Evaluations of Five Advanced Driver Assistance System (ADAS) Features, Including:

- **Automatic Emergency Braking (AEB),**
- **Blind Spot Warning (BSW),**
- **Lane Keeping Assistance (LKA),**
- **Pedestrian AEB or Detection (PAEB/PD), and**
- **Rear Cross Traffic Warning (RCTW)**

David B. Brown, PhD, PE
University of Alabama
brown@cs.ua.edu

The University of Alabama
Center for Advanced Public Safety (CAPS)
Alabama Transportation Institute (ATI)

January 15, 2021

Table of Contents

Introduction

Generally, the goal of the analytics approach applied in this document is to determine the effectiveness of specific ADAS features (those given in the title). There are some others mentioned in Consumer Reports (CR) that will be discussed below when a more complete table of ADAS features is given. For now, we want to keep the discussion general to apply to any ADAS feature that is subject to evaluation.

There seems to be no alternative to accomplishing an evaluation of an ADAS feature than that of comparing the crash history of vehicles with the ADAS feature against a comparable set of vehicles that do not have this feature. This would need to be done over a relatively large number of test and control cases in order to get practically significant results. In this case the "test" subset will be crashes for those vehicles with a given ADAS feature. A control subset is defined to be a subset that is (ideally) in all other respects like the test subset, but which does not have the ADAS feature. If the ADAS feature is to reduce a given type of crash (e.g., pedestrian crashes), the Primary Contributing Circumstances and/or the Contributing Circumstance given in the crash records might be used to determine the effectiveness in reducing those crash types.

Consumer Reports (CR) has provided a list of ADAS features that indicates the Year, Make and Model in which a variety of features were present. We searched for other similar make, model year and model specifications but this is the only one that was found. We assume that if an ADAS feature is present in a given year, it will also be present in subsequent years. It was also generally required that we specify the makes, models and years for which the given ADAS feature was not present so that a legitimate control group could be created.

It is essential that we understand what is being measured and compared by these analytics. We will call the numbers that will be produced below in the IMPACT displays *Vehicle-Crashes*. This can be thought of as one vehicle that is involved in one crash. This definition is mindful of the fact that a vehicle cannot get into the database unless it has had a crash. It is obviously impossible when this is the primary metric to determine how many crashes were averted by a given ADAS feature. However, we can determine the extent to which the various attributes of these crashes change.

As an example, consider Section 2.0 of this report, which documents the study of Blind Spot Warning (BSW). The decisions was made to use Toyotas for the BSW subset (592 vehicle-crashes) , and Mazdas for the NonBSW subset (361 vehicle-crashes). These two subsets were compared by a CARE IMPACT analysis, and the results are given at the end of Section 2.0.

Table 1 lists all of the ADAS feature types that are given in CR. These will be discussed in more detail after the table.

Zzzz Update

Table 1. ADAS Acronym Checklist

Acronym	Acronym Meaning	Status	Comment
ACC*	Adaptive Cruise Control	0	No models given by CR
AEB ss	Automatic Emergency Braking V07	6	AEB=CAEB+HAEB
AEB/FCW	Combination Of AEB and FCW	7	Nissan AEB = FCW
BSW	Blind Spot Warning	6	
CAEB	City Automatic Emergency Braking	6	AEB=CAEB+HAEB
FCW ss	Forward Collision Warning Ss And Validation	6	**No AEB; Review SS**
HAEB	High-Speed Automatic Emergency Braking	6	AEB=CAEB+HAEB
LCA*	Lane-Centering Assist	0	No models given by CR
LDW ss	Lane Departure Warning	6	**Review SS**
LKA	Lane Keeping Assistance	6	Needs work
PD	Pedestrian AEB and Detection, PD/PAEB	6	Used Crash comparison
RCTW	Rear Cross Traffic Warning	6	
Rear AEB*	Rear Automatic Emergency Braking	0	No models given by CR

* ACC, LCA and Rear AEB were not listed in any of the Consumer Reports ADAS tables.

SS after the acronym indicates that there is a separate special study on this ADAS feature. These are available here:

http://www.safehomealabama.gov/caps-special-studies/

under the Vehicle-Related subject heading.

Status Codes that were used in the process of these studies to manage further development:

0. No applicable models in CR
1. No consideration yet
2. Being investigated for processing
3. Initial processing
4. Preliminary draft
5. In final draft revision
6. Project completed but needs further review, e.g. addition of more vehicle-crash cases
7. No further review anticipated

To get a brief description of each of the above features, please see the *Consumer Reports (CR)* article.

Brief Clarification of the ADAS features listed in Table 1

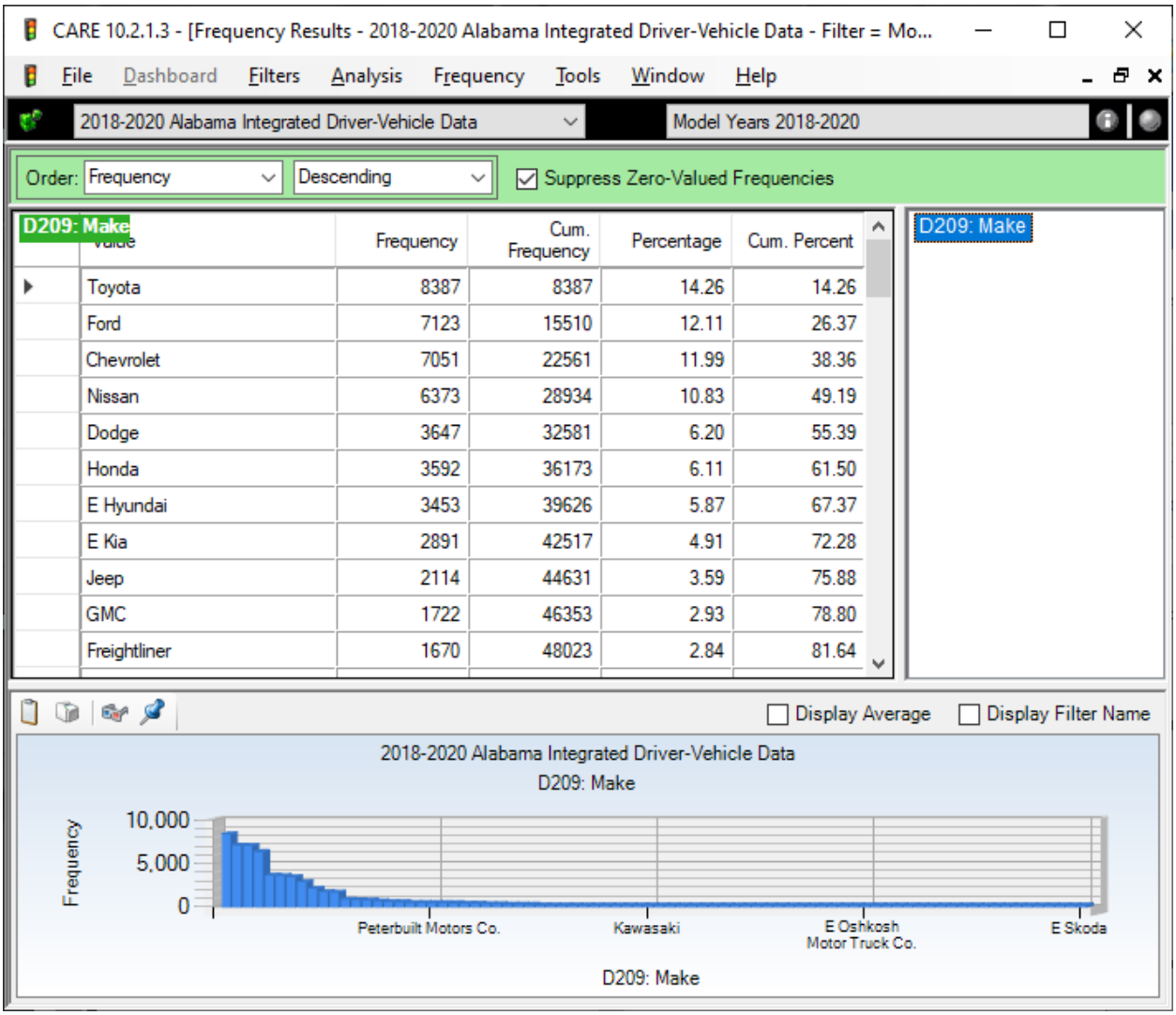
The following presents the ADAS features given in Table 1, and indicates if they have prior studies, and how they will be handled in the remainder of this report:

- Adaptive Cruise Control (ACC*). This feature will not be considered further at this time since no models were given by CR.
- Automatic Emergency Braking (AEB ss). A special study exists for this feature that is available on SafeHomeAlabama, and so it will not be documented further here. This report is a combination of Automatic Emergency Braking (AEB) for both City (CAEB) and High-Speed (HAEB).
- AEB Combined with FCW (AEB/FCW). Section 1.0 in this report.
- Blind Spot Warning (BSW). Section 2 of this report.
- City Automatic Emergency Braking (CAEB). See Automatic Emergency Braking (AEB), above, which is a combination of CAEB and HAEB.
- Forward Collision Warning Ss and Validation (FCW ss). A special study exists for this feature that is available on SafeHomeAlabama, and so it will not be documented here.
- High-Speed Automatic Emergency Braking (HAEB). See Automatic Emergency Braking (AEB), above, which is a combination of CAEB and HAEB.
- Lane-Centering Assist (LCA*). This feature will not be considered further at this time since no models were given by CR.
- Lane Departure Warning (LDW ss). A special study exists for this feature that is available on SafeHomeAlabama, and so it will not be documented further here.
- Lane Keeping Assistance (LKA). Section 3.0 of this report.
- Pedestrian AEB or Detection (PAEB/PD). Section 4.0 of this report.
- Rear Cross Traffic Warning (RCTW). Section 5 of this report.
- Rear Automatic Emergency Braking (Rear AEB*). This feature will not be considered further at this time since no models were given by CR.

The table in the next section below was generated to assist in choosing which vehicles makes to consider. Those in the top tier (1000 and above) were used most often. It is obvious that a large number of vehicles of a given make will potentially produce more models that are of a given feature as well as those without the feature for the control. However, the features (or absence of such) had to be specified in the CR report in order to be used.

This report will continue by providing the procedure applied in each of the five evaluations and the findings in terms of IMPACT displays.

Number of Vehicles in 2018-2020 Database (Minimum 3000)



1.0 ADAS AES Combined with FCW

Combination of Automatic Emergency Braking (AEB) and Forward Collision Warning (FCW)

Introduction

This section evaluates the combination of AEB and FCW working together as a unit.

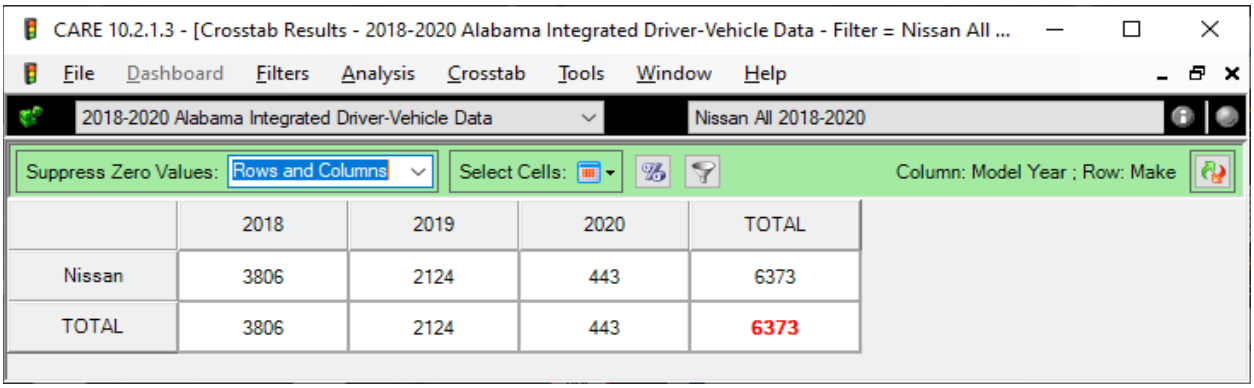
Consumer Reports listed two types of Automatic Emergency Braking (AEB); CAEB (city automatic emergency braking) and HAEB (high-speed automatic emergency braking), the only difference being the speeds at which they are designed to work. However, in most of their makes they combined these two features into what they called CAEB/HAEB. To abbreviate this further, we will analyze them combined and refer to them collectively as AEB.

In addition to this combination, it was found that the same models and model years that defined the AEB and Non-AEB subsets, also defined the FCW and Non-FCW subsets. This means that whenever a Nissan model had AEB, it also had FCW, and whenever a Nissan model was Non-AEB it was also Non-FCW. This led to the opportunity to evaluate these two ADAS features as one collective ADAS unit, which we will reference as AEB/FCW.

Methodology Applied

The All-Nissan Subset was used in to create models with AEB/FCW and Non-AEB/FCW.

1. Start with all Nissan 2018-2020



	2018	2019	2020	TOTAL
Nissan	3806	2124	443	6373
TOTAL	3806	2124	443	6373

This same raw data will be used to generate both the Nissan AEB/FCW and the Nissan Non-AEBFCW subsets since the differences between them will be in the models. Note a total of 6373 Nissan vehicle-crashes are in the 2018-2020 Driver-Vehicle file. The model years of 2018-2020 will be for the specific AEB/FCW and Non-AEB/FCW subset generations. In the discussions that follow, the FCW has been eliminated from AEB/FCW strictly for brevity purposes.

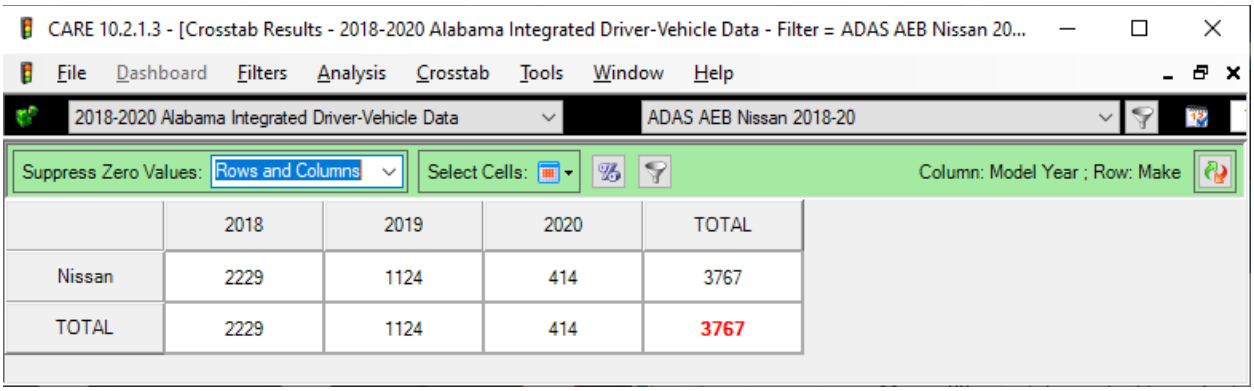
2. The contents of the subset from 1 is obtained from a DataGen using the filter above. Essential variables that must be included in this DataGen are:

- **208 Model Year,**
- **209 Make,**
- **NCV003 Care DV Case Number NCV, and**
- **NCV005 Vehicle Model NCV**.

The contents generated by the DataGen are under the **Nissan ALL 2018-2020** tab of the **ADAS AEB Datagen Proc-v01.xlsx** Excel file. The DataGen for the filter above produced 6,373 records. These were then used to produce the Nissan AEB and the Nissan NonAEB filters.

3. Creating AEB/FCW filter for 2018-2020 Nissans. To qualify for AEBFCW: 2020: **Altima, Armada, Kick, Leaf, Maxima, Murano, Pathfindes, Rogue, Rogue Sport, Sentra, Titan, TitanXD and Versa;** 2019: **Altima, Armada, Kick, Leaf, Maxima, Murano, Pathfindes, Rogue, Rogue Sport;** 2018: **Altima, Kick, Leaf, Maxima, Murano, Pathfindes, Rogue.** Number found with AEB features = 3767.

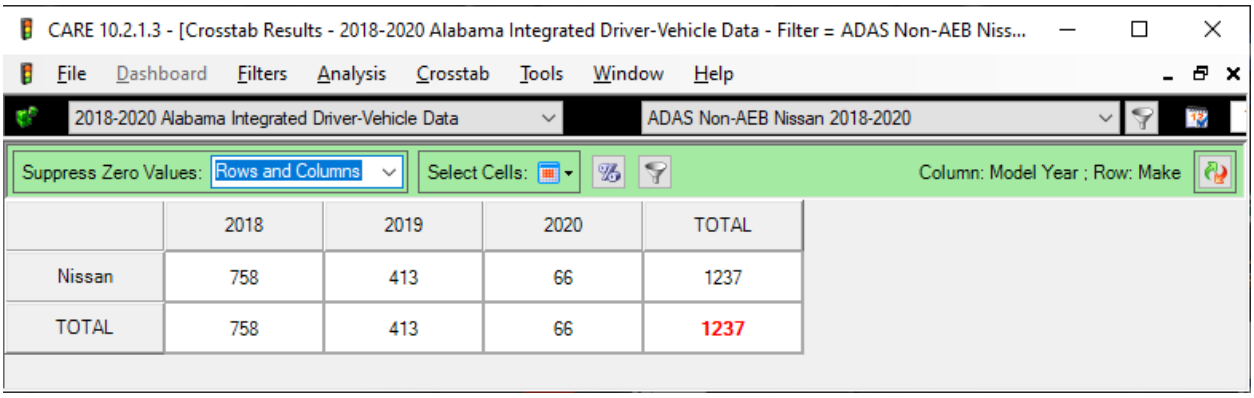
The text file name generated from this reduced DataGen is **ADAS AEB Nissan 2018-20.txt**. The filter generated by this text file was called **ADAS AEB Nissan 2018-2020. It produced the following:**



	2018	2019	2020	TOTAL
Nissan	2229	1124	414	3767
TOTAL	2229	1124	414	3767

All vehicle-crashes specified here were 2018-20 Nissans.

4. Creating Non-AEB/FCW filter for 2018-2020 Nissans. To qualify for Non-AEB: 2018: **Frontier, GT-R; NV, NV200, Titan, TitanXD, Versa, VersaNote;** 2019: **Frontier, GT-R; NV, NV200, Titan, TitanXD, Versa, VersaNote;** 2020: **GT-R; NV, NV200.** The number found with Non-AEB feature = 1237. The text file name generated from this reduced DataGen is **ADAS Non-AEB Nissan 2018-20.txt**. The filter generated by this text file was called **ADAS Non-AEB Nissan 2018-2020. It produced the following:**



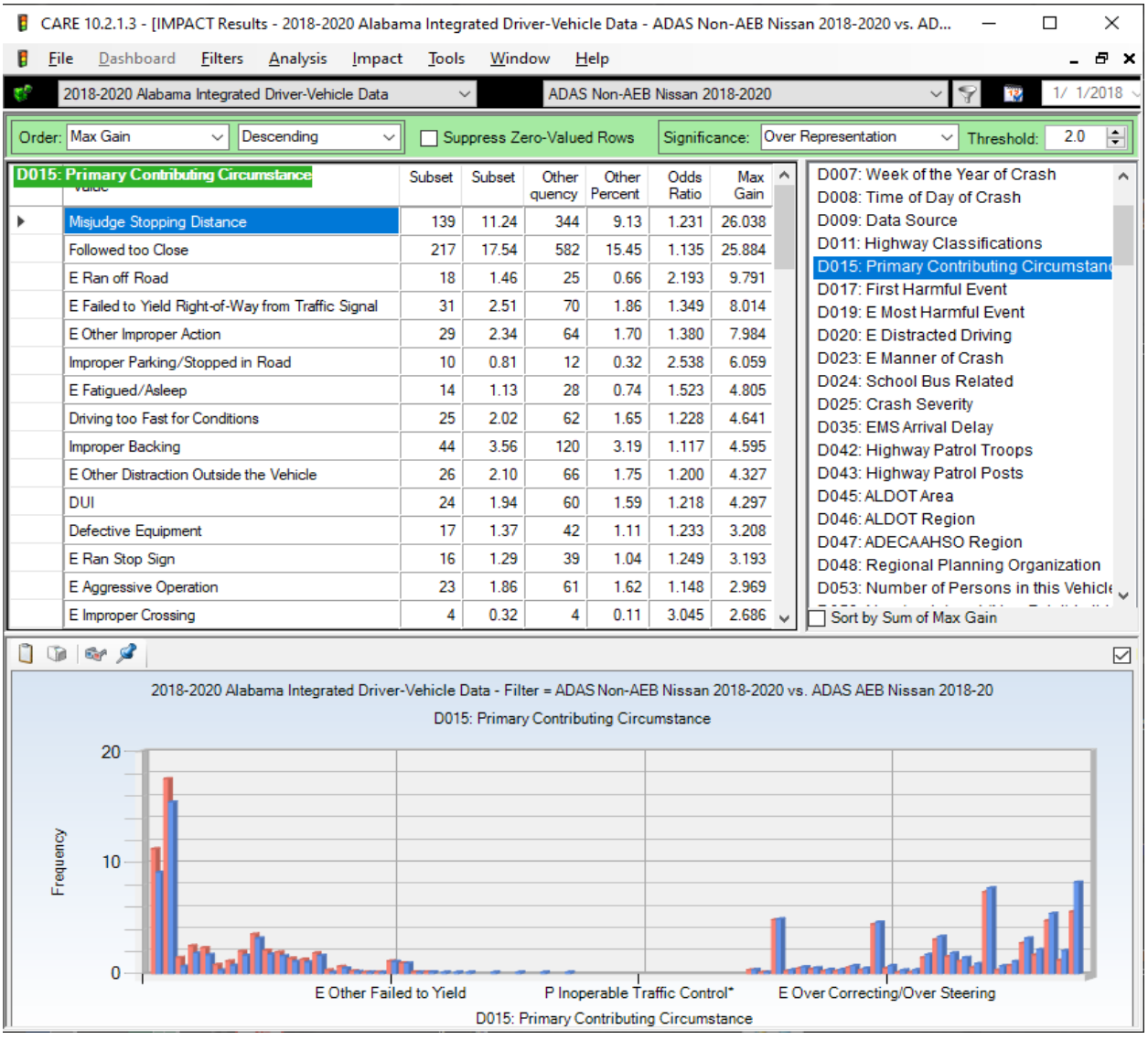
	2018	2019	2020	TOTAL
Nissan	758	413	66	1237
TOTAL	758	413	66	1237

5. The AEB/FCW subset can now be compared with the Non-AEB/FCW subset. The **ADAS Non-AEB Nissan 2018-2020** filter is made current, and it is compared against the subset generated by the **ADAS AEB Nissan 2018-2020** filter. The following IMPACT comparisons were obtained for the combination of AEB and FCW, since both had the same applicable model years.

IMPACT Evaluations for the AEB and FCW Combination

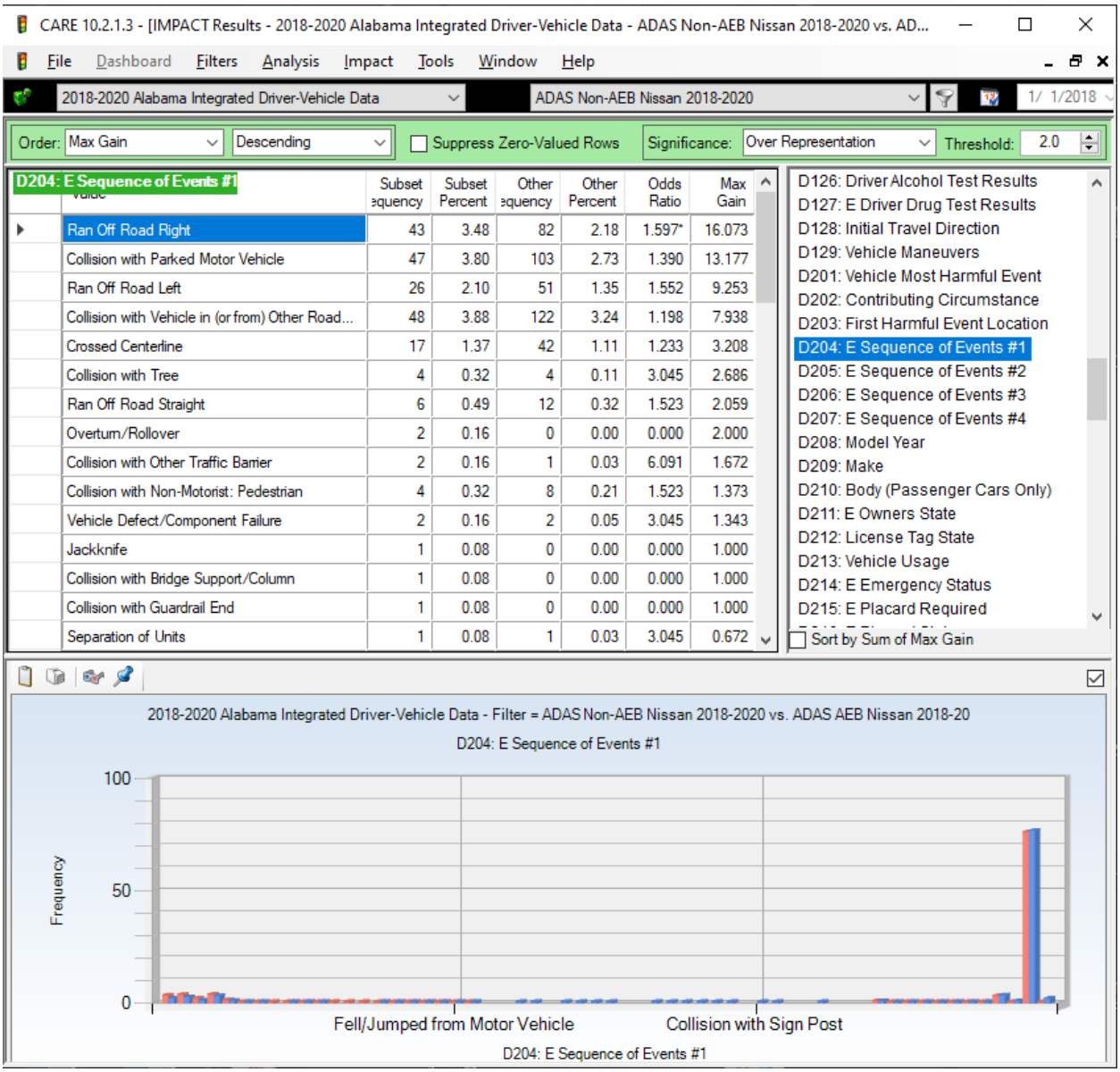
Because the Nissans used in these comparisons have effectively the same models in effect for AEB and Forward Collision Warning (FCW), these IMPACT displays should be viewed as applying when both of these features are in effect simultaneously.

D015 Primary Contributing Circumstances AEB and FCW Combination



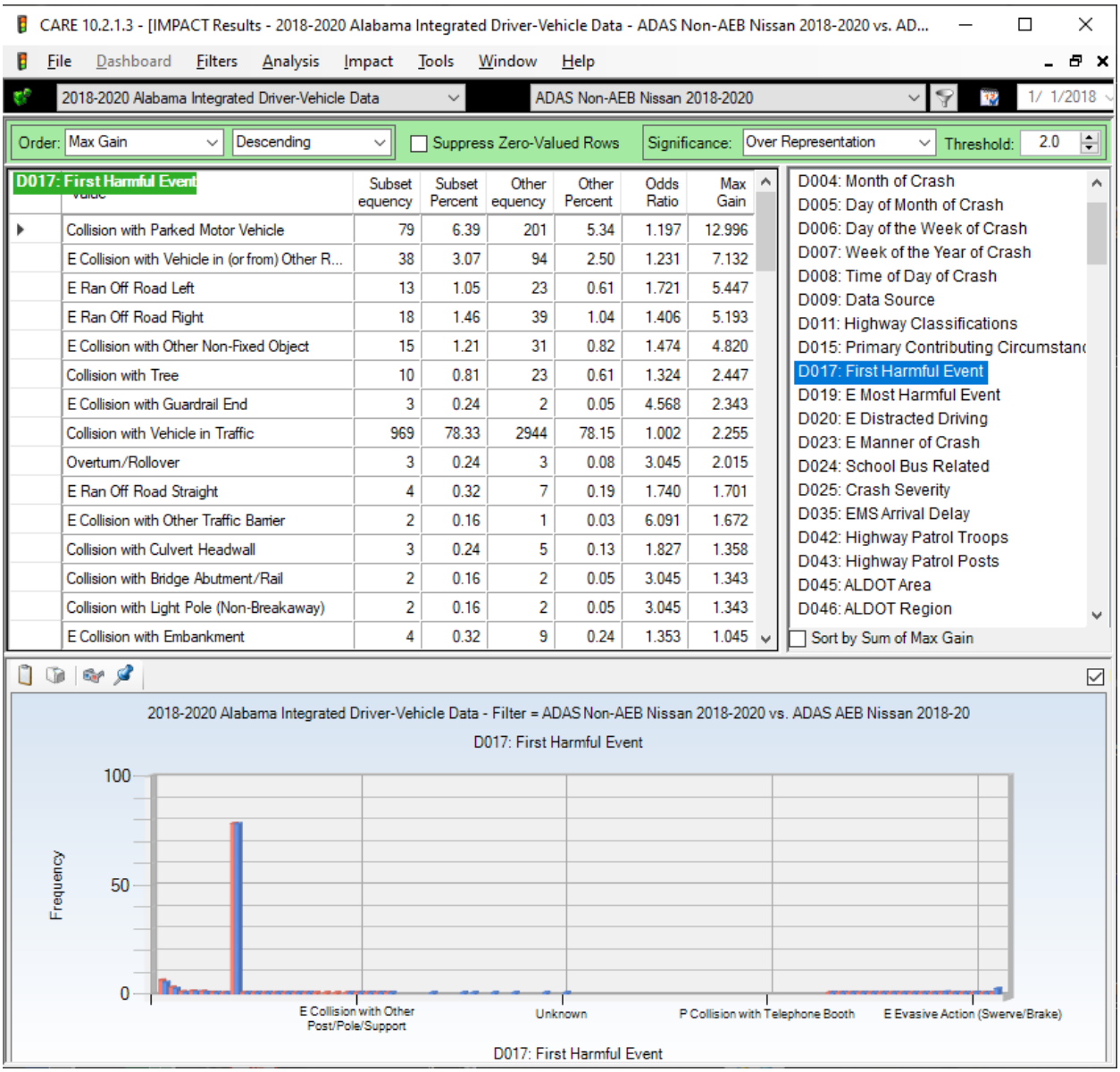
Items with a Max Gain less that 2.0 are not shown. The following crash types could possibly be eliminated or mitigated by the AEB/FCW combination (rounded Max Gain): Misjudge Stopping Distance(26), Following too Close (26), Ran Off Road (10), Driving Too Fast for Conditions (5).

D204 Sequence of Events #1



Collision with Parked Motor Vehicle, which rarely has one of the highest Max Gains is probably the crash type that has the highest potential to be reduced by the AEB/FCW combination. The Odds Ratio shows that the reduction of the Ran Off the Road Right crash type is significant, with a reduction in the proportion of about 60%. The rationale for including this as a positive factor is that the chances of there being some obstacle on the roadside is very high, especially on roads that do not have large cleared roadsides. Many of the other crash types could be reduced by AEB/FCW.

D017 First Harmful Event



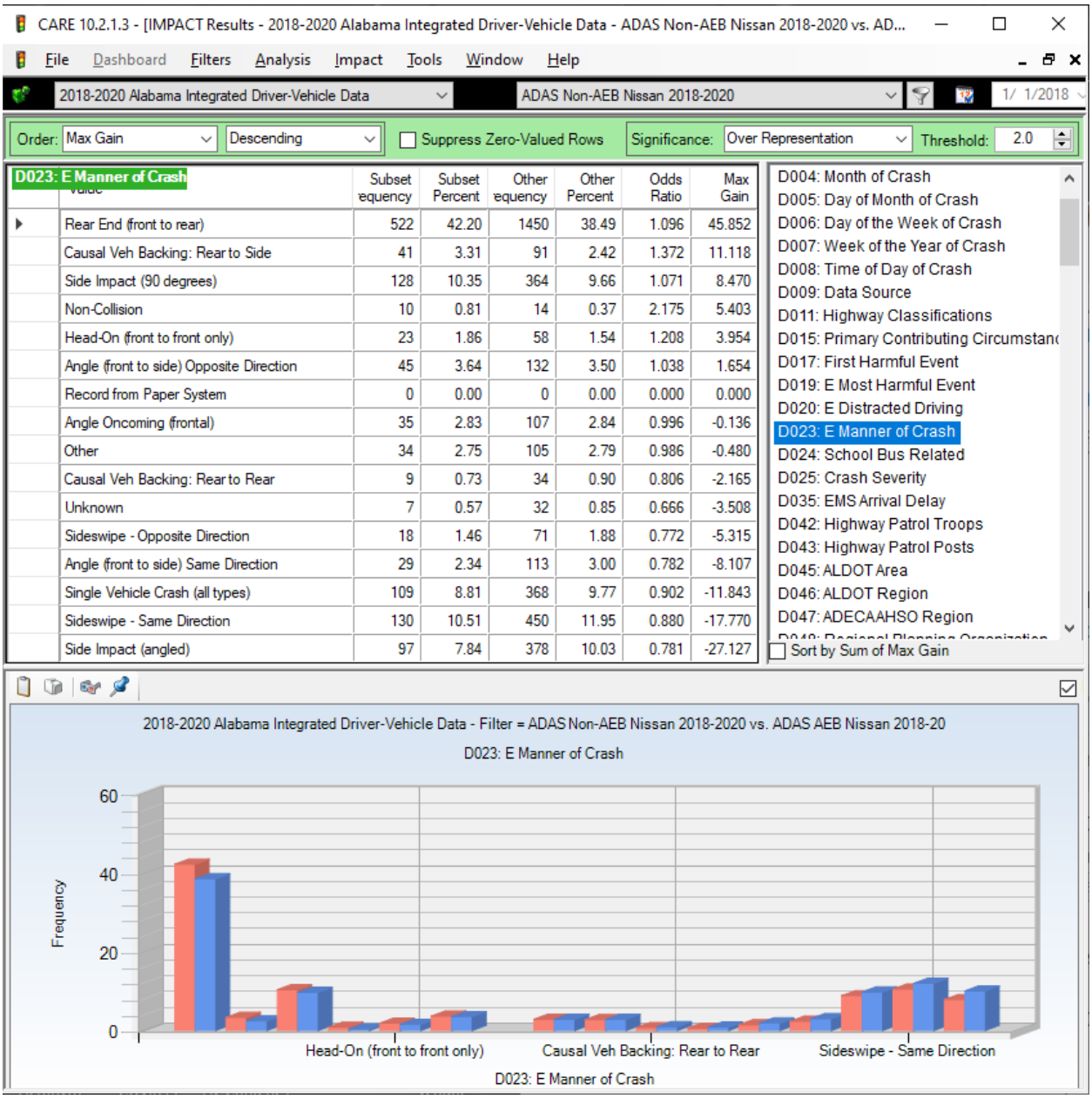
Items with a Max Gain of one or less are not shown. It is notable that the item with the highest Max Gain is relevant to AEB/FCW in that this is exactly the type of crash that these features were designed to prevent, i.e., any type of crash with a stationary object. About half of the items listed would qualify. See the list on the next page.

List of Crash Types that Could be Reduced by AEB/FCW

Collision with Parked Motor Vehicle
E Collision with Vehicle in (or from) Other Roadway
E Ran Off Road Left
E Ran Off Road Right
E Collision with Other Non-Fixed Object
Collision with Tree
E Collision with Guardrail End
E Collision with Other Traffic Barrier
Collision with Culvert Headwall
Collision with Bridge Abutment/Rail
Collision with Light Pole (Non-Breakaway)
E Collision with Embankment
Collision with Bridge Support/Column
E Collision with Other Post/Pole/Support

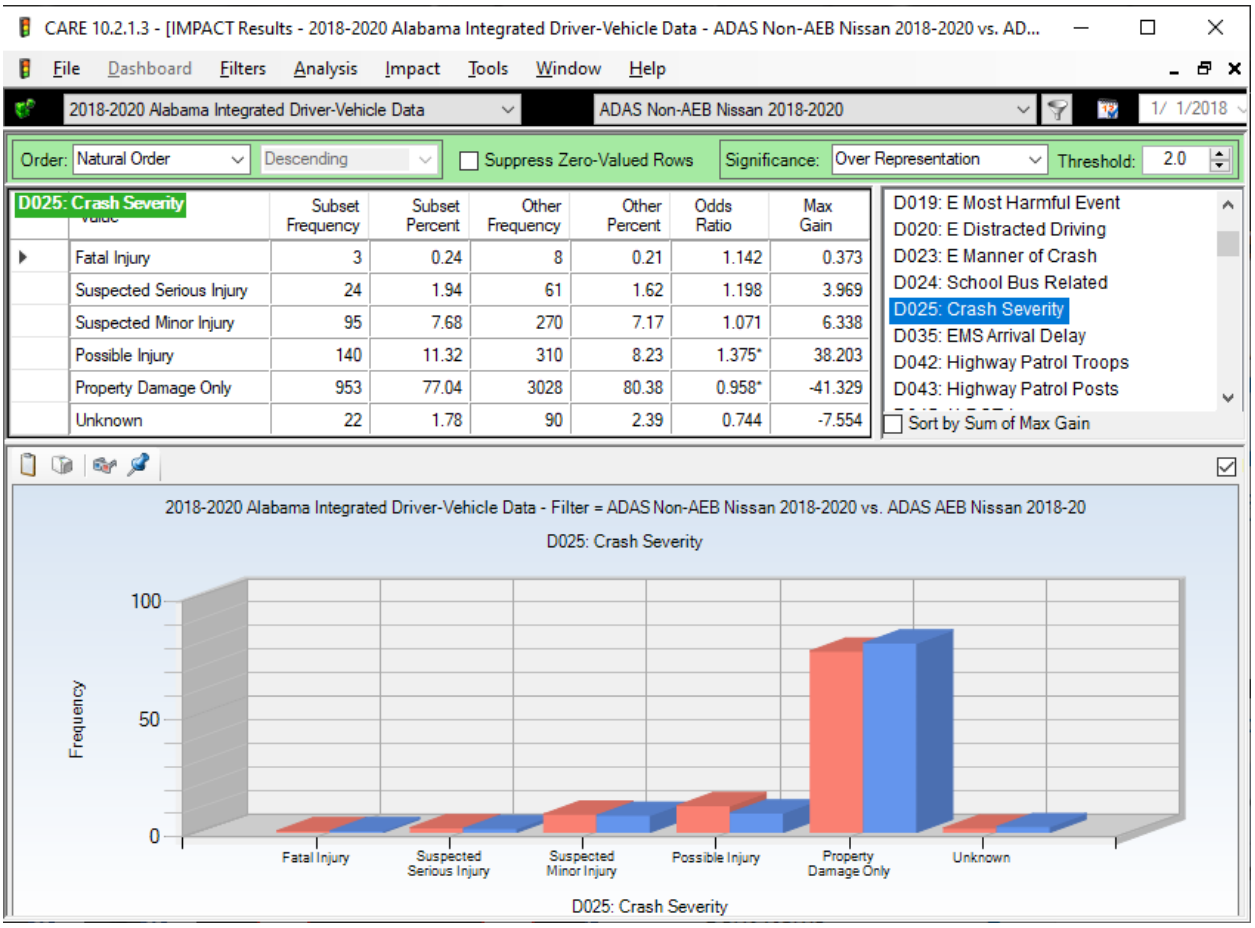
The total Max Gain that indicates the potential reduction is 196 vehicle-crashes.

D023 Manner of Crash



The attribute with the highest Max Gain (46) here would definitely be influenced by AEB/FCW. Side impacts could also be reduced or mitigated by AEB/FCW.

D025 Crash Severity (in worst first order)



There are severity gains in all injury categories, and the gain in Possible Injury is statistically significant. This demonstrates that even if a crash is not averted by AEB/FCW, its severity could be reduced to prevent fatalities and severe injuries.

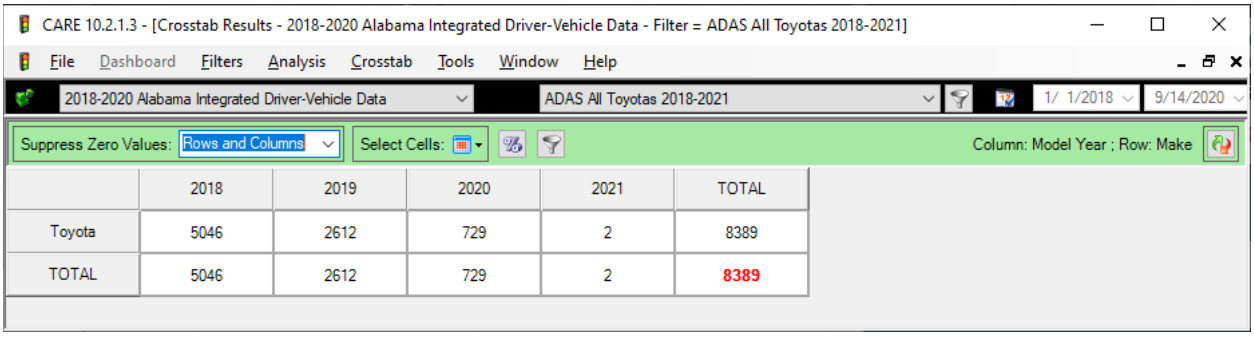
End of AES combined with FCW analysis.

2.0 ADAS Blind Spot Warning (BSW) Example

Methodology Applied to Blind Spot Warning

Toyota subset used in to create models with BSW:

1. Start with all Toyotas 2018-2021



	2018	2019	2020	2021	TOTAL
Toyota	5046	2612	729	2	8389
TOTAL	5046	2612	729	2	8389

This same basic subset will be used to generate both the Toyota BSW and the Toyota Non-BSW subsets since the differences between them will be the models. Note a total of 8389 Toyota vehicle-crashes are in the 2018-2020 Dri-Veh file. The model years of 2018-2021 will be for the specific BSW and Non-BSW subset generations.

2. The contents of the subset from 1 is obtained from a DataGen using the filter above. Essential variables that must be included in this DataGen are:

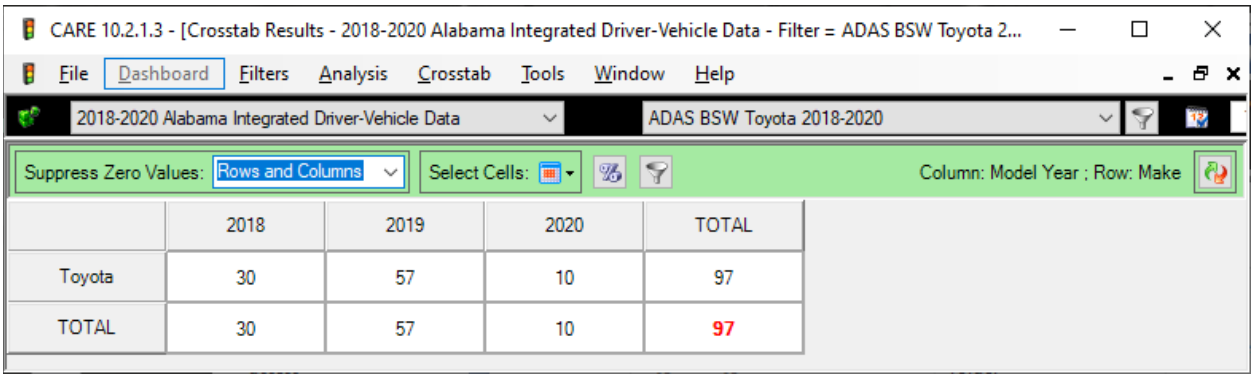
- **208 Model Year,**
- **209 Make,**
- **NCV003 Care DV Case Number NCV, and**
- **NCV005 Vehicle Model NCV**.

The contents generated by the DataGen are under the **Toyota ALL 2018-21** tab of the **ADAS BSW Datagen Proc-v01.xlsx** Excel file. The DataGen for the filter above produced 8,389 records. These will be used to produce the Toyota BSW and the Toyota NonBSW filters.

3. **Creating BSW filter for 2018-2020 Toyotas.** To qualify for BSW: 2019 and 2020: **Avalon, Land Cruiser, Marai (not listed for 2020; possible discontinue), Sequoia;** 2018: **Not Avalon, Land Cruiser, Marai, Sequia (if all three, underlined).**

Number after eliminating doubtful and non-BSW models = 97. The text file name generated from the reduced DataGen is **ADAS BSW Toyota.txt**.

4. The filter generated from the was called **ADAS BSW Toyota 2018-2020**. Of the 97 in the original list, 97 vehicle crashes were generated according to this filter generation:

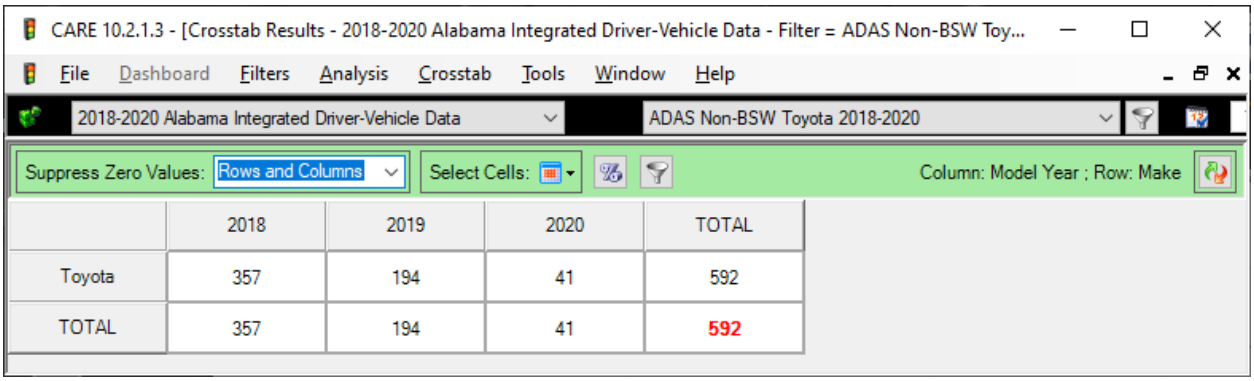


All vehicle-crashes specified here were 2018-20 Toyotas; not sure how/why we lost the 2021s.

5. Creating Non-BSW filter for 2018-2020 Toyotas. To qualify for Non-BSW: all 2018, 2019 and 2020: **4Runner and 86.** Some others qualified but not in all years. Yaris was ambiguous.

Number after eliminating doubtful and clearly non-BSW models = 592. These are in the ADAS LKA Datagen Proc-v01.xlsx under the **Toyota Non-BSW 2018-2020** tab. The text file name generated from this DataGen is **ADAS Non-BSW Toyota.txt**.

6. The filter generated from this was called **ADAS Non-BSW Toyota 2018-2020**.
Of the 592 in the original list, all 592 survived the filter generation.

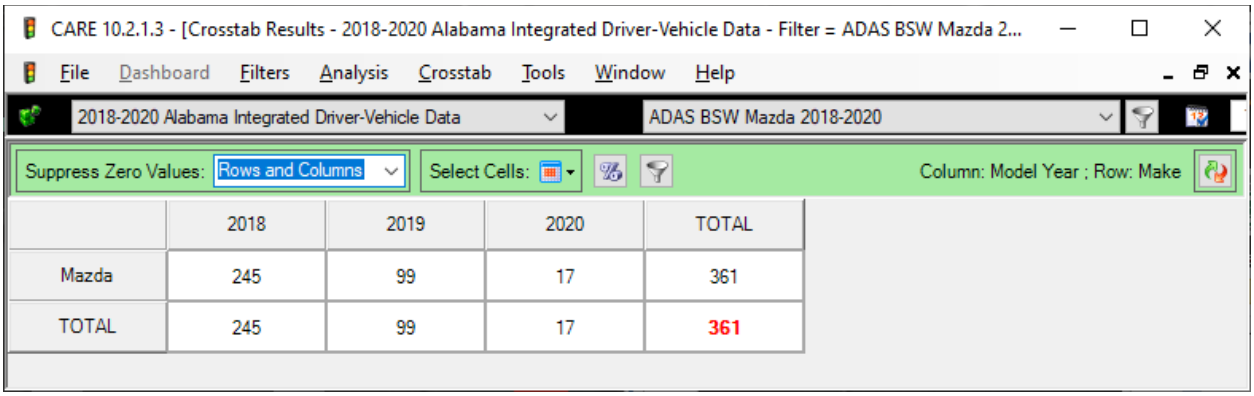


7. The BSW subset can now be compared with the Non-BSW subset. The **ADAS Non-BSW Toyota 2018-2020** filter is made current, and it is compared against the subset generated by the **ADAS BSW Toyota 2018-2020** filter.

8. However, since there does not seem to be a comparable number of vehicle-crashes in the two subsets, we will look to add to the BSW effective subset by adding vehicles from the **All Mazda file. Models** that qualify as BSW in that subset include: 2020: **6, CX-3, CX-5, CX-9;** 2019:

same; 2018: **all but CS-3**. These were selected in the and others eliminated under the **Mazda BSW 2018-2020 tab**. Of the 592 Mazda units, 361 qualified according to specifications above.

9. The filter generated from these produced:

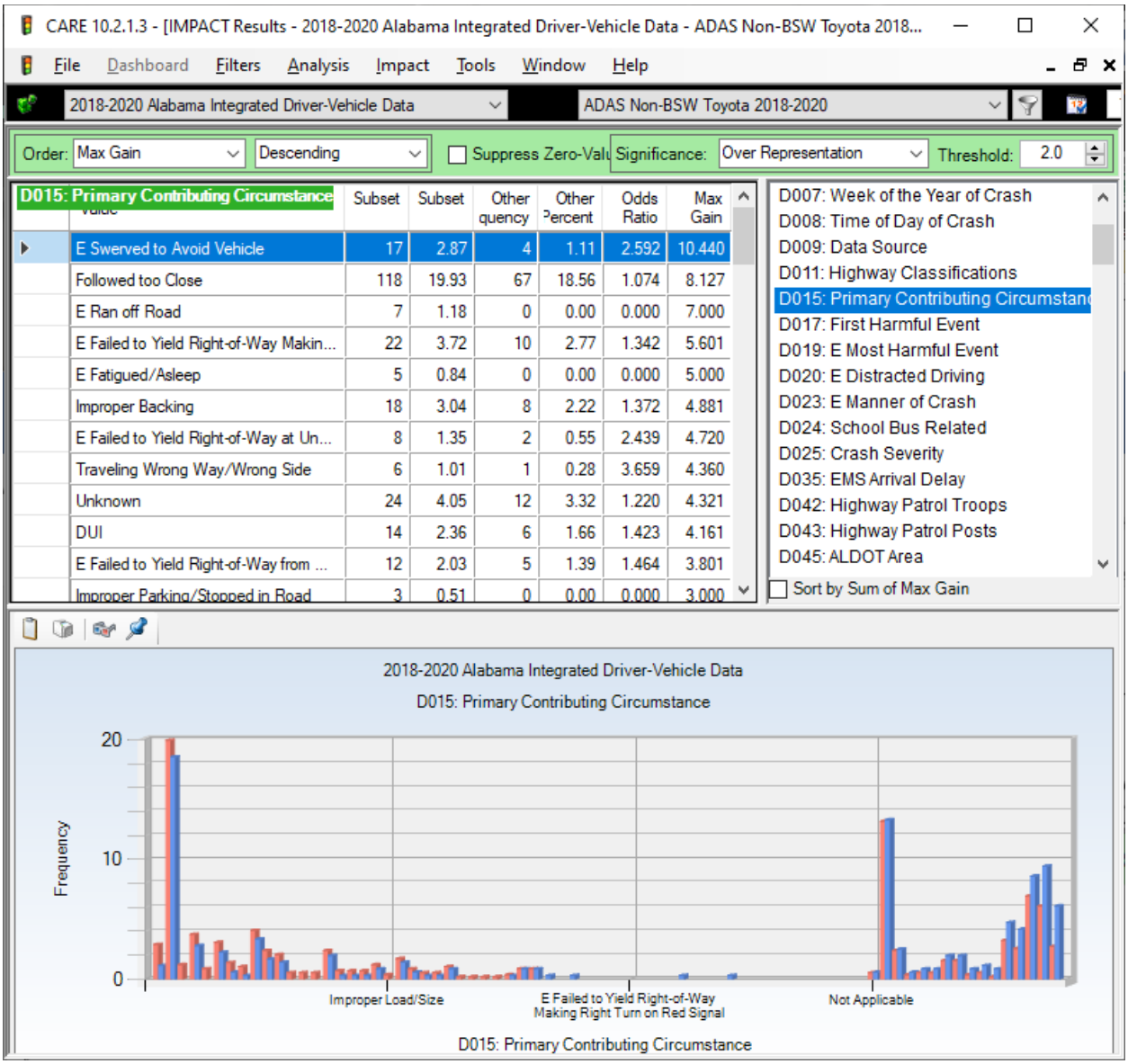


	2018	2019	2020	TOTAL
Mazda	245	99	17	361
TOTAL	245	99	17	361

This filter was used as the "Other" filter and compared against the ADAS Non-BSW Toyota 2018-2020 filter, which was set up as the Subset filter, with the results that follow.

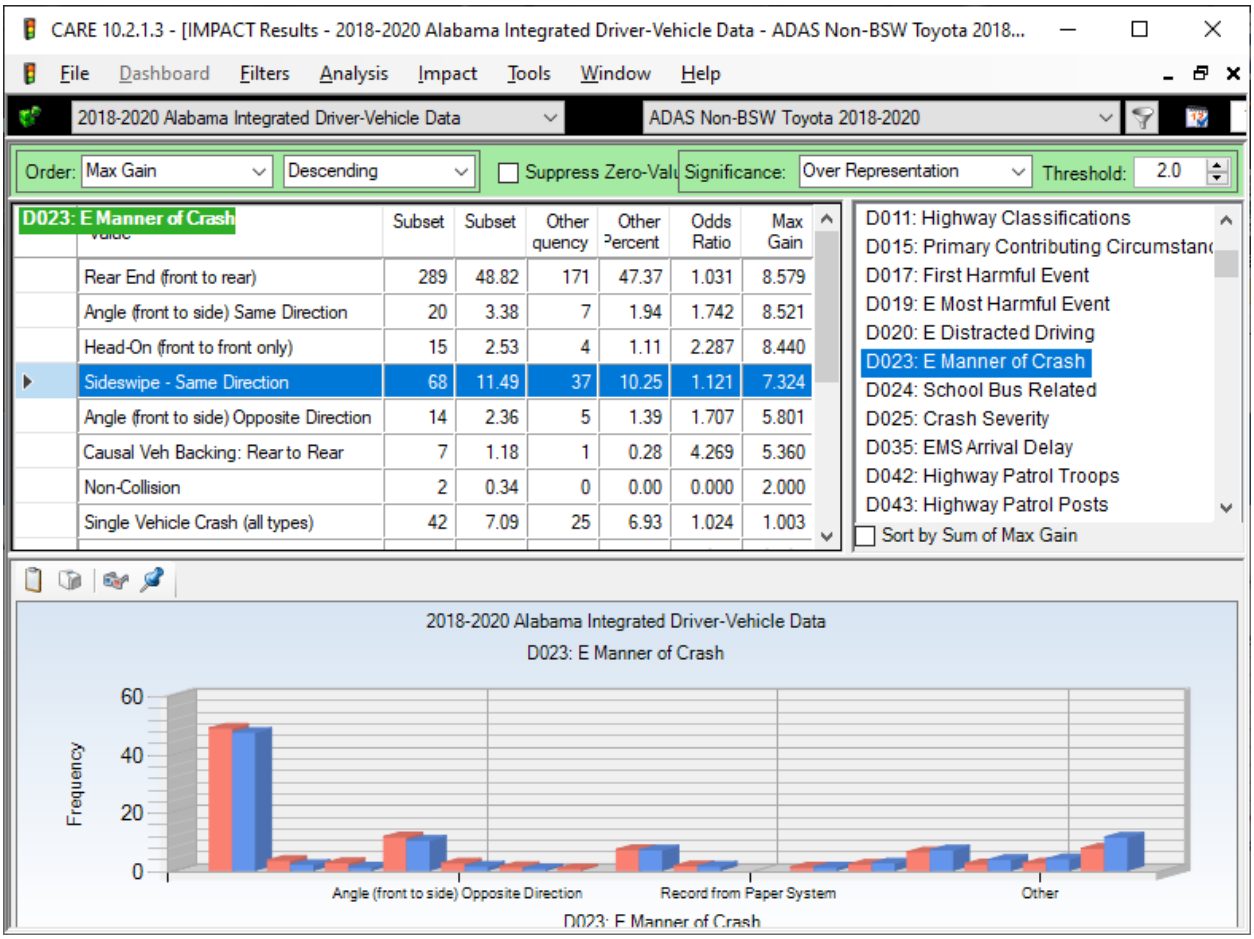
IMPACT Evaluations for Blind Spot Warning

D015 Primary Contributing Circumstances



Swerved to Avoid Vehicle type crashes could have been affected by BSW, which had a Max Gain of a little over 10 vehicle-crashes.

D023 Manner of Crash



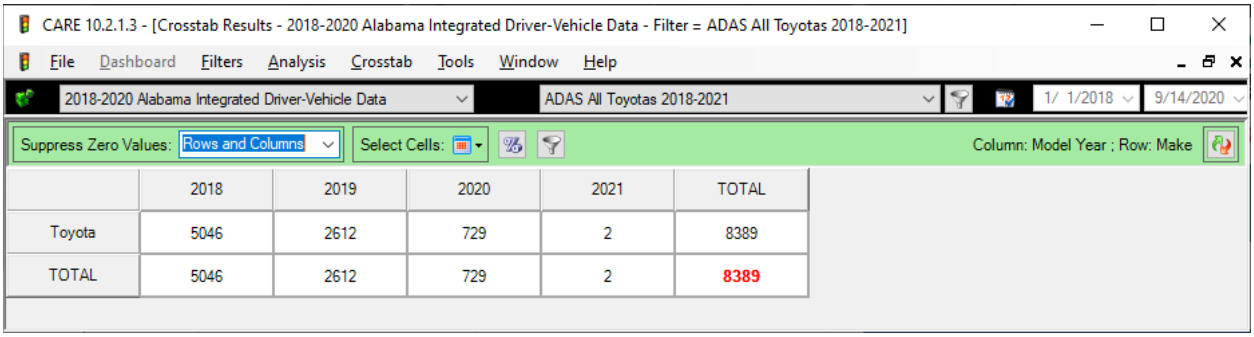
Although not statistically significant, there was a reduction in the proportion of cases in the Side-swipe – Same Direction category of a little over 12%. The low sample size made it impossible to draw any conclusions with regard to Crash Severity, and it is recommended that this analysis be repeated with higher sample sizes.

End of BSW anslysis.

3.0 ADAS Lane Keeping Assistance (LKA)

Procedure Implemented for LKA

1. Toyota subset used in to create models with LKA; start with all Toyotas 2018-2021



	2018	2019	2020	2021	TOTAL
Toyota	5046	2612	729	2	8389
TOTAL	5046	2612	729	2	8389

This same basic subset will be used to generate both the Toyota LKA and the Toyota Non-LKA subsets since the differences between them will be the models. Note a total of 8389 Toyota vehicle-crashes are in the 2018-2020 Dri-Veh file. 2018-2021 will be the model years for the specific LKA and Non-LKA subset generations.

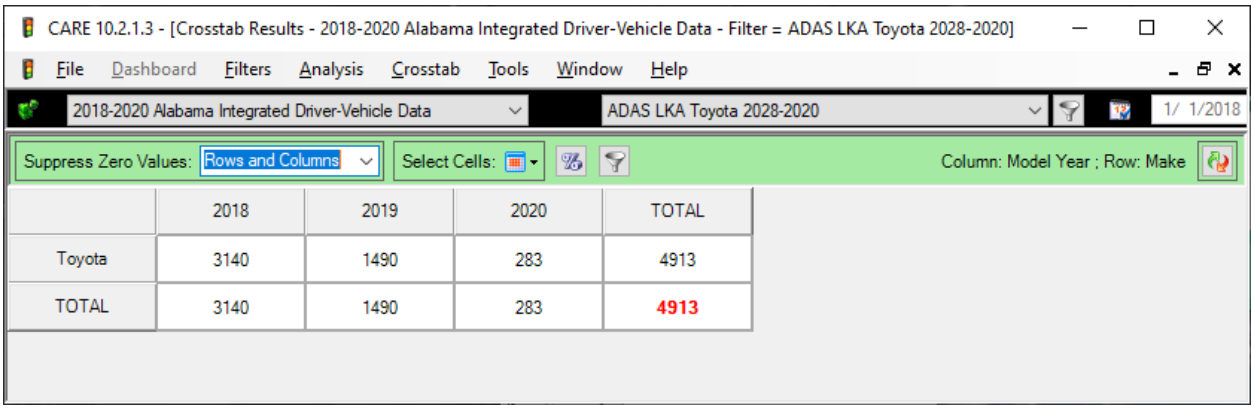
2. The contents of the subset from 1 is obtained from a DataGen using the filter above. Essential variables that must be included in this DataGen are:

- **208 Model Year,**
- **209 Make,**
- **NCV003 Care DV Case Number NCV, and**
- **NCV005 Vehicle Model NCV**.

The contents generated by the DataGen are under the **Toyota ALL 2018-21** tab of the **ADAS LKA Datagen Proc-v01.xlsx** Excel file. The DataGen for the filter above produced 8,392 records. These will be used to produce the Toyota LKA and the Toyota Non-LKA filters.

3. **Creating LKA filter for 2018-2020 Toyotas.** To qualify for LKA: all 2018, 2019 and 2020: **Avalon, C-HR, Camry, Highlander, Oeius, Prius prime, [NOT PriusC,] Rav4 and Sienna**. Number after eliminating non-qualifyin non-LKA models = 4914. The text file name generated from the reduced DataGen is **ADAS LKA Toyota.txt**.

4. The filter generated from the was called. Of the 4914 in the original list, 4913 vehicle crashes were generated according to this filter generation:

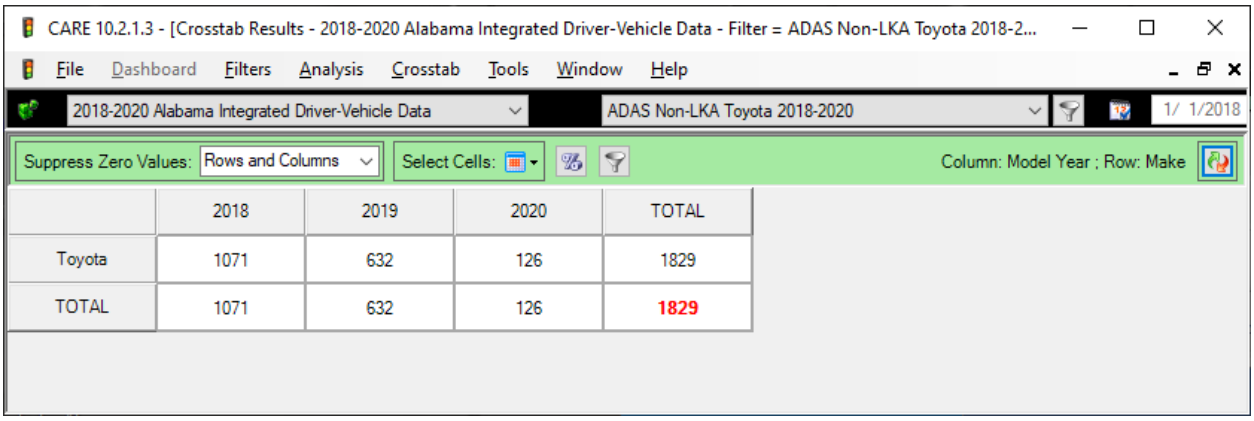


	2018	2019	2020	TOTAL
Toyota	3140	1490	283	4913
TOTAL	3140	1490	283	**4913**

All vehicle-crashes specified here were 2018-20 Toyotas; not sure how/why e lost the 2021s.

5. Creating Non-LKA filter from 2018-2020 Toyotas. To qualify for Non-LKA: all 2018, 2019 and 2020: **4Runner, 86, Land Cruiser, Sequoia, Tacoma, Tundra, Yaris Sedan (IA), Yaris Hatchback.** Number after eliminating doubtful and non-LKA models = 1830. These are in the ADAS LKA Datagen Proc-v01.xlsx under the **Toyota Non-LKA 2018-2020** tab. The text file name generated from this DataGen is **ADAS Non-LKA Toyota.txt**.

6. The filter generated from this was called **ADAS Non-LKA Toyota 2018-2020**.
Of the 1829 in the original list, all 1829 survived the filter generation.

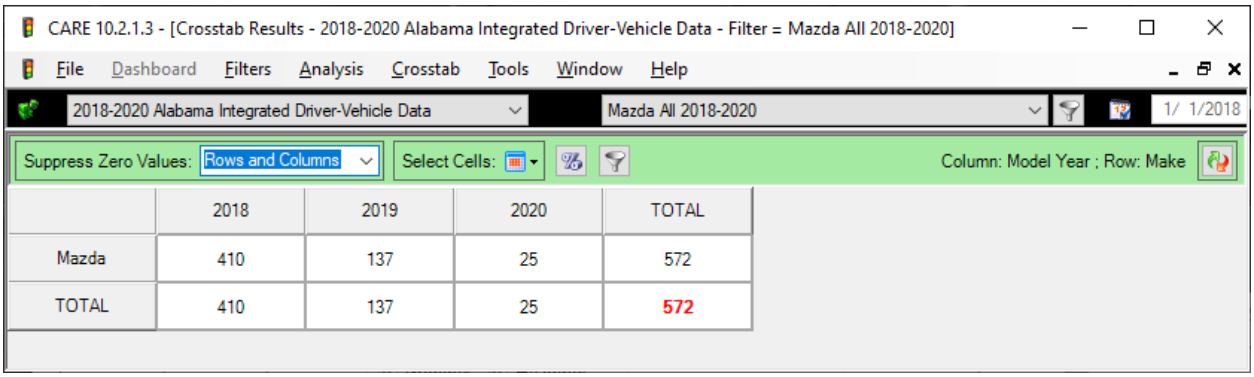


	2018	2019	2020	TOTAL
Toyota	1071	632	126	1829
TOTAL	1071	632	126	**1829**

7. The LKA subset can now be compared with the Non-LKA subset. The **ADAS Non-LKA Toyota 2018-2020** filter is made current, and it is compared against the subset generated by the **ADAS LKA Toyota 2018-2020** filter.

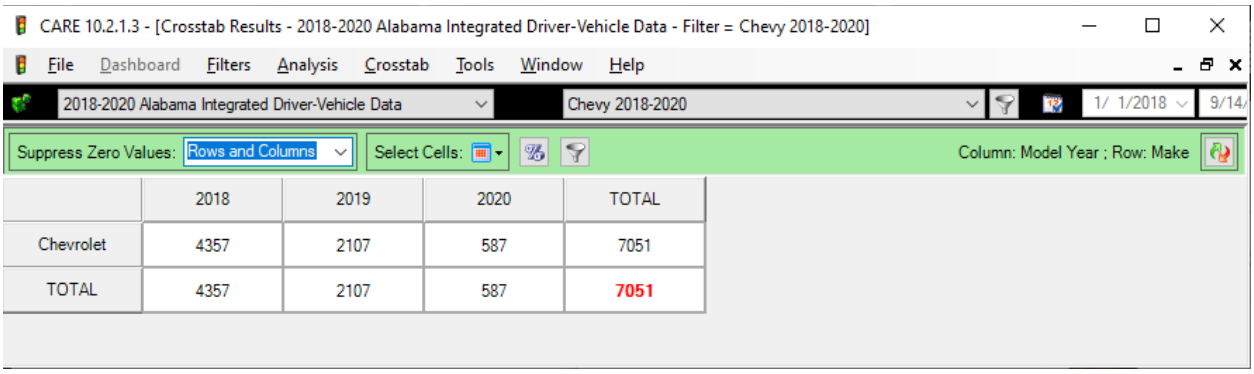
Creating Additional Non-LKA Models

8. Addition of Mazda Non-LKA models. DataGen got 572 cases for all Mazdas, but only 51 were the right models.



	2018	2019	2020	TOTAL
Mazda	410	137	25	572
TOTAL	410	137	25	572

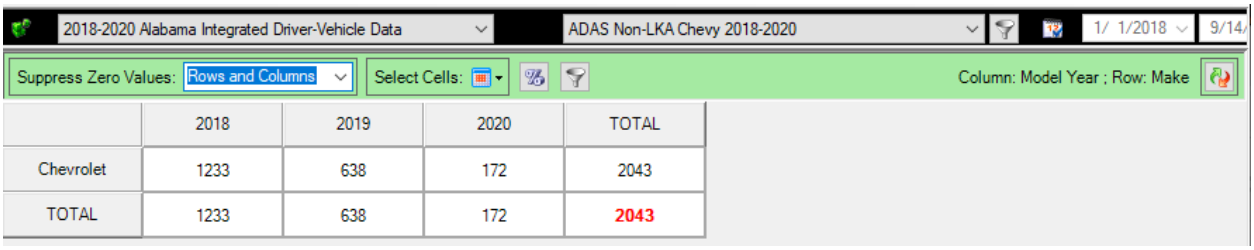
9. Addition of Chevys for non-LKA models. **Chevy Non-LKA models: Camaro, Colorado, Corvette, Silverado (all except 1500), Sonic, Spark, Trax.** DataGen exported 7051 vehicle-crashes. The filter for all Chevys is Chevy 2018-2020, which may be useful in other analyses.



	2018	2019	2020	TOTAL
Chevrolet	4357	2107	587	7051
TOTAL	4357	2107	587	7051

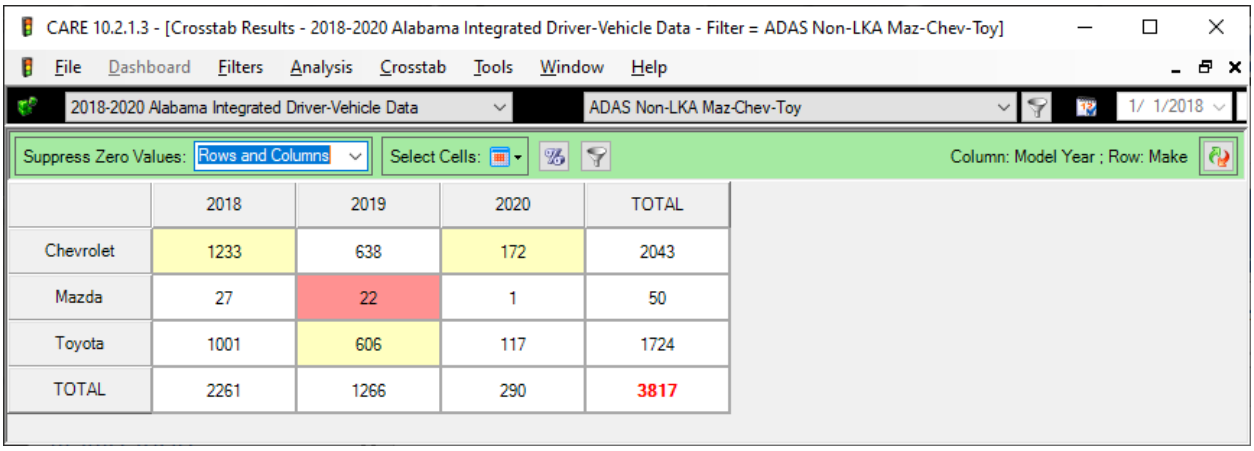
10. Sort by model to easily find the applicable Non-LKA models. 2043 were found to be Non-LKA. The text file for these was called **ADAS Non-LKA Chevy.txt.**

11. The filter generated for these was called **ADAS Non-LKA Chevy 2018-2020.** It included all 2043 vehicle-crashes.



	2018	2019	2020	TOTAL
Chevrolet	1233	638	172	2043
TOTAL	1233	638	172	2043

12. The Mazda, Chevy and Toyota Non-LKA models were concatenated to form a collective filter that was called **ADAS Non-LKA Maz-Chev-Tot.** This produced the following:

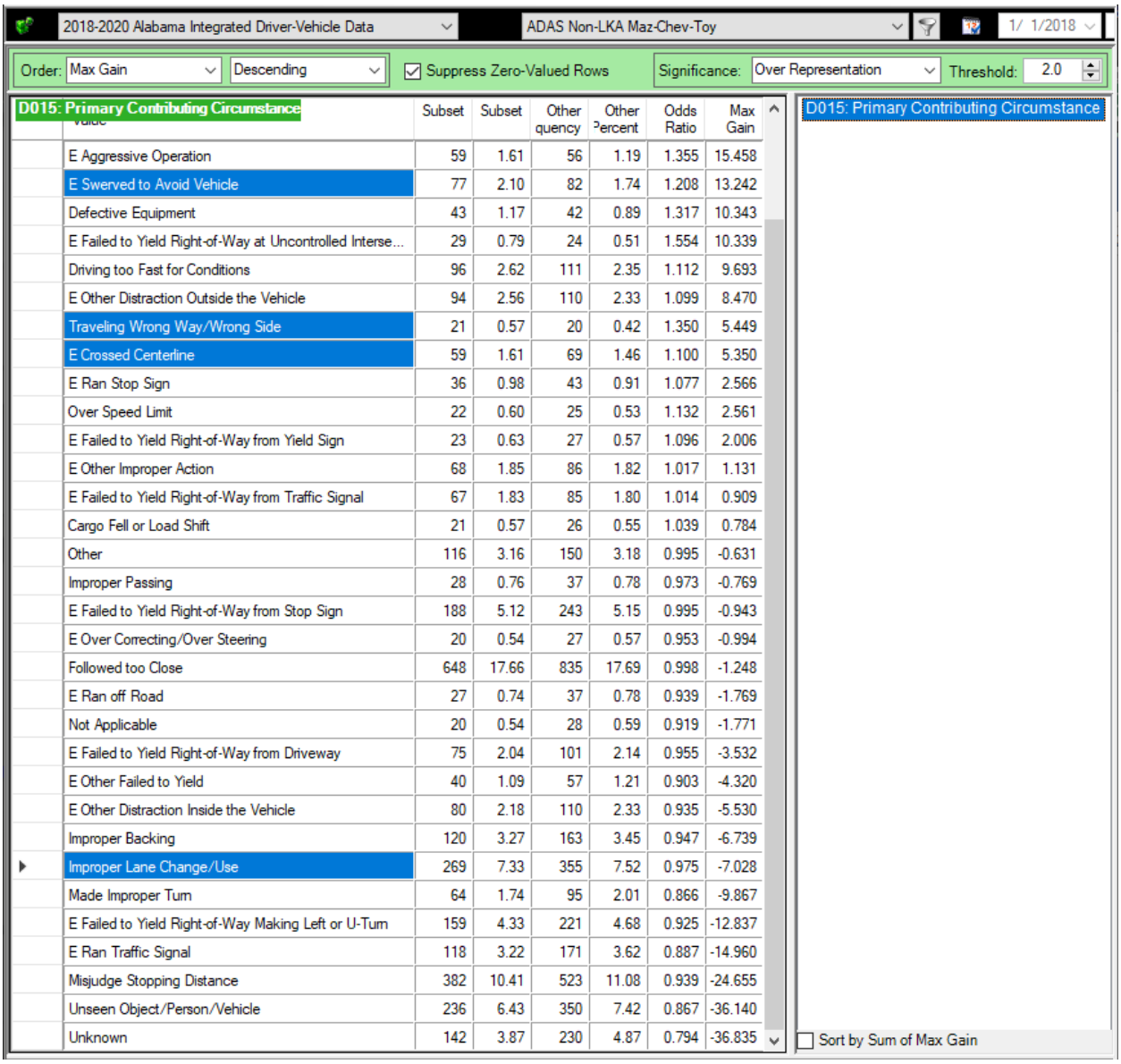


	2018	2019	2020	TOTAL
Chevrolet	1233	638	172	2043
Mazda	27	22	1	50
Toyota	1001	606	117	1724
TOTAL	2261	1266	290	3817

This Non-LKA filter was run against the ADAS LKA Toyota 2018-2020 filter to generate the IMPACT results given below.

IMPACT Results for LKA

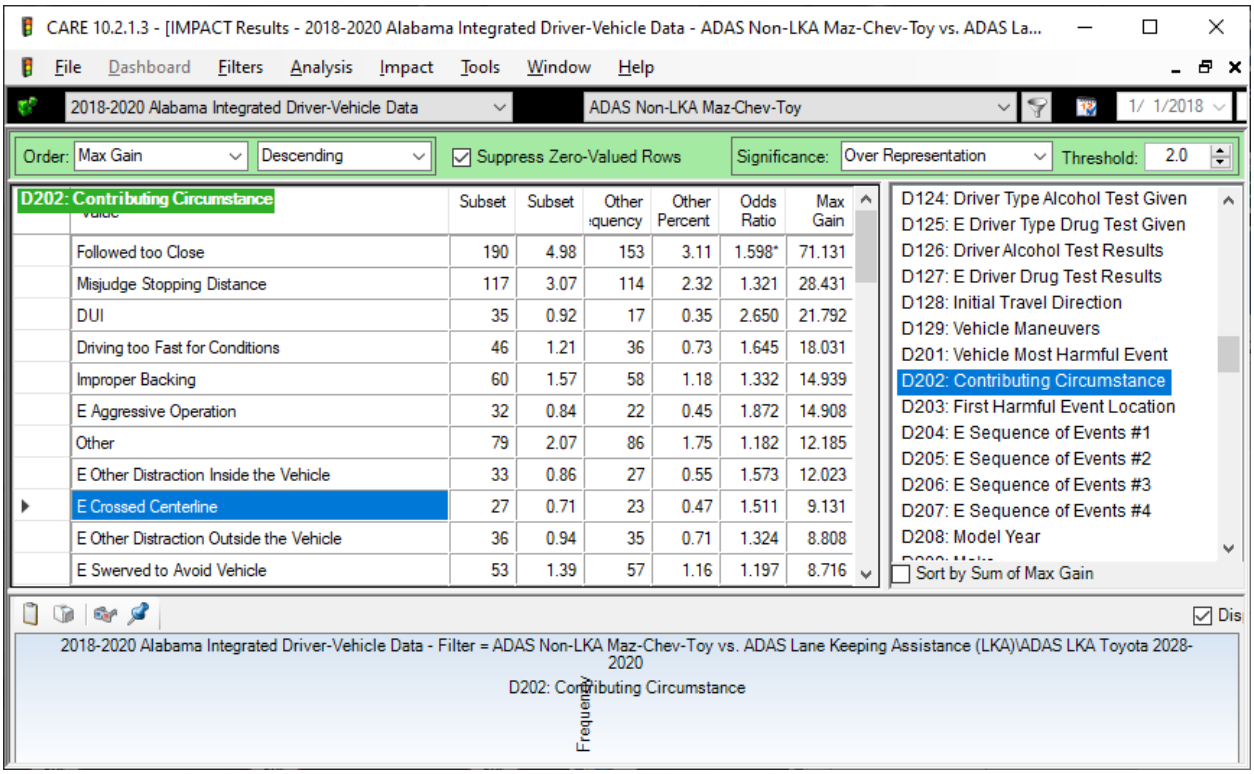
D015 Primary Contributing Circumstances

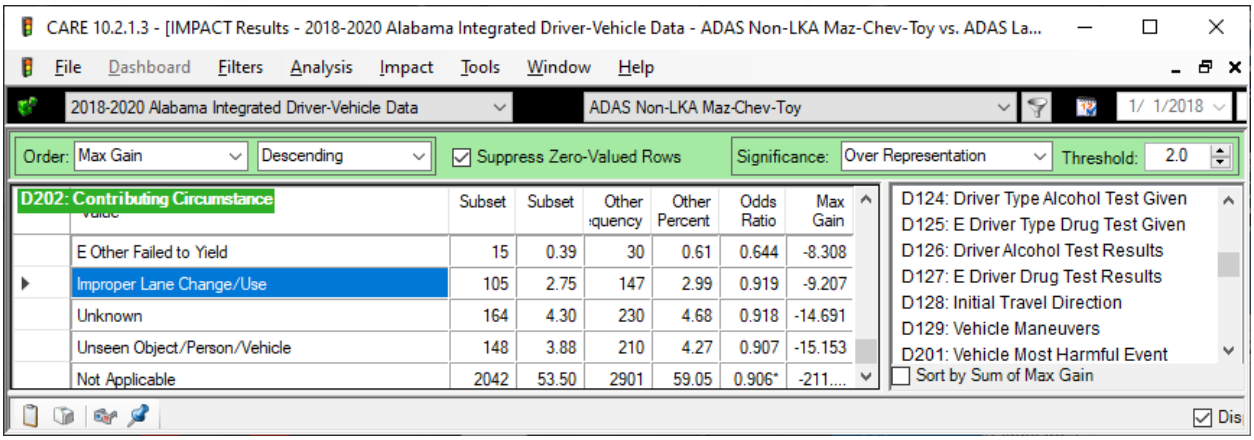


D015: Primary Contributing Circumstance	Subset	Subset	Other quency	Other Percent	Odds Ratio	Max Gain
E Aggressive Operation	59	1.61	56	1.19	1.355	15.458
E Swerved to Avoid Vehicle	77	2.10	82	1.74	1.208	13.242
Defective Equipment	43	1.17	42	0.89	1.317	10.343
E Failed to Yield Right-of-Way at Uncontrolled Intersе...	29	0.79	24	0.51	1.554	10.339
Driving too Fast for Conditions	96	2.62	111	2.35	1.112	9.693
E Other Distraction Outside the Vehicle	94	2.56	110	2.33	1.099	8.470
Traveling Wrong Way/Wrong Side	21	0.57	20	0.42	1.350	5.449
E Crossed Centerline	59	1.61	69	1.46	1.100	5.350
E Ran Stop Sign	36	0.98	43	0.91	1.077	2.566
Over Speed Limit	22	0.60	25	0.53	1.132	2.561
E Failed to Yield Right-of-Way from Yield Sign	23	0.63	27	0.57	1.096	2.006
E Other Improper Action	68	1.85	86	1.82	1.017	1.131
E Failed to Yield Right-of-Way from Traffic Signal	67	1.83	85	1.80	1.014	0.909
Cargo Fell or Load Shift	21	0.57	26	0.55	1.039	0.784
Other	116	3.16	150	3.18	0.995	-0.631
Improper Passing	28	0.76	37	0.78	0.973	-0.769
E Failed to Yield Right-of-Way from Stop Sign	188	5.12	243	5.15	0.995	-0.943
E Over Correcting/Over Steering	20	0.54	27	0.57	0.953	-0.994
Followed too Close	648	17.66	835	17.69	0.998	-1.248
E Ran off Road	27	0.74	37	0.78	0.939	-1.769
Not Applicable	20	0.54	28	0.59	0.919	-1.771
E Failed to Yield Right-of-Way from Driveway	75	2.04	101	2.14	0.955	-3.532
E Other Failed to Yield	40	1.09	57	1.21	0.903	-4.320
E Other Distraction Inside the Vehicle	80	2.18	110	2.33	0.935	-5.530
Improper Backing	120	3.27	163	3.45	0.947	-6.739
Improper Lane Change/Use	269	7.33	355	7.52	0.975	-7.028
Made Improper Turn	64	1.74	95	2.01	0.866	-9.867
E Failed to Yield Right-of-Way Making Left or U-Turn	159	4.33	221	4.68	0.925	-12.837
E Ran Traffic Signal	118	3.22	171	3.62	0.887	-14.960
Misjudge Stopping Distance	382	10.41	523	11.08	0.939	-24.655
Unseen Object/Person/Vehicle	236	6.43	350	7.42	0.867	-36.140
Unknown	142	3.87	230	4.87	0.794	-36.835

All PCCs with less than 20 occurrences were removed from the display. The following show a potential positive result of LKA (Max Gain to the nearest number of vehicle-crashes reduced): Swerved to Avoid Vehicle (13), Traveling Wrong Way/Wrong Side (5), and Crossed Centerline (5). On a negative note, the Improper Lane Change/Use showed a higher proportion of this crash type for the LKA than for the non-LKA, although the small difference would argue that they were effectively the same.

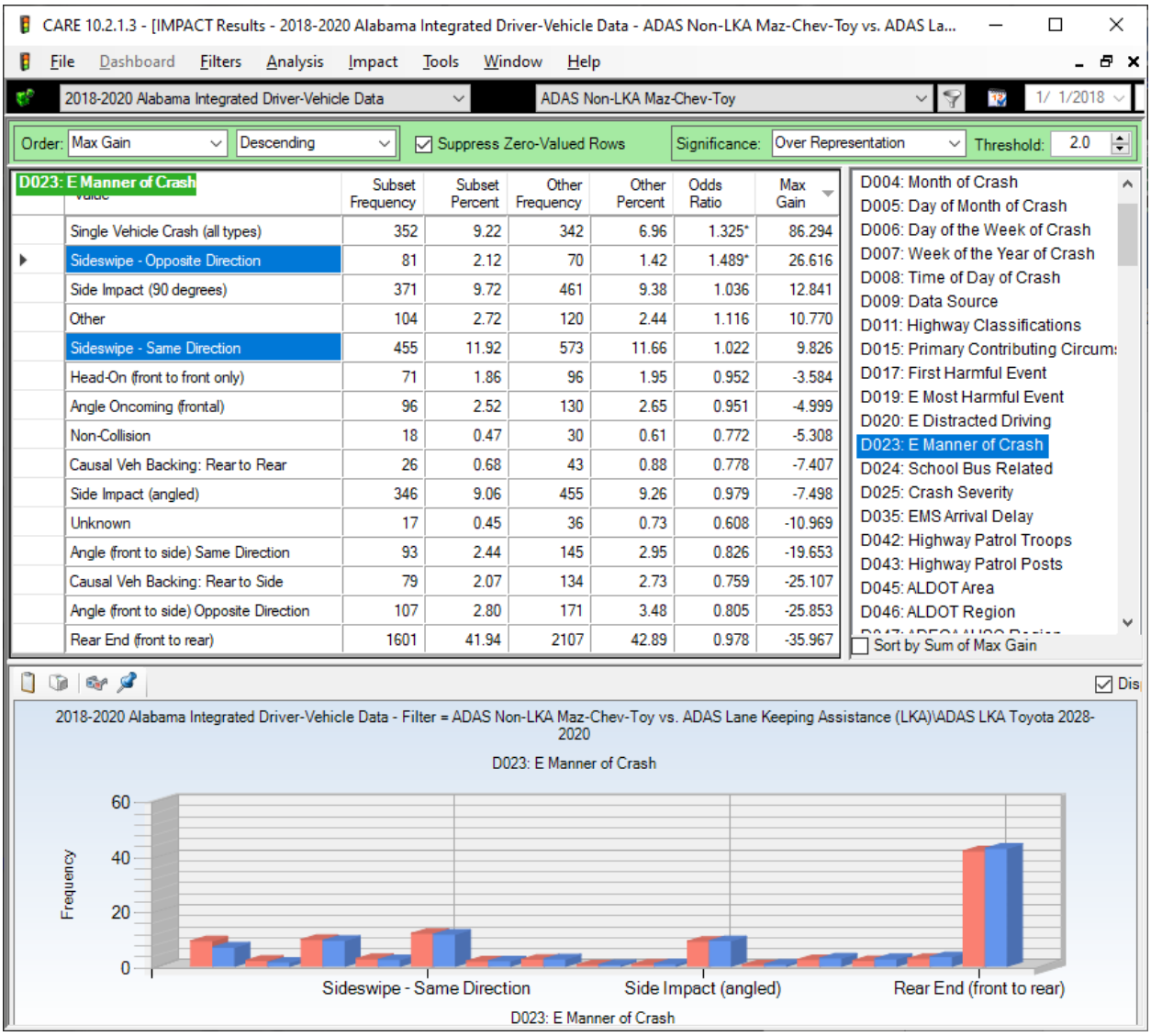
D202 Contributing Circumstances





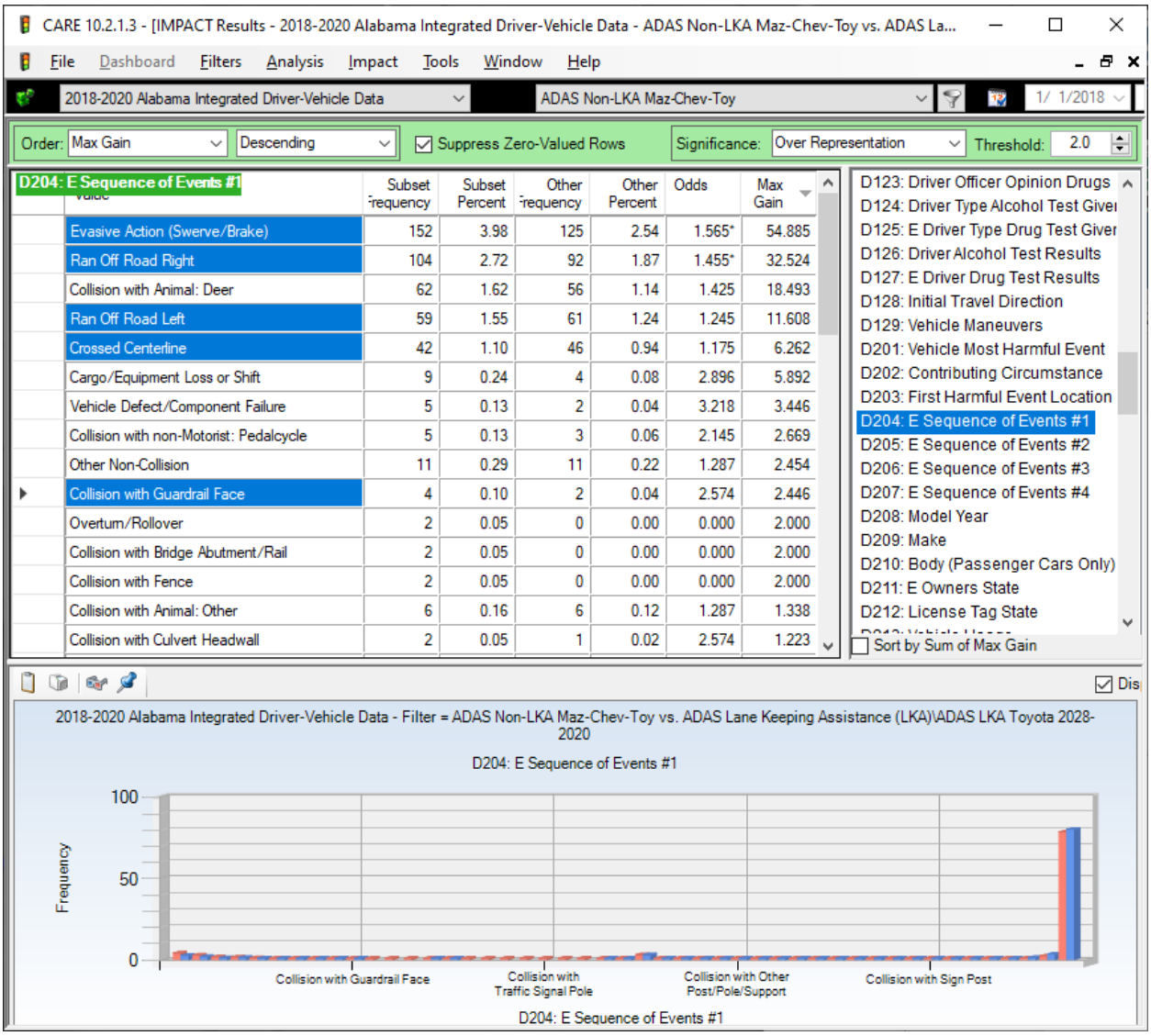
This attribute has one positive result. At the top, there is a reduction of over 50% in the proportion of Crossed Centerline crashes, indicating a savings of over 9 crashes. However, at the bottom of this attribute is an Improper Lane Change/Use result that shows a larger proportion in the LKA subset than in the non-LKA subset.

D023 Manner of Crash



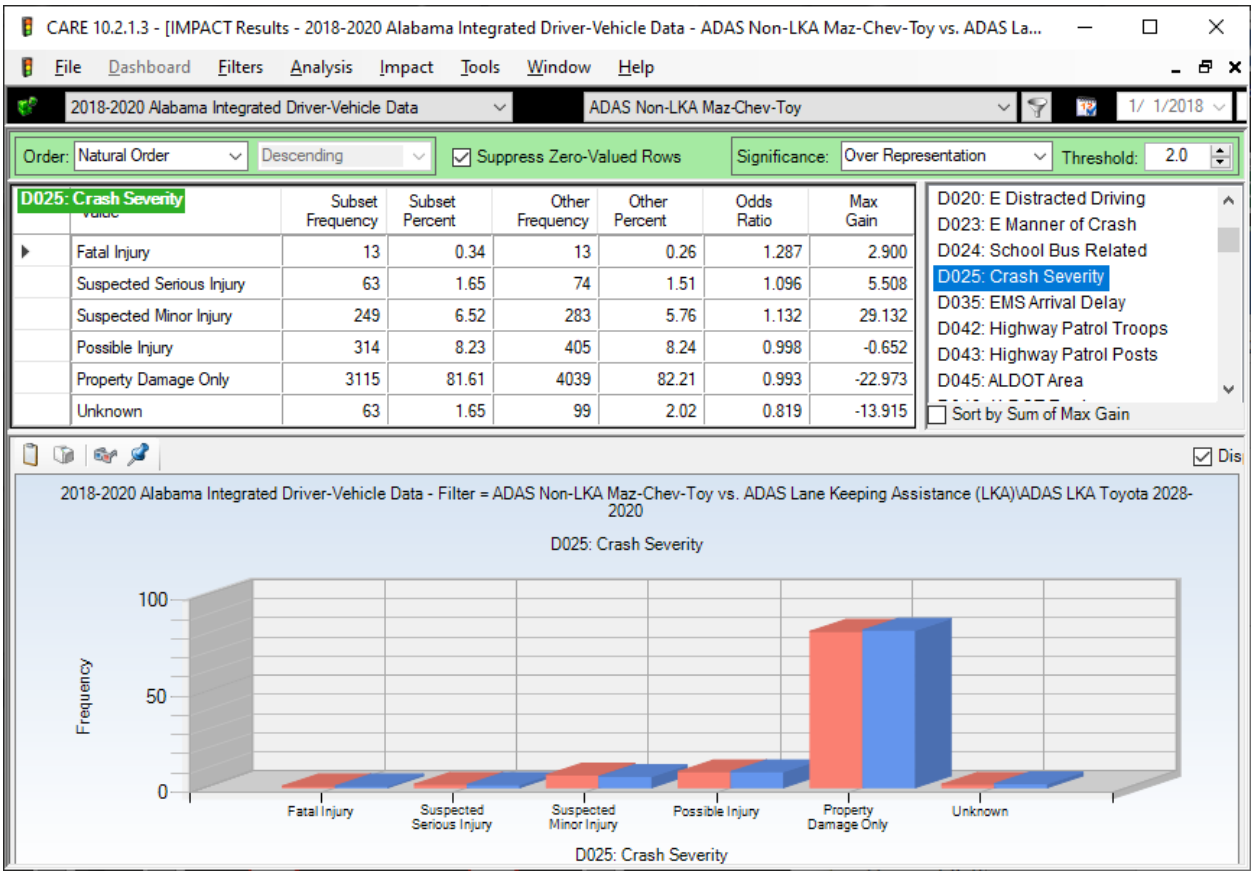
LKA may have caused potential proportionate reductions in Sideswipe – Opposite Direction (26) and Sideswipe – Same Direction (10).

D204 Sequence of Events #1



The proportion of the following crash types (Max Gain) could have been the result of LKA: Evasive Action -- Swerve/Brake (55), Ran Off the Road Right (33), Ran Off the Road Left (12), Colliion with Guardrail/Fence (2).

D025 Crash Severity



All of the most severe crash types were reduced. This shows that LKA could have the effect of warning the driver so that preventive or defensive action could be taken prior to an imminent crash.

End of LKA analysis.

4.0 ADAS Pedestrian AEB (PAEB) and Pedestrian Detection (PD)

The original pedestrian study that used vehicle models is available in version v01 of this document. It was determined that this *Crash-Based* study was more complete and accurate.

Application of the Crash-Based Analysis to PAEB/PD

A Crash-Based study is one where the initial data are obtained from the CARE Crash files as opposed to the CARE Vehicle-Driver files, which is the approach used in all of the other studies in this document.

Pedestrian Automatic Emergency Braking (PAEB) and Pedestrian Detection (PD) were chosen as the first example of a Crash-Based study because it is fairly easy to separate pedestrian crashes from non-pedestrian crashes. We will henceforth call the two pedestrian protection features PAEB/PD. The objective of these types of studies are to determine the change in the probability of a give crash type based on the number of crashes that qualify divided by the total number of crashes in the particular data subset. Consider the data to be in four divisions, as follows:

Numerator	Denominator
Number of Pedestrian crashes in PAEB/PD subset	Total in All-PAEB/PD subset
Number of Pedestrian crashes in Non-PAEB/PD	Total in All-Non-PAEB/PD Subset

Establishing the records (makes and model years) that qualify as PAEB/PD

Makes and Years for which All Models Were Predominantly PAEB/PD

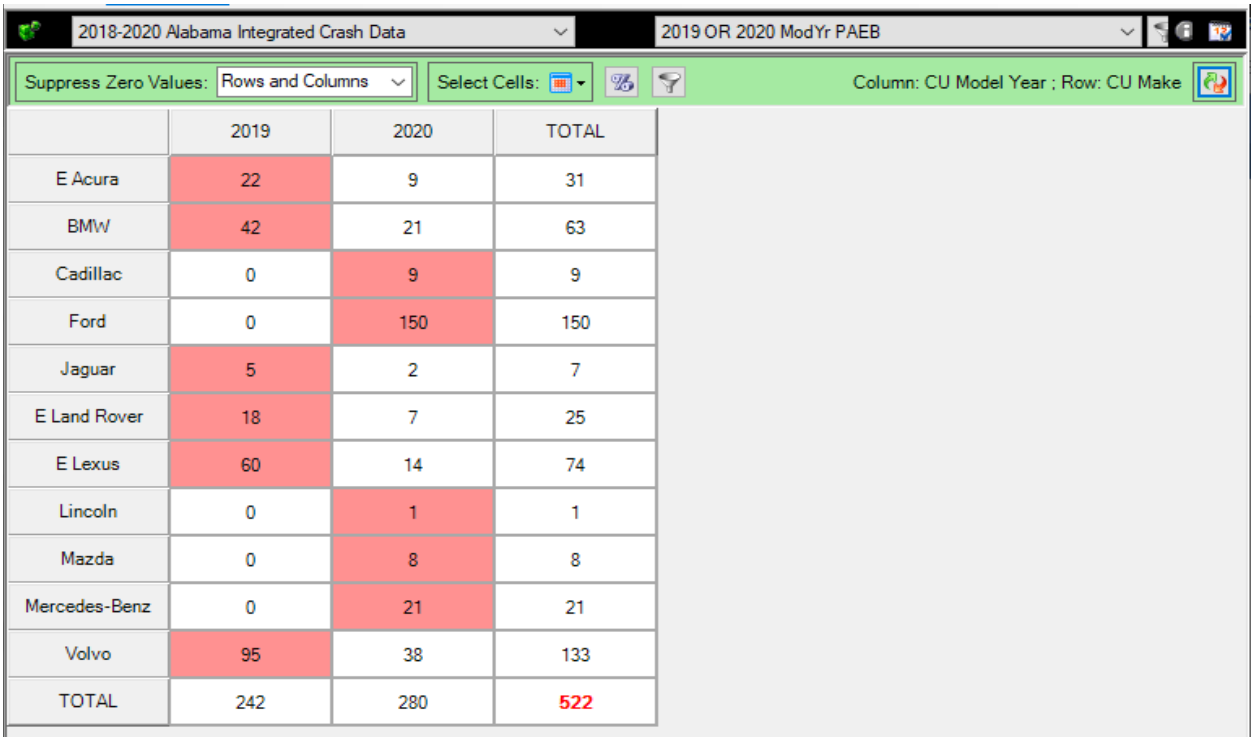
Make	Applicable Years	PAEB Year	PD Year	E-	Eo	#M	#Crashes
Acura	2020 and 2019	2020	2019	2	0	12	31
BMW	2020 and 2019	2020	2019	0	3	31	63
Cadillac	2020	2020		1	1	7	9
Ford	2020	2020		1	3	14	150
Genesis	2020 and 2019	Not Found	Not Found	0	0	3	
Jaguar	2020 and 2019	2020	2019	0	4	13	7
Land Rover	2020 and 2019	2020	2019	0	2	13	25
Lexus	2020 and 2019	2020	2019	1	0	22	74
Lincoln	2020	2020		0	0	6	1
Mazda	2020	2020		0	0	6	8
Mercedes	2020	2020		3	3	18	21
Mini	2020	Not Found	Not Found	0	0	3	
Tesla	2020 and 2019	Not Found	Not Found	0	0	7	
Volvo	2020 and 2019	2020	2019	0	0	14	123

Applicable Years. Either 2020 or 2019, or both. Entered are the years that were selected that best qualified. In the All Models PAEB/PD table, years that had a significant number of models with a not required (-) or an optional (o) entry were excluded and that year would appear as blank space in the table. For the Non-PAEB/PD Models table, all of the makes were found to be predominantly Non-PAEB/PD.

PAEB and PD Years. In both tables this shows where PAEB and PD were recorded in the Consumer Reports headings for their model tables. In all cases, model year 2020 had an indication for PAEB but none for PD, and model year 2019 had an indication for PD but none for PAEB. This led us to believe that they were probably using these two acronyms interchangeably.

Exception Acronyms. E- (E minus) is the number of exceptions where the model was not PAEB/PD. Eo is the number of exceptions where PAEB/PD was optional. #M is the total number of models listed for each make. All make, model and model year information is from Consumer Reports: [Cars With Advanced Safety Systems - Consumer Reports]

Blank Space and Not Found. Not found indicates that no crashes could be found for that make. This could be that these makes had no crashes. Or, it is also possible that they did not appear in the list of possible makes in the data entry process. Also, if a given year did not qualify because there were too many Non-PD entries in 2019, then a blank space will appear where 2019 might be expected.



	2019	2020	TOTAL
E Acura	22	9	31
BMW	42	21	63
Cadillac	0	9	9
Ford	0	150	150
Jaguar	5	2	7
E Land Rover	18	7	25
E Lexus	60	14	74
Lincoln	0	1	1
Mazda	0	8	8
Mercedes-Benz	0	21	21
Volvo	95	38	133
TOTAL	242	280	522

The cross-tabulation above indicates the number of crashes for each make and year for the PAEB/PD vehicles. The following is a summary of these results:

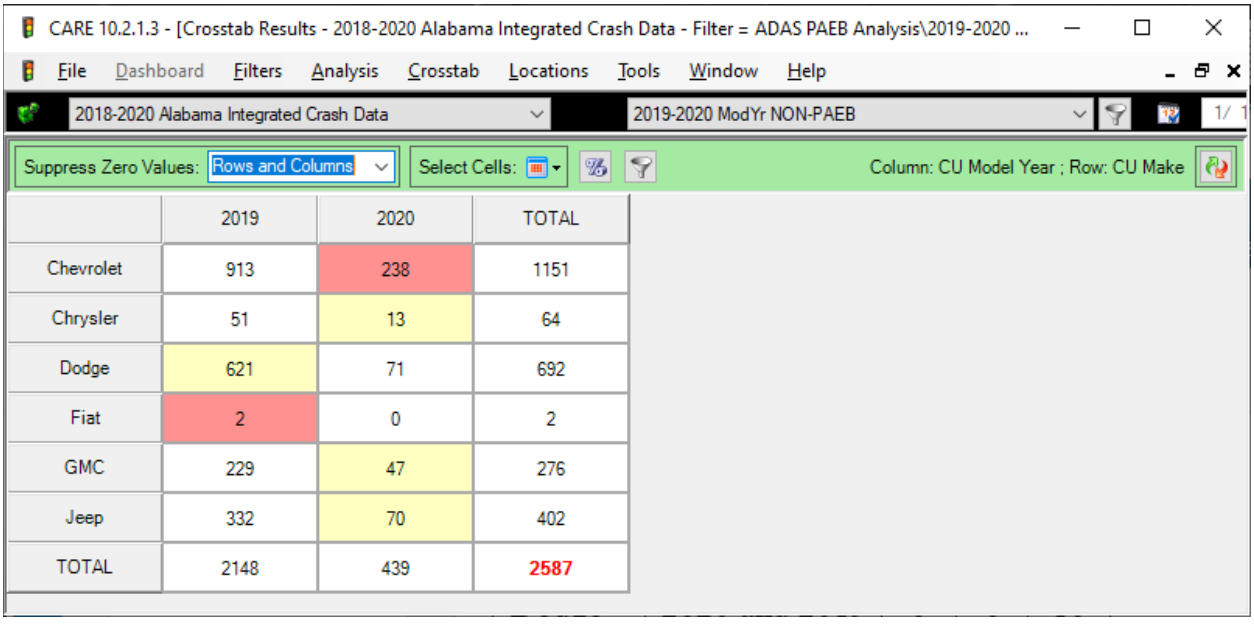
Total number of crashes for the above: 522
Total number of pedestrian crashes of the PAEB/PD vehicles: 0

Establishing the records (makes and model years) that qualify as Non-PAEB/PD

Makes and Years for which All Models Were Predominantly Non-PAEB/PD

Make	Applicable Years	PAEB Year	PD Year	ES	Eo	#M	# Crashes
Chevy	2020 and 2019	2020	2019	1	12	34	1151
Chrysler	2020 and 2019	2020	2019	0	0	5	64
Dodge	2020 and 2019	2020	2019	0	0	10	692
Fiat	2020 and 2019	2020	2019	0	0	7	2
GMC	2020 and 2019	2020	2019	1	5	16	276
Jeep	2020 and 2019	2020	2019	0	0	11	402
Ram*	2020 and 2019	Not Found	Not Found	0	0	8	

*Not found in the crash database, and was assumed to be part of the Dodge crashes reported.

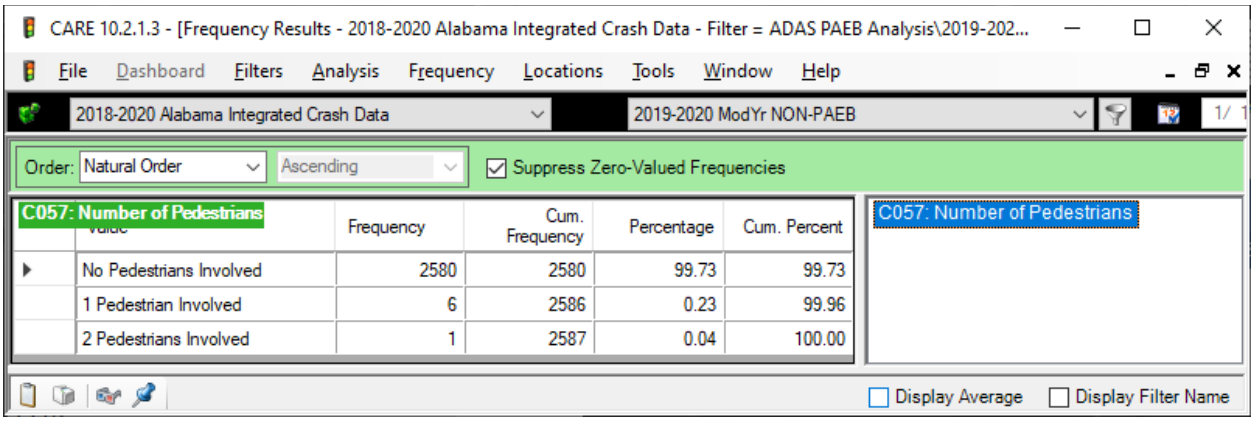


	2019	2020	TOTAL
Chevrolet	913	238	1151
Chrysler	51	13	64
Dodge	621	71	692
Fiat	2	0	2
GMC	229	47	276
Jeep	332	70	402
TOTAL	2148	439	2587

The cross-tabulation above indicates the number of crashes for each make and year for the PAEB/PD vehicles. The following is a summary of these results:

Total number of crashes for the above: 2587
Total number of pedestrian crashes of the Non-PAEB/PD vehicles: 7

This last result was obtained by looking at the C057 Number of Pedestrians for the crashes defined by the filter for the Non-PAED/PD crashes given above. The following is the frequency display for that result:



According to this estimate, the probability of a Non-PAEB/PD vehicle being involved in a pedestrian strike is 7/2587 or 0.00271, which is about one in every 370 crashes.

In the absence of PAEB/PD, the PAEB/PD subset would expect to have 522/370 = 1.41 pedestrian crashes in the 522 crashes that were experienced. Zero crash frequency is a significant reduction from this estimate.

The probability that any given Non-PAEB/PD crash will *not* involve a pedestrian is 1.0 - 0.00271 = 0.9973. Thus, the probability that all 522 are not pedestrian strikes is 0.9973 ^ 522 = 0.243. This is the probability that all of the 522 crashes were non-pedestrian crashes given that PAEB/PD had no effect. If we assumed that PAEB/PD had no effect, the probability that one or more of the crashes in the Non-PAEB/PD subset would involve a pedestrian is 1.0 - 0.243 or about 76%. This represents the confidence that PAEB/PD had the effect of eliminating all of the pedestrian crashes in the PAED/PD subset.

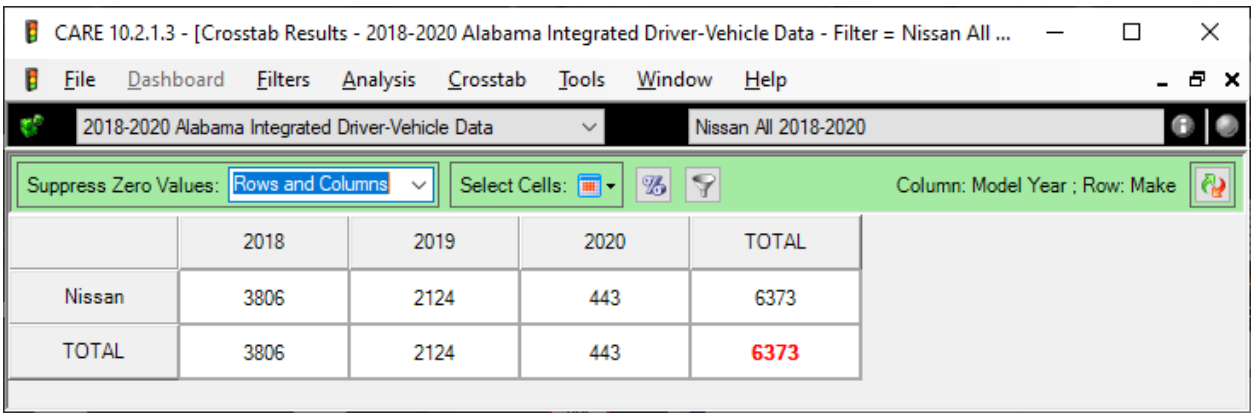
End of PAEB/PD analysis.

5.0 ADAS Rear Cross Traffic Warning (RCTW)

Application of Methodology to RCTW

Nissan subset used in to create models with RCTW:

1. Start with all Nissan 2018-2020



	2018	2019	2020	TOTAL
Nissan	3806	2124	443	6373
TOTAL	3806	2124	443	6373

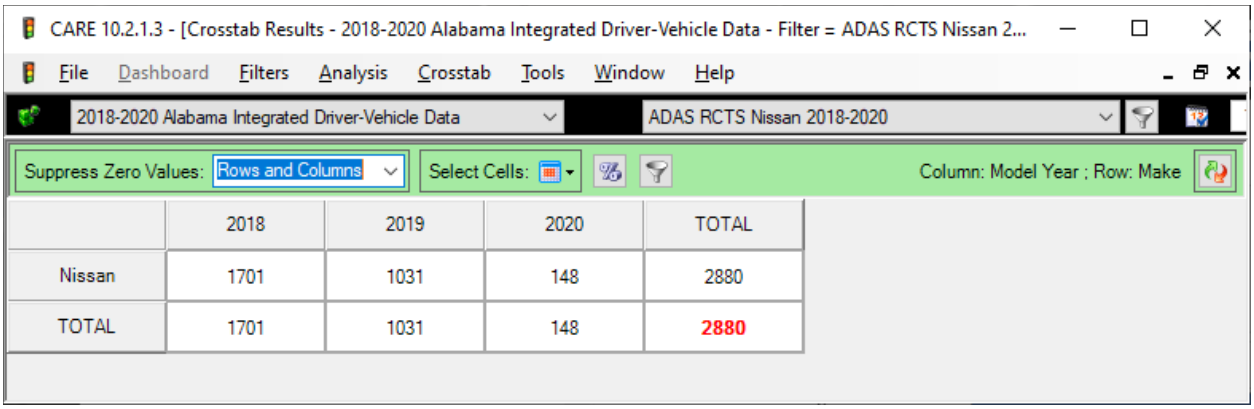
This same basic subset will be used to generate both the Nissan RCTW and the Nissan Non-RCTW subsets since the differences between them will be the models. Note a total of 6373 Nissan vehicle-crashes are in the 2018-2020 Dri-Veh file. The model years of 2018-2020 will be for the specific RCTW and Non-RCTW subset generations.

2. The contents of the subset from 1 is obtained from a DataGen using the filter above. Essential variables that must be included in this DataGen are:

- **208 Model Year,**
- **209 Make,**
- **NCV003 Care DV Case Number NCV, and**
- **NCV005 Vehicle Model NCV**.

The contents generated by the DataGen are under the **Nissan ALL 2018-21** tab of the **ADAS RCTW Datagen Proc-v01.xlsx** Excel file. The DataGen for the filter above produced 6,373 records. These will be used to produce the Nissan RCTW and the Nissan NonRCTW filters. *[Note: these filters were mis-named RCTS.]*

3. **Creating RCTW filter for 2018-2020 Nissans.** To qualify for RCTW: 2020: **Kick, Leaf, Maxima, Rogue, Rogue Sport, Sentra, Titan, Titan XD;** 2019: **Rogue, Rogue Sport;** 2018: **Rogue.** Number found with RCTW feature = 2881. The text file name generated from this reduced DataGen is **ADAS RCTW Nissan.txt**. The filter generated by this text file was called **ADAS RCTS Nissan 2018-2020. It produced the following:**

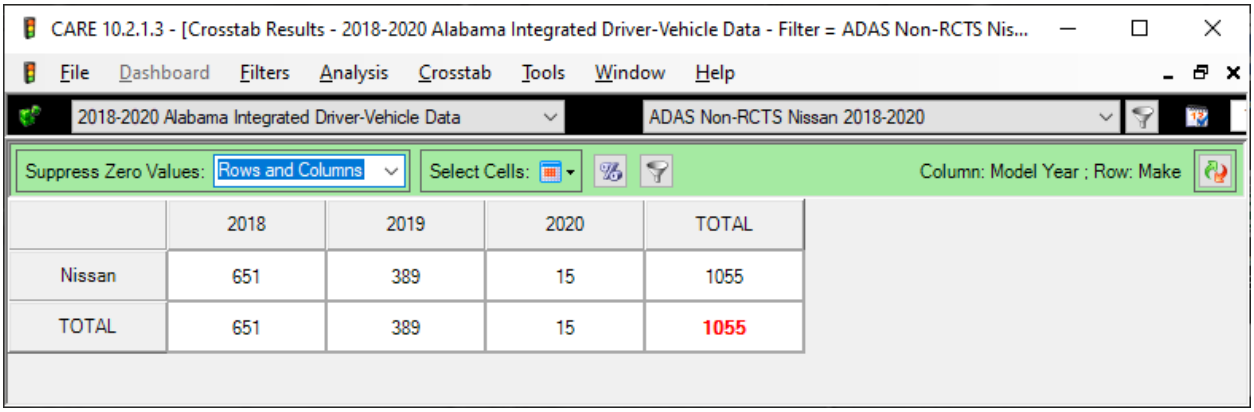


	2018	2019	2020	TOTAL
Nissan	1701	1031	148	2880
TOTAL	1701	1031	148	**2880**

All vehicle-crashes specified here were 2018-20 Nissans.

4. **Creating Non-RCTW filter for 2018-2020 Nissans.** To qualify for Non-RCTW: 2020: **NV, NV200**; 2019: ***Frontier***, **NV, NV200**, ***Versa, VersaNote***; 2018: ***Frontier***, **NV, NV200**, ***Versa, VersaNote.*** Underlined is all three; italicized are 2019 and 2018.

Number found with Non-RCTW feature = 1055. The text file name generated from this reduced DataGen is **ADAS Non-RCTW Nissan.txt**. The filter generated by this text file was called **ADAS Non-RCTS Nissan 2018-2020. It produced the following:**

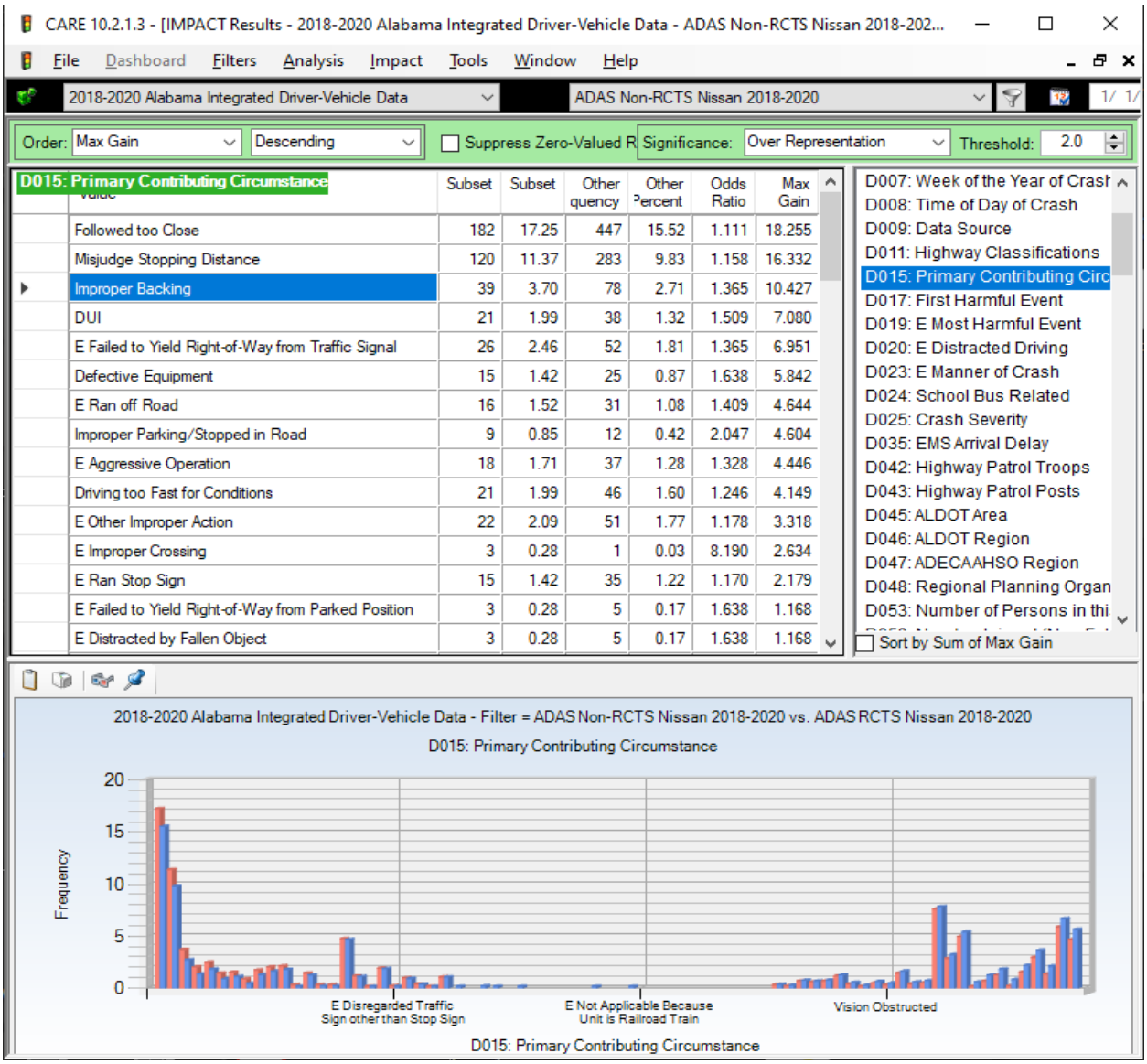


	2018	2019	2020	TOTAL
Nissan	651	389	15	1055
TOTAL	651	389	15	**1055**

5. The RCTW subset can now be compared with the Non-RCTW subset. The **ADAS Non-RCTW Nissan 2018-2020** filter is made current, and it is compared against the subset generated by the **ADAS RCTW Nissan 2018-2020** filter. The following IMPACT comparisons were obtained.

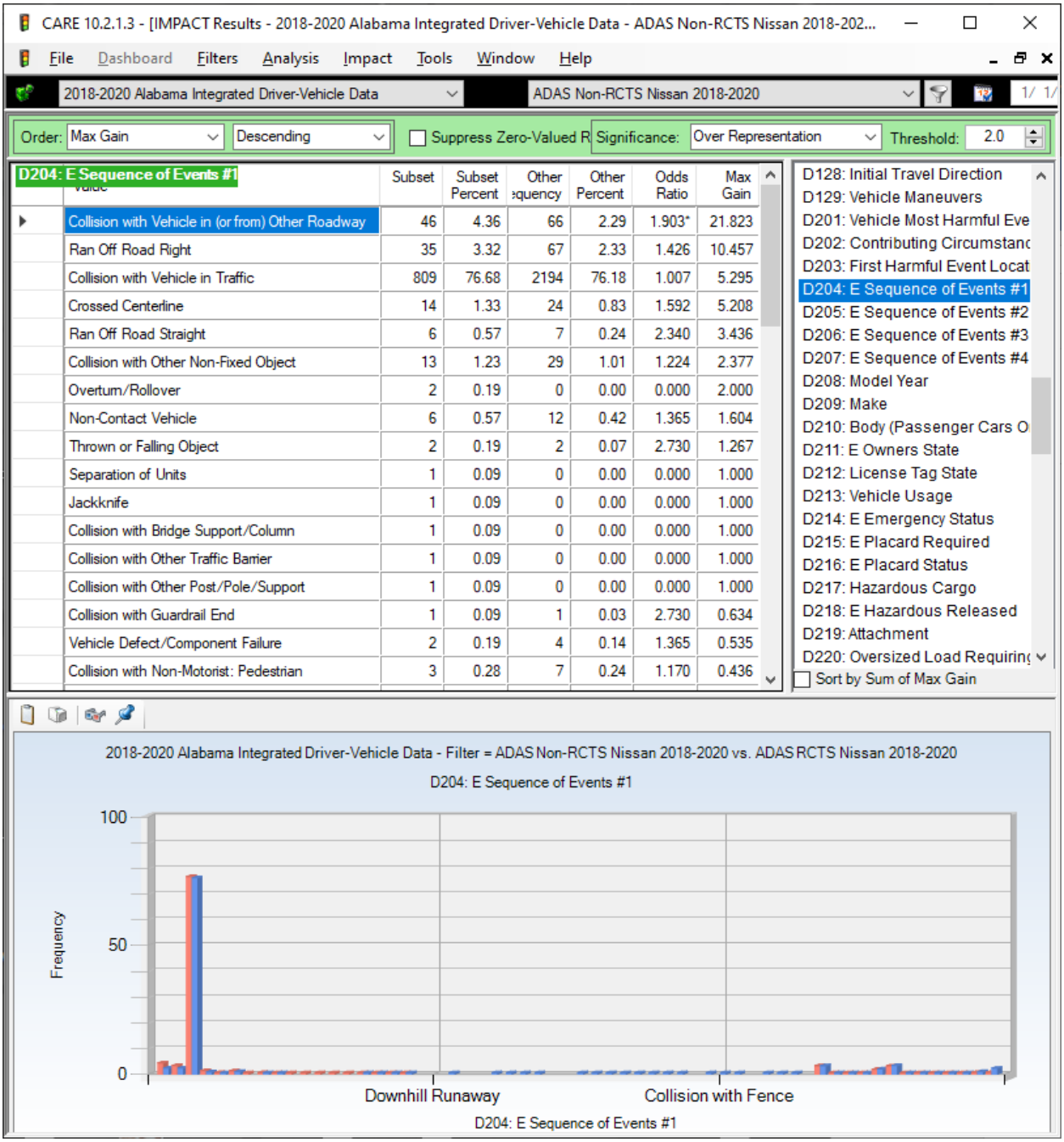
IMPACT Evaluations RCTW

D015 Primary Contributing Circumstances



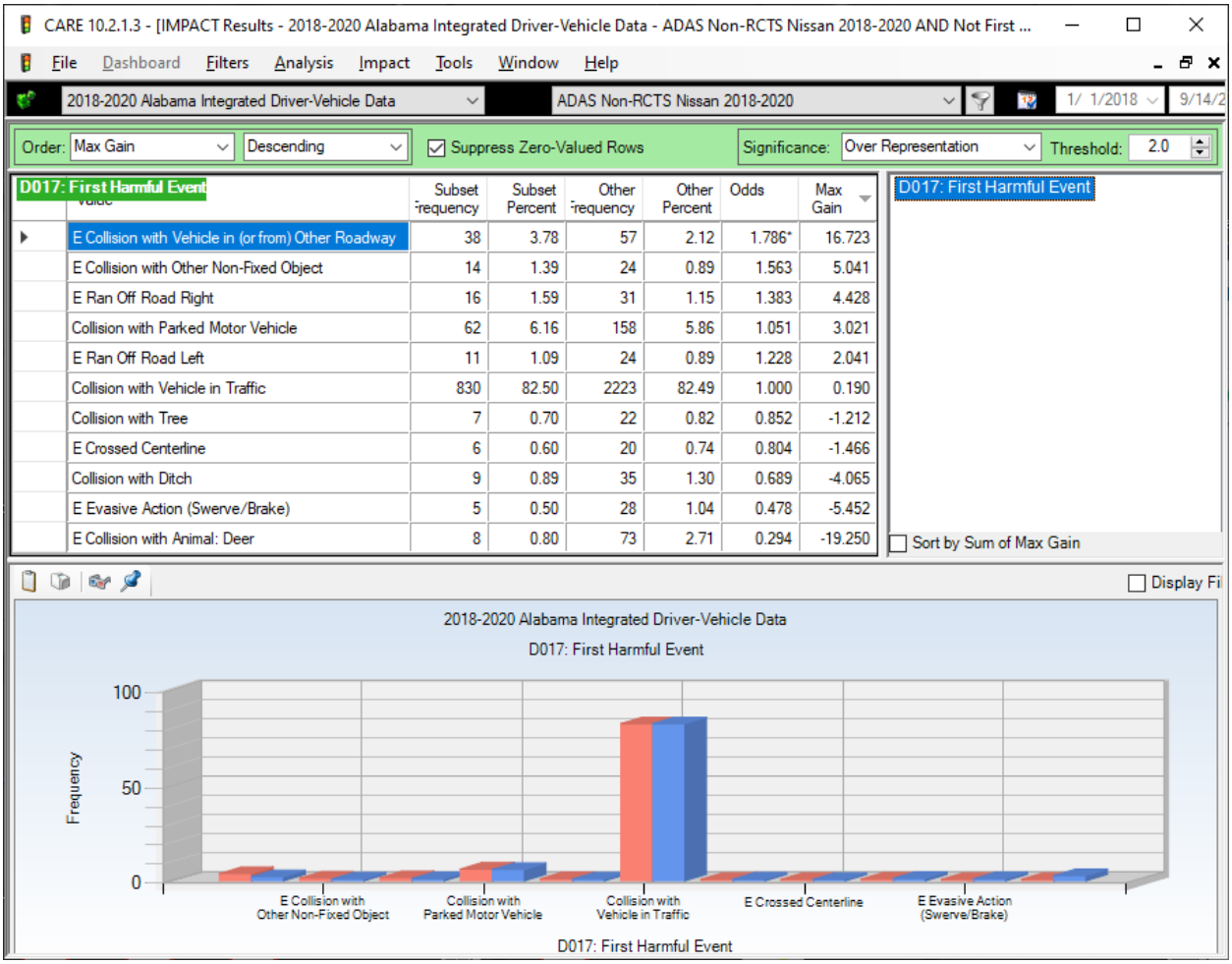
Items with a Max Gain less that 1.0 are not shown. In reviewing these results recognize that the vehicles involved were in a crash, but most of the crashes had nothing to do with RCTW in any way. The results for Improper Backing would be the exception, and they showed a 36.5% reduction proportion of these crash types for this RCTW. The estimate reduction in crashes for these vehicle-crashes is over 10 crashes as measured by the Max Gain.. See also D204 below.

D204 Sequence of Events #1



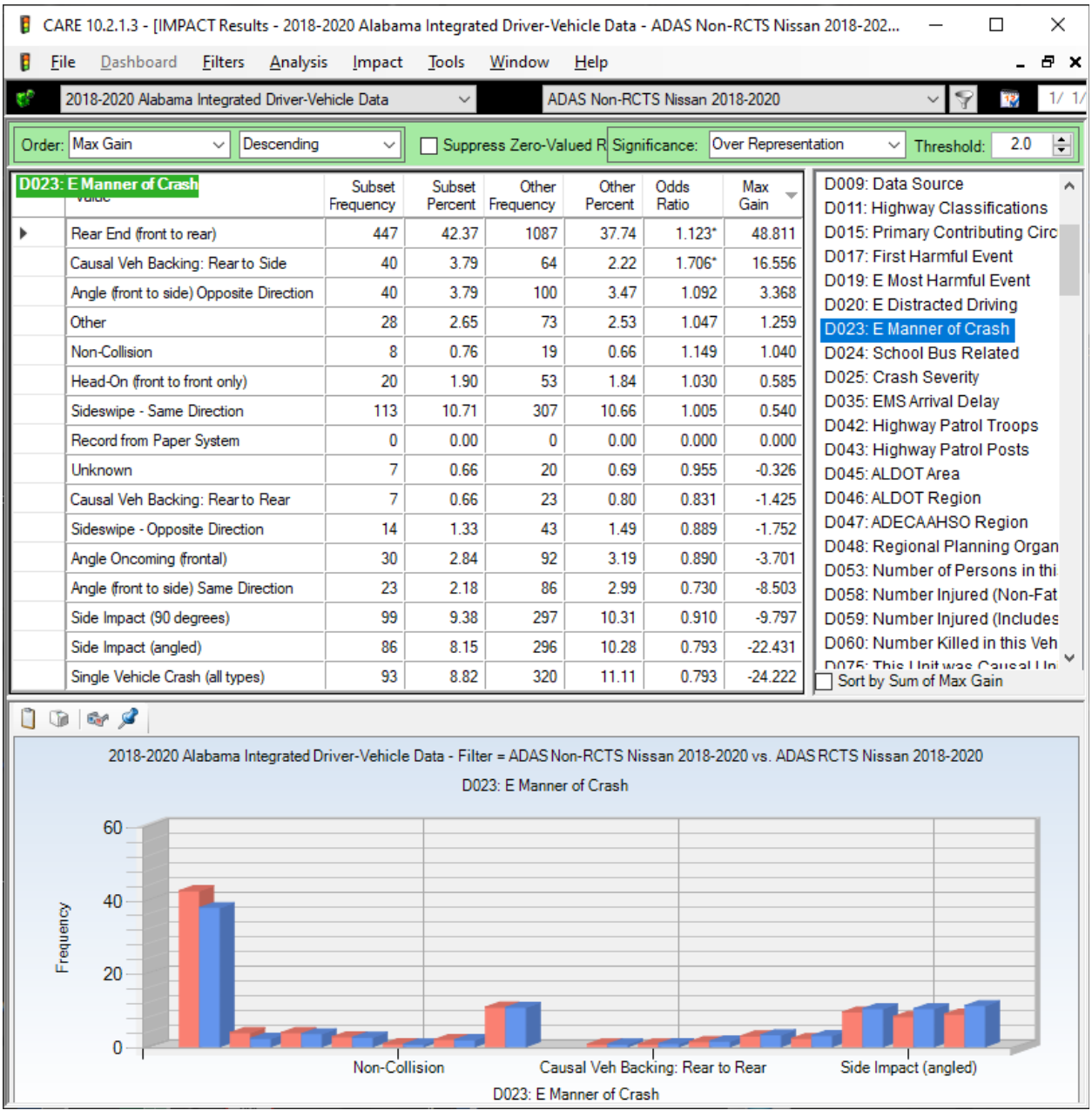
Collision with Vehicle from Other Roadway is not a category that usually rises to the top, but it well could be that this would be the source of vehicles in cross traffic that would be prevented by RCTW. The reduction in the proportions is statistically significant with a Max Gain of about 22.

D017 First Harmful Event



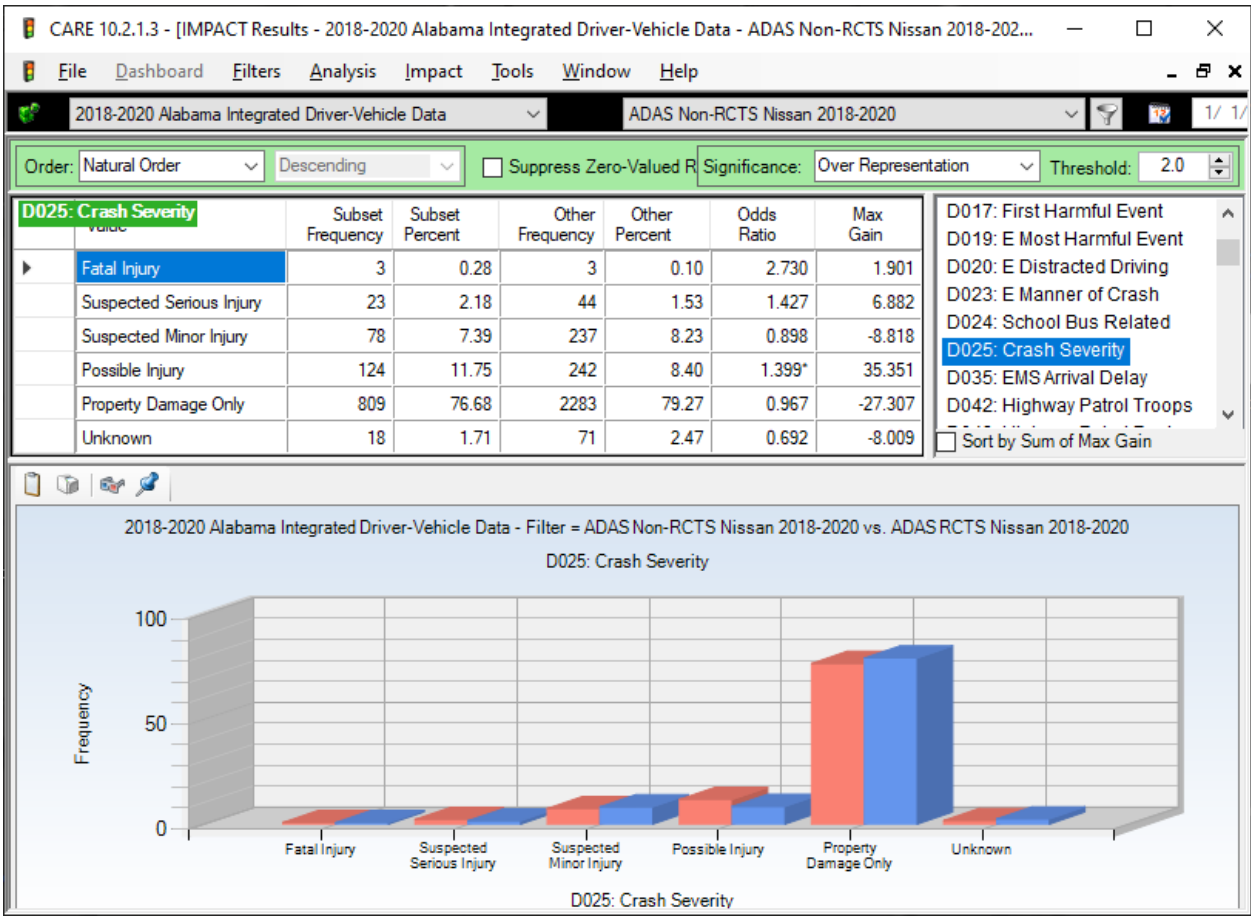
Items with less than 5 subset frequency values were removed from the display. It is notable that the item with the highest Max Gain is relevant to RCTW in that this is exactly the type of crash that RCTW was designed to prevent, i.e., where a vehicle is backing into a cross-street and fails to detect or properly allow for an oncoming vehicle.

D023 Manner of Crash



The top two Max Gain items are both statistically significant, and they would seem to be relevant to RCTW. The first (Rear End, front to rear) has a 12.3% reduction in the crash proportion, while the second (Causal vehicle Backing: Rear to Side) has a 70.6% reduction.

D025 Crash Severity (in worst first order)



There are severity gains in all categories except Suspected Minor Injury. The gain in Possible Injury is statistically significant.

End of RCTW analysis.