

I-95 Corridor Coalition Vehicle Probe Project: HERE, INRIX and TOMTOM Data Validation

Report for Maryland (#12)
US-40



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Executive Summary

Wireless re-identification traffic monitoring (WRTM) data is collected to validate data from the Vehicle Probe Project, and includes Bluetooth, Wi-Fi and other wireless traffic monitoring devices that collect signals emitted by in-vehicle electronic equipment. Specifications used for comparison between WRTM and probe vendor data include Average Absolute Speed Error (AASE) and Speed Error Bias (SEB).

- Both Bluetooth and Wi-Fi re-identification sensors were deployed at the beginning and end points of 9 different segments along US-40 corridors.
- US-40 segments stretch from Park Dr. to Old Orchard Rd. (Refer to Figure 1 below).
- Travel time data was collected for both directions along the corridors, between March 19 and March 30, 2018. This data collection period included:
 - A storm with freezing rain
 - Signal timing adjustments by Maryland DOT at intersections along the corridor
- The dataset collected represents approximately 2700 hours of observations along 9 arterial segments, totaling approximately 10 miles.
- The total number of effective five-minute travel time samples observed was 12,008.
- The vendor probe data is compared against the mean of the ground truth data as well as the 95th percent confidence interval for the mean, referred to as the Standard Error of the Mean (SEM) band.

ES Table 1 provides a summary description of the study corridor.

ES Table 1 - US-1 and US-9 Arterial Corridor Description			
Corridor Name	Number of Lanes	AADT	Speed Limit
US-40	6 lanes	37,000	45 <i>mph</i>

ES Tables 2, 3 and 4 below summarize the results of the comparison between the WRTM reference data and the probe data from each vendor for arterial segments during the data collection time period.

ES Table 2 - HERE Arterial Evaluation Summary for Maryland

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	3.13	9.59	3.13	9.58	674
15-25 MPH	1.28	5.53	1.2	4.82	4436
25-35 MPH	1.34	5.2	0.34	1.07	4557
>35 MPH	2.7	6.57	-2.56	-5.2	2341
All Speeds	1.69	5.84	0.25	1.71	12008

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

When HERE probe data was compared with WRTM data:

- The average absolute speed error (AASE) was within specification (<10 mph) in all speed bins.
- The Speed Error Bias (SEB) was within the specifications (< 5mph) for all speed bins when compared with the Standard Error of the Mean (SEM) Band

ES Table 3 - INRIX Arterial Evaluation Summary for Maryland

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	6.08	13.25	6.07	13.19	649
15-25 MPH	2.8	8.74	2.61	8.06	4290
25-35 MPH	1.85	6.07	1.26	3.67	4407
>35 MPH	2.42	6.46	-1.95	-3.64	2256
All Speeds	2.55	7.53	1.41	4.4	11602

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

When INRIX probe data was compared with WRTM data:

- The average absolute speed error (AASE) was within specification (<10 mph) in all speed bins when compared with the Standard Error of the Mean (SEM) Band.
- The Speed Error Bias (SEB) was within the specifications (< 5mph) for all but the lowest speed bin (0-15 mph) when compared with the Standard Error of the Mean (SEM) Band

ES Table 4 - TOMTOM Arterial Evaluation Summary for Maryland					
Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	2.37	8.75	2.37	8.75	674
15-25 MPH	1.21	5.55	1.18	5.04	4436
25-35 MPH	1.57	5.23	1.05	2.55	4557
>35 MPH	2.44	6.27	-2.31	-4.38	2341
All Speeds	1.65	5.75	0.52	2.47	12008

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

When TOMTOM probe data was compared with WRTM data:

- The average absolute speed error (AASE) was within specification (<10 mph) in all speed bins.
- The Speed Error Bias (SEB) was within the specifications (< 5mph) for all speed bins when compared with the Standard Error of the Mean (SEM) Band

Methodology

Corridor Description and Data Collection

Travel time samples were collected along 9 arterial segments with the assistance of Maryland Department of Transportation (MDOT) personnel. The arterial segments are located on the US-40 corridor from Park Drive to Old Orchard Road and were selected because they often experience recurrent congestion during peak periods. Travel time data was collected for both directions along the arterial segments between March 19 and March 30, 2018.

Figure 1 presents an overview of the sensor placements along the US-40 corridor in Maryland. Markers shows the start and end points of arterial segments selected for analysis.

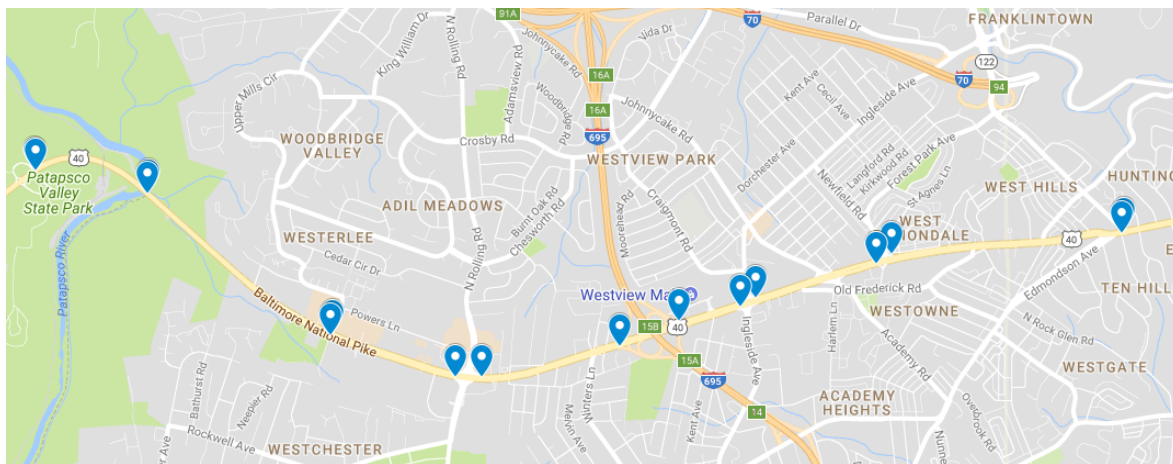


Figure 1- Locations of all segments selected on the US-40 corridor for analysis in Maryland

Segments selected for validation in Maryland

Table 1 presents the data collection segments from Maryland, which encompass approximately 10 arterial miles. Data collection segments are comprised of one or more Traffic Message Channel (TMC) base segments, such that the total length of the data collection segment is, in most cases, one mile or greater for arterials. When appropriate, consecutive TMC segments are combined to form a data collection segment longer than one mile. The results of the validation performed on 9 directional arterial segments are included in this report.

Table 1 contains the summary information for each data collection segment including the latitude/longitude coordinates of the locations at which the WRTM sensors were deployed along the US-40 corridors in Maryland, as well as an active map link, which can be followed to view each data collection segment in detail. Please note that the configuration of the test

segments is often such that the endpoint of one segment coincides with the start point of the next segment, so that one WRTM sensor covers both data collection segments.

An algorithm was developed and documented in a separate report¹ as part of the initial VPP project and is being used for the validation of all vendors in VPPII. Details of the algorithm used to estimate equivalent path travel times based on probe data feeds for individual data collection segments are provided in this separate report. This algorithm finds an equivalent probe travel time (and therefore travel speed) corresponding to each sample WRTM travel time observation on the test segment of interest.

¹ Ali Haghani, Masoud Hamed, Kaveh Farokhi Sadabadi, Estimation of Travel Times for Multiple TMC Segments, prepared for I-95 Corridor Coalition, February 2010 ([link](#))

Table 1

Segments selected for validation in Maryland

Segment (Map Link)	DESCRIPTION					Deployment	
	Highway Direction	Starting at Ending at	Lane (Min) Lane (Max)	AADT (Min) AADT (Max)	Access Points Speed Limit	Begin Lat/Lon End Lat/Lon	Length (mile)
Arterial							
A1 MD12-0001	US-40 Eastbound	Park Dr N Rolling Rd	3 3	50,454 54,256	4 45	39.29547 -76.78814 39.28355 -76.75359	2.15
A2 MD12-0002	US-40 Eastbound	N Rolling Rd 695	3 3	49,055 54,256	5 45	39.28355 -76.75359 39.28559 -76.74102	0.69
A3 MD12-0003	US-40 Eastbound	695 Ingleside Ave	3 3	49,932 60,537	2 45	39.28559 -76.74102 39.28796 -76.73151	0.53
A4 MD12-0004	US-40 Eastbound	Ingleside Ave St Agnes Ln	3 3	56,582 62,089	2 45	39.28796 -76.73151 39.29049 -76.72091	0.59
A5 MD12-0005	US-40 Eastbound	St Agnes Ln Old Orchard Rd	3 3	26,348 58,560	5 45	39.29049 -76.72091 39.29230 -76.70202	1.02
A6 MD12-0006	US-40 Westbound	Old Orchard Rd St Agnes Ln	3 3	23,485 26,483	5 45	39.29243 -76.70218 39.29074 -76.72067	1.00
A7 MD12-0007	US-40 Westbound	St Agnes Ln 695	3 3	26,483 26,483	4 45	39.29074 -76.72067 39.28685 -76.73679	0.90
A8 MD12-0008	US-40 Westbound	695 N Rolling Rd	3 3	26,483 27,168	5 45	39.28685 -76.73679 39.28372 -76.75351	0.93
A9 MD12-0009	US-40 Westbound	N Rolling Rd Park Dr	3 3	27,168 29,138	3 45	39.28372 -76.75351 39.29542 -76.78840	2.17

Analysis of Arterials

The following sections summarize the data quality measures obtained as a result of comparison between WRTM and all reported probe speeds. Specifications used for comparison include the Average Absolute Speed Error (AASE) and the Speed Error Bias (SEB).

Average Absolute Speed Error (AASE)

The AASE is defined as the mean absolute value of the difference between the mean speed reported from the VPP and the ground truth mean speed for a specified time period. The AASE is the primary accuracy metric. Based on the contract specifications, the speed data from the VPP shall have a maximum average absolute error of 10 miles per hour (MPH) in each of four speed ranges: 0-15 MPH, 15-25 MPH, 25-35 MPH, and > 35 MPH.

Speed Error Bias (SEB)

The SEB is defined as the average speed error (not the absolute value) in each speed range. SEB is a measure of whether the speed reported in the VPP consistently under or over estimates speed as compared to ground truth speed. Based on the contract specifications, the VPP data shall have a maximum SEB of +/- 5 MPH in each of speed ranges as defined above.

The results are presented as compared against the mean of the ground truth data as well as the 95th percent confidence interval for the mean, referred to as the Standard Error of the Mean (SEM) band. The SEM band takes into account any uncertainty in the ground truth speed as measured by WRTM equipment due to limited samples and/or data variance. Contract specifications are assessed against the SEM band. (See the *Vehicle Probe Project: Data Use and Application Guide* for additional details on the validation process.) The AASE in the lower two speed bins have proven to be the critical specification (and most difficult) to attain².

² The ground-truth data collected for this report as well as detailed daily comparison graphs for all segments are available for download upon request. Please email zvanderl@umd.edu for such inquiries.

Results

Analysis of Arterial Results for HERE Data

Table 2 shows the results of the comparison between the WRTM reference data and the HERE data. As stated before, the average absolute speed error (AASE) was within specification in all speed bins. The Speed Error Bias (SEB) was within specifications for all speed bins when compared with the Standard Error of the Mean (SEM) Band.

Table 2- HERE Data quality measures for arterial segments in Maryland

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	3.13	9.59	3.13	9.58	674
15-25 MPH	1.28	5.53	1.2	4.82	4436
25-35 MPH	1.34	5.2	0.34	1.07	4557
>35 MPH	2.7	6.57	-2.56	-5.2	2341
All Speeds	1.69	5.84	0.25	1.71	12008

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

Table 3 shows the percentage of the time the HERE data falls within 5 mph of the SEM band and the mean for each speed bin for all arterial data segments in this validation report.

Table 3- Percent observations meeting HERE data quality criteria for arterial segments in Maryland

SPEED BIN	Data Quality Measures for				No. of Obs.
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage falling within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0-15	41%	74%	0%	16%	674
15-25	69%	90%	0%	54%	4436
25-35	62%	90%	0%	54%	4557
35+	52%	78%	0%	49%	2341

Analysis of Arterial Results for INRIX Data

Table 4 shows the results of the comparison between the WRTM reference data and the INRIX data. As stated before, the average absolute speed error (AASE) was within specification for all speed bins when compared with the Standard Error of the Mean (SEM) Band. The Speed Error Bias (SEB) was within specifications for all but the lowest speed bin (0-15 MPH) when compared with the Standard Error of the Mean (SEM) Band.

Table 4- INRIX Data quality measures for arterial segments in Maryland

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	6.08	13.25	6.07	13.19	649
15-25 MPH	2.8	8.74	2.61	8.06	4290
25-35 MPH	1.85	6.07	1.26	3.67	4407
>35 MPH	2.42	6.46	-1.95	-3.64	2256
All Speeds	2.55	7.53	1.41	4.4	11602

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

Table 5 shows the percentage of the time the INRIX data falls within 5 mph of the SEM band and the mean for each speed bin for all arterial data segments in this validation report.

Table 5- Percent observations meeting INRIX data quality criteria for arterial segments in Maryland

SPEED BIN	Data Quality Measures for				No. of Obs.
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage falling within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0-15	22%	49%	0%	9%	649
15-25	52%	76%	0%	28%	4290
25-35	62%	85%	0%	51%	4407
35+	54%	81%	0%	46%	2256

Analysis of Arterial Results for TOMTOM Data

Table 6 shows the results of the comparison between the WRTM reference data and the TOMTOM data. As stated before, the average absolute speed error (AASE) was within specification in all speed bins. The Speed Error Bias (SEB) was within specifications for all speed when compared with the Standard Error of the Mean (SEM) Band.

Table 6- TOMTOM Data quality measures for arterial segments in Maryland

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
0-15 MPH	2.37	8.75	2.37	8.75	674
15-25 MPH	1.21	5.55	1.18	5.04	4436
25-35 MPH	1.57	5.23	1.05	2.55	4557
>35 MPH	2.44	6.27	-2.31	-4.38	2341
All Speeds	1.65	5.75	0.52	2.47	12008

Based upon data collected from March 19, through March 30, 2018 across 10 miles of roadway.

Table 7 shows the percentage of the time the TOMTOM data falls within 5 mph of the SEM band and the mean for each speed bin for all arterial data segments in this validation report.

Table 7- Percent observations meeting TOMTOM data quality criteria for arterial segments in Maryland

SPEED BIN	Data Quality Measures for				No. of Obs.
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage falling within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0-15	41%	85%	0%	19%	674
15-25	67%	92%	0%	50%	4436
25-35	65%	86%	0%	58%	4557
35+	55%	80%	0%	51%	2341

Appendix

Table A.1 to A.3 presents detailed data for individual segments in this validation for all three vendors. Note that for some segments and in some speed bins the comparison results may not be reliable due to the small number of observations.

Table A. 1

HERE data quality measures for individual arterial validation segments in the state of Maryland

Path	Standard TMC length	Sensor distance	SPEED BIN	Data Quality Measures for				No. of Obs.
				1.96 SEM Band		Mean		
				Speed Error Bias	Average Absolute Speed Error	Speed Error Bias	Average Absolute Speed Error	
MD12-0001	2.15	2.15	0-15	6.52	6.52	9.04	9.04	13*
			15-25	6.07	6.07	10.67	10.67	166
			25-35	2.62	2.62	6.93	7.07	1201
			35+	0.01	0.74	0.57	3.66	307
MD12-0002	0.69	0.69	0-15	2.44	2.44	8.85	8.86	109
			15-25	0.74	0.87	3.98	4.67	1049
			25-35	-0.6	0.79	-0.87	4.38	469
			35+	-3.39	3.39	-7.69	7.88	138
MD12-0003	0.53	0.53	0-15	2.31	2.31	8.58	8.58	119
			15-25	0.44	0.56	3.21	4.44	747
			25-35	-1.15	1.15	-4.08	5.26	287
			35+	-8.25	8.25	-15.06	15.07	86
MD12-0004	0.59	0.59	0-15	4.26	4.26	13.09	13.17	54
			15-25	0.63	0.69	5.78	6.6	464
			25-35	-0.61	0.9	-0.98	5.51	465
			35+	-5.22	5.23	-9.59	9.97	297
MD12-0005	1.02	1.02	0-15	4.26	4.26	12.18	12.18	30
			15-25	1.96	1.98	7.08	7.4	539
			25-35	-0.04	0.8	0.36	4.19	878
			35+	-2.33	2.35	-6.61	6.94	65
MD12-0006	1.00	1.00	0-15	4.05	4.05	14.33	14.33	3*
			15-25	1.08	1.27	4.98	5.78	219
			25-35	-0.68	0.92	-1.89	4	926
			35+	-4.86	4.86	-9.85	9.88	213
MD12-0007	0.90	0.90	0-15	2.23	2.23	8.55	8.55	174
			15-25	1.2	1.29	3.3	4.22	513
			25-35	-0.76	0.76	-3.5	4.66	117
			35+	-7.5	7.5	-13.48	13.48	21*
MD12-0008	0.92	0.92	0-15	4.17	4.17	10.31	10.31	165
			15-25	1.34	1.38	5	5.43	721
			25-35	-0.95	0.95	-3.31	4.41	88
			35+	-4.82	4.82	-9.91	9.91	10*
MD12-0009	2.17	2.17	0-15	5.59	5.59	7.15	7.15	7*
			15-25	2.27	2.27	9.06	9.06	18*
			25-35	1.04	1.04	5.95	6.17	126
			35+	-1.56	1.64	-3.52	4.97	1204

*Results in the specified row may not be reliable due to a small number of observations. Based on the central limit theorem, the trigger for this result is when there are less than 30 observations.

Table A.2 presents detailed data for individual segments for INRIX.

Table A. 2
INRIX data quality measures for individual arterial validation segments in the state of Maryland

Path	Standard TMC length	Sensor distance	SPEED BIN	Data Quality Measures for				No. of Obs.
				1.96 SEM Band		Mean		
				Speed Error Bias	Average Absolute Speed Error	Speed Error Bias	Average Absolute Speed Error	
MD12-0001	2.15	2.15	0-15	10.25	10.25	13.07	13.07	13*
			15-25	7.96	7.97	12.37	12.45	163
			25-35	4.14	4.23	8.78	9.09	1159
			35+	0.05	1.62	2.07	5.45	298
MD12-0002	0.69	0.69	0-15	3.69	3.74	9.87	10.04	102
			15-25	1.86	2.32	5.84	7.27	1013
			25-35	-0.28	1.44	1.17	5.73	456
			35+	-3.49	3.57	-7.17	8.45	134
MD12-0003	0.53	0.53	0-15	6.11	6.11	13.73	13.83	116
			15-25	2	2.05	9.14	9.59	720
			25-35	-0.14	0.76	1.68	5.51	274
			35+	-4.36	4.36	-9.78	10.05	83
MD12-0004	0.59	0.59	0-15	6.19	6.19	16.02	16.02	51
			15-25	1.57	1.68	9.93	10.44	453
			25-35	0.21	0.79	2.94	6.12	449
			35+	-3.14	3.38	-6.62	8.02	285
MD12-0005	1.02	1.02	0-15	7.46	7.46	15.95	16.09	30
			15-25	2.67	2.81	8.48	8.88	518
			25-35	0.55	1.08	2.23	4.46	847
			35+	-1.3	1.77	-4.85	6.16	65
MD12-0006	1.00	1.00	0-15	4.17	4.17	14	14	3*
			15-25	2.41	2.64	7.7	8.37	212
			25-35	0.24	0.92	1.18	4.26	900
			35+	-3.09	3.13	-6.98	7.43	199
MD12-0007	0.90	0.90	0-15	6.11	6.11	13.57	13.57	168
			15-25	3.5	3.53	7.8	8.04	494
			25-35	-0.14	0.35	-0.54	3.89	115
			35+	-6.19	6.19	-11.98	11.98	20*
MD12-0008	0.92	0.92	0-15	6.85	6.85	13.28	13.28	159
			15-25	3.11	3.25	7.82	8.44	699
			25-35	-0.27	0.62	0.36	4.71	84
			35+	-1.86	1.86	-6.46	6.48	9*
MD12-0009	2.17	2.17	0-15	7.55	7.55	9.14	9.14	7*
			15-25	4.38	4.38	11.81	11.87	18*
			25-35	1.59	1.72	6.31	7.05	123
			35+	-1.6	1.98	-2.72	5.61	1163

*Results in the specified row may not be reliable due to a small number of observations. Based on the central limit theorem, the trigger for this result is when there are less than 30 observations.

Table A.3 presents detailed data for individual segments for TomTom.

Table A. 3

TOMTOM data quality measures for individual arterial validation segments in the state of Maryland

Path	Standard TMC length	Sensor distance	SPEED BIN	Data Quality Measures for				No. of Obs.
				1.96 SEM Band		Mean		
				Speed Error Bias	Average Absolute Speed Error	Speed Error Bias	Average Absolute Speed Error	
MD12-0001	2.15	2.15	0-15	3.9	3.9	6.72	6.72	13*
			15-25	6.23	6.23	10.72	10.72	166
			25-35	4.54	4.59	9.72	9.86	1201
			35+	0.07	0.48	2.06	3.51	307
MD12-0002	0.69	0.69	0-15	3.25	3.25	10.39	10.39	109
			15-25	1.41	1.41	6.33	6.42	1049
			25-35	0.03	0.3	2.53	3.99	469
			35+	-1.9	1.9	-5.95	5.95	138
MD12-0003	0.53	0.53	0-15	2.04	2.04	8.37	8.37	119
			15-25	0.34	0.45	3.29	4.39	747
			25-35	-0.84	0.88	-3.64	4.64	287
			35+	-7.72	7.72	-14.46	14.46	86
MD12-0004	0.59	0.59	0-15	2.11	2.11	9.04	9.04	54
			15-25	0.17	0.26	2.97	4.12	464
			25-35	-1.15	1.15	-4.62	4.94	465
			35+	-8.44	8.44	-14.13	14.13	297
MD12-0005	1.02	1.02	0-15	3.35	3.35	11.26	11.26	30
			15-25	1.65	1.65	7.68	7.74	539
			25-35	-0.05	0.17	0.66	2.52	878
			35+	-2.16	2.16	-7.66	7.66	65
MD12-0006	1.00	1.00	0-15	6.31	6.31	16.58	16.58	3*
			15-25	2.2	2.2	7.84	7.98	219
			25-35	0.04	0.25	1.15	2.65	926
			35+	-2.38	2.38	-7	7	213
MD12-0007	0.90	0.90	0-15	2.05	2.05	8.98	8.98	174
			15-25	0.8	0.81	3.05	3.62	513
			25-35	-0.6	0.6	-3.78	4.04	117
			35+	-8.86	8.86	-15.68	15.68	21*
MD12-0008	0.92	0.92	0-15	2.01	2.01	7.27	7.27	165
			15-25	0.76	0.77	3.47	4.11	721
			25-35	-0.66	0.69	-2.39	3.67	88
			35+	-4.29	4.29	-10.57	10.57	10*
MD12-0009	2.17	2.17	0-15	4.26	4.26	5.85	5.85	7*
			15-25	2.83	2.83	11.23	11.23	18*
			25-35	1.72	1.77	7.82	8.11	126
			35+	-0.93	1.04	-1.82	4.08	1204

*Results in the specified row may not be reliable due to a small number of observations. Based on the central limit theorem, the trigger for this result is when there are less than 30 observations.