Post-Task 2 Report

To the
New England Transportation Consortium (NETC)

Project 2021101200000000359

In-Service Performance Evaluation of New England Transportation Consortium (NETC) Steel Bridge Railings

Task 2: Assemble ISPE Dataset

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Introduction

The primary objective of task 2 was to collect crash data for five years (more if possible) and available traffic data for the NETC bridge railings identified during Task 1. The secondary objective was to assemble the data collected under Tasks 1 and 2 into a single dataset following the NCHRP Project 22-33 Guidance Document specifications for ISPE datasets

The research team worked with the contact person from each member state to collect and assemble the crash data and traffic data. Challenges to assembling the data were identified and discussed during the data attributes meeting on May 18, 2021. These challenges are further discussed in the state-specific methodology sections of this post-task report. The most challenging aspect of the data collection was determining if the crash occurred with the bridge rail, the transition, or on the approach guardrail section near the transition, this challenge was mitigated by careful review of the applicable crash reports.

The location attributes identified under Task 1 (i.e., TOWN, ROUTE, LAT, and LONG) were used to facilitate linking the crash data with the bridge rail and AGT inventory established in Task 1. In most cases the assembled data distinguishes between crashes with each of the inventoried bridge railings as well as the transitions.

Methodology for Identifying Crashes with NETC style Bridge Rails

MaineDOT

MaineDOT provided the 2016-2020 crash data as a single excel workbook file to the research team. Each year was contained on unique worksheet within the workbook, and all worksheets had 267 fields (i.e., columns). Each row of data represented a single person involved in a motor vehicle crash, the number of cases (persons) each year is shown in the upper left corner of Table 1. The data was reduced from the full dataset to only crashes with an NETC bridge rail or AGT in the steps indicated by the flags in Table 1, and described in the paragraphs below.

The first dataset reduction step, indicated by flag 1 in Table 1, was to keep only a single row for each vehicle. In cases where there were multiple occupants in the vehicle the most severe injury sustained by any one occupant of the vehicle was retained as the MAX_SEV of the vehicle. The dataset was further reduced by retaining only crashes which were coded with a longitudinal barrier or bridge code that could be understood as being a bridge rail, transition, or approach guardrail somewhere in the sequence of events. Based on the crash data dictionary definitions provided by MaineDOT the analyst determined that crashes with NETC bridge rails or AGTs could be coded with any of the following in the SEQ_OF_EVENTS fields: ‘28’ Bridge Pier or Support which can include ends or abutments, ‘29’ Bridge Rail, and ‘35’ Guardrail Face.

The second data reduction step, indicated by flag 2 in Table 1, was to identify which vehicles crashed within 1 mile of a bridge with an NETC type bridge rail. This step was accomplished by importing the BRIDGE_NO, LAT, and LONG from the bridge inventory developed in Task 1 along with REPORT_NUMBER, LATITUDE, and LONGITUDE from the MaineDOT crash data into an Excel file. Logic was programed into the excel worksheet to identify which bridge was closest to each crash and what the straight-line distance between the crash and nearest bridge was. Crashes which occurred further than one mile from a bridge with an NETC bridge rail or AGT were eliminated.

The third data reduction step, indicated by flag 3 in Table 1, was to “visit” each crash location that was retained through data reduction step 2 on Google Earth Street View to determine if the vehicle’s crash was likely to have occurred on a bridge with an NETC bridge rail or AGT. This determination was made based on what roadway the crash occurred on, and distance to the bridge. Crashes that were difficult to determine were retained through this data reduction step. The research team requested and received (on July 09, 2021) crash reports for each of the crashes identified in Step 3. Crash scene photos were also requested however, after extensive dialogue between the research team, MaineDOT, and the Maine State Police (MSP) it was revealed that photos are not taken at all crashes and that when photos do exist, they are not maintained in a single state-wide location but rather at each individual precinct. Therefore, the effort to compile photos was determined to be unnecessarily time-intensive and the final step of data reduction would be completed using crash reports only.

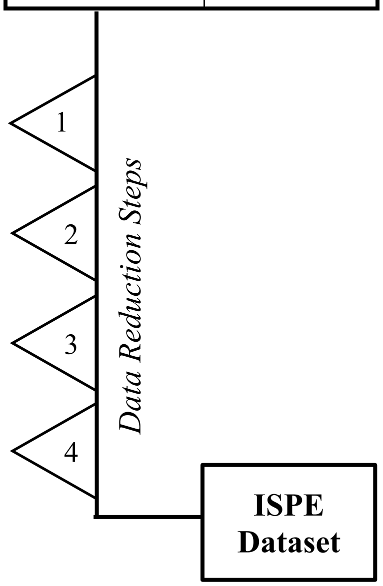
The final data reduction step, indicated by flag 4 in Table 1, was to review each police crash report and identify if the crash involved a NETC bridge rail or AGT and identify the specific bridge rail or AGT design when applicable. This step was accomplished by reading the police report, reviewing the scene diagram, reviewing the crash data, visiting the crash location on Google Earth Street View, and reviewing the bridge inventory. When it was determined that a crash occurred on a bridge with an NETC bridge rail or AGT the ACCIDENT_DATE of the crash data was compared to the bridge inventory INSTALL_YR to ensure that the NETC bridge rail was installed at the time of the crash. In some instances, it was necessary to adjust some data fields based on the review of the police reports. The two most common reasons for editing the crash data were:

1. "Motor vehicle in transport" was coded in Seq of Events 1 for single vehicle crashes. It appears that in some cases officers code Seq of Events 1 the way that Pre-Crash Actions is intended to be used. When this change was made often it led to changes in the FHE and FOHE fields.
2. Multiple impacts into the bridge rail only coded as a single event. Each vehicle interaction with the bridge rail was included as additional lines.

A full listing of changes made to the crash data based on the review of police reports and the reasoning is contained in the Crash Data Change Log sheet of the ME NETC Bridge Rail Crash Dataset Deliverable. Based on the addition of lines for secondary impacts with the bridge rail, the numbers indicated by flag 4 are interactions with an NETC bridge rail or AGT, rather than vehicle crashes.

Table 1. MaineDOT Crash Data Reduction for ISPE of NETC Bridge Rails

Crash Database	
Year	**Cases (persons)**
2016	90,346
2017	94,458
2018	93,344
2019	94,154
2020	71,412



Data Reduction			
◁	**Intent/Codes Removed**	**Data Years**	**Cases (vehicles) Remaining**
1	Retain crashes (one row per vehicle with most severe injury in the vehicle) coded with: '28' Bridge Pier or Support '29' Bridge Rail '35' Guardrail Face in the SEQ_OF_EVENTS1-4 fields.	2016	814
		2017	909
		2018	798
		2019	862
		2020	734
2	Retain only vehicles which crashed within 1 mile of a bridge with an NETC bridge rail/AGT.	2016	150
		2017	160
		2018	134
		2019	141
		2020	137
3	Retain only crashes which are likely to have occurred on a bridge with an NETC bridge rail/AGT.	2016	32
		2017	31
		2018	27
		2019	23
		2020	28
4	Retain crashes which are confirmed, based on review police report and photos, to have interacted with a NETC bridge rail or AGT. Also, add rows for crashes where the vehicle interacted with the SFUEs multiple times.	2016	18
		2017	21
		2018	13
		2019	11
		2020	13

The final number of vehicle interactions with NETC bridge rails or AGTs in the State of Maine from 2016-2020 is 76. The breakdown of number of impacts with each type of bridge rail or AGT design is shown in Table 2. Based on these collected data, an ISPE which does not distinguish by values of NAME (i.e., 2-bar, 3-bar, 4-bar) is recommended. Recent ISPEs of longitudinal barriers that have been performed using the NCHRP Project 22-33 method indicate point estimates ($\hat{p}$) for the Occupant Risk and Post Impact Trajectory Evaluation Measures vary from between 0.02 and 0.05. A precision of 0.01 at 85% confidence interval necessitates a sample size of between 505 and 985 crashes to distinguish between values of NAME, as seen in

Table 3. Assuming an average of 32 interactions per 5-year interval (i.e., maximum for any level of NAME from this dataset) a sample size large enough to provide statistical significance between the different rails would require between 79 and 154 years of Maine data collection. It is recommended that the ISPE does not distinguish between values of NAME, but rather considers the field performance of all the identified NETC rails.

Table 2: Number of Crashes with Specific NETC Bridge Rail or AGT Type in Maine

Component	NAME	Number of Crashes
NETC 2-bar steel bridge rail	a	32
Inconclusive - NETC 2-bar steel bridge rail or MaineDOT 2-bar concrete transition barrier	a or g	6
NETC 3-bar steel bridge rail	b	10
NETC 4-bar bridge rail	c	4
MaineDOT 2-bar concrete transition barrier	g	10
MaineDOT 2-bar concrete transition barrier non typical installation	g (non typ)	1
MaineDOT 3-bar concrete transition barrier	h	1
MaineDOT 4-bar concrete transition barrier	i	1
MaineDOT 4-bar steel traffic/bicycle bridge rail	k	9
Inconclusive - MaineDOT 4-bar steel traffic/bicycle bridge rail or MaineDOT 4-bar steel traffic/bicycle concrete transition barrier	k or l	2

Table 3: Recommended Sample Size (n) for Investigative ISPE at 85% C.I.

	Precision (w)						
$\hat{p}$	0.001	0.002	0.003	0.004	0.005	0.01	0.02
0.005	10316	2579	1146				
0.010	20529	5132	2281	1283	821		
0.015	30637	7659	3404	1915	1225		
0.020	40643	10161	4516	2540	1626	406	
0.025	50544	12636	5616	3159	2022	505	
0.030	60342	15085	6705	3771	2414	603	
0.035	70036	17509	7782	4377	2801	700	175
0.040	79626	19907	8847	4977	3185	796	199
0.045	89113	22278	9901	5570	3565	891	223
0.050	98496	24624	10944	6156	3940	985	246
0.055	107775	26944	11975	6736	4311	1078	269

NHDOT

On June 15, 2021 the NHDOT provided the 2010-2019 crash data to the research team as two separate excel workbook files (i.e., 2010-2017 in one file, 2017-2019 in a second file). Starting in 2017 New Hampshire has begun moving towards one crash reporting method which is the reason for the separate files. When the research team began digging into the 2017-2019 data some issues became clear.

- The CRASHTYPE and FIXEDOBJECTSTRUCK fields are not reliably populated. This makes identification what type of object was struck difficult and inconsistent to confirm.
- GPS coordinates in the crash data excel files were different than the coordinates in the shape files, and the shape files seemed to be more accurate. Without reliable coordinates it would be difficult to locate the crashes on or near bridges with NETC bridge rails installed.
- The severity level for many of the crashes were unknown. Without crash severity information the ISPE would be largely inconclusive.

For these reasons the decision was made to proceed with the 5-year period of 2012-2016. The 2012-2016 data was more consistent and appeared to be more reliable. The final data files sent from NHDOT on July 09, 2021, included crash data files, vehicle record files, and an injury record files. The data was reduced from the full dataset to only crashes with an NETC bridge rail or AGT in the steps indicated by the flags in Table 1, and described in the paragraphs below.

The first data reduction step, indicated by flag 1 in Table 4, was to retain only crashes that were coded in the OBJECTSTRUCK field with inputs that could be associated with NETC bridge railings or AGTs. The inputs in the OBJECTSTRUCK field included text fields and numerical codes. The text inputs that were retained were 1) Barrier/Fence, 2) Guard Rail, and 3) Bridge/Pier. The numerical code equivalencies were assumed to be those defined in the State of New Hampshire Uniform Police Traffic Crash Report DSMV 159 (REV. 11/07): 1) '22' Bridge Pier or Support, and 2) '23' Bridge Rail.

The second data reduction step, indicated by flag 2 in Table 4,was to retain only single vehicle crashes. Since the OBJECTSTRUCK field is contained in the crash file, not the vehicle file, and there is no sequence of events fields for each individual vehicle in the vehicle files, it was not possible to determine which vehicle in multi-vehicle collisions interacted with the objects of interest. Therefore, multi-vehicle crashes were removed from the dataset.

The third data reduction step, indicated by flag 3 in Table 4, was to identify which crashes occurred within 0.25 miles of a bridge with a NETC type bridge rail or AGT installed. None of the data files (i.e., crash data, vehicle record or injury record) contain latitude or longitude. NHDOT provided the raw shape files to the research team. The shape files contained crash data and were opened with QGIS where all attributes were removed from the data set except ACD Number (to reduce file size). The modified shape file was saved and loaded into Google Earth Pro. From Google Earth Pro, this data was exported as a .kml file which was loaded into excel as .xml where ACD Number, LAT and LONG were isolated. LAT and LONG were combined as a complete string of coordinates for each crash and ACD Number was converted to ACDYEAR_NUMBER. The list of 6,670 crashes retained through data reduction step 2 were then cross referenced with the coordinates Excel workbook using the ACDYEAR_NUMBER field. The bridge inventory fields BRIDGE_NO, LAT, and LONG were then imported into a new Excel worksheet. Logic was programed into the Excel workbook to identify which bridge was closest to each crash and what the straight-line distance between the crash and nearest bridge was. Crashes which occurred further than one quarter of a mile from a bridge with an NETC bridge rail or AGT were eliminated.

The fourth data reduction step, indicated by flag 4 in Table 4, was to "visit" each crash location that was retained through data reduction step 3 on Google Earth Street View to determine if the vehicle's crash was likely to have occurred on a bridge with an NETC bridge rail or AGT. This determination was made based on what roadway the crash occurred on, and distance to the bridge. Crashes that were difficult to determine were retained through this data reduction step. The research team requested crash reports for each of the crashes identified in Step 4. On August 05, 2021, NHDOT provided the crash reports for crashes occurring in 2013-2016, however, crash reports occurring in 2012 were not available due to document retention protocols at the NH DMV.

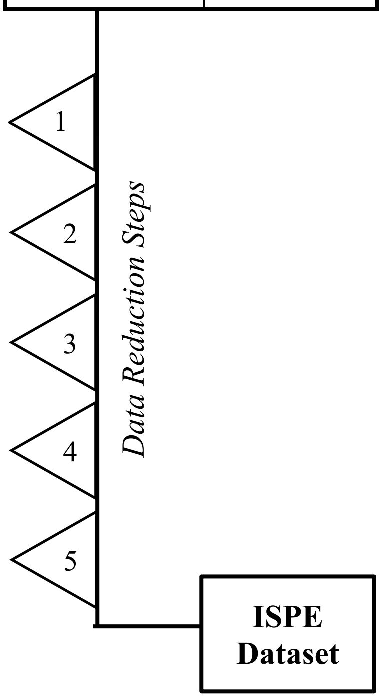
The final data reduction step, indicated by flag 4 in Table 4, was to review each police crash report and identify if the crash involved a NETC bridge rail or AGT and identify the specific bridge rail or AGT design when applicable. This step was accomplished by reading the police report, reviewing the scene diagram, reviewing the crash data, visiting the crash location on Google Earth Street View, and reviewing the bridge inventory. In some instances, it was necessary to adjust some data fields based on the review of the police reports. The two most common reasons for editing the crash data were:

1. Adding SPEED_LIMIT when unknow, based on SPEEDCARDS.kml file provided by NHDOT.
2. Changing PostHE, FHE and FOHE based on sequence of events explained in the crash narrative.

A full listing of changes made to the crash data based on the review of police reports and the reasoning is contained in the Crash Data Change Log sheet of the NH NETC Bridge Rail Crash Dataset Deliverable. Based on the addition of lines for secondary impacts with the bridge rail, the numbers indicated by flag 4 are interactions with an NETC bridge rail or AGT, rather than vehicle crashes.

Table 4: NHDOT Crash Data Reduction for ISPE of NETC Bridge Rails

Crash Database	
Year	**Cases**
2012	28,336
2013	29,721
2014	31,784
2015	33,895
2016	34,314



Data Reduction			
◁	**Intent/Codes Removed**	**Data Years**	**Cases Remaining**
1	Retain crashes coded with: Barrier/Fence; Guard Rail; Bridge/Pier; ‘22’ Bridge Pier or Support; ‘23’ Bridge Rail; in the OBJECTSTRUCK field.	2012	1,412
		2013	1,367
		2014	1,375
		2015	1,349
		2016	1,431
2	No Sequence of Events fields available in the vehicle file so OBJECTSTRUCK was used. In multi-vehicle collisions it is not specified which vehicle collided with the SFUE, thus only single vehicle crashes were retained.	2012	1,362
		2013	1,321
		2014	1,327
		2015	1,288
		2016	1,372
3	Retain only crashes which occurred within 0.25 miles of a bridge with an NETC bridge rail/AGT.	2012	31
		2013	8
		2014	33
		2015	26
		2016	31
4	Retain only crashes which are likely to have occurred <u>on</u> a bridge with an NETC bridge rail/AGT.	2012	16
		2013	1
		2014	9
		2015	13
		2016	7
5	Retain crashes which are confirmed, based on review police report, to have interacted with a NETC bridge rail or AGT	2012	0*
		2013	0
		2014	4
		2015	3
		2016	1

* Crash reports for 2012 crashes were no longer available when requested by the research team.

The final number of vehicle interactions with NETC bridge rails or AGTs in the State of New Hampshire from 2013-2016 is 8. The breakdown of number of crashes with each type of bridge rail or AGT design is shown in Table 5. ISPEs of longitudinal barriers that have been performed using the NCHRP Project 22-33 method indicate point estimates ($\hat{p}$) for the Occupant Risk and Post Impact Trajectory Evaluation Measures vary from between 0.02 and 0.05. A precision of 0.01 at 85% confidence interval necessitates a sample size of between 505 and 985 crashes to distinguish between values of NAME. It is recommended that the ISPE does not distinguish between values of NAME, but rather considers all field performance of all the identified NETC rails. It is recommended that the ISPE report for New Hampshire be developed primarily to allow for the combining of the results with the other states. The results obtained from the Meta-analysis, where the data are combined with the other states, will provide the best available information on the field performance of NETC rails and AGTs.

Table 5: Number of Crashes with Specific NETC Bridge Rail or AGT Type in New Hampshire

Component	NAME	Number of Crashes
NETC 2-bar steel bridge rail	a	5
NETC 4-bar bridge rail	c	1
2-bar Steel Bridge Rail, non-NETC	m	2

RIDOT

RIDOT provided the 2016-2020 crash data as a single excel workbook file to the research team. Each year was contained on unique worksheet within the workbook, and all worksheets had 24 fields (i.e., columns). Each row of data represented a single person involved in a motor vehicle crash, the number of crashes each year is shown in the upper left corner of Table 6. Prior to data reduction the data was combined so that only one row appeared for each vehicle, regardless of the number of persons involved in the vehicle. In cases where there were multiple occupants in the vehicle the most severe injury sustained by any one occupant of the vehicle was retained as the MAX_SEV of the vehicle. The data was reduced from the full dataset to only crashes with an NETC bridge rail or AGT in the steps indicated by the flags in Table 6, and described in the paragraphs below.

The first dataset reduction step, indicated by flag 1 in Table 6, retain only crashes which were coded with a longitudinal barrier or bridge code that could be understood as being a bridge rail, transition, or approach guardrail somewhere in the sequence of events. Based on the crash report form definitions provided by RIDOT the analyst determined that crashes with NETC bridge rails or AGTs could be coded with any of the following in the SEQUENCE fields: 'Guardrail Face', 'Guardrail End', 'Other Traffic Barrier', 'Bridge Rail', or 'Bridge Pier or Support'.

The second data reduction step, indicated by flag 2 in Table 6, was to identify which vehicles crashed within 0.25 miles of a bridge with an NETC type bridge rail. This step was accomplished by importing the BRIDGE_NO, LAT, and LONG from the bridge inventory developed in Task 1 along with CrashReportId, Latitude, and Longitude from the RIDOT crash data into an Excel file. Logic was programed into the excel worksheet to identify which bridge was closest to each crash and what the straight-line distance between the crash and nearest bridge was. Crashes which occurred further than 0.25 miles from a bridge with an NETC bridge rail or AGT were eliminated.

The third data reduction step, indicated by flag 3 in Table 6, was to "visit" each crash location that was retained through data reduction step 2 on Google Earth Street View to determine if the vehicle's crash was likely to have occurred on a bridge with an NETC bridge rail or AGT. This determination was made based on what roadway the crash occurred on, and distance to the bridge. Crashes that were difficult to determine were retained through this data reduction step. The research team requested crash reports for each of the crashes identified in Step 4. On August 24, 2021, RIDOT provided the crash reports for crashes occurring in 2016-2020.

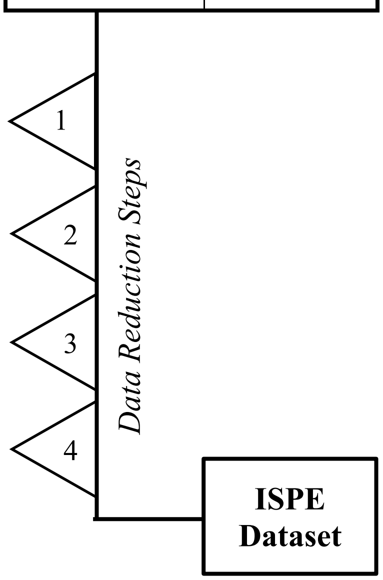
The final data reduction step, indicated by flag 4 in Table 6, was to review each police crash report and identify if the crash involved a NETC bridge rail or AGT and identify the specific bridge rail or AGT design when applicable. This step was accomplished by reading the police report, reviewing the crash data, visiting the crash location on Google Earth Street View, and reviewing the bridge inventory. In some instances, it was necessary to adjust some data fields based on the review of the police reports. The two most common reasons for editing the crash data were:

1. Multiple impacts into the bridge rail only coded as a single event. Each vehicle interaction with the bridge rail was included as additional lines.
2. Changing PostHE, FHE and FOHE based on sequence of events explained in the crash narrative.

A full listing of changes made to the crash data based on the review of police reports and the reasoning is contained in the Crash Data Change Log sheet of the RI NETC Bridge Rail Crash Dataset Deliverable. Based on the addition of lines for secondary impacts with the bridge rail, the numbers indicated by flag 4 are interactions with an NETC bridge rail or AGT, rather than vehicle crashes.

Table 6: RIDOT Crash Data Reduction for ISPE of NETC Bridge Rails

Crash Database	
Year	**Cases**
2016	83,659
2017	80,036
2018	78,444
2019	88,278
2020	64,166



Data Reduction			
◁	**Intent/Codes Removed**	**Data Years**	**Cases Remaining**
1	Retain crashes coded with: 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support' in the Sequence 1-4 fields.	2016	658
		2017	648
		2018	589
		2019	720
		2020	692
2	Retain only crashes which occurred within 0.25 miles of a bridge with an NETC bridge rail/AGT.	2016	59
		2017	66
		2018	54
		2019	53
		2020	42
3	Retain only crashes which are likely to have occurred on a bridge with an NETC bridge rail/AGT.	2016	19
		2017	30
		2018	27
		2019	32
		2020	23
4	Retain crashes which are confirmed, based on review police report and photos, to have interacted with a NETC bridge rail or AGT	2016	6
		2017	7
		2018	5
		2019	9
		2020	9

The final number of vehicle interactions with NETC bridge rails or AGTs in the State of Rhode Island from 2016-2020 is 36. The breakdown of number of crashes with each type of bridge rail or AGT design is shown in Table 7. ISPEs of longitudinal barriers that have been performed using the NCHRP Project 22-33 method indicate point estimates ($\hat{p}$) for the Occupant Risk and Post Impact Trajectory Evaluation Measures vary from between 0.02 and 0.05. A precision of 0.01 at 85% confidence interval necessitates a sample size of between 505 and 985 crashes to distinguish between values of NAME. It is recommended that the ISPE does not distinguish between values of NAME, but rather considers all field performance of all the identified NETC rails. It is recommended that the ISPE report for Rhode Island be developed primarily to allow for the combining of the results with the other states. The results obtained from the Meta-analysis, where the data are combined with the other states, will provide the best available information on the field performance of NETC rails and AGTs.

Table 7: Number of Crashes with Specific NETC Bridge Rail or AGT Type in Rhode Island

Component	NAME	Number of Crashes
NETC 2-bar steel bridge rail	a	23
Inconclusive - NETC 2-bar steel bridge rail or 2-bar Concrete Transition Barrier, non-NETC	a or t	3
2-bar Steel Bridge Rail, non-NETC	m	4
Inconclusive – 2-bar Steel Bridge Rail, non-NETC or 2-bar Steel AGT, non-NETC	m or q	3
2-bar Steel AGT, non-NETC	q	2
2-bar Concrete Transition Barrier, non-NETC	t	1

VTrans

RIDOT provided the 2015-2019 crash data as five separate excel workbook files for each year (i.e., 25 files) to the research team. Each row of data in the vehicle file represented a single vehicle involved in a motor vehicle crash; the number of vehicles involved in crashes each year is shown in the upper left corner of Table 8. The ISPE dataset fields were pulled in for each applicable case by importing values by using cross-references the applicable files. The data was reduced from the full dataset to only crashes with an NETC bridge rail or AGT in the steps indicated by the flags in Table 8, and described in the paragraphs below.

The first dataset reduction step, indicated by flag 1 in Table 8, was to retain only crashes which were coded with a longitudinal barrier code that could be understood as being a bridge rail, transition, or approach guardrail somewhere in the sequence of events. Based on the data dictionary definitions provided by VTrans the analyst determined that crashes with NETC bridge rails or AGTs could be coded with the following in the Veh 1 Collided With 1 or 2 field: ‘Guard rail, curb’.

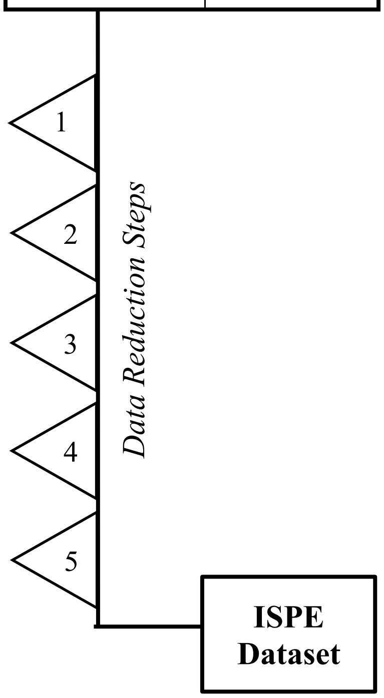
The second dataset reduction step, indicated by flag 2 in Table 8, was to eliminate crashes in towns that do not have bridges with NETC type bridge rails or AGTs installed. The research team would have preferred to use the latitude and longitude of the crash to perform this reduction however the GPS fields in the Vermont crash data files was input in a variety of ways, including decimal degrees, easting/westing using the VT state plane coordinates, decimal degrees with direction (N/W). The variety of coordinate inputs created problems with conversion. Therefore, the City or Town field entries for each crash that was retained through data reduction step 1 was compared to the bridge inventory TOWN field and only crashes which occurred in the nine towns which have bridges with NETC bridge rails were retained.

The third data reduction step, indicated by flag 3 in Table 8, was to “visit” each crash location, based on latitude and longitude, that was retained through data reduction step 2 on Google Earth Street View to determine if the vehicle’s crash was likely to have occurred on a bridge with an NETC bridge rail or AGT. This determination was made based on what roadway the crash occurred on, and distance to the bridge. Crashes that were difficult to determine were retained through this data reduction step. Additionally, there were 15 crashes with questionable latitude and longitude inputs that were retained. The research team requested crash reports for each of the crashes identified in Step 4. On August 30, 2021, VTrans provided the crash reports for crashes occurring in 2015-2019.

The final data reduction step, indicated by flag 5 in Table 8, was to review each police crash report and identify if the crash involved a NETC bridge rail or AGT and identify the specific bridge rail or AGT design when applicable. This step was accomplished by reading the police report, reviewing the scene diagram, reviewing the crash data, visiting the crash location on Google Earth Street View, and reviewing the bridge inventory. It was determined that none of the requested crash reports involved an NETC type bridge rail or AGT. Due to the lack of crashes with bridge rails in the scope of this study, in the 5-year period from 2015-2019, it is recommended to not include Vermont in the remaining tasks of this project.

Table 8: VTrans Crash Data Reduction for ISPE of NETC Bridge Rails

Crash Database	
Year	**Vehicles**
2015	24,567
2016	22,407
2017	19,879
2018	19,534
2019	22,416



Data Reduction			
◁	**Intent/Codes Removed**	**Data Years**	**Cases Remaining**
1	Retain crashes coded with: 'Guard rail, curb' in the Veh 1 Collided With 1 or 2 field.	2015	467
		2016	531
		2017	487
		2018	484
		2019	469
2	Retain crashes which occurred in a town listed on the bridge inventory: Bennington, Bristol, Castleton, Concord, Londonderry, Marlboro, Richford, Townshend, Hubbardton	2015	29
		2016	33
		2017	24
		2018	33
		2019	20
3	Retain only crashes which occurred within 0.25 miles of a bridge with an NETC bridge rail/AGT, or questionable GPS.	2015	8
		2016	6
		2017	3
		2018	6
		2019	1
4	Retain only crashes which are likely to have occurred on a bridge with an NETC bridge rail/AGT or questionable GPS.	2015	7
		2016	6
		2017	3
		2018	1
		2019	1
5	Retain crashes which are confirmed, based on review police report and photos, to have interacted with a NETC bridge rail or AGT	2015	0
		2016	0
		2017	0
		2018	0
		2019	0

ConnDOT

As discussed in the Post Task 1 Report, ConnDOT adopted modified versions of the NETC bridge rail, and the research team recommended that analysis of the crash data not be performed for Connecticut. Therefore, no Connecticut crash data was reviewed as part of Task 2 of this project.

MassDOT

As discussed in the Post Task 1 Report, MassDOT adopted modified versions of the NETC bridge rail, and the research team recommended that analysis of the crash data not be performed for Massachusetts. Therefore, no Massachusetts crash data was reviewed as part of Task 2 of this project.

Data Fields for Crash Dataset

The ISPE dataset layout for the applicable crashes in each state's has been standardized into the fields recommended by the NCHRP Project 22-33 ISPE Guidance Document (Carrigan 2022 [expected]) and shown in Table 9. Detailed definitions for each field are provided in the NCHRP Project 22-33 ISPE Guidance Document and are summarized in Table 9.

Table 9: Crash Dataset Fields and Definitions

Column	Field Name	Definitions
A	SFUE	Safety feature under evaluation = 1 (longitudinal barriers)
B	CRN	Crash number
C	CRASH_DATE	Date of crash
D	TOTAL_UNITS	Number of units involved in the crash
E	MAX_SEV	Maximum severity in the vehicle which interacted with the SFUE
F	VEH_TYPE	Body type of vehicle
G	SPEED_LIMIT	Speed limit
H	PostHE	Next harmful event after safety feature crash
I	MHE	Safety feature crash was most harmful event
J	FHE	Safety feature crash was first harmful event
K	AHE	Safety feature crash was any harmful event
L	FOHE	Safety feature crash was first and only harmful event
M	BREACH	Vehicle breached SFUE
N	*BREAK*	*Predictable breakaway – Not applicable*
O	*PRS*	*Controlled penetration, redirection, or stop – Not applicable*
P	PEN	SFUE intrusion into occupant compartment
Q	ICP	Initial contact point
R	NAME	Subgroupings of safety feature
S	AADT	Average annual daily traffic in vehicles per day
T	INSTALL	Construction inspection
U	MAINT	Maintenance inspection
V	LAT	Latitude of the crash
W	LONG	Longitude of the crash
X	ROUTE	Roadway along which the crash occurred
Y	BRIDGE_NO	Closest bridge to the crash, linkable to NETC bridge rail bridge inventory

MaineDOT

The specific MaineDOT data source for each ISPE data field is provided in Table 10 while equivalencies between the MaineDOT data inputs and the ISPE dataset format are shown in Tables 11 through 13.

Table 10: MaineDOT Crash Data Mapping

Column	Field	Source
A	SFUE	= "1" if one of the following codes appears in Crash data field: **SEQ_OF_EVENTS1-4:** '28' Bridge Pier or Support '29' Bridge Rail '35' Guardrail Face *And* located on a bridge identified as having an NETC type bridge rail or AGT confirmed to have interacted with the NETC bridge rail or AGT during the crash from Police Report review.
B	CRN	Crash data field: **REPORT_NUMBER**.
C	CRASH_DATE	Crash data field: **ACCIDENT_DATE**, requires conversion to standard ISPE format.
D	TOTAL_UNITS	Crash data fields: **REPORT NUMBER** *and* **UNIT ID**.
E	MAX_SEV	Crash data fields: **REPORT NUMBER** *and* **UNIT ID** *and* **PERSON_ID** *and* **INJURY DEGREE**; see equivalency table below (Table 11). Maximum injury sustained by an occupant of the vehicle which interacted with the NETC bridge rail or AGT.
F	VEH_TYPE	**Crash data fields: UNIT_TYPE *and* VEHICLE_CONFIG (for SUT and TT); see equivalency table below (** Table 12).
G	SPEED_LIMIT	Crash data field: **SPEED_LIMIT**, 'UNK' for unknown.
H	PostHE	Harmful event coded directly after SUFE (ignore '00' codes) in crash data field: **SEQ_OF_EVENTS1-4**, see equivalency table below (Table 13).
I	MHE	Crash data field: **MOST_HARMFUL_EVENT** coded with '20' Bridge Pier or Support (from MaineDOT Reporting Manual "Support for a bridge structure including the ends (abutments).") '21' Bridge Rail '27' Guardrail Face Note: **MOST_HARMFUL_EVENT** codes are different than the codes used in **SEQ_OF_EVENTS1-4**.
J	FHE	Crash data field: **SEQ_OF_EVENTS1-4** coded with '28', '29', or '35' and is only preceded by event codes listed in 00 row of PostHE table (Table 13).
K	AHE	Crash data field: **SEQ_OF_EVENTS1-4** coded with '28', '29', or '35'.

Column	Field	Source
L	FOHE	Crash data field: **SEQ_OF_EVENTS1-4** coded with '28', '29', or '35' and is only preceded by and followed by event codes listed in 00 row of PostHE table. (Table 13).
M	BREACH	Assigned by analyst after review of police report for crashes.
N	BREAK	Not applicable to this ISPE.
O	PRS	Not applicable to this ISPE.
P	PEN	Assigned by analyst after review of crash narrative, coded as unknown ('99') if not specified in crash report.
Q	ICP	Not available for this ISPE
R	NAME	Linked to bridge inventory and review of crash narrative.
S	AADT	Crash data field: **AADT**, '0' for unknown.
T	INSTALL	MaineDOT inspects hardware as it is installed on MaineDOT roadways. Installation inspections are not performed on local jurisdictions. Owner of all bridges involved in crashes with NETC bridge rails or AGT have been determined to be owned by the State Highway Agency ('01' in OWNER field of bridge inventory).
U	MAINT	MaineDOT has a maintenance inspection program on MaineDOT roadways. Maintenance inspections are not performed on hardware installed on local roadways. Owner of all bridges involved in crashes with NETC bridge rails or AGT have been determined to be owned by the State Highway Agency ('01' in OWNER field of bridge inventory).
V	LAT	Crash data field: **LATITUDE**.
W	LONG	Crash data field: **LONGITUDE**.
X	ROUTE	Crash data field: **ROUTE_NAME**.
Y	BRIDGE_NO	Linked to Bridge Inventory using Crash data fields: **LATITUDE** and **LONGITUDE** and Bridge Inventory **LAT** and **LONG**.

Table 11: MaineDOT MAX_SEV Equivalency Table

MAX_SEV	Crash data field code for INJURY DEGREE
K	'1' (K) Fatal Injury
A	'2' (A) Suspected Serious Injury
B	'3' (B) Suspected Minor Injury
C	'4' (C) Possible Injury
O	'5' (O) No Apparent Injury
U	' ' Null

Table 12: MaineDOT VEH_TYPE Equivalency Table

VEH_TYPE	Crash data field code for UNIT_TYPE and VEHICLE_CONFIG
MC *Motorcycle*	11 Motorcycle 12 Moped 14 Autocycle
PC *Passenger Car*	1 Passenger Car 17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 1 Passenger Car (only if vehicle has Hazardous Materials Placard)
PU *Pick-Up Truck*	2 (Sport) Utility Vehicle 3 Passenger Van 4 Cargo Van (10k lbs or less) 5 Pickup 17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 2 Light Truck (only if vehicle has Hazardous Materials Placard)
SUT *Single Unit Truck*	17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 5 Single-Unit Truck (2 axles, 6 tires) 6 Single-Unit Truck (3 axles) 7 Single-Unit Truck (4 axles with rear tri-axle) 8 Single-Unit Truck (5 or more axles)
BUS *Bus*	7 School Bus 8 Transit Bus 9 Motor Coach 17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 3 Bus (Seats for 9-15 people, including driver) 4 Bus (Seats for 16 people or more, including driver)
TT *Tractor Trailer*	17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 10 Truck Tractor (without trailer, bobtail or saddle mount) 11 Tractor/Semi-Trailer (one trailer - 5 axles) 12 Tractor/Semi-Trailer (one trailer - 6 axles) 13 Tractor/Semi-Trailer (one trailer – All other axle configurations)

VEH_TYPE	Crash data field code for UNIT_TYPE and VEHICLE_CONFIG
OTR *Other Vehicle Type*	6 Motor Home 10 Other Bus 13 Low Speed Vehicle 15 Experimental 16 Other Light Trucks (10,000 lbs or Less) 17 Medium/Heavy Trucks (More than 10,000 lbs) *and* **VEHICLE_CONFIG** 9 Truck/Trailer(s) [Single-Unit Truck with Trailer(s)] 14 Tractor/Doubles (two trailers) 15 Tractor/Triples (three trailer) 99 Other Truck Greater than 10,000 lbs. (not listed above) 18 ATV – (4 wheel) 19 ATV – (3 wheel) 20 ATV – (2 wheel) 21 Snowmobile 22 Pedestrian 23 Bicyclist 24 Witness 25 Other 26 Construction 27 Farm Vehicle
99 *Unknown*	Null

Table 13: MaineDOT PostHE Equivalency Table

PostHE ***Post Impact Harmful Event***	**Crash data field codes for SEQ_OF_EVENTS1-4 fields.**
00 *Non-Harmful Event*	6 Equipment Failure (blown tire, brake failure, etc.) 7 Separation of Units 8 Went Off Roadway Right 9 Went Off Roadway Left 10 Cross Median 11 Cross Centerline 12 Downhill Runaway 14 Reentering Roadway 49 Pressure Ridge 50 No Other Events
99 *Unknown Event*	47 Unknown Null
RFS *Rollover on the Field Side*	*Assigned after review of police report for crashes with PostHE = 'ROLL'*
RSS *Rollover on the Traffic Side*	*Assigned after review of police report for crashes with PostHE = 'ROLL'*
ROLL *Rollover, Unknown Side*	1 Overturn / Rollover – *RFS or RSS assigned after review of police if it can be determined which side the vehicle rolled.*
TER *Terrain Crash*	31 Culvert 33 Ditch 34 Embankment
VEH *Motor Vehicle Crash*	21 Motor Vehicle in Transport
PED *Non-Motorized Bicycle or Pedestrian Crash*	17 Pedestrian 18 Pedalcycle
FO *Fixed Object Crash*	28 Bridge Pier or Support 39 Tree 40 Utility Pole/Light Support 42 Traffic Signal Support 43 Other Post, Pole, or Support 45 Mailbox 46 Other Fixed Object (wall, building, tunnel, etc.)
BA *Breakaway Object Crash*	41 Traffic Sign Support

PostHE ***Post Impact Harmful Event***	**Crash data field codes for SEQ_OF_EVENTS1-4 fields.**
BAR *Barrier Crash*	26 Impact Attenuator/Crash Cushion 29 Bridge Rail 30 Cable Barrier 35 Guardrail Face 36 Guardrail End 37 Concrete Traffic Barrier 38 Other Traffic Barrier
CURB *Curb Crash*	32 Curb
OTR *Other Crash Type*	2 Fire / Explosion 3 Immersion 4 Jackknife 5 Cargo / Equipment Loss Or Shift 13 Fell/Jumped From Motor Vehicle 15 Thrown or Falling Object 16 Other Non-Collision 19 Railway Vehicle (train, engine) 20 Animal 22 Parked Motor Vehicle 23 Struck by Falling, Shifting Cargo or Anything Set in Motion by a Motor Veh. 24 Work Zone/Maintenance Equipment 25 Other Non-Fixed Object 27 Bridge Overhead Structure 44 Fence 48 Gate or Cable *Other harmful events determined from review of the police reports that don't fit into another category.*

NHDOT

The specific NHDOT data source for each ISPE data field is provided in Table 14 while equivalencies between the NHDOT data inputs and the ISPE dataset format are shown in Tables 15 and 16.

Table 14: NHDOT Crash Data Mapping

Column	Field	Source in 2012-2014_20210714 and NHDOT Crash Data 2015-2017 files.
A	SFUE	= "1" if one of the following codes appears in Crash Data field: **OBJECTSTRUCK**: Barrier/Fence Guard Rail Bridge/Pier '22' Bridge Pier or Support* '23' Bridge Rail* *And* located on a bridge identified as having an NETC type bridge rail or AGT confirmed to have interacted with the NETC bridge rail or AGT during the crash from Police Report review.
B	CRN	Crash Data field: **ACDYEAR_NUMBER**.
C	CRASH_DATE	Crash Data field: **ACDDATE**.
D	TOTAL_UNITS	Crash Data field: **NUMVEHICLES**.
E	MAX_SEV	Injury Records field: **INJURYTYPE**, see Table 15.
F	VEH_TYPE	Vehicle Records field: **VEHICLE TYPE**, see Table 16.
G	SPEED_LIMIT	Crash Data field: **POSTEDSPEED**. For unknowns - populated by linking to SPEEDCARDS .kml file.
H	PostHE	Assigned by analyst after review of police report for crashes
I	MHE	Not available for this ISPE.
J	FHE	Assigned by analyst after review of police report for crashes
K	AHE	If Barrier/Fence Guard Rail Bridge/Pier '22' Bridge Pier or Support* '23' Bridge Rail* appears in Crash Data field: **OBJECTSTRUCK**.
	FOHE	Assigned by analyst after review of police report for crashes
M	BREACH	Assigned by analyst after review of police report for crashes
N	BREAK	Not applicable to this ISPE.
O	PRS	Not applicable to this ISPE.

Column	Field	Source in 2012-2014_20210714 and NHDOT Crash Data 2015-2017 files.
P	PEN	Assigned by analyst after review of crash narrative, coded as unknown ('99') if not specified in crash report.
Q	ICP	Not available for this ISPE.
R	NAME	Linked to Bridge Inventory and review of crash narrative.
S	AADT	Linked to Bridge Inventory field: **AADT**.
T	INSTALL	
U	MAINT	
V	LAT	Shape file data: **LATITUDE**.
W	LONG	Shape file data: **LONGITUDE**.
X	ROUTE	Crash Data field: **ACDSTREET**.
Y	BRIDGE_NO	Linked to Bridge Inventory using Shape file data fields: **LATITUDE** and **LONGITUDE** and Bridge Inventory **LAT** and **LONG**.

Table 15: NHDOT MAX_SEV Equivalency Table

MAX_SEV	Injury Record field code - INJURYTYPE
K	K
A	A
B	B
C	C
O	N
U	U ACDYEAR_NUMBER not provided in Injury Records.

Table 16: NHDOT VEH_TYPE Equivalency Table

VEH_TYPE	Vehicle Record field code - VEHICLE_TYPE				
MC *Motorcycle*	Moped Motorcycle				
PC *Passenger Car*	Automobile				
PU *Pick-Up Truck*	Other/Unknown Light Truck Panel/Van Passenger Light Van Pick-Up/Light Truck Utility Vehicle (4x4)				
SUT *Single Unit Truck*	Not present in this dataset				
BUS *Bus*	Not present in this dataset				
TT *Tractor Trailer*	Not present in this dataset				
OTR *Other Vehicle Type*	Motor Carrier Motor Home Other				
99 *Unknown*	4*	5*	6*	7*	14*
	15*	16*	20*	26*	27*
	99*	04*	05*	06*	14*
	15*	16*	17*	19*	20*
	26*	27*	99*		
	ACDYEAR_NUMBER not provided in Vehicle Records				

*Text values come from crash database, number code definitions are assumed to be equivalent to the definitions in DSMV 159 (Rev. 11/07) → (see: nh_par_rev_11_2007_sub_4_3_2008.pdf)

RIDOT

The specific RIDOT data source for each ISPE data field is provided in Table 17 while equivalencies between the RIDOT data inputs and the ISPE dataset format are shown in Tables 18 through 21.

Table 17: RIDOT Crash Data Mapping

Column	Field	Source
A	SFUE	= "1" if one of the following codes appears in **Sequence 1-4** 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support' *And* located on a bridge with applicable NETC bridge rail or AGT *and* confirmed to have interacted with the NETC bridge rail or AGT during the crash from Police Report review.
B	CRN	Crash data field: **ReportNumber**.
C	CRASH DATE	Crash data field: **Crash Date**, requires conversion to standard ISPE format.
D	TOTAL UNITS	Crash data fields: **Report Number** *and* **UnitId**.
E	MAX SEV	Crash data fields: **Report Number** *and* **UnitId** *and* **PersonId** *and* **Injury**; see Table 18.
F	VEH TYPE	Crash data fields: **Unit Type** *and* **Vehicle Configuration** (for SUT and TT); see Table 19.
G	SPEED LIMIT	Crash data field: **Posted Speed Limit**, 'UNK' for unknown.
H	PostHE	Harmful event coded directly after SUFE (ignore '00' codes) in crash data field: **Sequence 1-4**, see Table 20.
I	MHE	Crash data field: **Most Harmful Event** coded with 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support'
J	FHE	If 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support' appears anywhere in crash data field: **Sequence 1-4** and is only preceded by event codes listed in 00 row of Table 20.

Column	Field	Source
K	AHE	If 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support' appears anywhere in crash data field: **Sequence 1-4**.
L	FOHE	If 'Guardrail Face' 'Guardrail End' 'Other Traffic Barrier' 'Bridge Rail' 'Bridge Pier or Support' appears anywhere in crash data field: **Sequence 1-4** <u>and</u> is only preceded by <u>and</u> followed by event codes listed in 00 row of Table 20.
M	BREACH	Assigned by analyst after review of police report for crashes.
N	BREAK	Not applicable to this ISPE.
O	PRS	Not applicable to this ISPE.
P	PEN	Assigned by analyst after review of crash narrative, coded as unknown ('99') if not specified in crash report.
Q	ICP	Crash data field: **Initial Impact Area**; see Table 21.
R	NAME	Linked to bridge inventory and review of crash narrative and/or photos.
S	AADT	Linked to Bridge Inventory using Crash data fields: **BRIDGE_NO**.
T	INSTALL	
U	MAINT	
V	LAT	Crash data field: **Latitude**.
W	LONG	Crash data field: **Longitude**.
X	ROUTE	Crash data field: **StreetOrHighway**.
Y	BRIDGE_NO	Linked to Bridge Inventory using Crash data fields: **Latitude** and **Longitude** and Bridge Inventory **LAT** and **LONG**.

Table 18: RIDOT MAX_SEV Equivalency Table

MAX_SEV	Crash data field code for Injury
K	Fatal
A	Incapacitating
B	Non-Incapacitating
C	Complains Of Pain
O	No Injury
U	Unknown NULL

Table 19: RIDOT VEH_TYPE Equivalency Table

VEH_TYPE	Crash data field code for Unit Type and/or Vehicle Configuration
MC *Motorcycle*	Motorcycle Moped
PC *Passenger Car*	Passenger Car Passenger Car
PU *Pick-Up Truck*	Pickup (Sport) Utility Vehicle Cargo Van (10K lbs [4,536 kg] or Less) Passenger Van Other Light Trucks (10K lbs [4,536 kg] or Less)
SUT *Single Unit Truck*	Medium Heavy Trucks (More than 10K lbs [4,563 kg]) Single-Unit Truck (3 or more axles) Single-Unit Truck (2 axles, 6 tires)
BUS *Bus*	Motor Coach Transit Bus School Bus Bus (seats for 16 people or more, including driver) Bus (seats for 9-15 people, including driver)
TT *Tractor Trailer*	Tractor Trailer or Combination (More than 10K lbs [4,563 kg]) Tractor/Semi-Trailer (one trailer) Truck Tractor (without trailer, bobtail or saddlemount)
OTR *Other Vehicle Type*	Other Motor Home Pedestrian Bicyclist Other Bus Tow Truck Low Speed Vehicle Truck/Trailer(s) [Single-Unit Truck with Trailer(s)] Other Truck Greater Than 10000 lbs. (not listed above)
99 *Unknown*	NULL

Table 20: RIDOT PostHE Equivalency Table

PostHE ***Post Impact Harmful Event***	**Crash data field codes for Sequence 1-4**
00 *Non-Harmful Event*	NULL Ran Off Roadway - Left Cross Median Cross Centerline Ran Off Roadway - Right Re-entered Roadway
99 *Unknown Event*	Unknown - Sequence of Events
RFS *Rollover on the Field Side*	Assigned after review of police report for crashes with PostHE = 'ROLL'
RSS *Rollover on the Traffic Side*	Assigned after review of police report for crashes with PostHE = 'ROLL'
ROLL *Rollover, Unknown Side*	Overturn / Rollover – RFS or RSS assigned after review of police if it can be determined which side the vehicle rolled.
TER *Terrain Crash*	Ditch Embankment Landscaping Culvert Immersion
VEH *Motor Vehicle Crash*	Motor Vehicle in Transport
PED *Non-Motorized Bicycle or Pedestrian Crash*	Pedestrian Pedalcycle
FO *Fixed Object Crash*	Tree (Standing) Utility Pole (Electric / Telephone) / Light Support Mailbox Other Fixed Object (Wall, Building, Tunnel, etc.) Other Post, Pole, or Support Highway Lighting / Light Standard Traffic Signal / Support Bridge Pier or Support Traffic Control Box
BA *Breakaway Object Crash*	Traffic Sign / Support

PostHE *Post Impact Harmful Event*	Crash data field codes for Sequence 1-4
BAR *Barrier Crash*	Guardrail Face Jersey / Concrete Traffic Barrier Guardrail End Other Traffic Barrier Impact Attenuator / Crash Cushion Bridge Rail
CURB *Curb Crash*	Curb
OTR *Other Crash Type*	Other Non-Fixed Object Fell / Jumped from Motor Vehicle Other Non-Collision Animal Cargo / Equipment Loss or Shift Fence Fire / Explosion Thrown or Falling Object Jackknife Variable Message Board / Arrow Board Work Zone / Maintenance Equipment Bridge Overhead Structure Railway Vehicle (Train, Engine)

Table 21: RIDOT ICP Equivalency Table

ICP	Crash data field codes for Initial Impact Area
12	Front(12)
1	Front Passenger Side(1)
2	Front Passenger Side(2)
3	Center Passenger Side(3)
4	Rear Passenger Side(4)
5	Rear Passenger Side(5)
6	Rear(6)
7	Rear Driver Side(7)
8	Rear Driver Side(8)
9	Center Driver Side(9)
10	Front Driver Side(10)
11	Front Driver Side(11)
13	Top/Roof(13)
14	Undercarriage(14)
99	Non-Collision(15) Unknown(16) NULL

References

(Carrigan 2022 [expected]) Christine E. Carrigan, "Multi-State In-Service Performance Evaluations of Roadsafe Safety Hardware," National Cooperative Highway Research Program, Transportation Research Board, NCHRP 22-33, Washington, D.C., 2022 [expected].