

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

Report for Maryland (#12)  
US-40



*Prepared by:  
Zachary Vander Laan, Sara Zahedian  
University of Maryland, College Park*

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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 nine (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 nine (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 95<sup>th</sup> 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.

| <b>ES Table 1 - US-1 and US-9 Arterial Corridor Description</b> |                        |             |                    |
|-----------------------------------------------------------------|------------------------|-------------|--------------------|
| <b>Corridor Name</b>                                            | <b>Number of Lanes</b> | <b>AADT</b> | <b>Speed Limit</b> |
| 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

| <b>ES Table 4 - TOMTOM Arterial Evaluation Summary for Maryland</b> |                                                 |                             |                                    |                             |                                   |
|---------------------------------------------------------------------|-------------------------------------------------|-----------------------------|------------------------------------|-----------------------------|-----------------------------------|
| <b>Speed Bin</b>                                                    | <b>Average Absolute Speed Error (&lt;10mph)</b> |                             | <b>Speed Error Bias (&lt;5mph)</b> |                             | <b>Number of 5 Minute Samples</b> |
|                                                                     | <b>Comparison with SEM Band</b>                 | <b>Comparison with Mean</b> | <b>Comparison with SEM Band</b>    | <b>Comparison with Mean</b> |                                   |
| 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 nine (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.

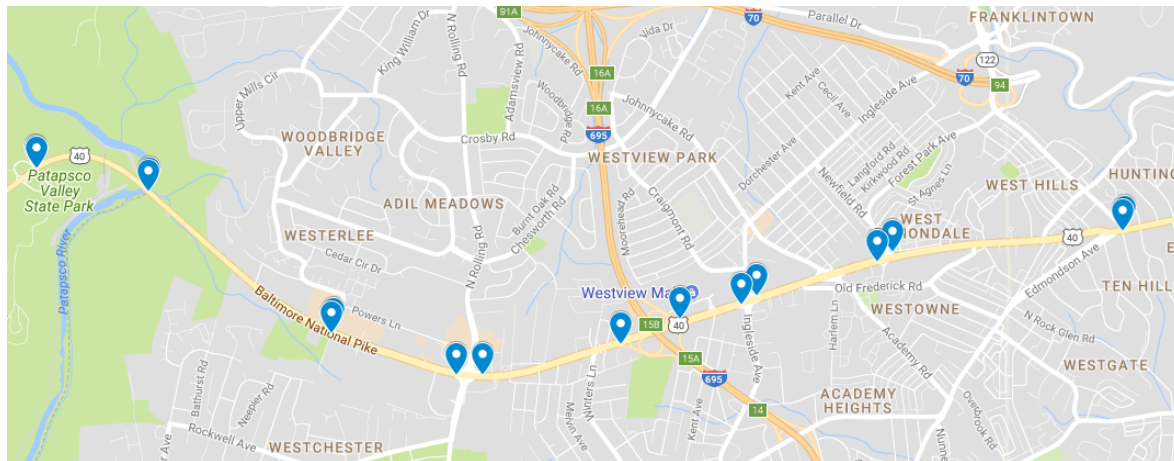


Figure 1- Locations of all segments selected on the US-40 corridor for analysis in Maryland

## 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 nine (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 report<sup>1</sup> 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.

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<sup>1</sup> 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<br>(Map Link)           | DESCRIPTION          |                               |                          |                          |                              | Deployment                               |                  |
|---------------------------------|----------------------|-------------------------------|--------------------------|--------------------------|------------------------------|------------------------------------------|------------------|
|                                 | Highway<br>Direction | Starting at<br>Ending at      | Lane (Min)<br>Lane (Max) | AADT (Min)<br>AADT (Max) | Access Points<br>Speed Limit | Begin Lat/Lon<br>End Lat/Lon             | Length<br>(mile) |
| <b>Arterial</b>                 |                      |                               |                          |                          |                              |                                          |                  |
| A1<br><a href="#">MD12-0001</a> | US-40<br>Eastbound   | Park Dr<br>N Rolling Rd       | 3<br>3                   | 50,454<br>54,256         | 4<br>45                      | 39.29547 -76.78814<br>39.28355 -76.75359 | 2.15             |
| A2<br><a href="#">MD12-0002</a> | US-40<br>Eastbound   | N Rolling Rd<br>695           | 3<br>3                   | 49,055<br>54,256         | 5<br>45                      | 39.28355 -76.75359<br>39.28559 -76.74102 | 0.69             |
| A3<br><a href="#">MD12-0003</a> | US-40<br>Eastbound   | 695<br>Ingleside Ave          | 3<br>3                   | 49,932<br>60,537         | 2<br>45                      | 39.28559 -76.74102<br>39.28796 -76.73151 | 0.53             |
| A4<br><a href="#">MD12-0004</a> | US-40<br>Eastbound   | Ingleside Ave<br>St Agnes Ln  | 3<br>3                   | 56,582<br>62,089         | 2<br>45                      | 39.28796 -76.73151<br>39.29049 -76.72091 | 0.59             |
| A5<br><a href="#">MD12-0005</a> | US-40<br>Eastbound   | St Agnes Ln<br>Old Orchard Rd | 3<br>3                   | 26,348<br>58,560         | 5<br>45                      | 39.29049 -76.72091<br>39.29230 -76.70202 | 1.02             |
| A6<br><a href="#">MD12-0006</a> | US-40<br>Westbound   | Old Orchard Rd<br>St Agnes Ln | 3<br>3                   | 23,485<br>26,483         | 5<br>45                      | 39.29243 -76.70218<br>39.29074 -76.72067 | 1.00             |
| A7<br><a href="#">MD12-0007</a> | US-40<br>Westbound   | St Agnes Ln<br>695            | 3<br>3                   | 26,483<br>26,483         | 4<br>45                      | 39.29074 -76.72067<br>39.28685 -76.73679 | 0.90             |
| A8<br><a href="#">MD12-0008</a> | US-40<br>Westbound   | 695<br>N Rolling Rd           | 3<br>3                   | 26,483<br>27,168         | 5<br>45                      | 39.28685 -76.73679<br>39.28372 -76.75351 | 0.93             |
| A9<br><a href="#">MD12-0009</a> | US-40<br>Westbound   | N Rolling Rd<br>Park Dr       | 3<br>3                   | 27,168<br>29,138         | 3<br>45                      | 39.28372 -76.75351<br>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 95<sup>th</sup> 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 attain<sup>2</sup>.

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<sup>2</sup> 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](mailto: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.

Note that TomTom cannot report speeds above the posted speed limit, which sometimes results in large negative speed error biases in the 35+ mph speed category. However, the overall performance (i.e., across all paths and time periods) for this speed bin is well within the contract specifications.