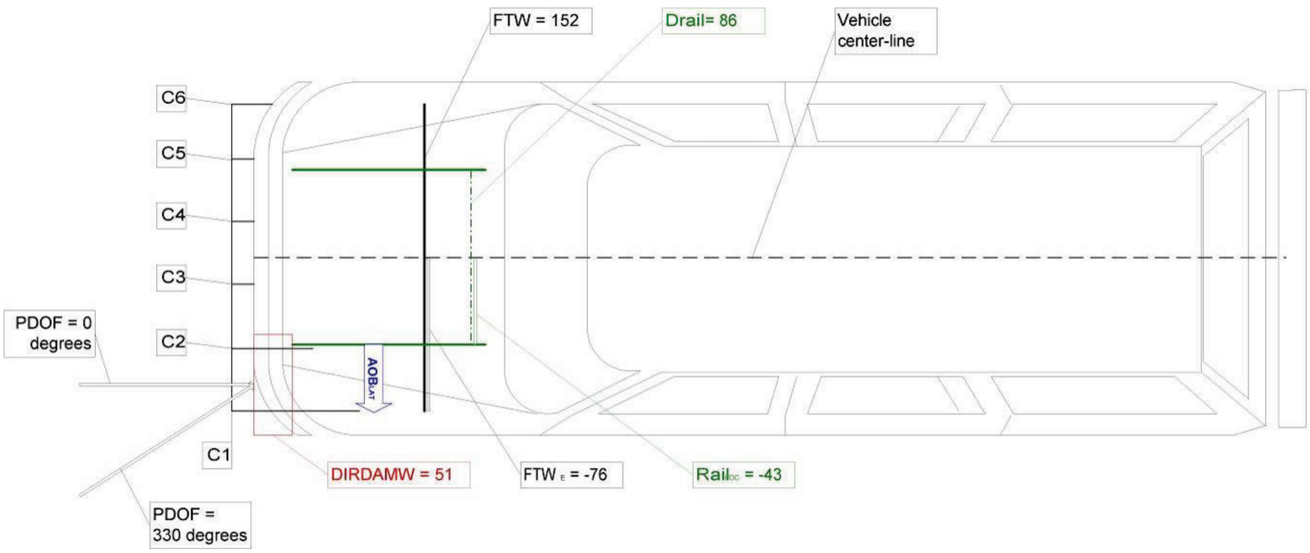

Figure 6: Crush Criteria Applied to Generic Compact SUV Model

Published NASS-CDS data

Published NASS-CDS data reports the CDC and any associated crush profiles for the events that are ranked as resulting in the two most severe impacts to a vehicle. The rankings may be based on the speed change modeled for a particular event or on a subjective basis using a set of ranged speed change estimates or simply as designated minor, moderate or severe impacts. The CDC and crush profile variables assigned the highest rank are distinguished by the number '1' used in the SAS variable name. For example, the clock direction for the highest severity speed change is denoted by the SAS value DOF1 in the dataset.

Selection of Vehicles as Sources of Representative Dimensions

Using published NASS-CDS data, a query was run for all highest speed change impacts assigned a CDC with the characters 'FLEE' in columns three to six. The cases were sorted on the basis of size class, however make, model and model year of each vehicle was noted. Neptune Engineering's 2008 Vehicle Year and Model Interchange[10] list was used to group make, model and model year combinations in to sister cohorts and establish clone relationships. These sub-groups were then ranked on the basis of the number of observations reported in each. The vehicles most frequently observed in these make/model-sister/clone sub-groups were identified as vehicles from which representative dimensions would be collected to construct the generic model for each of the eleven vehicle size classes. A minimum of four vehicle make/model-sister/clone combinations became the references to construct the generic model for the Van size class and a maximum of 22 vehicle make/model-sister/clone combinations became the references to construct the generic model for the compact SUV size class. The averages of the vehicle specifications and the calculations of estimated vehicle front-end structures were used to construct the models used when interrogating the NASS crush profile data.

Adequacy of Size Class Models

Two vehicle size classes were selected for evaluation, to check the adequacy of the models: Compact cars and compact SUVs. Compact cars were selected because it was noted that that key specifications and calculated values of the generic model were virtually identical to those for the sub-compact size class. Compact SUVs were selected because it was observed that for approximately half of the vehicles serving as a source of representative dimensions, the second and fourth C-measurements were estimated to be outboard the longitudinal beams. The variance in the location of the beam relative to C2 seems to be an artifact of whether or not a Compact SUV is built on a truck frame or is a unit body ‘crossover’ or CUV type vehicle.

Published NASS-CDS data for the year 2007 was queried for all highest speed-change impacts with a general area of damage code of ‘F’. The query sorted vehicles into the defined vehicle classes and then the observations were sub-grouped by make/model-sister/clone. The compact SUV model was the most rigorously evaluated and the process is reported in detail. The query for highest speed-change frontal impacts for CY 2007 returned 2885 observations. Out of these 411 were coded as being members of compact SUV size class. However, on the basis of wheelbase length 13 observations were identified as miscoded sub-compact passenger cars. The remaining 398 observations were placed in sub-groups by make/model-sister/clone differentia to evaluate additional makes and models to serve as sources of representative dimensions. Sister and clone sub-groups that included vehicles of a model year extending back into the 1980’s were excluded from consideration. Also excluded were most makes and models that were represented by six or fewer observations; the exceptions were newer model year vehicles. The expanded list of representative compact SUV makes and models accounted 74% of the observations. After comparing the expanded list with the original, the specifications for five more makes/models were added to the model. The results (Table 2) are as follows:

Table 2: Initial and Final Specifications for Generic Compact SUV Model

Indicator	Initial Model	Expanded Model
Number of representatives	17	22
Average front-track width	152-cm	152-cm
Average overall width	174-cm	175-cm
Average ½ D-rail	49.5-cm	43-cm
Standard deviation D-rail	6.4-cm	6.3-cm
Interval between C-measurements	30-cm	30-cm

For compact cars a similar process was followed in evaluating makes/models as sources of representative dimension specifications. A spot check was made of the specifications for some of the most frequently observed makes/models not initially selected as sources of representative vehicle dimensions. When it was observed that the specifications of potential additions to the model were within one standard deviation of the specification already included in the model, the existing model was judged adequate.

Application of the Frontal-impact Component to NASS-CDS data

The frontal-impact component of the MCW-WIC method concatenates two modes of interrogation. The first mode interrogates data on the basis of CDC codes followed by an interrogation of the crush profile data in published NASS-CDS data. The two modes are complementary.

Because impacts in NASS-CDS data are classified in terms of damage to 'sheet metal', the MCW-WIC frontal-impact component when querying crush-profile data incorporates some rules used in the assignment of a CDC code to constrain the set of cases the crush filter is applied to. In defining all highest speed-change impacts through the front-end plane the range of acceptable Principal Direction of Force (PDOF1)* values was restricted to +/- 30 degrees from 0/360. PDOF is expressed in columns one and two of a CDC code as the o'clock direction (DOF1)* in published NASS-CDS data. This restriction limited the query to impacts with an 11, 12 or 1 o'clock direction of force. It should be noted that not all highest speed-change frontal-impacts with a direction of force of 11 or 1 o'clock are captured by the frontal-impact component. This is because the direction of force (DOF1) 11 o'clock is defined as impacts assigned a principal direction of force of either 340, 330 or 320 degrees and direction of force (DOF1) 1 o'clock is defined as impacts assigned a principal direction of force of either 20, 30 or 40 degrees. Further, while an 11 o'clock impact can occur to the right third of the front-end, impacts of this type are not construed as SOI impacts in the MCW-WIC methodology. They are excluded by the crush criterion that requires the center of damage be to the left vehicle center line (have a '–' value), for FL and FY impacts, and that the center of damage be to the right vehicle center line (have a '+' value), for FR and FZ impacts. Finally, SOI are presumed not to result in shifting of both longitudinal members, so DOF incremented by adding 20, 40, 60 or 80 are excluded.

Restricting the PDOF1 to +/- 30 degrees from 0/360 was done because to appropriately assign the general type of damage distribution classification code 'S' which denotes a narrow-end damage distribution, the PDOF1 must be within 30 degrees of the longitudinal axis of the vehicle when the damage initiates on the front-end plane and the deformation location code in column three of a CDC code (GAD1)* equals 'F'. The set of cases the crush filter is applied is further restricts by requiring that the specific longitudinal or lateral location of deformation code (SHL1)* equal 'L' or 'Y' when the PDOF is between 330 and 360/0 degrees and 'R' or 'Z' when the PDOF is between 0/360 and 30 degrees.

The specific lateral location of deformation codes 'Y' or 'Z' are typically applied to impacts that 'straddle' the center and either the left or right thirds of the front ends. The presupposition has been that impacts of this type necessarily involving axial loading of the longitudinal beam or occur between the longitudinal beams and do not meet the definition of SOI. The use of and 'L' or 'R' code in column two is limited to cases where damage to 'sheet metal' is one-third of the front of the vehicle. The use of a 'Y' or 'Z' code in column two is limited to cases where damage to 'sheet metal' is only marginally more that one-third of the front of the vehicle.

Potentially qualifying FY and FZ codes have the maximum direct-damage width for each generic vehicle size model defined as one-third of the specified overall width divided by three. The maximum direct-damage width is the quotient plus ten-percent, to approximate the expected DDW value (DIRDAMW1)* in NASS-CDS data within which potential SOI may occur. The center of direct-damage (DVD1)* reported in published NASS-CDS data is referenced to the calculated AOB value for a generic model. AOB represents the range within DVD1 is expected to fall in between and have the center of direct-damage to 'sheet metal' be located at point outboard a longitudinal beam. $Rail_{LOC}$ represents the inboard limit and FTW_E the outboard limit of the range. Because Potentially qualifying FY and FZ codes may have a direct-damage width that extends inboard of the longitudinal member the maximum DVD1 located at a point inboard of the longitudinal member equal to the width of the AOB.

For frontal-impacts which are off-set to the left, the MCW-WIC method looks for a relationship between the C-measurements (DVC1 to DVC6)* so that C1 is greater than C2, C3, C4 and C5 and C6 is less than or equal to C3. For frontal-impacts off-set to the right, it looks for a relationship where C6 is greater than C5, C4, C3 and C2 and C1 is less than or equal to C4. Any crush profile where DVD1 falls within AOB and has C-measurements exhibiting the interrelationships described above are identified as a SOI.

Oblique Side-impact to the Fender Component

The generic models used in the frontal-impact component of the MCW-WIC methodology provide an estimate of the area outboard of the longitudinal beams (AOB). In the diagram of the compact SUV model in Figure 6, the lateral dimension of the AOB is 33-cm or about 22% of the FTW. Within the AOB, the Lindquist model denotes three frontal-impact load paths along the vehicle longitudinal axis: Direct load to the A- or hinge pillar, displacement of the wheel rearward resulting in a load to the hinge pillar and sill and loading of the 'shotgun beam' and the shock tower resulting in a load to the hinge pillar.[11] A cursory examination of Figure 6 indicates that an oblique impact +/- 40 degrees from 0/360 to either the left or right side-plane forward of the A-pillar at the fender could possibly result in loads principally along the vehicle longitudinal axis to these same structures. It seems reasonable to extend the definition of SOI to oblique impacts through a side plane into the AOB.

*Equivalent SAS variable names in published NASS-CDS data.

Figure 7 below is an example taken from a series of CIREN case studies on oblique 'LY' impacts done to assess the method for estimating the location of the A-pillar and establishing the relationships between the center of direct-damage (DVD) and the C-measurements. Note: The SAS value DVD has the label Crush Profile D. The label is accurate when referring to side-plane impacts only. For end-plane impacts is refers to the center of the direct-damage.

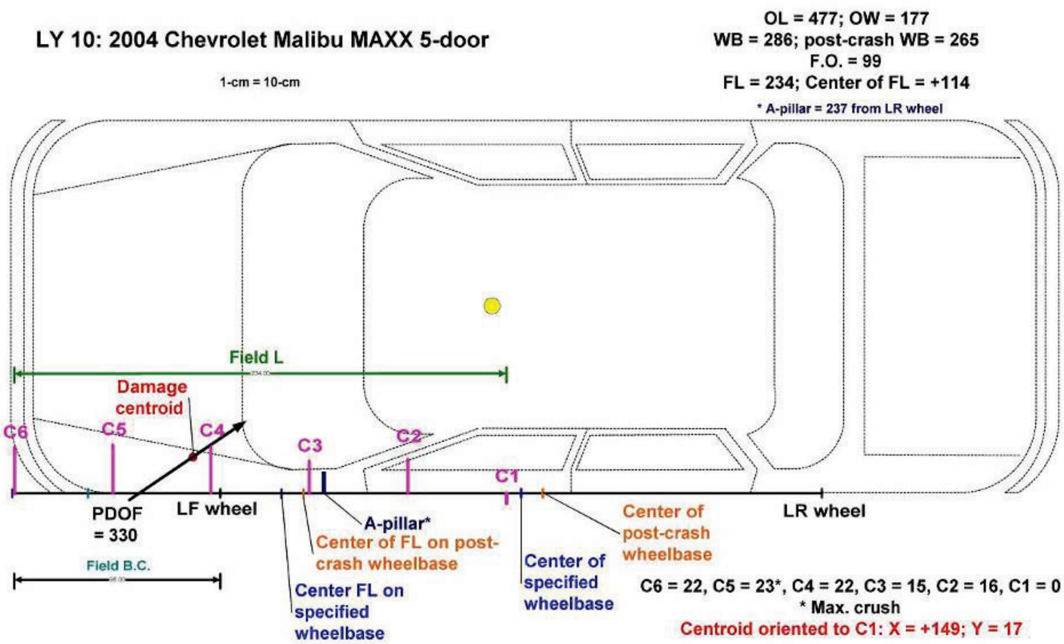

Figure 7: Oblique 'LY' Small-Overlap Impact

Schematic Description of Side-plane Impacts

To collect a crush profile on the side plane for use in the WinSMASH program the field investigator records six crush measurements to describe the depth of the crush on the lateral axis. The locations identified for the deflection points determines where the Field-L begins and ends as it extends down the longitudinal axis of the side plane. By convention the first C-measurement (C1) is taken at the deflection point farthest rearward and the sixth C-measurement (C6) is taken at the deflection point farthest forward (Figure 8).

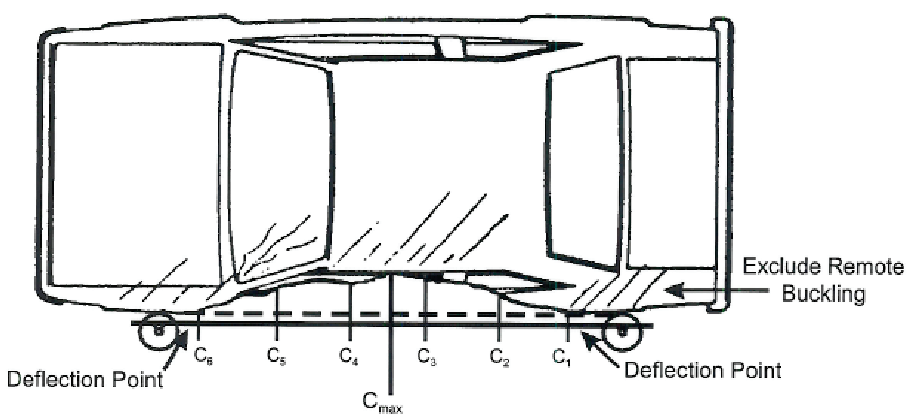

Figure 8: Field Protocol for Documenting a Crush Profile for a Side Impact

For oblique side-impacts that do not extend to a corner of the vehicle the expected crush values for C1 and C6 are 0. A crush profile predictive of a SOI on the side-plane is expected to extend from or to the front corner to a deflection point. In this case, only C1 is expected to be 0. The length of the Field-L is not identical to the direct-damage width, although Field-L and direct-damage width may have the same value. The direct-damage width should include any surface scratched due to direct contact with the object struck or collision partner outside the 'yoke'. For this reason side impacts are evaluated by referring to the location of the center of the Field-L and not the center of direct-damage.

In WinSMASH, the length of the post-crash wheelbase must also be documented since the center of the Field-L and the location of direct-damage is referenced to the center of the post-crash wheelbase. When a SOI type impact through the side-plane results in a wheel being torn off, the determination of the length of the post-crash wheelbase is difficult to ascertain and may be recorded as unknown. Consequently, unlike the filter for front-end plane impacts where the vehicle center line is a constant reference point on the vehicle, the reference point on the vehicle side plane impacts is variable. When vehicle models have a wheelbase that is consistent across the line this variability is adequately accounted for by the assumption that the specified wheelbase is reasonable estimation. However, when vehicle models have a wheelbase that varies across the line, for example a regular cab, short box pick-up vs. a crew-cab, long box version of the same model pick-up truck, the specified wheelbase is not reasonable estimation and the crush profile and only be evaluated within the context of a CDC code indicating General Area of Damage (column 3) L and Specific Longitudinal Location (column 4) F or Y.

Application of the Oblique Side-impact Component Method to NASS-CDS data

The oblique Side-impact to the fender component of the MCW-WIC methodology refers to the rule for applying the 'F' and 'Y' characters in column four of a CDC code for a side impact, in combination with an evaluation of the crush profile to identify SOI. The 'F' character in column four indicates that the damage is restricted to the fender forward of the base of the windshield for all classes of vehicle except vans and minivans where damage may extend back to the front-seat back-rest. The 'Y' character indicates that the damage includes the fender and extends back beyond the base of the windshield for all classes of vehicle except vans and minivans where damage must extend back beyond the front-seat back-rest.

Like the frontal-impact component, the oblique side-impact to the fender component of the MCW-WIC method refers to the location of the center of direct-damage (DVD) to locate the crush profile with reference to an estimated location of a structural component of the vehicle: the A- or hinge pillar. The DVD value in NASS-CDS data for impacts to a side plane, locates the center-of-direct-damage relative to the center of the length of the post-crash wheelbase. While this field measurement is not reported in published NASS-CDS data, it can be requested as a supplement. However, the original wheelbase is included and half of original wheelbase is taken as an adequate approximation.

To allow the orientation of the crush profile with reference to the longitudinal dimension of the AOB, the generic vehicle size class models include an estimate of the location of the A- or hinge pillar to the front of the vehicle and by inference to front axle. Referring to Can Specs the value for the longitudinal distance between the center of the front bumper and the center of the base of the windshield (BL), the front overhang (FOH) and the wheelbase (WB) for each vehicle providing representative dimensions in a size class were collected and averaged. Except minivans and vans, the average BL value for each class was multiplied by .20 and the product added to the BL value for the class to derive an estimate of the location of the A- or hinge pillar (A_{LOC}). For the minivan size class the average BL value for each class was multiplied by .40 to account for the observation that the base of the windshield of minivans project forward more relative to the A-pillar than the windshield does on passenger cars, SUVs and pick-ups*. The FOH value for the class was subtracted from A_{LOC}. The result is the estimated distance from the front 'axle' to the estimated A- or hinge pillar location (Axle-A). The WB value for the class was divided by two. The quotient approximates the center of the damaged wheelbase (1/2WB), which serves as the reference point for locating of the center-of-damage (DVD) on the side of the vehicle (Figure 9).

To locate of the A- or hinge pillar with reference to 1/2WB, Axle-A (the subtrahend) is subtracted from 1/2WB (the minuend). The difference expresses the approximate location of the A- or hinge pillar forward of the approximated center of the damaged wheelbase.

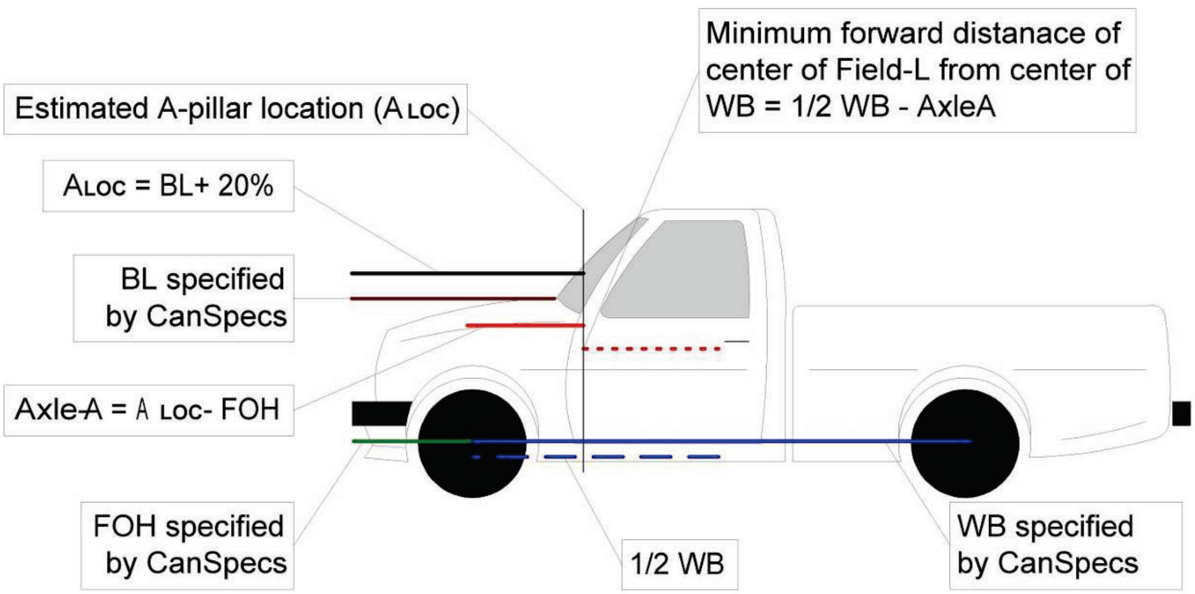

Figure 9: Estimating the A-pillar Location

*Note: Starting in the 2010, the CDC rules for assigning the SHL1 code 'F' to a side-plane impact changed in NASS. Instead of the rules for vans, the rules station wagons will be applied.

The van model does not accurately project the estimated distance from the front 'axle' to the estimated A-pillar location. This appears to be due to the fact that only three manufacturers market vans built on a truck frame and that two of the three are marketing designs that have the base of the windshield projecting forward of front axle (Table 3). For the van class FOH is used to estimate the location of the A- or hinge pillar (A_{LOC}).

Table 3: Front Over-Hang Specifications for Full-Size Vans

Make/Model Referenced	Center of Bumper to Center of Base of Windshield	Front Overhang	Projected Distance of Base of Windshield Beyond Front Axle
2003 Chevrolet G1500 Express passenger van	72	88	16
1998 Dodge 1500 Maxivan	74	97	23
1999 Ford E-150 Econoline Wagon	84	76	N/A

Any oblique impact with 'F' or 'Y' in CDC column four, +/- 40 degrees from 0/360 to either the left or right side-plane with a center of damage forward of the A-pillar is a potential SOI. A_{LOC} then is assumed to be the rearward most longitudinal extent of the AOB. See Figure 10 below. It is also taken as the minimum value the location of center of the crush profile can have relative to the center of the wheelbase to predict a potential SOI. To be identified as a SOI impact, the following relationship between the C-measurements must also exist: C2 is greater than C1, C3 is greater than C2, C4 is greater than C2, C5 is greater than C2 and C6 is greater than or equal to C1 (Figure 10).

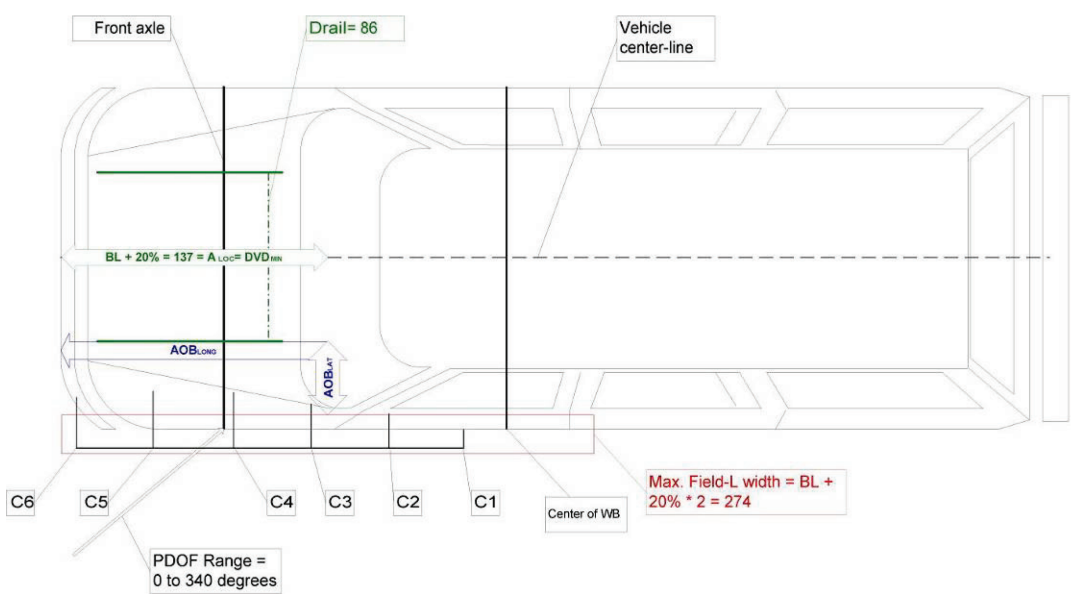

Figure 10: Locating the Center of the Crush Profile Relative to the Area Outboard of the Longitudinal Members

Because the field documentation protocol uses a field measurement to reference the center of direct-contact damage the oblique side-impact to the fender component of the operational definition is not as definitive as frontal-impact component. Further, the assumption that 1/2WB adequately approximates the center of the damaged wheelbase is most reasonable in vehicle classes where within the make/model-sister/clone cohorts of the vehicles used as sources of representative dimensions there are few if any models that are offered with differing wheelbase sizes. In the case of the minivan class the specifications for base model were used to get the average WB value. For example, to estimate the location of the A- or hinge pillar for the minivan size class, the specifications for a Caravan and not a Grand Caravan were used. In the case of the large van, compact pick-up and full size pick-up vehicle size classes, an A_{LOC} estimate was not included as a boundary condition in the query of the data due to the variability of wheelbase sizes offered with in a line of models. To limit probability that an oblique ‘LY/RY’ impact with a crush-pocket rearward of the base of the windshield is selected a limit on the size of the field-L (DVL) is imposed. This was done by taking the A_{LOC} estimate for a vehicle size class and multiplying it by two.

RESULTS

Using 2005 to 2008 NASS-CDS data, a universe of all frontal and oblique side impacts assigned a Principal Direction of Force (PDOF1) between 320 and 40 degrees ranked as the most severe impact was constructed; cases with lesser severity rollover events were not excluded. SAS queries using the criteria described above were on run on this comprehensive data set. To evaluate the differences in the number of frontal-impact cases identified as small over-lap impacts, the SAS routine designated those impacts identified solely by CDC rules as ‘Filter 1’ cases and those identified on the basis of CDC and crush profile criterion were designated ‘Filter 2’ cases. By merging the ‘Filter 1’ and ‘Filter 2’ cases the number of SOI cases identified solely on the basis crush criteria was established. This number was added to the number of ‘Filter 1’ cases to determine the total number of front-end-plane SOI. Subsequently, the results of the LY/RY query were added to the number of front-end-plane SOI to determine the number of SOI impacts to the area outboard of the longitudinal members and forward of the cowl/fire wall. Table 4 below summaries the results by highest severity injury sustained by a surviving vehicle occupant and number of fatally injured vehicle occupants.

Table 4: Number of Occupants in SOI by Fatalities and Injury Severity

Data Set	Type of N	MAIS 0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
Overall	Raw	9206	13522	3660	1092	961
	Weighted	5800295	4324773	269042	219481	44906
CDC	Raw	1071	1468	364	82	87
	Weighted	758052	504779	32135	21707	3683
Crush	Raw	401	664	155	59	38
	Weighted	241059	190608	9823	9632	1348
CDC/Crush	Raw	1472	2132	519	141	125
	Weighted	999111	695387	41958	31339	5031
LY/RY	Raw	104	154	22	14	6
	Weighted	57448	73064	1868	4258	130
(CDC/Total SOI) -1	Raw	32%	35.7%	32.7%	52.9%	33.5%
Increase as %	Weighted	28.2%	34.3%	26.6%	60.9%	28.6%
Total SOI	Raw	1576	2286	541	155	131
	Weighted	1056559	768451	43826	35597	5161

NASS-CDS data for the years 2005 to 2008

Expressed as a percentage of the overall population of highest ranked impacts with an assigned PDOF within 320 to 40 degrees to the front end or either the left or right side plane, the results of queries run on the overall population dataset are summarized in Table 5 below.

Table 5: Percentage of the Overall Population of Vehicle Occupants in SOI by Fatalities and Injury Severity

Data Set	N	MAIS 0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
CDC	Raw	11.6%	10.8%	9.9%	7.5%	9%
	Weighted	13%	11.6%	11.9%	9.8%	8.2%
CDC/Crush	Raw	15.9%	15.7%	14.1%	12.9%	13%
	Weighted	17.2%	16%	15.5%	14.2%	11.2%
Total SOI	Raw	17.1%	16.9%	14.7%	13.4%	13.6%
	Weighted	17.2%	17.7%	16.2%	16.2%	11.4%

Tables 6 and 7 detail the raw and weighted numbers of cases identified in 2005 to 2008 published NASS-CDS data for each vehicle class by maximum AIS score sustained by an occupant and fatalities.

Table 6: Filter 1 Cases (CDC Criteria – Frontal Impacts)

Vehicle Class		MAIS = 0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
1	Raw	90	116	31	5	5
Sub-compact	Weighted	89392	46535	2645	1250	79
2	Raw	200	315	65	26	13
Compact	Weighted	147333	119669	5654	8055	479
3	Raw	212	345	81	22	22
Intermediate	Weighted	166437	100415	10638	5266	718
4	Raw	76	116	30	1	7
Full	Weighted	56177	29370	1568	116	260
5	Raw	25	38	9	3	2
Largest	Weighted	18701	13130	752	1995	30
6	Raw	134	203	63	6	19
Compact SUV	Weighted	93960	83214	2982	578	1182
7	Raw	55	52	8	2	0
SUV	Weighted	28288	14965	740	961	0
8	Raw	93	78	21	0	7
Minivan	Weighted	68818	27740	3040	0	160
9	Raw	31	21	4	1	3
Van	Weighted	5969	4647	98	7	88
10	Raw	63	61	26	6	4
Compact PU	Weighted	45697	29501	2647	1490	522
11	Raw	72	123	26	10	5
PU	Weighted	37280	35593	1371	1989	165
Total	Raw	1071	1468	364	82	87
	Weighted	758052	504779	32135	21707	3683

Table 7: Filter 2 Cases (CDC & Crush Criteria – Frontal Impacts)

Vehicle Class		MAIS = 0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
1	Raw	64	120	37	6	6
Sub-compact	Weighted	39406	48415	2802	290	212
2	Raw	165	298	73	20	15
Compact	Weighted	103190	116485	6119	7389	524
3	Raw	176	288	82	23	25
Intermediate	Weighted	125471	66781	8572	3612	794
4	Raw	78	133	35	14	5
Full	Weighted	42351	32761	1693	2839	132
5	Raw	25	46	13	5	2
Largest	Weighted	12280	16830	481	3469	67
6	Raw	144	229	56	9	13
Compact SUV	Weighted	100449	81912	4532	892	1135
7	Raw	55	72	10	1	2
SUV	Weighted	27246	19398	825	319	49
8	Raw	59	71	22	5	4
Minivan	Weighted	55566	23376	3494	556	128
9	Raw	22	27	5	0	2
Van	Weighted	3038	6107	78	0	41
10	Raw	53	56	28	7	9
Compact PU	Weighted	39457	21784	1761	1621	699
11	Raw	68	123	27	11	5
PU	Weighted	49045	33489	1207	1579	137
Total	Raw	909	1463	388	101	88
	Weighted	597499	467338	31564	22566	3918

Table 8 below details the raw and weighted numbers of cases uniquely identified by the crush filter combined with those identified by the CDC criteria for each vehicle class by maximum AIS score and fatalities.

Table 8: Combined CDC and Crush Filter – Frontal Impacts

Vehicle Class		MAIS =0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
1	Raw	116	168	48	10	9
Sub-compact	Weighted	106050	59978	3555	1410	277
2	Raw	271	438	94	33	21
Compact	Weighted	192958	167644	6736	9361	813
3	Raw	280	470	111	30	32
Intermediate	Weighted	197080	126037	13070	5718	1030
4	Raw	119	177	46	14	9
Full	Weighted	80596	47506	2277	2839	278
5	Raw	37	62	17	7	3
Largest	Weighted	28851	19415	1035	3527	85
6	Raw	207	312	79	12	22
Compact SUV	Weighted	142766	116017	5174	1001	1290
7	Raw	77	92	13	3	2
SUV	Weighted	42453	24847	1084	1280	49
8	Raw	125	111	31	5	7
Minivan	Weighted	80300	32764	4233	556	160
9	Raw	39	42	6	1	3
Van	Weighted	6780	9508	126	7	88
10	Raw	85	80	36	11	9
Compact PU	Weighted	61066	38192	2958	2923	699
11	Raw	116	180	38	15	8
PU	Weighted	60211	53479	1710	2717	262
Total	Raw	1472	2132	519	141	125
	Weighted	999111	695387	41958	31339	5031

Table 9 details the raw and weighted numbers of cases uniquely identified by the crush filter criteria in published NASS-CDS data for each vehicle class by maximum AIS score and fatalities.

Table 9: Crush Criteria – Frontal Impacts

Vehicle Class		MAIS =0	MAIS 1-2	MAIS 3-6	MAIS 7	Fatal
1	Raw	26	52	17	5	4
Sub-compact	Weighted	16658	13443	910	160	198
2	Raw	71	123	29	7	8
Compact	Weighted	45625	47975	1082	1306	334
3	Raw	68	125	30	8	10
Intermediate	Weighted	30643	25622	2432	452	312
4	Raw	43	61	16	13	2
Full	Weighted	24419	18136	709	2723	18
5	Raw	12	24	8	4	1
Largest	Weighted	10150	6285	283	1532	55
6	Raw	73	109	16	6	3
Compact SUV	Weighted	48806	32803	2192	423	108
7	Raw	22	40	5	1	2
SUV	Weighted	14165	9882	344	319	49
8	Raw	32	33	10	5	0
Minivan	Weighted	11482	5024	1193	556	0
9	Raw	8	21	2	0	0
Van	Weighted	811	4861	28	0	0
10	Raw	22	19	10	5	5
Compact PU	Weighted	15369	8691	311	1433	177
11	Raw	44	57	12	5	3
PU	Weighted	22931	17886	339	728	97
Total	Raw	401	664	155	59	38
	Weighted	241059	190608	9823	9632	1348

SUMMARY

Databases containing coded field data on motor vehicle crashes, such as NASS-CDS, rely on the CDC system to categorize damage. The CDC system does not consider the role structural elements play in managing crash energy. Consequently, attempts at a statistical analysis of data dependent on CDC type-of-damage-distribution codes to investigate the problem of poor structural engagement in small-overlap impacts result in the scope of the problem being understated.

'The September, 2009 NHTSA report Fatalities in Frontal Crashes Despite Seat Belts and Air Bags Review of All CDS Cases Model and Calendar Years 2000-2007: 122 Fatalities, used a case-analysis approach to investigate the problem of poor structural engagement in small-overlap impacts. An analysis of case-histories is expensive. There is an impetus for establishing a method for identifying SOI in queries of coded data. The operational definition of SOI uses criteria that can be applied to crush profile data.

Using 2005 to 2008 NASS-CDS data, a universe of all frontal and oblique side impacts ranked as the most severe impact and assigned a PDOF1 between 320 and 40 degrees was constructed. Cases with lesser severity rollover events were not excluded. Two queries were on run on this data set. One query examined for highest ranked frontal plane impacts that included CDC type of damage-distribution codes that define SOI as corner (E type) and narrow end engagement (S type) impacts. This query had a second sub-routine that employed crush profile data.

The definition of SOI was expanded to include impacts through the front fenders defining oblique side-plane SOI are defined as impacts with an assigned PDoF between 0/40 and 320/360 degrees. A second query, using oblique side-plane criteria was run. The results of this query were added to the results of the combined CDC/Crush query to estimate the number of overall SOI type impacts.

Relative to the overall population of all front-end plane and side and oblique side-plane impacts, the query utilizing CDC criteria identified 87 raw cases with fatally injured occupants or 3683 occupants on the basis of case weights. Using crush criteria 38 raw cases with fatally injured occupants or 1348 occupants on the basis of case weights. Using oblique side-impact criteria 6 raw cases with fatally injured occupants or 130 occupants on the basis of case weights. A total of 44 additional raw cases with fatally injured occupants or 1478 occupants on the basis of case weights were identified using the operation definition presented here.

Relative to the overall population of all front-end plane and side and oblique side-plane impacts, the query utilizing CDC criteria identified 364 of the raw cases with an occupant sustaining a MAIS 3-6 injury were identified or 32135 occupants on the basis of case weights. Using crush criteria 155 raw cases with an occupant sustaining a MAIS 3-6 injury were identified or 9823 on the basis of case weights. Using oblique side-impact criteria 22 raw cases with an occupant sustaining a MAIS 3-6 injury were identified or 1868 on the basis of case weights. A total of 177 an additional raw cases with an occupant sustaining a MAIS 3-6 injury or 11691 on the basis of case weights were identified.

Citations:

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4. **FATAL CAR CRASH CONFIGURATIONS AND INJURY PANORAMA- WITH SPECIAL EMPHASIS ON THE FUNCTION OF RESTRAINT SYSTEM**
   Lindquist, Mats.
   Department of Surgical and Perioperative Science, Umeå University
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   ISSN 0346-6612-1079 ISBN 978-91-7264-247-8

5. **Collision Deformation Classification**
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6. **A Frontal Impact Taxonomy for USA Field Data**
   Sullivan, K., Henry, S., Laituri, T.
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   www.carsp.ca

8. **Mitchell Information Center**
   Mitchell International, Inc.
   9889 Willow Creek Road, San Diego, CA 92131

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    Neptune Engineering, Inc.
    P.O. Box 1597
    Clovis, CA 93613-2465
    Neptuneeng.com

11. Lindquist, 2003.

Appendix A

Dimensions for Frontal-impact Component (All values rounded to nearest centimeter)

Vehicle Class	Overall Width (OW)	Front-track Width (FTW)	Distance Between Rails (D-rail)	½ Front-track Width (FTW_E)	½ Distance Between Rails ($Rail_{LOC}$)	Area Outboard of Rail (AOB)
Sub-compact	172	147	98	73	49	24
Compact	173	148	98	74	49	25
Intermediate	179	153	101	76	51	25
Full	186	158	104	79	52	27
Largest	194	160	98	80	49	31
Compact SUV	176	152	85	76	43	33
SUV	195	165	90	83	45	38
Minivan	192	162	104	81	52	29
Van	201	172	98	86	49	37
Compact pick-up	175	146	78	73	39	34
Pick-up	198	167	83	84	42	42

Dimensions for Oblique Side-impact to Fender Component

Vehicle Class	Wheelbase (WB)	Bumper lead (BL)	Bumper lead + 20% (A_{LOC})	Front Over-hang (FOH)	Axle to A-pillar (Axle-A)
Sub-compact	250	121	145	94	51
Compact	261	120	144	93	51
Intermediate	271	123	147	98	49
Full	284	125	150	106	44
Largest	294	148	177	104	73
Compact SUV	264	116	139	84	55
SUV	290	123	147	97	50
Minivan	293	103	144*	98	46
Van	N/A	77	N/A	87	0**
Compact pick-up	N/A	123	148	86	62
Pick-up	N/A	131	158	97	61

*Bumper lead + 40%
**Assumed to = FOH which is the equivalent of ½ WB

Appendix B

SAS code

Universe of All Frontal and Side Impacts

```
**YEAR04**;

DATA GVVE;MERGE NASS04.GV(IN=A) NASS04.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA04;MERGE GVVE(IN=A) NASS04.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2004;
IF A*B=1
THEN OUTPUT GVVEOA04;

**YEAR05**;

DATA GVVE;MERGE NASS05.GV(IN=A) NASS05.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA05;MERGE GVVE(IN=A) NASS05.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2005;
IF A*B=1
THEN OUTPUT GVVEOA05;

**YEAR06**;

DATA GVVE;MERGE NASS06.GV(IN=A) NASS06.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA06;MERGE GVVE(IN=A) NASS06.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2006;
IF A*B=1
THEN OUTPUT GVVEOA06;

**YEAR07**;

DATA GVVE;MERGE NASS07.GV(IN=A) NASS07.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;
```

```
DATA GVVEOA07;MERGE GVVE(IN=A) NASS07.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2007;
IF A*B=1
THEN OUTPUT GVVEOA07;

**YEAR08**;

DATA GVVE;MERGE NASS08.GV(IN=A) NASS08.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA08;MERGE GVVE(IN=A) NASS08.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2008;
IF A*B=1
THEN OUTPUT GVVEOA08;

DATA GVVEOA;SET GVVEOA04 GVVEOA05 GVVEOA06 GVVEOA07 GVVEOA08;
BY  YEAR PSU CASEID VEHNO OCCNO;

         ** VEHICLE CLASS VARIABLE **;
IF 1<= BODYTYPE <= 13
THEN   DO;
     IF 0 <= WHEELBAS <=253 THEN VEHCLASS=1;
         ELSE IF 254 <= WHEELBAS <=264 THEN VEHCLASS=2;
         ELSE IF 265<=WHEELBAS <=277 THEN VEHCLASS=3;
         ELSE IF 278 <=WHEELBAS <=290 THEN VEHCLASS=4;
     ELSE IF 291 <=WHEELBAS<=400 THEN VEHCLASS=5;
  END;
ELSE IF BODYTYPE=14 THEN VEHCLASS=6;
ELSE IF BODYTYPE IN (15,16,19) THEN VEHCLASS=7;
ELSE IF BODYTYPE=20 THEN VEHCLASS=8;
ELSE IF BODYTYPE IN (21,22,29) THEN VEHCLASS=9;
ELSE IF BODYTYPE=30 THEN VEHCLASS=10;
ELSE IF BODYTYPE IN(31,32,33,39) THEN VEHCLASS=11;

IF TREATMNT=1 THEN DEATH=1; ELSE DEATH=0;
/* ----- comment out ------------
IF (GAD1='F'
OR
(GAD1 IN ('R','L')AND (320<=PDOF1<=360 OR 0<=PDOF1<=40)));
AND ROLLOVER=0;
------------ end comment out ------------ */

IF ((GAD1='F') OR (GAD1 IN ('R','L') AND (PDOF1 >=320 AND PDOF1<=360 OR PDOF1>=0
AND PDOF1<=40)));

RUN;

DATA UNIVERSE;
SET GVVEOA;

RUN;
PROC FORMAT;
 VALUE MAISF 1-2='1-2'
              3-6='3-6';
VALUE FATALS 0='NOO'
             1='YES';
RUN;
```

```
PROC FREQ DATA=UNIVERSE;
TABLE MAIS;
FORMAT MAIS MAISF.;
TITLE ' RAW NUMBERS UNIVERS';
RUN;
PROC FREQ DATA=UNIVERSE;
TABLE MAIS;
FORMAT MAIS MAISF.;
WEIGHT RATWGT;
TITLE ' WEIGHTED  NUMBERS UNIVERSE';
RUN;
PROC FREQ DATA=UNIVERSE;
TABLE DEATH;
FORMAT DEATH FATALS.;
TITLE ' RAW NUMBERS UNIVERS';
RUN;
PROC FREQ DATA=UNIVERSE;
TABLE DEATH;
FORMAT DEATH FATALS.;
WEIGHT RATWGT;
TITLE ' WEIGHTED  NUMBERS UNIVERSE';
RUN;
```

CDC/Crush Query

```
**NHTSA MERGE**;
**YEAR04**;

DATA GVVE;MERGE NASS04.GV(IN=A) NASS04.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA04;MERGE GVVE(IN=A) NASS04.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2004;
IF A*B=1
THEN OUTPUT GVVEOA04;

**YEAR05**;

DATA GVVE;MERGE NASS05.GV(IN=A) NASS05.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA05;MERGE GVVE(IN=A) NASS05.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2005;
IF A*B=1
THEN OUTPUT GVVEOA05;

**YEAR06**;

DATA GVVE;MERGE NASS06.GV(IN=A) NASS06.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA06;MERGE GVVE(IN=A) NASS06.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2006;
```

```
IF A*B=1
THEN OUTPUT GVVEOA06;

**YEAR07**;

DATA GVVE;MERGE NASS07.GV(IN=A) NASS07.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA07;MERGE GVVE(IN=A) NASS07.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2007;
IF A*B=1
THEN OUTPUT GVVEOA07;

**YEAR08**;

DATA GVVE;MERGE NASS08.GV(IN=A) NASS08.VE(IN=B);
BY PSU CASEID VEHNO;
IF A*B=1
THEN OUTPUT GVVE;

DATA GVVEOA08;MERGE GVVE(IN=A) NASS08.OA(IN=B);
BY PSU CASEID VEHNO;
YEAR=2008;
IF A*B=1
THEN OUTPUT GVVEOA08;

DATA GVVEOA;SET GVVEOA04 GVVEOA05 GVVEOA06 GVVEOA07 GVVEOA08;
BY  YEAR PSU CASEID VEHNO OCCNO;

         ** VEHICLE CLASS VARIABLE **;
IF 1<= BODYTYPE <= 13
THEN   DO;
     IF 0 <= WHEELBAS <=253 THEN VEHCLASS=1;
         ELSE IF 254 <= WHEELBAS <=264 THEN VEHCLASS=2;
         ELSE IF 265<=WHEELBAS <=277 THEN VEHCLASS=3;
         ELSE IF 278 <=WHEELBAS <=290 THEN VEHCLASS=4;
     ELSE IF 291 <=WHEELBAS<=400 THEN VEHCLASS=5;
  END;
ELSE IF BODYTYPE=14 THEN VEHCLASS=6;
ELSE IF BODYTYPE IN (15,16,19) THEN VEHCLASS=7;
ELSE IF BODYTYPE=20 THEN VEHCLASS=8;
ELSE IF BODYTYPE IN (21,22,29) THEN VEHCLASS=9;
ELSE IF BODYTYPE=30 THEN VEHCLASS=10;
ELSE IF BODYTYPE IN(31,32,33,39) THEN VEHCLASS=11;

IF TREATMNT=1 THEN DEATH=1; ELSE DEATH=0;

IF (GAD1='F'
OR
(GAD1 IN ('R','L')AND (320<=PDOF1<=360 OR 0<=PDOF1<=40)));

RUN;

/* ******************* */
/* CRUSH PROFILE       */
/* ******************* */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=1
AND GAD1='F'
```

```
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=1
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 54
AND -74 LE DVD LE -25
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno;
run;
DATA L_ONE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;
RUN;
/* ----- VEHCALSS=2 ------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=2
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=2
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 54
AND -74 LE DVD LE -25
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno occno;
run;
DATA L_TWO;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----VEH CLASS=3 --------- */
```

```
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=3
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno occno;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=3
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 56
AND -77 LE DVD LE -26
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_THREE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----------VEH CLASS=4 ------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=4
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=4
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 58
AND -79 LE DVD LE -27
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_FOUR;
```

```
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -------VEH CLASS=5 --------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=5
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=5
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 58
AND -80 LE DVD LE -31
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_FIVE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;


RUN;
/* -------VEH CLASS=6 ----------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=6
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=6
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 56
AND -76 LE DVD LE -33
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
```

```
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_SIX;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* --------- VEH CLASS=7 ---------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=7
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=7
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 61
AND -83 LE DVD LE -38
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno;
run;
DATA L_SEVEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ---- VEHCLASS=8 ------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=8
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;

DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=8
AND SHL1 IN ('L','Y')
```

```
AND 0 LE DIRDAMW LE 59
AND -81 LE DVD LE -29
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;

DATA L_EIGHT;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ------VEHCLASS=9 -------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=9
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=9
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 63
AND -81 LE DVD LE -37
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_NINE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ------VEHCLASS=10 ---------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=10
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
```

```
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=10
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 54
AND -73 LE DVD LE -34
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA L_TEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----------VEHCLASS=11------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=11
AND GAD1='F'
AND SHL1='L'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (330 LE PDOF1 LE 360 OR PDOF1=0);

RUN;
proc sort data=master;
by YEAR psu caseid vehno OCCNO;
run;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=11
AND SHL1 IN ('L','Y')
AND 0 LE DIRDAMW LE 62
AND -84 LE DVD LE -42
AND DVC1>DVC2
AND DVC1>DVC3
AND DVC1>DVC4
AND DVC1>DVC5
AND DVC6<=DVC3;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno;
run;
DATA L_ELEVEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
DATA CRUSH_LEFT;
SET L_ONE L_TWO L_THREE L_FOUR L_FIVE L_SIX L_SEVEN
L_EIGHT L_NINE L_TEN L_ELEVEN;

CRUSH='LEFT';
RUN;
/* -------------------------------- */
```

```
/*    CRUSH RIGHT SIDE              */
/* ------------------------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=1
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=1
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 54
AND 25 LE DVD LE 74
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;
RUN;
proc sort data=master1;
by YEAR psu caseid vehno OCCNO;
run;
DATA R_ONE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ----- VEHCALSS=2 ------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=2
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=2
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 54
AND 25 LE DVD LE 74
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_TWO;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----VEH CLASS=3 --------- */
DATA MASTER;
```

```
SET GVVEOA;
IF VEHCLASS=3
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=3
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 56
AND 26 LE DVD LE 77
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_THREE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----------VEH CLASS=4 ------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=4
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=4
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 58
AND 27 LE DVD LE 79
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_FOUR;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -------VEH CLASS=5 --------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=5
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
```

```
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=5
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 58
AND 31 LE DVD LE 80
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;

DATA R_FIVE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;


RUN;
/* -------VEH CLASS=6 ----------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=6
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=6
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 56
AND 33 LE DVD LE 76
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;

DATA R_SIX;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* --------- VEH CLASS=7 ---------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=7
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);
```

```
RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=7
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 61
AND 38 LE DVD LE 83
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_SEVEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ---- VEHCLASS=8 ------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=8
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=8
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 59
AND 29 LE DVD LE 81
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;

DATA R_EIGHT;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ------VEHCLASS=9 ------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=9
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
```

```
IF VEHCLASS=9
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 63
AND 37 LE DVD LE 86
AND DVC6>DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_NINE;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* ------VEHCLASS=10 ---------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=10
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;
DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=10
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 54
AND 34 LE DVD LE 73
AND DVC6>=DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_TEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
/* -----------VEHCLASS=11------------- */
DATA MASTER;
SET GVVEOA;
IF VEHCLASS=11
AND GAD1='F'
AND SHL1='R'
AND SVL1 IN ('E','M','H','A','L','G')
AND TDD1 IN ('S','E')
AND (0 LE PDOF1 LE 30);

RUN;

DATA MASTER1;
SET GVVEOA;
IF VEHCLASS=11
AND SHL1 IN ('R','Z')
AND 0 LE DIRDAMW LE 62
AND 42 LE DVD LE 84
```

```
AND DVC6>=DVC5
AND DVC6>DVC4
AND DVC6>DVC3
AND DVC6>DVC2
AND DVC1<=DVC4;

RUN;
DATA R_ELEVEN;
MERGE MASTER1 MASTER;
BY YEAR PSU CASEID VEHNO OCCNO;

RUN;
DATA CRUSH_RIGHT;
SET R_ONE R_TWO R_THREE R_FOUR R_FIVE R_SIX R_SEVEN
R_EIGHT R_NINE R_TEN R_ELEVEN;
CRUSH='RGHT';
RUN;
DATA ALL_CRUSH;
SET CRUSH_LEFT CRUSH_RIGHT;
RUN;

PROC FORMAT;
VALUE MAISF 1-2='1-2'
            3-6='3-6';
RUN;

/*data out.gvveoa;
set gvveoa;
run;
*/
data out.all_crush;
set all_crush;
run;

/* ====== FREQUENCY TABLES ==== */
PROC FREQ DATA=ALL_CRUSH;
TABLE MAIS;
FORMAT MAIS MAISF.;
TITLE 'NOT WEIGHTED FRONTAL CRUSH PROFILE ';
RUN;
PROC FREQ DATA=ALL_CRUSH;
TABLE MAIS;
FORMAT MAIS MAISF.;
WEIGHT RATWGT;
TITLE 'WEIGHTED FRONTAL CRUSH PROFILE ';
RUN;

PROC FREQ DATA=ALL_CRUSH;
TABLE DEATH;
TITLE 'NOT WEIGHTED FRONTAL CRUSH PROFILE FATALITY';
RUN;
PROC FREQ DATA=ALL_CRUSH;
TABLE DEATH;
WEIGHT RATWGT;
TITLE 'WEIGHTED FRONTAL CRUSH PROFILE FATALITY';
RUN;
/* ---ALL FRONTAL RIGHT/LEFT 0/-40 320/360---- */
PROC FREQ DATA=GVVEOA;
TABLE MAIS;
FORMAT MAIS MAISF.;
TITLE 'NOT WEIGHTED ALL: FRONTAL LEFR/RIGHT 0/-40 AND 320/360 ';
RUN;
PROC FREQ DATA=GVVEOA;
```

```
TABLE MAIS;
FORMAT MAIS MAISF.;
WEIGHT RATWGT;
TITLE 'WEIGHTED ALL: FRONTAL LEFR/RIGHT 0/-40 AND 320/360 ';
RUN;

PROC FREQ DATA=GVVEOA;
TABLE DEATH;
TITLE 'NOT WEIGHTED:FRONTAL LEFT/RIGHT 0/-40 AND 320/360   ';
RUN;
PROC FREQ DATA=GVVEOA;
TABLE DEATH;
WEIGHT RATWGT;
TITLE 'WEIGHTED: FRONTAL LEFR/RIGHT 0/-40 AND 320/360 ';
RUN;
```

LY/RY Query

```
data gv04;
set nass04.gv;

run;
proc sort data=gv04;
by psu caseid vehno;
run;
data ve04;
set nass04.ve;

run;
proc sort data=ve04;
by psu caseid vehno;
run;
data oa04;
set nass04.oa;

run;
proc sort data=oa04;
by psu caseid vehno occno;
run;
data gvve04;
merge gv04 (in=a) ve04 (in=b);
by psu caseid vehno;
if a and b;

run;
proc sort data=gvve04;
by psu caseid vehno;
run;
data gvveoa04;
merge gvve04 (in=a) oa04(in=b);
by psu caseid vehno;
if a and b;

year=2004;
run;
/* nass 05 ****/
data gv05;
set nass05.gv;


run;
proc sort data=gv05;
```

```
by psu caseid vehno;
run;
data ve05;
set nass05.ve;

run;
proc sort data=ve05;
by psu caseid vehno;
run;
data oa05;
set nass05.oa;

run;
proc sort data=oa05;
by psu caseid vehno occno;
run;
data gvve05;
merge gv05 (in=a) ve05 (in=b);
by psu caseid vehno;
if a and b;

run;
proc sort data=gvve05;
by psu caseid vehno;
run;
data gvveoa05;
merge gvve05 (in=a) oa05(in=b);
by psu caseid vehno;
if a and b;

year=2005;

run;
data gv06;
set nass06.gv;

run;
proc sort data=gv06;
by psu caseid vehno;
run;
data ve06;
set nass06.ve;

run;
proc sort data=ve06;
by psu caseid vehno;
run;
data oa06;
set nass06.oa;


run;
proc sort data=oa06;
by psu caseid vehno occno;
run;
data gvve06;
merge gv06 (in=a) ve06 (in=b);
by psu caseid vehno;
if a and b;

run;
proc sort data=gvve06;
by psu caseid vehno;
```

```
run;
data gvveoa06;
merge gvve06 (in=a) oa06(in=b);
by psu caseid vehno;
if a and b;

year=2006;
run;
/* ** NASS 07 *** */
data gv07;
set nass07.gv;

run;
proc sort data=gv07;
by psu caseid vehno;
run;
data ve07;
set nass07.ve;

run;
proc sort data=ve07;
by psu caseid vehno;
run;
data oa07;
set nass07.oa;

run;
proc sort data=oa07;
by psu caseid vehno occno;
run;
data gvve07;
merge gv07 (in=a) ve07 (in=b);
by psu caseid vehno;
if a and b;

run;
proc sort data=gvve07;
by psu caseid vehno;
run;
data gvveoa07;
merge gvve07 (in=a) oa07(in=b);
by psu caseid vehno;
if a and b;

year=2007;
run;
/* ***** nass 2008 ****/
data gv08;
set nass08.gv;

run;
proc sort data=gv08;
by psu caseid vehno;
run;
data ve08;
set nass08.ve;

run;
proc sort data=ve08;
by psu caseid vehno;
run;
data oa08;
set nass08.oa;
```

```
run;
proc sort data=oa08;
by psu caseid vehno occno;
run;
data gvve08;
merge gv08 (in=a) ve08 (in=b);
by psu caseid vehno;
if a and b;

run;
proc sort data=gvve08;
by psu caseid vehno;
run;
data gvveoa08;
merge gvve08 (in=a) oa08(in=b);
by psu caseid vehno;
if a and b;

year=2008;

run;

data year0408;
set gvveoa04 gvveoa05 gvveoa06 gvveoa07 gvveoa08;
if treatmnt=1 then death=1; else death=0;

IF BODYTYPE >=1 AND BODYTYPE<=13
THEN DO;
 IF WHEELBAS>=0 AND WHEELBAS<=253
 THEN VEHCLASS=1;
 IF WHEELBAS>=254 AND WHEELBAS<=264
 THEN VEHCLASS=2;
 IF WHEELBAS>=265 AND WHEELBAS<=277
 THEN VEHCLASS=3;
 IF WHEELBAS>=278 AND WHEELBAS<=290
 THEN VEHCLASS=4;
 IF WHEELBAS>=291 AND WHEELBAS<=400
 THEN VEHCLASS=5;
END;
IF BODYTYPE=14
THEN VEHCLASS=6;
IF BODYTYPE IN(15, 16, 19)
THEN VEHCLASS=7;
IF BODYTYPE=20
THEN VEHCLASS=8;
     IF BODYTYPE IN(21, 22, 29)
THEN VEHCLASS=9;
IF BODYTYPE=30
THEN VEHCLASS=10;
IF BODYTYPE IN(31, 32, 33, 39)
THEN VEHCLASS=11;

IF (GAD1='F' OR (GAD1 IN ('R','L')AND (320<=PDOF1<=360 OR 0<=PDOF1<=40)));

RUN;

/* ------------------------ */
/*         LY RY NEW        */
/* ------------------------ */

DATA ONE;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
```

```
IF VEHCLASS=1
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=290
AND DVD>=71 AND DVD<=218
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**COMPACT SIZE VEHICLES LYRY CRUSH**;

DATA TWO;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=2
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=288
AND DVD>=79 AND DVD<=223
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**MEDIUM SIZE VEHICLES LYRY CRUSH**;

DATA THREE;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=3
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=294
AND DVD>=87 AND DVD<=234
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;

**FULL SIZE VEHICLES LYRY CRUSH**;

DATA FOUR;SET YEAR0408;
```

```
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=4
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=300
AND DVD>=98 AND DVD<=248
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;

**LARGESTSIZE  VEHICLES LYRY CRUSH**;

DATA FIVE;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=5
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=354
AND DVD>=74 AND DVD<=251
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**COMPACT SIZE SUV VEHICLES LYRY CRUSCH**;

DATA SIX;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=6
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=278
AND DVD>=87 AND DVD<=243
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;


**FULL SIZE SUV VEHICLES LYRY CRUSH**;
```

```
DATA SEVEN;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=7
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=294
AND DVD>=95 AND DVD<=242
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**MINI VAN SIZE VEHICLES LYRY CRUSH**;

DATA EIGHT;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=8
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=248
AND DVD>=120 AND DVD<=224
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**VAN SIZE VEHICLES LYRY CRUSH**;

DATA NINE;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=9
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=180
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**COMPACT PICK UP SIZE VEHICLES LYRY CRUSH**;

DATA TEN;SET YEAR0408;
```

```
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=10
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=296
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
**FULL SIZE PICK UP VEHICLES LYRY CRUSH**;
DATA ELEVEN;SET YEAR0408;
BY YEAR PSU CASENO VEHNO OCCNO;
IF VEHCLASS=11
AND GAD1 IN('L', 'R')
AND SHL1 IN('F', 'Y')
AND SVL1 IN('E', 'M', 'H', 'A', 'L','G')
AND TDD1 IN('S', 'W', 'K', 'A', 'N')
AND EXTENT1 IN(1, 2, 3, 4, 5, 6)
AND ((PDOF1>=320 AND PDOF1<=360) OR (PDOF1>=0 AND PDOF1<=40))
AND DOF1 IN('11', '31', '51', '71', '12', '32', '52', '72', '92', '1', '21', '41',
'81')
AND DVL>=0 AND DVL<=316
AND DVC2>DVC1
AND DVC3>DVC2
AND DVC4>DVC2
AND DVC5>DVC2
AND DVC6>=DVC1;
RUN;
DATA LY_RY;
SET ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT NINE TEN ELEVEN;
RUN;
/*
data out.ly_ry;
set ly_ry;
run;
*/
PROC FORMAT;
VALUE MAISF 1-2='1-2'
            3-6='3-6';
VALUE DEATHF 1='YES'
            0='NOO';

VALUE PDOF 320-360='320-360'
           370-900='>> 360'
                 50-310='50-310'
             0-40='0-40';
RUN;
* ========= freaquency ============= ;
PROC FREQ DATA=LY_RY;
TABLE MAIS;
FORMAT MAIS MAISF.;
TITLE 'NOT WEIGHTED NUMBERS NASS 2004- 2008 LY RY';
RUN;
PROC FREQ DATA=LY_RY;
TABLE MAIS;
```

```
FORMAT MAIS MAISF.;
WEIGHT RATWGT;
TITLE 'WEIGHTED NUMBERS NASS 2004- 2008 LY RY';
RUN;
PROC FREQ DATA=LY_RY;
TABLE DEATH;
FORMAT MAIS MAISF.;
TITLE 'NOT WEIGHTED NUMBERS NASS 2004- 2008 LY RY';
RUN;
PROC FREQ DATA=LY_RY;
TABLE DEATH;
FORMAT MAIS MAISF.;
WEIGHT RATWGT;
TITLE 'WEIGHTED NUMBERS NASS 2004- 2008 LY RY';
RUN;

/* --ALL FRONTALS AND RIGHT/LEFT
     0/-40 AND 320/360 */
proc freq data=year0408;
table mais;
format mais maisf.;
title 'NOT WEIGHTED: ALL FRONTAL SIDE 0/-40,320/360 2004 - 2008';
RUN;
proc freq data=year0408;
table mais;
format mais maisf.;
weight ratwgt;
title 'WEIGHTED: ALL FRONTAL SIDE 0--40,320-360 2004 - 2008';
RUN;
proc freq data=year0408;
table death;
title 'NOT WEIGHTED: UNIVERSE';
RUN;
proc freq data=year0408;
table death;
weight ratwgt;
title 'WEIGHTED: WEIGHTED: ALL FRONTAL SIDE 0--40,320-360 2004 - 2008';
RUN;
```

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**National Highway
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Administration**

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