NETC Project 20-1

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

Project Summary Presentation

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Outline

- Welcome/Introduction
- Scope
- Task 1 – NETC Bridge Rail and AGT Inventory
- Task 2 – Crash Data Collection and Dataset Assembly
- Task 3 – State Specific ISPE Results and Meta-Analysis
- Implementation Plan
- Questions / Comments / Further Discussion

Problem Statement

- The 2-bar, 3-bar, and 4-bar NETC designs were developed and tested in compliance with the AASHTO GSBR PL2 and/or Report 350 test procedures.
- Recent FEA evaluations indicated that they also comply with the current test performance criteria of MASH.
- These bridge rail systems have been used in the New England states for more than 20 years.

2-bar

3-bar

4-bar

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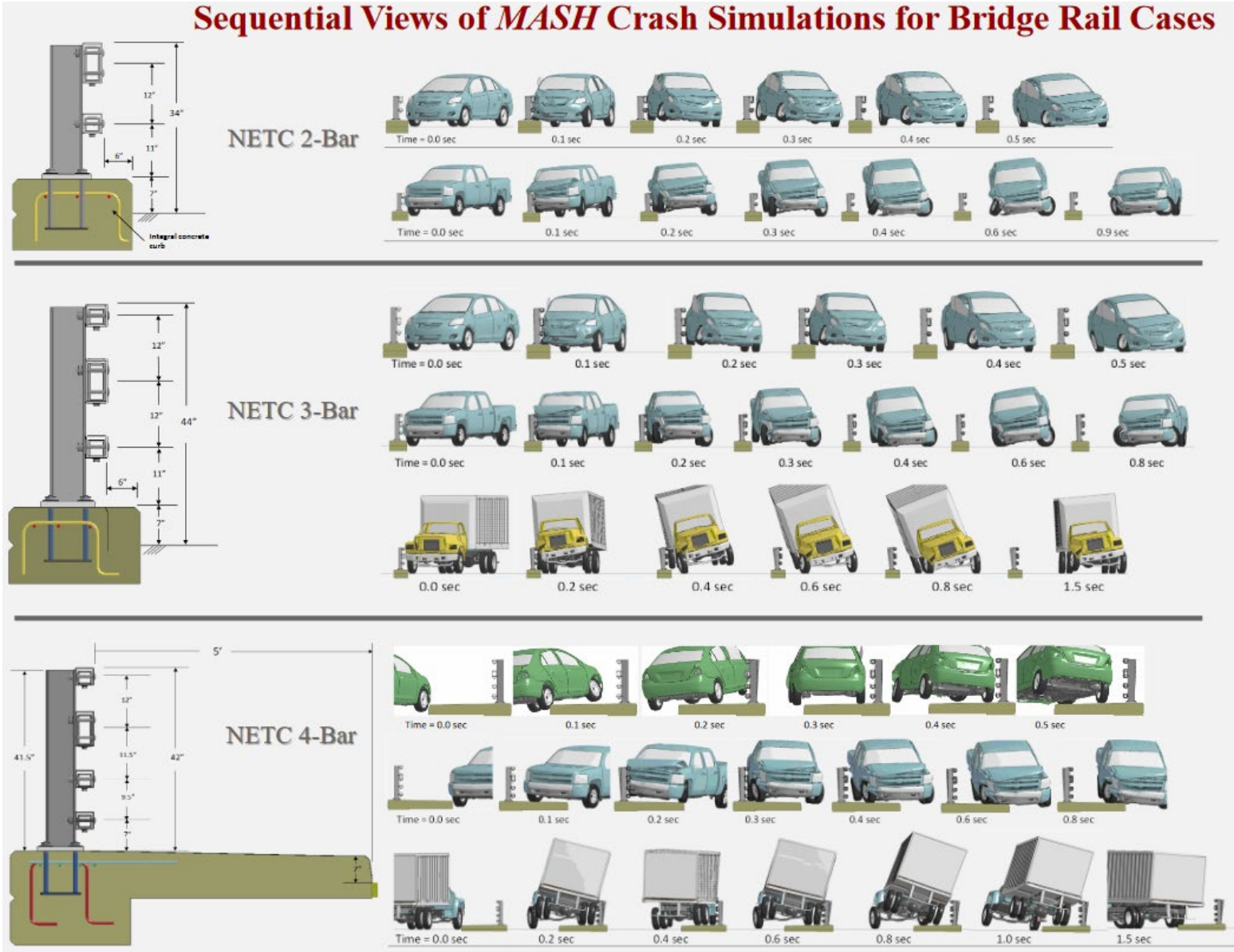
- The joint MASH implementation agreement required MASH compliant bridge rails for new and full replacements on the NHS with contract letting after December 31, 2019.
- Establishing that these long-standing designs are performing well in the field would provide further confidence.



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Objectives

- The objective of this work is to determine the in-service performance of the NETC steel bridge railings and transition systems.

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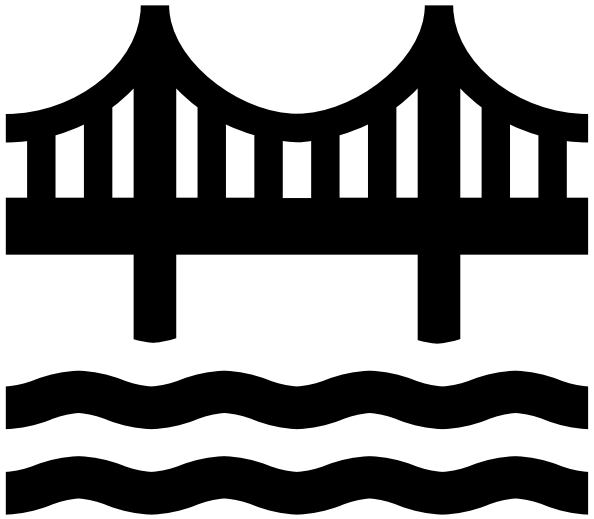
Task No. 1 – Bridge Inventory



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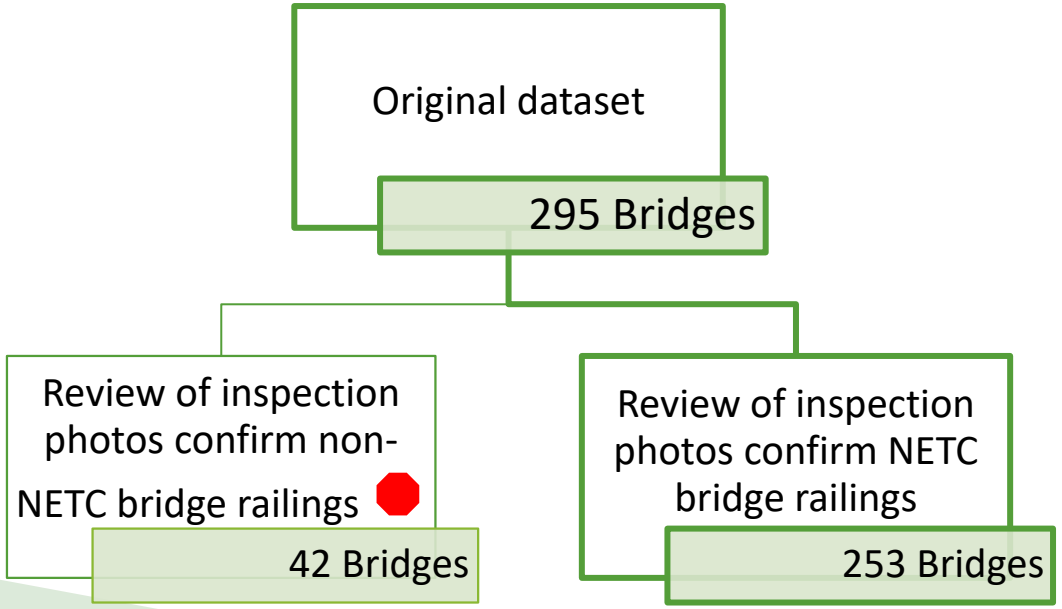
MaineDOT – Task No. 1 – Bridge Inventory

- MaineDOT provided access to inspection photos and reports on their AssetWise web portal
- MaineDOT provide a list of 271 bridges in Maine suspected to have NETC style bridge rails
- 253 bridges in Maine identified as having NETC type bridge rail or AGT by reviewing the inspection photos and reports and occasionally Google Earth Street View.



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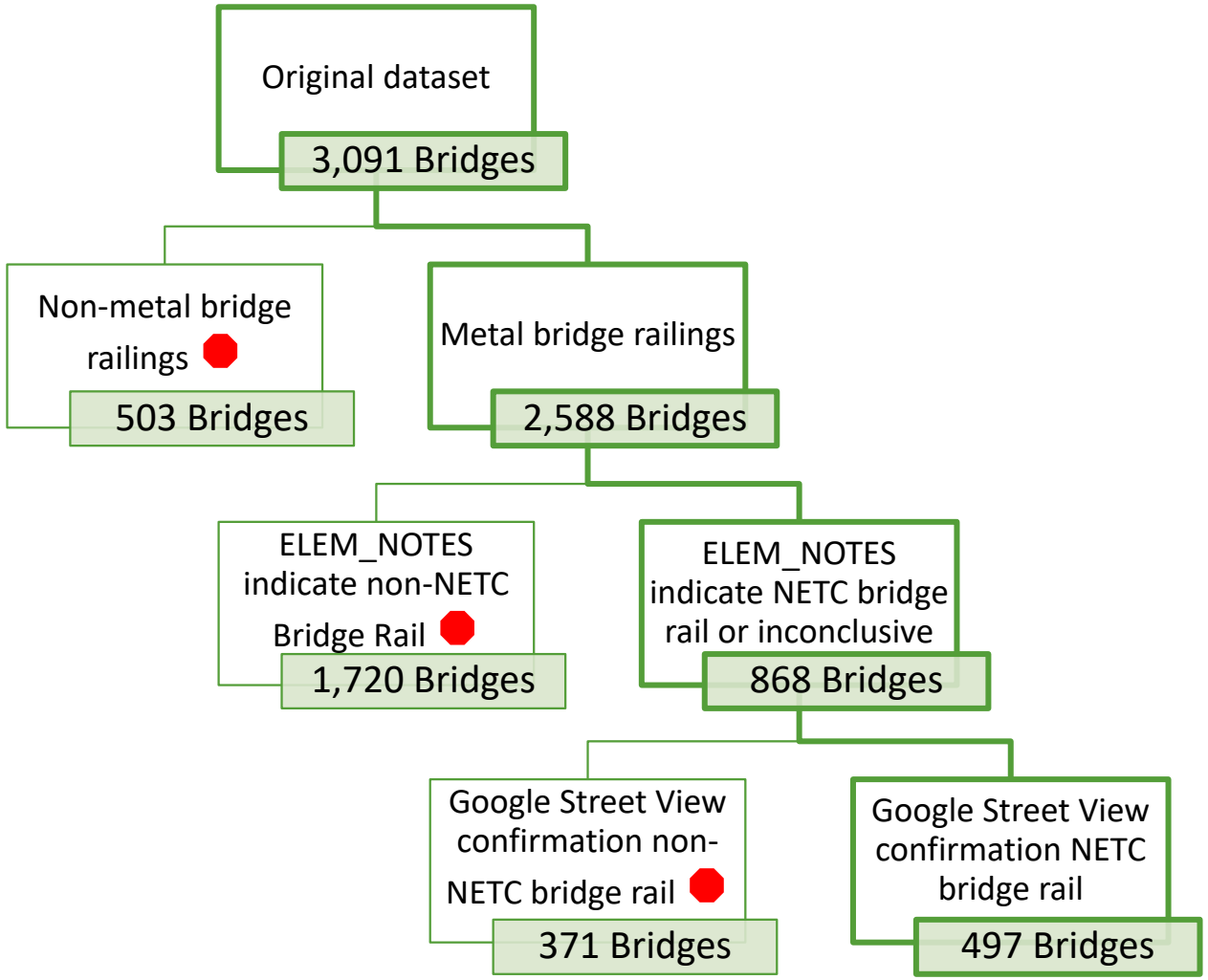
NHDOT – Task No. 1 – Bridge Inventory

- NHDOT provided a list of 3,091 bridges in NH with bridge railings
  - 2,588 bridges in NH with metal bridge railings
  - 868 bridges in NH with ELEM_NOTES field suggesting NETC rail or inconclusive
  - 497 bridges in NH were identified as having NETC type bridge rail or AGT by “visiting” each bridge on Google Earth Street View.



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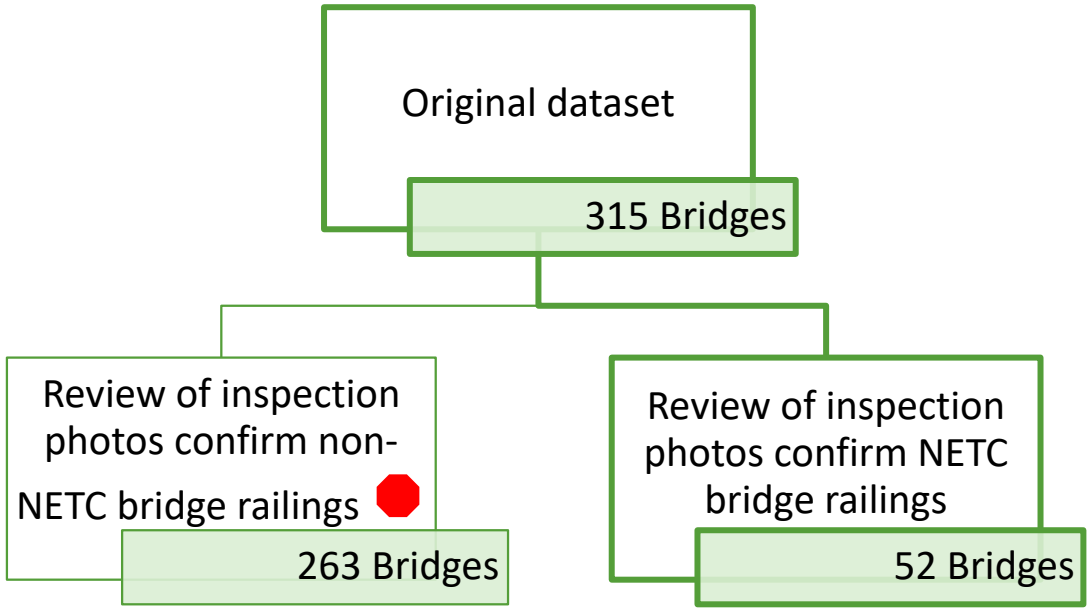
RIDOT – Task No. 1 – Bridge Inventory

- RIDOT provided access to inspection photos and reports on the RIDOT BrM web portal
- 315 bridges in RI are coded with BMI Element 330 (metal railing)
  - 52 bridges in RI were identified as having NETC type bridge rail or AGT by reviewing the inspection photos and reports.



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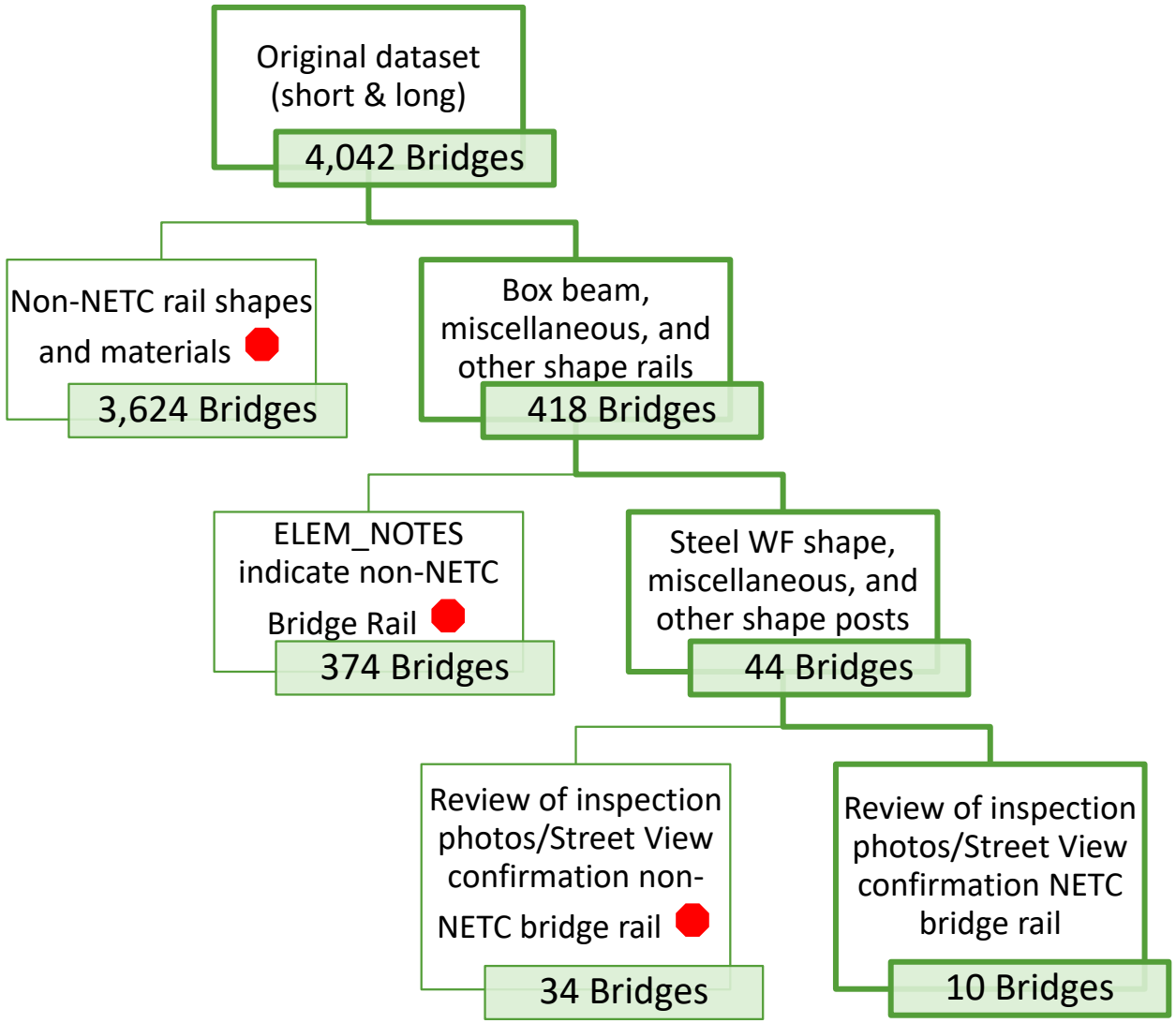
VTrans – Task No. 1 – Bridge Inventory

- VTrans has a public ProjectWise web portal which links to bridge inspection reports and photos.
- 4,042 bridges (long and short structures) in VT with bridge railings
  - 418 bridge in VT with NETC rail or inconclusive in Element 221C (material/design of rail)
  - 44 bridges in VT with NETC post or inconclusive in Element 221A (material/design of post)
  - 10 bridges in VT were identified as having NETC type bridge rail or AGT by reviewing inspection photos and “visiting” each bridge on Google Earth Street View.



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ConnDOT – Task No. 1 – Bridge Inventory

- Connecticut never adopted the NETC rail, but a modified version of it.
- Most full tube bridge rail systems are on local roads with only a few on the State network.
- ConnDOT performed a search for metal beam-type railings and sent the list of nine bridges with bridge railings similar to the NETC design to the research team.

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ConnDOT – Task No. 1 – Bridge Inventory

- Since Connecticut does not have any bridge railings that conform to the NETC designs that are being studied; the research team did not develop a data attributes map and recommended not performing analysis of the ConnDOT crash data.

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MassDOT – Task No. 1 – Bridge Inventory

- There was not a MassDOT representative on the TAC.
- The research team performed a literature search of the MassDOT published Standard Details for Railing/Traffic Barrier Systems and confirmed that the steel tube railings designs differ in multiple ways from the NETC design (e.g., tube size, base plate design)
- Since Massachusetts does not have any bridge railings that conform to the NETC designs that are being studied; the research team did not develop a data attributes map and recommended not performing analysis of the MassDOT crash data.

Task No. 2 – Crash Data

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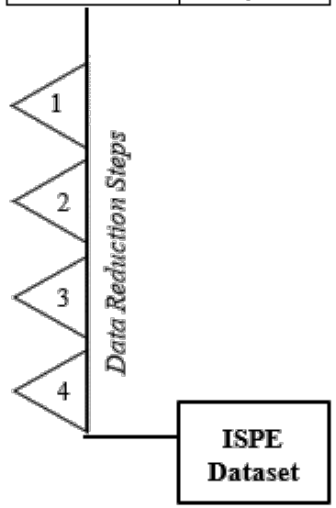
MaineDOT – Task No. 2 – Crash Data Reduction

Crash Database	
Year	**Cases (persons)**
2013	82,780
2014	86,129
2015	91,538
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.	2013	795
		2014	764
		2015	727
		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.	2013	162
		2014	158
		2015	140
		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.	2013	16
		2014	14
		2015	14
		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 an NETC bridge rail or AGT. Also, add rows for crashes where the vehicle interacted with the SFUEs multiple times.	2013	7
		2014	6
		2015	10
		2016	18
		2017	21
		2018	13
		2019	11
		2020	13

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MaineDOT – Task No. 2 – Crash Data Numbers

Sev	Qty
K	0
A	5
B	10
C	20
O	64
U	0

Veh	Qty
MC	1
PC	53
PU	40
SUT	0
TT	1
OTR	4

Occupant Risk	Qty
BREACH	2
PEN	1

NAME	Rail or AGT	Qty
a	NETC 2-Bar Bridge Rail	**42**
a or g	Inconclusive; NETC 2-Bar Bridge Rail or Concrete Transition Barrier	**8**
b	NETC 3-Bar Bridge Rail	**13**
c	NETC 4-Bar Bridge Rail	**5**
g	MaineDOT 2-Bar Concrete Transition Barrier	**12**
g (non typ)	MaineDOT 2-Bar Concrete Transition Barrier; Non-Typical Installation	**1**
h	MaineDOT 3-Bar Concrete Transition Barrier	**1**
i	MaineDOT 4-Bar Concrete Transition Barrier	**1**
k	MaineDOT 4-Bar Traffic/Bicycle Bridge Rail	**13**
k or l	Inconclusive; MaineDOT 4-Bar Traffic/Bicycle Bridge Rail or Concrete Transition Barrier	**3**
	Total	**99**

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NHDOT – Task No. 2 – Crash Data Reduction

- Issues with the 2017-2019 data.
  - CRASHTYPE and FIXEDOBJECTSTRUCK not reliably populated.
  - GPS coordinate inaccuracies and inconsistencies.
  - Many unknown crash severities.
- Therefore 2012-2016 data used for better consistency and reliability.

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

1
2
3
4
5

Data Reduction Steps

ISPE Dataset

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 on 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

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NHDOT – Task No. 2 – Crash Data Numbers

Sev	Qty
K	0
A	0
B	0
C	0
O	8
U	0

Veh	Qty
MC	0
PC	5
PU	2
SUT	0
TT	0
OTR	1

NAME	Rail or AGT	Qty
a	NETC 2-Bar Bridge Rail	**5**
c	NETC 4-Bar Bridge Rail	**1**
m	2-Bar Steel Bridge Rail, non-NETC	**2**
	Total	**8**

Occupant Risk	Qty
BREACH	0
PEN	0

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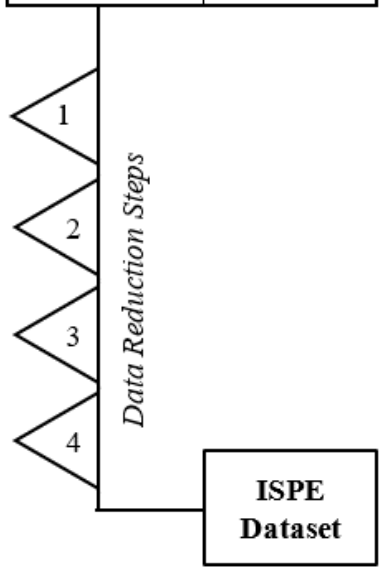
RIDOT – Task No. 2 – Crash Data Reduction

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

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RIDOT – Task No. 2 – Crash Data Numbers

Sev	Qty
K	0
A	1
B	8
C	3
O	24
U	0

Veh	Qty
MC	0
PC	30
PU	6
SUT	0
TT	0
OTR	0

Occupant Risk	Qty
BREACH	3
PEN	0

NAME	Rail or AGT	Qty
a	NETC 2-bar steel bridge rail	23
a or t	Inconclusive - NETC 2-bar steel bridge rail or 2-bar Concrete Transition Barrier, non-NETC	3
m	2-bar Steel Bridge Rail, non-NETC	4
m or q	Inconclusive – 2-bar Steel Bridge Rail, non-NETC or 2-bar Steel AGT, non-NETC	3
q	2-bar Steel AGT, non-NETC	2
t	2-bar Concrete Transition Barrier, non-NETC	1
	Total	**36**

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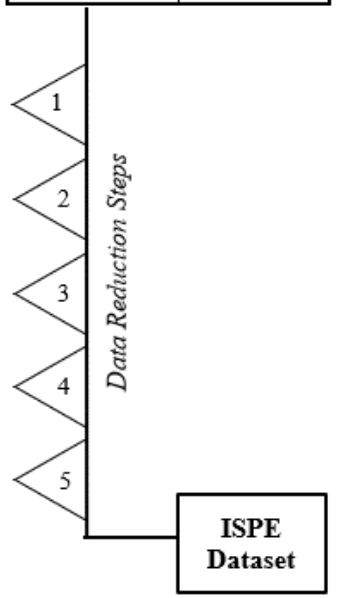
VTrans – Task No. 2 – Crash Data Reduction

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

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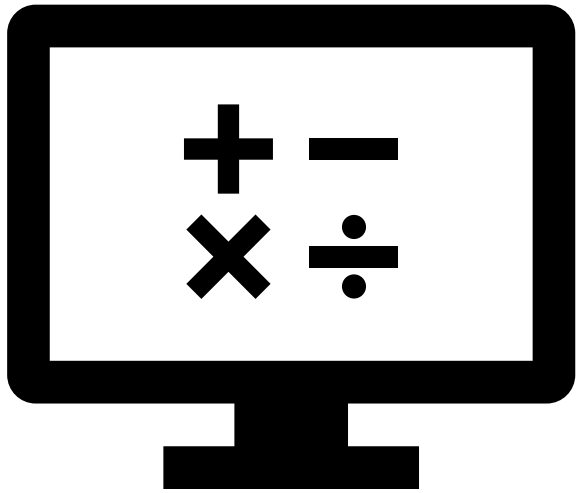
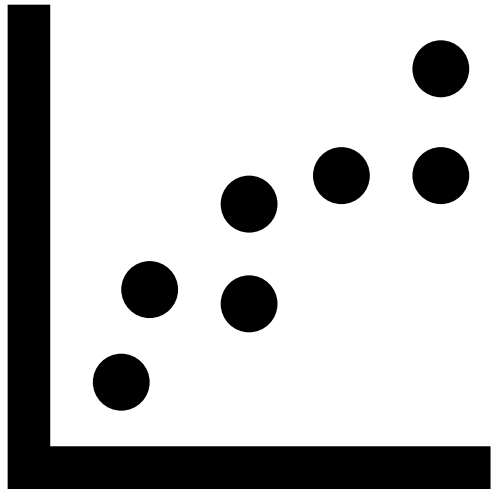
Task 1 & 2 Recommendations:

- **ME, NH, and RI:** 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 and AGTs.
- **ME, NH, and RI:** It is recommended that an ISPE report be developed for these states. This will support the combining of the results with the other states.
- **VT, MA, and CT:** It is recommended that no further data collection or analysis be conducted.
- **All:** It is recommended that a meta-analysis be conducted using the competed ME, NH, and RI ISPE reports. This will provide the best available information on the field performance of NETC rails and AGTs.

Task No. 3 – Conduct ISPE





MaineDOT – Task No. 3 – Conduct ISPE

Data Collection Area:	Public roads within the State of Maine
Data Collection Period:	1/1/2013 to 12/31/2020 → 8 years
Safety Features Under Evaluation:	NETC Bridge Railings and AGTs (i.e., SFUE=1)
Values of NAME Considered:	None
Number of SFUE Interactions in Dataset:	99
Evaluation Measures:	A Safety Feature Breach ~~D Occupant Compartment Penetration~~ F Rollover H Vehicle Mix J Secondary Impact on Roadside K Secondary Impact on Roadway ~~M Impact Orientation~~

Do Not Meet Condition 1, Unknowns

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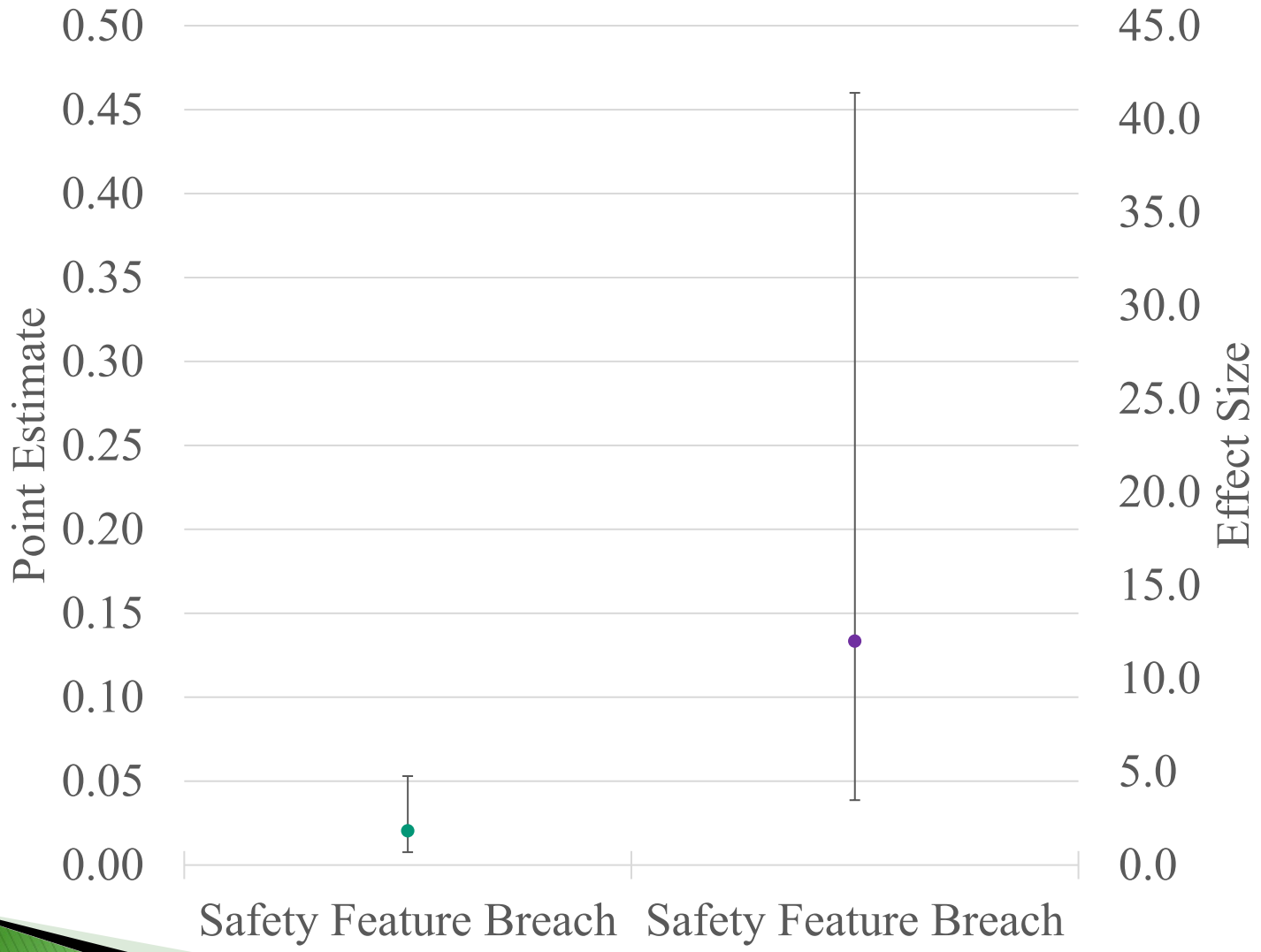
MaineDOT – Task No. 3 – Conduct ISPE



The containment of vehicles impacting the studied NETC rails and AGTs is similar or better than other studied bridge rails.

(NCHRP Project 22-12(03), *Recommended Guidelines for the Selection of Test Levels 2 Through 5 Bridge Rails*, 2015)

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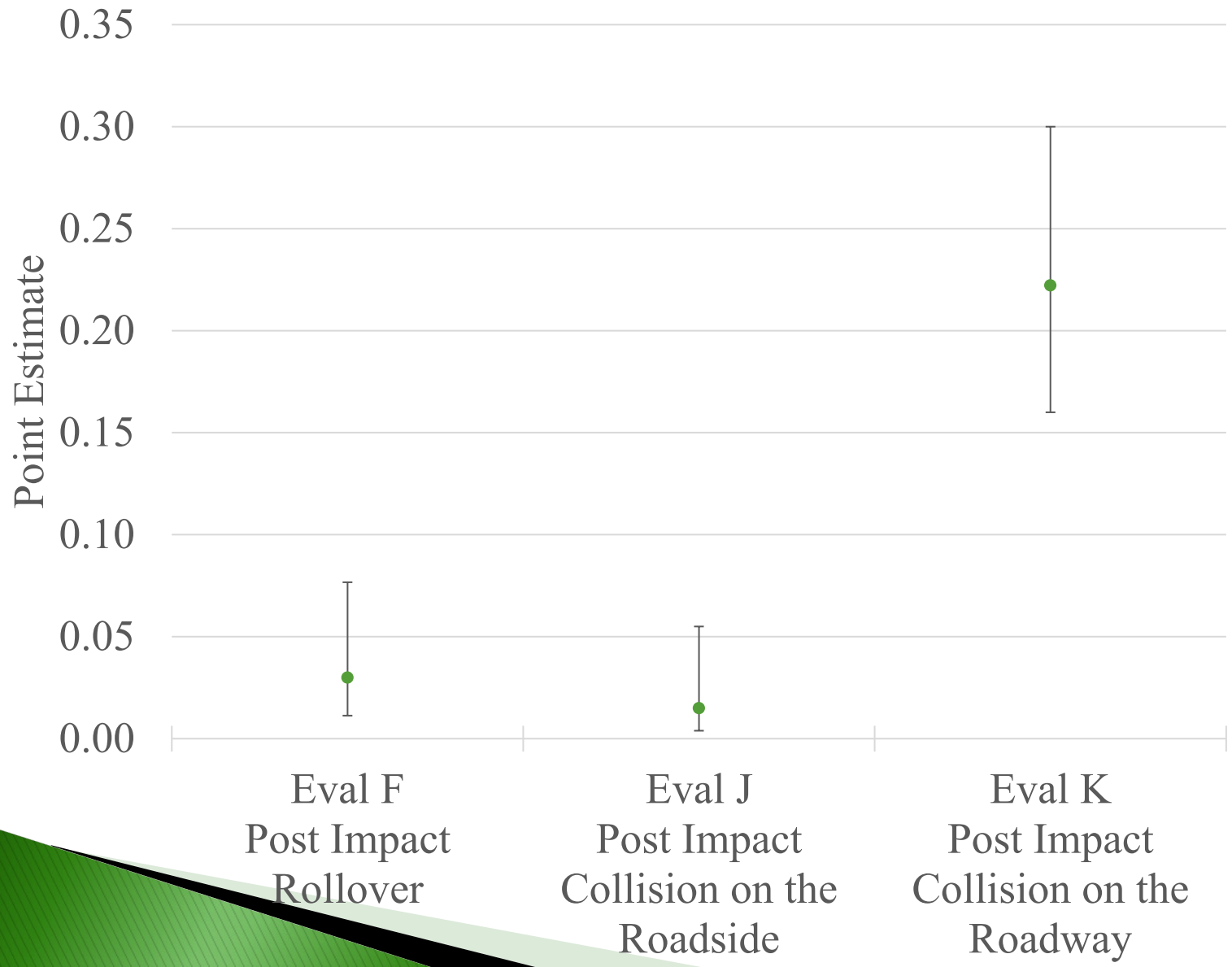
MaineDOT – Task No. 3 – Conduct ISPE



The NETC hardware has demonstrated a reduced risk of post-impact secondary collisions on the roadway when compared to other rigid longitudinal barriers.

(Ray, Michie, et al, *Evaluation of Design Analysis Procedures and Acceptance Criteria for Roadside Hardware Volume V. Hazards of the Redirected Car*, 1987)

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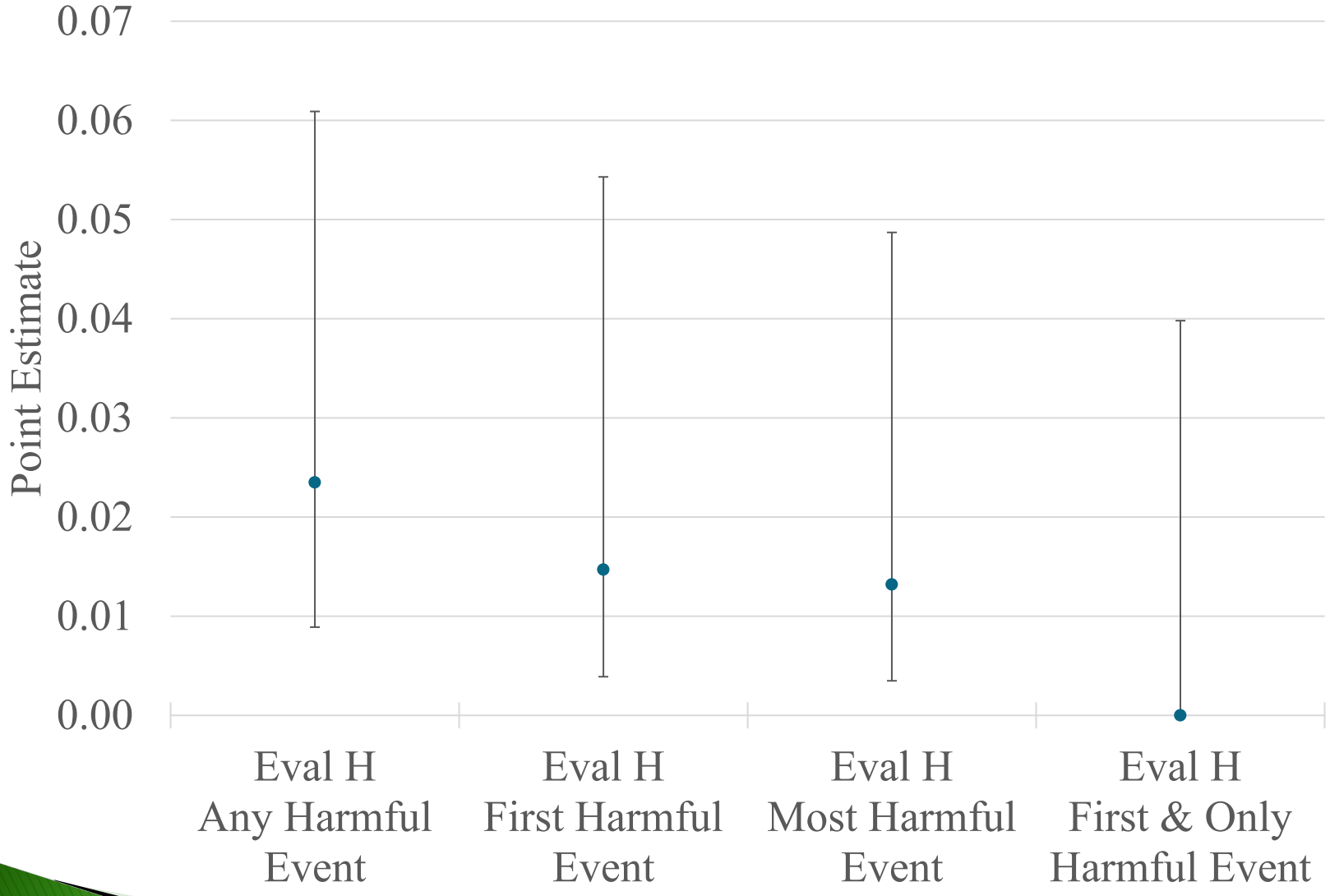
MaineDOT – Task No. 3 – Conduct ISPE



The NETC bridge rails and AGTs have demonstrated a reduced occupant risk when compared to other rigid longitudinal barriers.

(Carrigan and Ray, *In-Service Performance Evaluation of Longitudinal Barrier to Study Occupant Risk*, 2019)

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NHDOT – Task No. 3 – Conduct ISPE

Data Collection Area:	All roads in the State of New Hampshire
Data Collection Period:	1/1/2013 to 12/31/2016 → 4 years
Safety Features Under Evaluation:	NETC Bridge Railings and AGTs (i.e., SFUE=1)
Values of NAME Considered:	None
Number of SFUE Interactions in Dataset:	8
Evaluation Measures:	None

RIDOT – Task No. 3 – Conduct ISPE

Data Collection Area:	Public roads within the State of Rhode Island
Data Collection Period:	1/1/2016 to 12/31/2020 → 5 years
Safety Features Under Evaluation:	NETC Bridge Railings and AGTs (i.e., SFUE=1)
Values of NAME Considered:	None
Number of SFUE Interactions in Dataset:	36
Evaluation Measures:	A Safety Feature Breach ~~D Occupant Compartment Penetration~~ F Rollover H Vehicle Mix J Secondary Impact on Roadside K Secondary Impact on Roadway M Impact Orientation

Did Not Meet Condition 1, Unknowns

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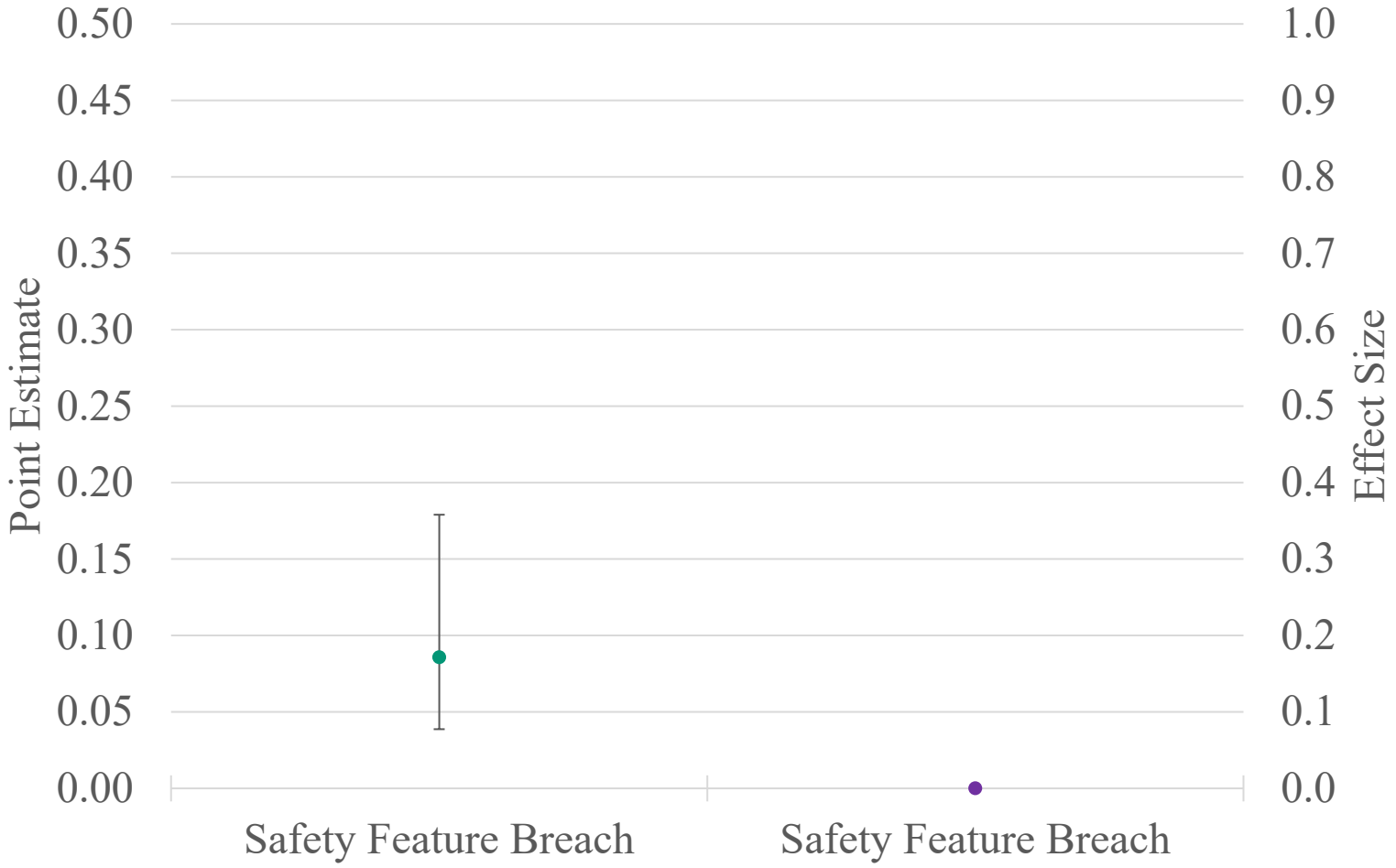
RIDOT – Task No. 3 – Conduct ISPE



The containment of vehicles impacting the studied NETC rails and AGTs is better than 27” tall bridge rails but not as good as for the 32” bridge rails studied by Ray and Carrigan

(NCHRP Project 22-12(03), *Recommended Guidelines for the Selection of Test Levels 2 Through 5 Bridge Rails*, 2015)

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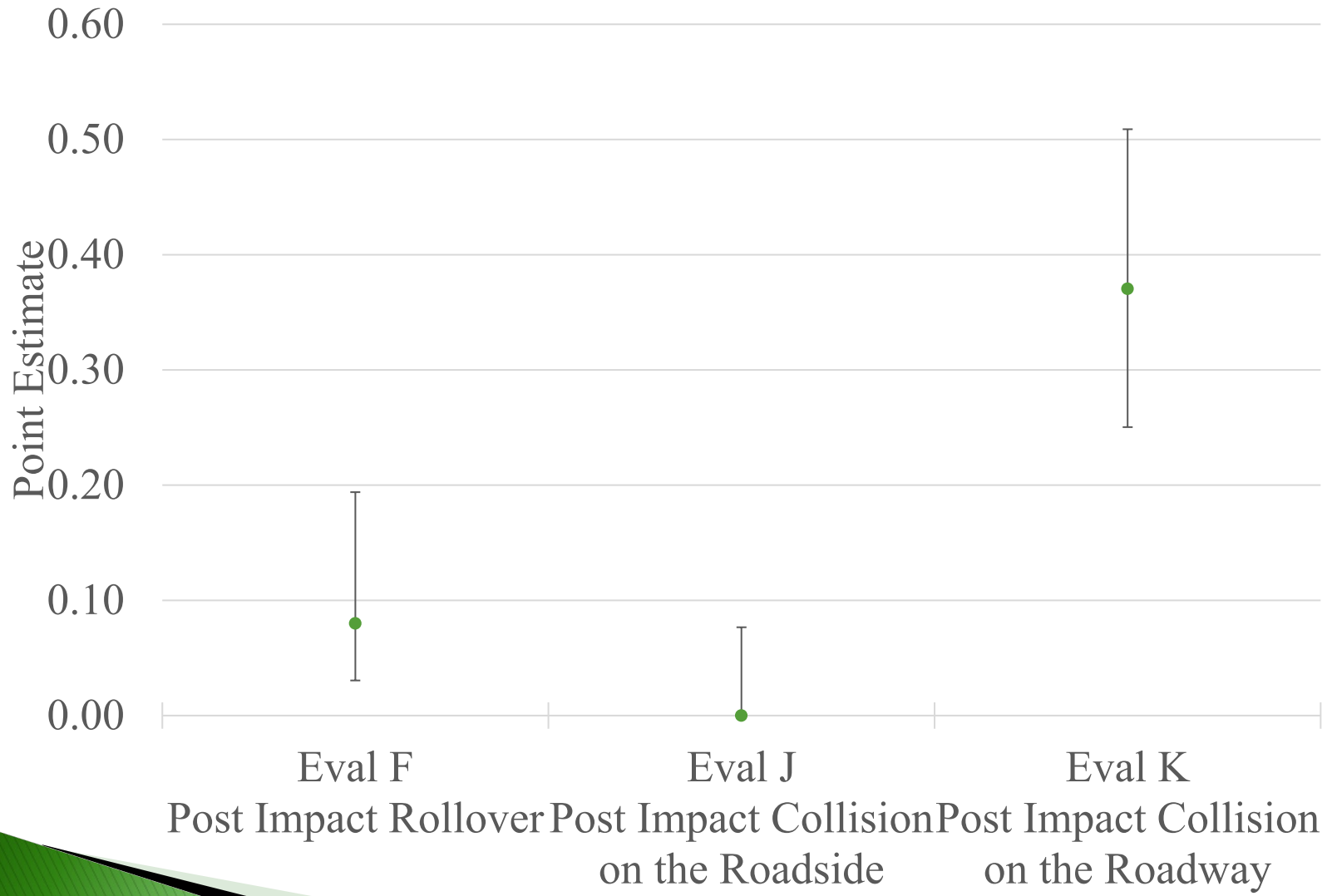
RIDOT – Task No. 3 – Conduct ISPE



The NETC hardware has demonstrated a reduced risk of post-impact secondary collisions on the roadway when compared to other rigid longitudinal barriers.

(Ray, Michie, et al, *Evaluation of Design Analysis Procedures and Acceptance Criteria for Roadside Hardware Volume V. Hazards of the Redirected Car*, 1987)

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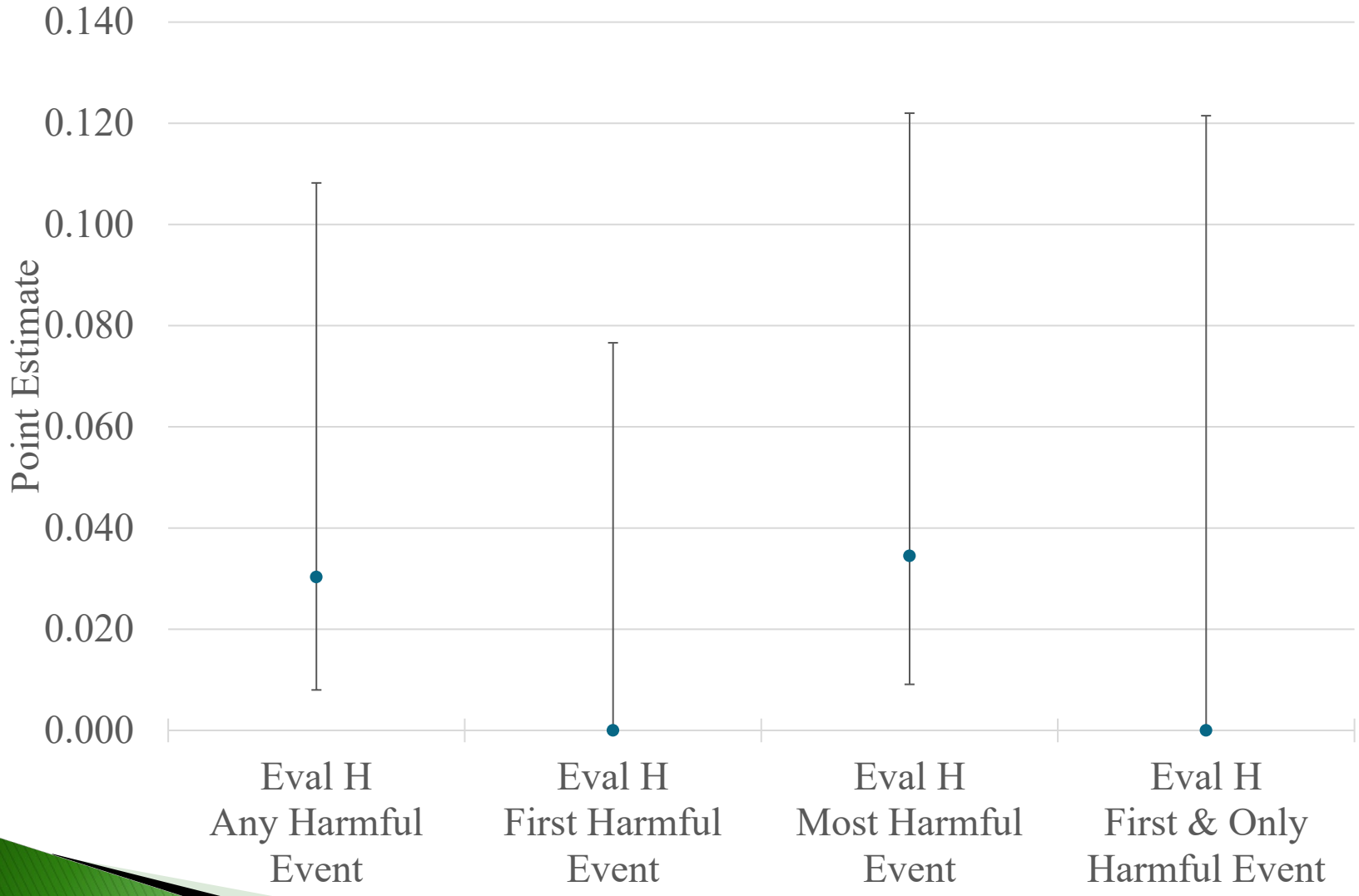
RIDOT – Task No. 3 – Conduct ISPE



The NETC bridge rails and AGTs have demonstrated a reduced occupant risk when compared to other rigid longitudinal barriers.

(Carrigan and Ray, *In-Service Performance Evaluation of Longitudinal Barrier to Study Occupant Risk*, 2019)

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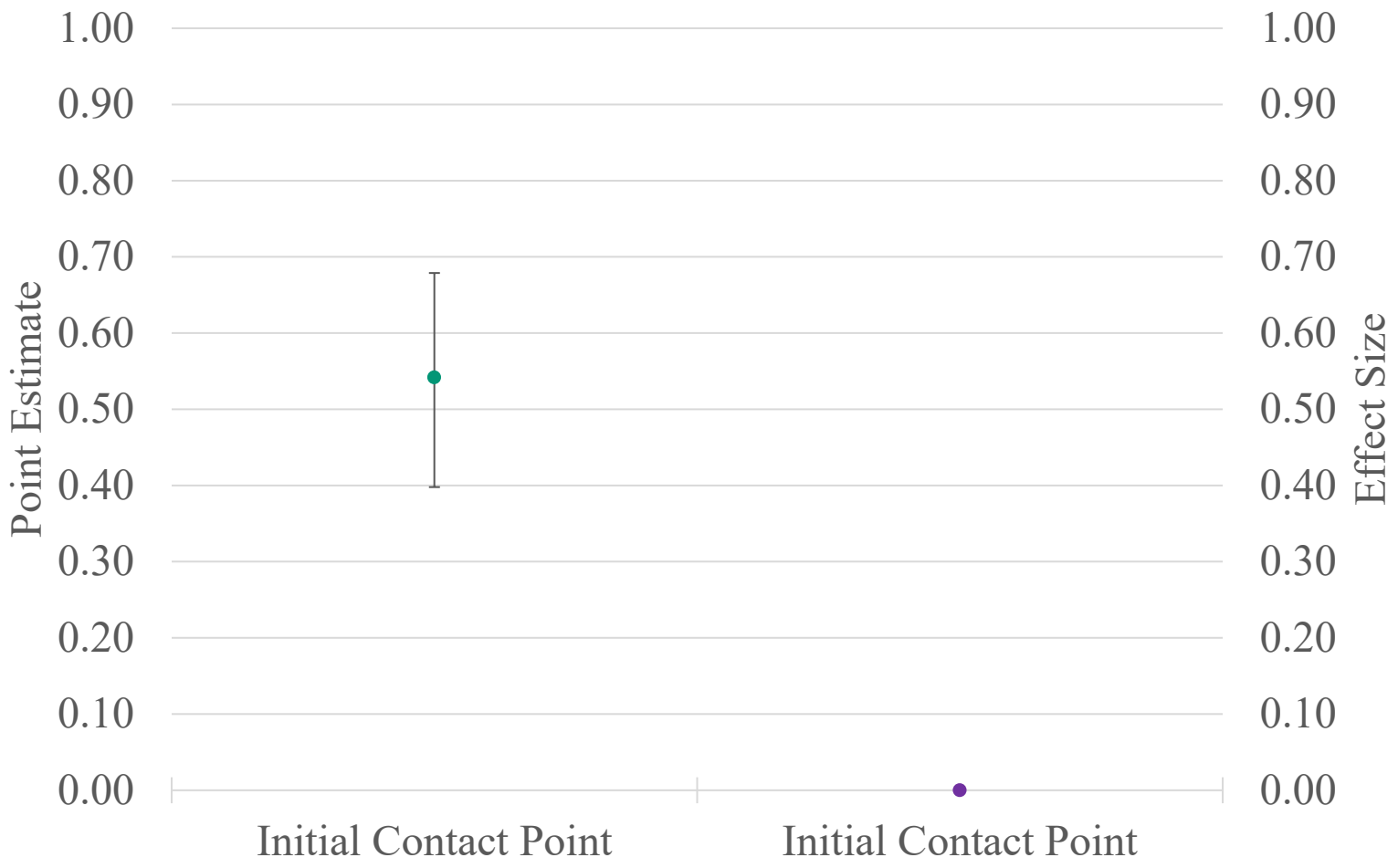
RIDOT – Task No. 3 – Conduct ISPE



The point estimate of nearly 55% of impacting vehicles impacting in an unexpected orientation (i.e., non-tracking) suggests that impacts on the roadway are more variable that what is accounted for in crash testing.

The low effect size (i.e., null) shows that crashes with unexpected orientation are not leading to dramatically more severe outcomes in the studied crashes.

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Meta-Analysis – Task No. 3

Meta-Analysis of Evaluation Measures for full vehicle mix (PAL1).

	State	Sample Size	R2 $\hat{p}$	σ	SE	w	Meta-analysis
A Safety Feature Breach	ME	98	0.0204	0.0143	0.0014	480,400.08	0.0225
	NH	8	*Null*	*Null*	*Null*	*Null*	
	RI	35	0.0857	0.0473	0.0080	15,631.51	
F Post Impact Rollover	ME	67	0.0299	0.0208	0.0025	155,008.62	0.0325
	NH	8	*Null*	*Null*	*Null*	*Null*	
	RI	25	0.0800	0.0543	0.0109	8,491.85	
H AHE Crash Severity	ME	85	0.0235	0.0164	0.0018	314,461.60	0.0242
	NH	8	*Null*	*Null*	*Null*	*Null*	
	RI	33	0.0303	0.0298	0.0052	37,060.03	
H MHE Crash Severity	ME	76	0.0132	0.0131	0.0015	444,829.01	0.0143
	NH	N/A	N/A	N/A	N/A	N/A	
	RI	29	0.0345	0.0339	0.0063	25,260.04	
K Post Impact Roadway	ME	72	0.2222	0.0490	0.0058	29,993.14	0.2362
	NH	8	*Null*	*Null*	*Null*	*Null*	
	RI	27	0.3704	0.0929	0.0179	3,126.12	

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Meta-Analysis – Task No. 3 – ISPE Conclusions

- This meta-analysis evaluated the structural adequacy, occupant risk, and vehicle trajectory for NETC bridge rails and AGTs using many evaluation measures.
- This meta-analysis shows that the studied systems have demonstrated similar or better field performance than other similar systems across all three performance outcomes.
- This exemplary field performance demonstrates the crashworthiness of the studied systems and supports their continued use.

Implementation Plan

Outcome	Recommendations	Stakeholders
ISPE dataset is populated as crashes occur allowing for performance monitoring.	The NETC member states are encouraged to continue to populate the ISPE dataset as crashes with NETC bridge railing and AGTs occur.	NETC TC
ISPE results are used in decision making and policy development.	The NETC member states are encouraged to periodically update the ISPE analysis to monitor in-field performance of the studied hardware.	NETC member states
	The NETC member states are encouraged to use the ISPE results now and into the future to support decisions to maintain existing hardware, when practical, in addition to reliance on evolving crash testing guidance.	
ISPE results are shared among transportation agencies.	The NETC member states are encouraged to share their ISPE results among other transportation agencies.	NETC TC

Conclusions

- The containment of vehicles impacting the studied NETC rails and AGTs is similar or better than other studied bridge rails.
- The risk of post impact secondary collisions on the roadway with NETC bridge rails and AGTs is considerably lower than other rigid barriers.
- The risk of a serious or fatal injuries when the studied hardware was impacted is lower than the risk found previously for rigid barriers.
- This ISPE shows that the studied hardware has demonstrated similar or better field performance than other similar systems across all three performance outcomes.
- This exemplary field performance demonstrates the crashworthiness of the studied systems and supports the continued use.
- Establishing that these long-standing designs are performing well in the field provides further confidence that the current designs adequately meet the higher performance criteria of MASH without further full-scale testing or FEA.

Questions and Discussion?

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