The Eastern Transportation Coalition Vehicle Probe Project: HERE, INRIX and TomTom Data Validation

Report for Georgia
Arterial Validation: Georgia #05

Data Collection: September 2021
Report Date: March 2022

Prepared by:
Zachary Vander Laan, Stanley Young, Sepideh Eshragh, Romina Jahangiri, Sanaz Aliari
University of Maryland, College Park

Acknowledgements:
The research team would like to express its gratitude for the assistance it received from Georgia DOT during the data collection phase of the validation effort.

1. Table of Contents

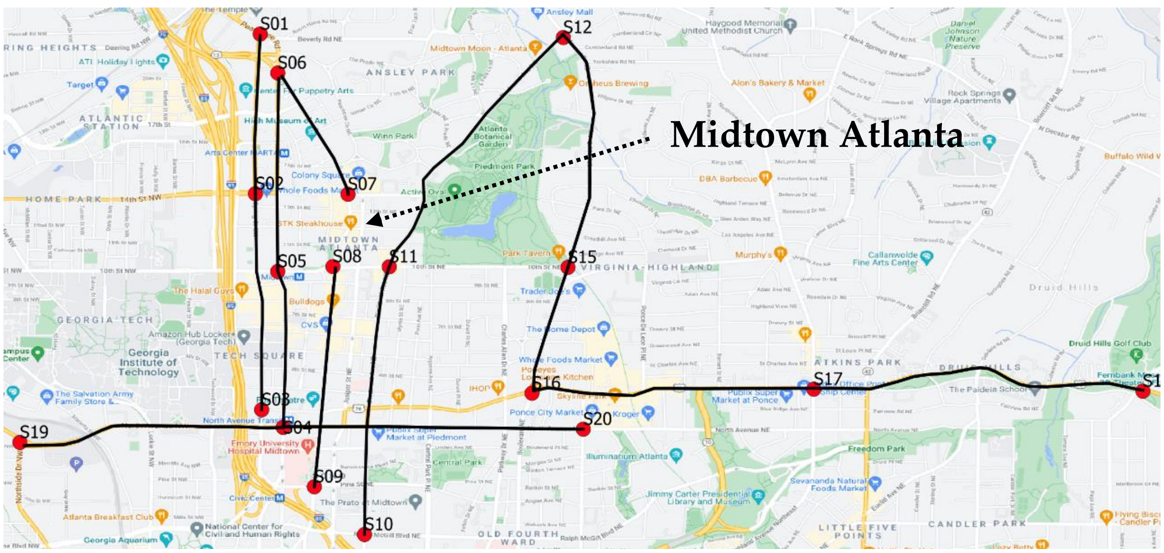
List of Tables

List of Figures

Executive Summary

This report provides the results of validation activities for the Eastern Transportation Coalition's (TETC's) Vehicle Probe Project in which multiple vendors provide travel time and speed data to our members for operations, planning and performance measures purposes. Wireless re-identification traffic monitoring (WRTM) technology (Bluetooth and/or Wi-Fi) is used to evaluate the quality of speeds reported by probe data vendors on selected validation road segments.

This study focuses on 7 signalized arterial corridors in Midtown Atlanta (see ES Figure 1 and ES Table 1, below), encompassing approximately 21 directional miles with an average signal density around 4-10 signals/mile and Average Annual Daily Traffic (AADT) values averaging 16k-39k. Data was collected between September 12-23, 2021.



ES Figure 1: Corridors along study area.

ES Table 1- Arterial Corridor Description

Name	Signal Density	AADT (bi-directional)	Speed Limit	Miles (directional)
Spring St NW	7.1	22.2k	35 mph	1.70
W Peachtree St NW	10.1	22.9k	35 mph	1.59
Peachtree St NE	10.1	16.0k	25 mph	3.17
Piedmont Ave NE	4.8	21.6k	35 mph	2.49
Monroe Dr NE	5.1	24.0k	30 mph	3.34
Ponce De Leon Ave NE	5.1	38.9k	35 mph	4.71
North Ave NW/NE	7.0	29.1k	35 mph	4.27

This study is markedly different than previous studies, as these roadways are highly urbanized, with the arterials serving as much for access to the surrounding developments as they are for through movements. Signalized arterials that have been the focus of past validations, although having access to local businesses and developments, still primarily served as through traffic corridors. The roadways in this validation (and corresponding test segments) serve primarily as access to the surrounding development, as evidenced by numerous access points and the low number of matching Bluetooth pairs relative to the overall traffic. Note that 'Major Arterials' as specified in the contract documents are those exceeding 20,000 AADT and that validation specification include 500 VPH of **through** traffic as the threshold for validation activities. ES Table 2 shows two Highly Desirable (HD) requirements pulled directly from the VPPII RFP[1] and illustrates that the language surrounding Major Arterials emphasizes through, rather than overall traffic.

ES Table 2 - Relevant evaluation requirement for major arterials		
3.1.6.4	Accuracy requirements will be in effect for vehicle flows exceeding 500 VPH of through traffic for Major Arterials.	HD/E
3.1.6.5	Maximum data latency shall be less than or equal to eight (8) minutes.	HD/E

As a result of the low through traffic, the reader should note the following:

- Several of the original segments were omitted from the report simply due to lack of through traffic, since high confidence reference ground truth data could not be established in these locations. Re-identification technology is a direct measure of travel time requiring any probe vehicles to traverse the entire length of the test corridor.

- Validation segment lengths were reduced in several locations to capture more through traffic. When reference data was too sparse, and an intermediary sensor was available, the validation team examined shorter segments (between 0.5 miles and 1.0 miles) that exhibited with higher re-identification data densities. Shorter segments helped counteract the local access nature of these roadways, but also introduced slightly more error into the reference data, noting that Bluetooth re-identification location accuracy is roughly 300 feet (~ two sigma boundary).

- The original intent of the travel time and speed data was with respect to freeway and signalized arterials that functioned primarily as through corridors and at higher speeds. Although error measures are provided later in the report, these results inform a 'corner case' with respect to outsourced travel time and speed.

- Even given the above, the validation activity revealed probe data's ability to accurately reflect travel time in urban environments, as well as its ability to capture congestion in real-time with minimal latency. The results also informed modifications in the validation method if/when such an environment is the focus of travel time validation in the future.

Given the unique circumstances of this collection, the error measure calculations that are typically summarized in each validation report, AASE (Average Absolute Speed Error) and Speed Error

[1] VPPII, Request for Proposal (RFP) No. 83794 To Provide Real-Time Traffic Data and Associated Products to I-95 Coalition Organizations and Affiliates (link)

Bias (SEB), as well as slow down analysis should be regarded with respect to a corner case analysis. Whether or not these segments fall inside or outside of the bounds of VPPII Contract Specifications for vendors with respect the through traffic volume requirements as noted above is debatable. Additionally, the sparse nature of the reference Bluetooth data makes ground truth referencing more challenging, and often requires large confidence bands that lower the bar for compliance. The usual AASE and SEB error measures are reported in the body of the report for completeness, noting that all vendors were within the contractual bounds for accuracy as compared to the arterial definition in the contract. The executive summary shares insights from data analysis deemed critical to coalition members – particularly at the few locations where speed fluctuations could be captured.

Several insights emerged from the data and shed light on both probe data performance in this environment and the limitations of our current validation processes and sensor technology. The remainder the Executive Summary will focus on the top-level findings and recommendations. Also, due to various concerns, **the results are provided without identifying the vendor, as this is considered a corner case relative to the specifications of the contract.**

Findings

- **All vendors met expected average accuracy levels** (AASE and SEB) in all speed bins. However, this was not a particularly 'high hurdle' to clear given the sparse nature of the reference data (large confidence bands) and low average speeds (usually lowest speed bin represents slowdown events, but here it represented typical operating conditions)

- **There was no evidence of any "urban canyon effect".** Georgia DOT was interested in whether the vendors' location data would be reliable in an urban environment with tall buildings, but all vendor speed/travel time data appeared reasonable and without any anomalies that might be explained by such a phenomenon.

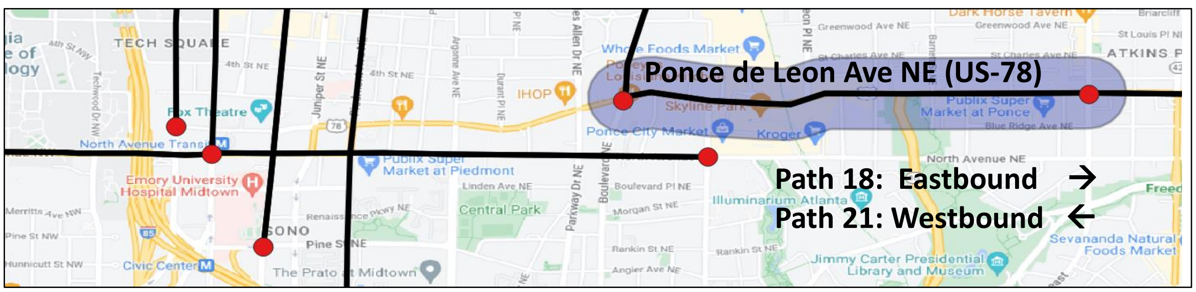
- **Urban arterials expose limitations in our validation methodology and data quality specifications**. Reference data was more difficult to capture owing to the numerous intersections and access points which provided many opportunities for vehicles to leave the road. Since Bluetooth re-identification sensors only capture through traffic, vehicles that turn off partway are not captured, thus making it more difficult to characterize ground truth travel time conditions along certain paths. Urban arterials such as these will require a different approach to establish a high confidence reference travel time, and appropriate specifications for such roadways (as opposed to freeways and high functioning suburban arterials) require attention as well.

- **One vendor had many instances of missing data in various locations and time periods.** We have not observed this in other recent validation efforts, so this appears as a novel issue, and will monitor moving forward. However, upon further inspection, there appear to be two root causes and issues associated with this:

- A road closure was inadvertently flagged in the data feed on both directions of one road segment (see ES Fig 2), causing all records to be reported with speed = 0 mph, confidence = 0 during specific hours of the day over the course of the study period, consistent with the policy for reporting speed on roadways flagged as closed.

- API timeout and/or network issues prevented data from being recorded each minute, resulting in several one-minute epochs that did not have speed/travel time data recorded on any segment in the study area.

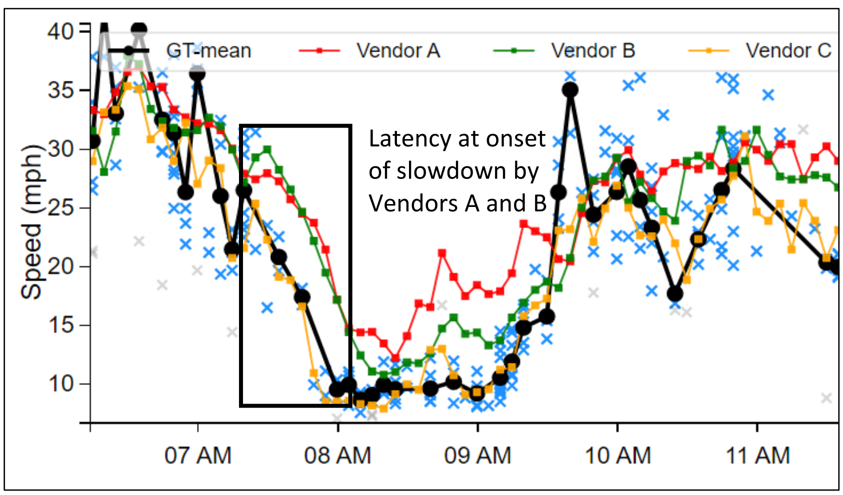
The latter issues prompted the validation team to review how each vendor provided data. The vendor with the missing data was the only one which could be confirmed as 'real-time' (recorded in real-time through UMD), while the two other vendors submitted data after-the-fact, and thus were not subject to network connectivity issues. The other two vendors indicated that their deliveries were also based on their real-time feed, but since their data was recorded internally rather than queried via API, they were not subject to possible transmission outages as was the other vendor.



ES Figure 2: Location where one vendor inadvertently flagged a road closure.

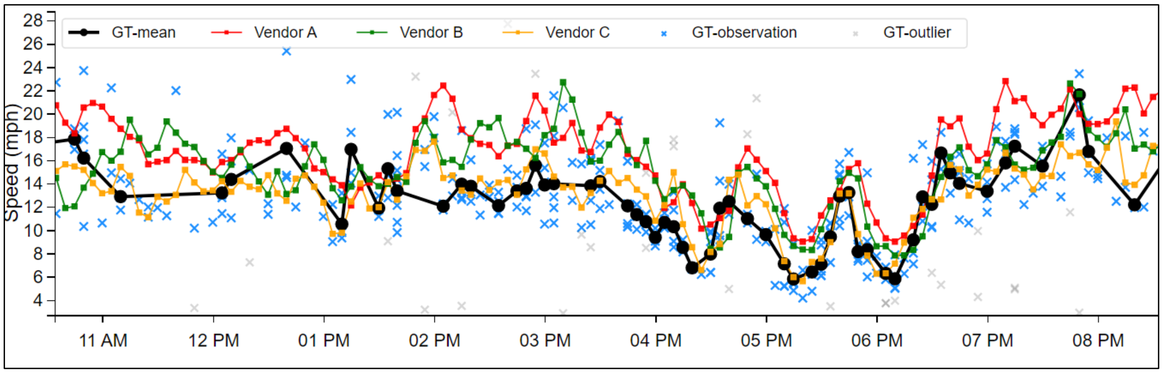
- **All vendors were generally able to identify the presence of congestion, but visual inspection of these scenarios highlighted differences in behavior.** There were limited opportunities to investigate performance during congestion because there were only 13 major slowdown events concentrated on only three validation paths; however, these few instances of congestion provided the following key insights:
  - All three vendors identified reasonable speed drops for each of the 13 major slowdown events – even in instances where the vendor did not sufficiently capture the required magnitude or duration of the true speed drop to be deemed "Fully Captured" in the Slowdown Analysis (see body of report for further details), the speed trace indicated some type of slowdown. In particular, the "Failed to Capture" slowdown classifications in this dataset are demonstrably better than such classifications in previous validations conducted just a couple years ago.

  - With respect to latency, ES Figure 3 below shows one example from segment GA05-0020 between 7 AM and 10 AM that is representative of many other slowdowns. Two vendors reported changes in speed with some latency of approximately 15 minutes, while one vendor consistently had no measurable latency. Latency is characteristic of real-time systems where there is communication delay and a desire to avoid preemptively reporting speed changes that may just be noise (particularly in urban areas where a wide range of speeds may be expected). To assess latency, data feeds need to be captured objectively and fairly in real-time and tagged with the time of receipt on a minute-by-minute basis. However, due to data processing efficiency concerns, the validation process does not capture real-time data feeds, but rather requests vendors to submit the data after the reference data has been collected. In this figure, Vendor A and Vendor B vendor curves show about 10-15 minutes of delay (latency) in responding to the slowdown event (as measured by the **black** reference data curve), while Vendor C does not have any measurable latency. Of the three data sets shown, the validation team had access to (simply through happenstance) a source that logged and time-tagged data from Vendor A in real-time. Moving forward, objective assessments of latency will require a supportable and efficient manner to record all vendor's data in a similar manner.



ES Figure 3: Representative slowdown with latency observed in two vendor feeds.

- **When traffic speeds were bimodal or distributed over a range of values, data vendors differed in whether they favored "optimistic" or "pessimistic" values.** ES Figure 4 shows one such example, where Vendors A and B tracked higher speed / lower travel time values, while Vendor C followed lower speed / higher travel time values. It was encouraging to note that most speed and travel time values reported by all vendors were within the range of legitimate reference data observations. The trend (optimistic versus pessimistic) was consistent with each vendor over the course of all observations.



ES Figure 4: Example of optimistic / pessimistic representations of roadway speed.

- **Vendor map representation, data exchange format, and segment conflation are variables that play a role in the validation process and should be monitored.** Reference data is collected along custom roadway locations that often do not align perfectly with traffic message channel (TMC) segments. As such, vendors may either report their travel time/speed data at the validation locations defined by the validation team, or along standard TMC segments, in which case the data is transformed from the TMC-based data to equivalent records representing the test segment. Differences in TMC map versions, limitations in the conflation process, and how data is archived and deliver (in real-time vs after-the-fact) add additional variables into the validation process and make direct comparison challenging. Future work will seek to standardize where possible.

Recommendations

Considering these findings, the validation team makes the following recommendations:

- **Appropriate expectation, specifications, and testing methods are needed for urban arterials.** Realize that urban arterials that significantly support access to the local developments as opposed to through movements represent an edge case for outsourced probe speed and travel time data in the marketplace. While the probe data may still be useful in many circumstances, it goes beyond the original intent of capturing through movements on freeways and arterials and is also difficult to evaluate using existing validation techniques.

- **Recommended modifications to testing:** The following modifications are needed to the validation methodology.
    - Determining optimal type, and sensor spacing to minimize the loss of through traffic without compromising accuracy.
    - Invest in newer Bluetooth and similar re-identification sensors that can capture a higher percentage of traffic (may be able to double or triple penetration rates which currently run about 5%).

- Concentrate on roadways / periods where there are known traffic disruptions, as these transition periods are particularly useful for understanding vendor performance.
- Develop and emphasize validation methods that focus on travel time (rather than just speed), which may be more relevant in low-speed conditions.

- **Develop a standard vendor data delivery mechanism that ensures validation is on real-time (as opposed to archive) data feeds.** A common API that uses geo-referencing protocols as opposed to static map segments delivered in real-time would address this concern. In the new Transportation Data Marketplace, vendors are required to support location references defined by the validation team – ideally via CATT Works Geo-Reference protocol (CWGP).

- **Engage the Transportation Data Marketplace validation technical advisory committee (TAC) to establish performance specifications (expectations) in this domain.** The fidelity of probe data continues to grow, the TDM validation TAC would be an appropriate forum to develop this moving forward.

Introduction

The University of Maryland (UMD), acting on behalf of the Eastern Transportation Coalition, was given the responsibility of evaluating the quality of Vehicle Probe Project (VPP) data at the inception of the project in 2009. To assess the quality of travel time and speed data, UMD developed a methodology using wireless re-identification traffic monitoring (WRTM) technology, which is documented in detail in the original report: *The I-95 Corridor Coalition Vehicle Probe Project: Validation of INRIX Data*[2].

At a high level, WRTM equipment is deployed at strategic locations along selected road segments and identifies – and later re-identifies – unique signals emitted by in-vehicle electronic equipment via Bluetooth, Wi-Fi and other technologies, thus allowing direct measurement of travel times from a sample of vehicles. Initial research conducted by UMD shows that this sampling approach is capable of accurately characterizing travel times (speeds) when the distance between sensors is 60 seconds or more in travel time (equating to one mile apart at freeway speeds); therefore, WRTM data serves as the ground-truth data source against which reported probe speeds are compared.

In 2014, the project moved to a second phase (VPPII), during which a probe data marketplace was created with multiple vendors. Currently there are three data vendors that provide travel time and speed data through this marketplace: HERE, INRIX, and TomTom. The purpose of this report, which is produced on a regular basis, is to continue to rigorously assess the accuracy of speeds reported by each vendor on various road segments from The Eastern Transportation Coalition member states.

Probe Data Vendors

Three probe data vendors are evaluated in this report: HERE, INRIX, and TomTom. Each vendor provides travel time and speed data along the road segments and time periods of interest, which are subsequently compared to ground truth WRTM observations to assess data accuracy.

Specifically, each vendor reports travel time and speed data in one-minute intervals either along road segments defined by the WRTM sensor locations (i.e., validation segmentation) or Traffic Message Channel (TMC) segments. In the latter case the TMC-based speeds must first be transformed to equivalent speeds on validation segments before a direct comparison can be made.

[2] Ali Haghani, Masoud Hamedi, Kaveh Farokhi Sadabadi: Validation of INRIX Data July–September 2008. Technical Report, Prepared for the I-95 Corridor Coalition, 2009 (link)

Methodology

The primary means of evaluating the vendor data is through the traditional validation analysis, which is documented in the original report (*The I-95 Corridor Coalition Vehicle Probe Project: Validation of INRIX Data*) and summarized below. Additionally, supplemental analyses may be conducted depending on the road type being evaluated and observed data characteristics. The most common supplemental analysis for signalized arterials is the slowdown analysis[3], which evaluates probe data quality during major congestion events on arterials.

Traditional validation analysis

Overview

The traditional validation analysis consists of comparing ground truth (i.e., WRTM) speeds against vendor speeds over five-minute intervals and quantifying the discrepancy in terms of two error metrics defined in the contract specifications.

Obtain vendor speed data along validation road segments

Road segments used for validation are defined based on WRTM sensor locations – often resulting in different segment definitions than those typically reported by the probe vendors. Accordingly, vendors may either report speeds directly on the validation road segmentation used for evaluation, or report speeds based on standard Traffic Message Channel (TMC) segments. In the latter case, equivalent vendor speeds must be obtained for the geometry specified by the WRTM sensors, which is accomplished via a trajectory reconstruction algorithm. This algorithm is described in another report[4] and works by (a) identifying the portions of vendor road segments that correspond to the validation segment, and (b) using the speeds reported on the vendor's segments during multiple time intervals to calculate the equivalent speed.

Filter and aggregate ground truth data

Raw travel time (speed) observations are first filtered to remove outliers. The filtering step is necessary because WRTM sensors sometimes re-identify vehicles that stop between sensors or record travel times from pedestrians or non-motorized vehicles that are not representative of actual traffic conditions. After the outlier observations are removed, the remaining representative observations are aggregated for each segment over five-minute intervals, and intervals with too few observations or excessive variation are discarded.

The remaining intervals are deemed suitable for evaluation of vendor probe data and are summarized in terms of (a) space-mean speed (SMS) and (b) confidence band around the mean.

---

[3] Sharifi, et. al., Outsourced probe data effectiveness on signalized arterials (link)

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

The space-mean speed captures average ground truth traffic behavior, while the confidence band accounts for sample size and variation in the observed speeds.

Several statistical measures were initially evaluated to define the width of this uncertainty band, all of which are described and reported in the original report. Ultimately, the standard error of the mean (SEM) measure was selected due to its simplicity and sensitivity to both variability and number of observations used for calculations. The SEM is calculated as the standard deviation (SD) of the WRTM speeds divided by the square root of the number WRTM data points (n) taken for a given time. In other words, $\text{SEM} = \frac{SD_{WRTM}}{\sqrt{n}}$. The confidence band based on this statistic, $[\text{SMS} - 1.96 \cdot \text{SEM},\ \text{SMS} + 1.96 \cdot \text{SEM}]$, narrows when there is a higher degree of confidence in the ground truth data (i.e., more observations or less variation) and widens when there is less confidence, serving as a proxy for a 95% confidence interval of ground truth speeds.

Compute Error Metrics

A statistical analysis of the data is conducted for four defined speed bins, where each five-minute interval is associated with a speed bin based on its corresponding ground truth space-mean speed (0-15 mph, 15-30 mph, 30-45 mph, 45+ mph for arterials; 0-30 mph, 30-45 mph, 45-60 mph, 60+ mph for freeways). Reported probe speeds are compared to both the space-mean and 1.96 SEM band speed for each five-minute time interval, and the discrepancies are quantified in terms of two error metrics: Average Absolute Speed Error (AASE) and Speed Error Bias (SEB), which are reported separately for each speed bin. According to contract specifications, AASE and SEB values must be within 10 mph and 5 mph, respectively, when compared with the SEM band.

AASE is calculated by summing up the absolute difference between probe vendor speeds (S_P) and ground truth speeds (S_{GT}) for each time interval and taking the average over n observations. That is, $\text{AASE} = \frac{1}{n}\sum_{i=1}^{n}|S_P - S_{GT}|$. Because the absolute value is used, positive and negative errors cannot cancel, and the result is always positive. Speed Error Bias is calculated similarly, with the difference that the absolute value of the errors is not taken. In other words, $\text{SEB} = \frac{1}{n}\sum_{i=1}^{n} S_P - S_{GT}$. Thus, positive and negative errors can cancel each other out, and the resulting value can provide insight into whether there is a consistent positive or negative error.

Slowdown analysis

The slowdown analysis is an offshoot of the traditional analysis, developed to provide a more intuitive measure of probe data's ability to capture congestion events. **The definition of a slowdown in this context is when traffic speeds (as identified by ground truth WRTM sensors) decrease by at least 15 mph for a period of one hour or more**.

An analyst visually compares ground truth and vendor speeds for each slowdown event, focusing on how well the vendor data captures the magnitude and duration of the speed reduction. Each slowdown is ultimately classified as 'Fully Captured', 'Partially Captured', or 'Failed to Capture' according to the following rules:

- A **Fully Captured slowdown** indicates that the probe data accurately characterized both the reduction in speed, and duration of the slowdown. The error in speed reduction or duration cannot exceed 20%.
- A **Partially Captured slowdown** indicates that the probe data reported a significant disruption to traffic, but the extent of speed reduction or duration of time were in error by more than 20%.
- **Failed to Capture** indicates that the probe data either completely missed the slowdown, or the extent of speed reduction or duration of the event were significant in error such that the slowdown would not be interpreted as a significant disruption to traffic.

It should be noted that these definitions were originally conceived for suburban arterials that have higher speed limits around 45-55 mph. As such, the criteria for identifying slowdowns (15 mph speed drops) and the corresponding classification logic are pushed to their limits on slow, local-access arterials with speed limits closer to 25 mph such as the ones considered in this study.

Additionally, there is some ambiguity regarding the difference between "Partially Captured" and "Failed to Capture" – especially in cases where both speed reduction magnitude and duration are in error by over 20%, but visual inspection of the vendor data still shows a sizeable disruption. This scenario does not quite fit neatly into either category, as a "Partially Captured" classification has historically been applied when *either* the magnitude or duration is in error by more than 20% (not both, as is the case here), while "Fail to Capture" scenarios have represented obvious misses with severe error that would not be registered as a disruption (also not the case). For the sake of this validation, we are keeping with recent precedent and requiring "Partially Captured" classifications to meet *either* the magnitude or duration criteria, with failure to meet at least one resulting in a "Fail to Capture" classification – even if it does not look as bad as some previous "Fail to Capture" examples.

Data Collection

Travel time samples were collected during September 12 – 23, 2021 across 26 segments (31 directional miles) in Atlanta, GA. In contrast to most previous arterial validations, these roadways are highly urbanized, with the arterials serving as much for access to the surrounding developments as for through movements. Because Bluetooth re-identification technology can only see vehicles that traverse the entire length of each segment, the reference data was very sparse in many locations in some cases insufficient for evaluating probe data. As such, several sections of the study area had to be omitted entirely, while other segments were shortened to increase the likelihood of capturing through traffic – a strategy that was only possible in a few locations where it was permitted by the sensor arrangement.

Figure 1 shows the final study area after these changes were made, resulting in 22 segments (21 directional miles) that were adequate for analysis. Of these 22 segments that could be used for analysis, only three contained significant slowdown events that could be used to evaluate vendor performance during congestion: GA05-0001A, GA05-0003A, and GA05-0020, with the majority falling on GA05-0020. Table 1 contains the summary information for each data collection segment, including WRTM sensor latitude/longitudes and an active map link, which can be followed to view each data collection segment in detail.

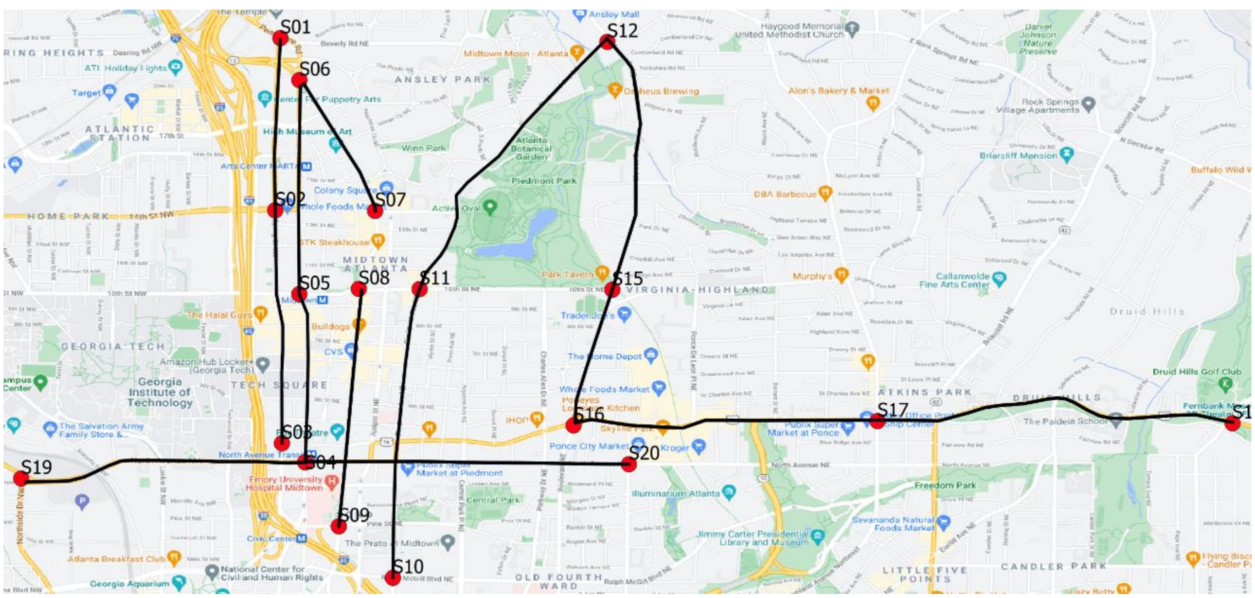


Figure 1 – WRTM Sensor locations

Table 1 - Validation Segment Attributes

Segment (Map Link)	DESCRIPTION						Deployment	
	Highway Direction	Starting at Ending at	Lane (Min) Lane (Max)	Signals Signal/mile	AADT	Access Points Speed Limit	Begin Lat/Lon End Lat/Lon	Length (mile)
Arterial								
A1-A GA05-0001A	Spring St. NW Southbound	Peachtree Rd 14th St NW	3 4	4 5.6	26614	18 35mph	33.7866 -84.3892 33.7866 -84.3892	0.717
A1-B GA05-0001B	Spring St. NW Southbound	14th St NW Ponce de Leon Ave NW	3 3	8 8.2	19042	25 35 mph	33.7866 -84.38924 33.7724 -84.38883	0.981
A2-A GA05-0002A	W Peachtree St NW Northbound	North Ave NE 10th St NW	3 5	8 11.3	19406	14 25 mph	33.77124 -84.38741 33.78147 -84.38776	0.71
A2-B GA05-0002B	W Peachtree St NW Northbound	10th St NW Peachtree St NE	4 5	8 9.1	25758	19 35 mph	33.78147 -84.38776 33.79418 -84.3877	0.876
A3-A GA05-0003A	Peachtree St NE Southbound	W Peachtree St NW 14th ST NE	2 3	5 8.4	16345	7 25 mph	33.79431 -84.38749 33.78657 -84.38312	0.592
A4 GA05-0004	Peachtree St NE Southbound	10th ST NE Pine ST NE	2 3	11 11.1	15744	17 25 mph	33.78172 -84.38396 33.76734 -84.3854	0.994
A5 GA05-0005	Peachtree St NE Northbound	Pine ST NE 10th ST NE	2 3	11 11.1	15744	15 25 mph	33.76734 -84.38536 33.78172 -84.384	0.994
A6-B GA05-0006B	Peachtree St NE Northbound	14th ST NE W Peachtree St NW	2 3	5 8.5	16345	13 25 mph	33.78658 -84.38315 33.79431 -84.38749	0.591
A7 GA05-0007	Piedmont Ave NE Northbound	Ralph McGill Blvd NE 10th ST NE	4 5	8 6.6	15472	40 35 mph	33.7642 -84.38206 33.7818 -84.3804	1.219
A8 GA05-0008	Piedmont Ave NE Northbound	10th ST NE Monroe Dr NE	2 4	4 3.1	27454	18 35 mph	33.7818 -84.38043 33.79707 -84.369	1.271
A9-A GA05-0009A	Monroe Dr NE Southbound	Piedmont Ave NE 10th ST NE	1 3	5 4.6	21046	24 30 mph	33.79707 -84.369 33.78177 -84.36867	1.096
A9-B GA05-0009B	Monroe Dr NE Southbound	10th ST NE Ponce De Leon Ave NE	1 3	4 6.9	29548	8 30 mph	33.78177 -84.36867 33.77366 -84.37094	0.576

Segment (Map Link)	DESCRIPTION						Deployment		
	Highway Direction	Starting at Ending at	Lane (Min) Lane (Max)	Signals Signal/mile	AADT	Access Points Speed Limit	Begin Lat/Lon End Lat/Lon		Length (mile)
Arterial									
A10-A GA05-0010A	Monroe Dr NE Northbound	Ponce De Leon Ave NE 10th ST NE	1 2	4 6.9	29548	8 30 mph	33.77366 33.7818	-84.37094 -84.36866	0.579
A10-B GA05-0010B	Monroe Dr NE Northbound	10th ST NE Piedmont Ave NE	2 3	4 3.7	21046	24 30 mph	33.7818 33.79707	-84.36866 -84.369	1.093
A18 GA05-0018	Ponce De Leon Ave NE Eastbound	Monroe Dr NE North Highland Avenue NE	2 3	7 6.5	37987	22 35 mph	33.77366 33.77382	-84.37094 -84.3525	1.071
A19 GA05-0019	Ponce De Leon Ave NE Eastbound	North Highland Avenue NE Clifton Rd NE	2 3	5 3.9	39636	10 35 mph	33.77382 33.77369	-84.35251 -84.3308	1.286
A20 GA05-0020	Ponce De Leon Ave NE Westbound	Clifton Rd NE North Highland Avenue NE	2 3	5 3.9	39636	10 25 mph	33.77369 33.77382	-84.33083 -84.3525	1.286
A21 GA05-0021	Ponce De Leon Ave NE Westbound	North Highland Avenue NE Monroe Dr NE	2 3	7 6.5	37987	25 35 mph	33.77382 33.77366	-84.35251 -84.3709	1.071
A23 GA05-0023	North Ave NW/NE Eastbound	Northside Dr NW W Peachtree St NW	2 4	7 7.0	29266	10 35 mph	33.77004 33.77124	-84.40444 -84.3874	1.0
A24 GA05-0024	North Ave NW/NE Eastbound	W Peachtree St NW Glen Iris Dr NE	2 4	8 7.0	29032	17 35 mph	33.77124 33.77112	-84.38741 -84.3677	1.137
A25 GA05-0025	North Ave NW/NE Westbound	Glen Iris Dr NE W Peachtree St NW	2 3	8 7.0	29032	22 35 mph	33.77112 33.77124	-84.36766 -84.3874	1.137
A26 GA05-0026	North Ave NW/NE Westbound	W Peachtree St NW Northside Dr NW	2 4	7 7.0	29266	13 35 mph	33.77124 33.77004	-84.38741 -84.4044	1.0

Validation Results

Traditional Validation Results

Vendor A

Table 2 summarizes the error metrics computed between ground truth (i.e., WRTM) and Vendor A speeds. Average Absolute Speed Error (AASE) and Speed Error Bias (SEB) measures were each within specification for all speed bins – a result that held whether the 1.96 SEM Band or Mean reference speed was used as the basis for quantifying reference conditions.

Table 2 – Vendor A data quality measures

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison w/ 1.96 SEM Band	Comparison with Mean	Comparison w/ 1.96 SEM Band	Comparison with Mean	
0-15	2.83	4.81	2.82	4.74	2535
15-25	1.29	3.51	1.13	2.49	4161
25-35	0.88	3.36	-0.35	-0.8	981
35+	2.13	5.31	-2.05	-4.84	133
All Speeds	1.75	3.94	1.44	2.68	7810

Table 3 shows the percentage of time the Vendor A data fell within 5mph of the mean and 1.96 SEM band for each speed bin.

Table 3 – Percent of Vendor A observations meeting data quality criteria

Speed Bin	Data Quality Measures for				Number of 5 Minute Samples
	1.96 SEM Band		Mean		
	Percent inside band	Percent within 5mph of band	Percent equal to mean	Percent within 5mph of mean	
0-15	23.1	79.2	-	58.8	2535
15-25	54.5	92.3	-	74.6	4161
25-35	68.8	95.4	-	78.3	981
35+	44.4	86.5	-	50.4	133

Table 4 reports the error metrics on individual validation segments. Note that some segments and time bins only have a few observations, and thus may not be representative of the overall performance in each speed bin.

Table 4 – Vendor A data quality measures by validation segment

Path	Speed Bin	Data Quality Measures for: Avg Absolute Speed Error – 1.96 SEM Band	Avg Absolute Speed Error – Mean	Speed Error Bias – 1.96 SEM Band	Speed Error Bias – Mean	No. of Obs.
GA05-0001A	0-15	1.42	2.99	1.41	2.75	179
	15-25	0.35	2.39	0.1	-0.27	359
	25-35	2.9	7.63	-2.9	-7.63	46
	35+	11.28	17.04	-11.28	-17.04	1
GA05-0001B	0-15	1.69	3.08	1.69	3.02	193
	15-25	1.03	2.86	0.97	1.19	24
	25-35	0	7.23	0	-7.23	1
	35+	-	-	-	-	-
GA05-0002A	0-15	0.56	2.79	0.56	2.61	41
	15-25	0.66	3.6	-0.57	-2.91	69
	25-35	6.12	12.16	-6.12	-12.16	11
	35+	-	-	-	-	-
GA05-0002B	0-15	2.08	4.51	2.08	4.49	186
	15-25	0.41	1.75	0.2	0.92	74
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0003A	0-15	2.4	4.32	2.39	4.27	490
	15-25	0.94	3.02	0.86	2.53	165
	25-35	2.62	6.85	-2.62	-6.85	2
	35+	-	-	-	-	-
GA05-0004	0-15	1.11	2.48	1.1	2.24	90
	15-25	1.64	2.77	-1.26	-2.05	21
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0005	0-15	1.36	2.64	1.25	2.35	85
	15-25	5.27	6.52	-3.57	-2.94	2
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0006B	0-15	2.3	4.61	2.3	4.6	31
	15-25	0.94	2.81	0.7	1.39	529
	25-35	2.79	5.59	-2.79	-5.59	28
	35+	16.56	18.78	-16.56	-18.78	1
GA05-0007	0-15	2.01	3.42	2.01	3.42	14
	15-25	0.58	2.16	0.28	1.1	80
	25-35	2.52	5.75	-2.52	-5.75	3
	35+	-	-	-	-	-
GA05-0008	0-15	3.27	6.28	3.27	6.28	21
	15-25	0.76	2.81	0.75	2.4	177
	25-35	0.34	1.95	-0.04	-0.68	71
	35+	0	7.69	0	-7.69	1
GA05-0009A	0-15	4.62	6.64	4.62	6.63	48
	15-25	0.82	2.7	0.71	1.92	415
	25-35	1	3.79	-1	-3.32	40
	35+	-	-	-	-	-

Path	Speed Bin	Data Quality Measures for				No. of Obs.
		Avg Absolute Speed Error		Speed Error Bias		
		1.96 SEM Band	Mean	1.96 SEM Band	Mean	
GA05-0009B	0-15	3.07	5.51	3.05	5.44	374
	15-25	0.57	3.11	0.41	1.85	138
	25-35	1.13	6.63	-1.13	-6.63	5
	35+	-	-	-	-	-
GA05-0010A	0-15	2.93	5.17	2.93	5.17	121
	15-25	0.59	2.48	0.47	1.35	194
	25-35	1.63	7.57	-1.63	-7.57	4
	35+	-	-	-	-	-
GA05-0010B	0-15	4.25	8.18	4.25	8.18	60
	15-25	1.17	4.06	1.13	3.67	326
	25-35	0.49	2.52	-0.31	-1.17	51
	35+	-	-	-	-	-
GA05-0018	0-15	2.39	3.78	2.37	3.74	61
	15-25	1	3.27	0.75	1.49	122
	25-35	2.74	5.71	-2.49	-3.74	25
	35+	7.91	15.52	-7.91	-15.52	1
GA05-0019	0-15	8.06	9.81	8.06	9.81	45
	15-25	2.84	5.79	2.84	5.76	530
	25-35	0.54	2.68	0.25	0.77	418
	35+	1.77	4.86	-1.69	-4.54	79
GA05-0020	0-15	7.33	8.96	7.33	8.96	195
	15-25	3.56	6.38	3.56	6.37	371
	25-35	0.58	2.94	0.18	1.27	183
	35+	1.27	4.12	-1.17	-3.1	37
GA05-0021	0-15	2.43	4.95	2.43	4.95	47
	15-25	0.54	2.21	0.37	1.19	111
	25-35	0.72	3.5	-0.61	-2.61	73
	35+	4.67	8.5	-4.67	-8.5	13
GA05-0023	0-15	1.94	3.74	1.93	3.67	180
	15-25	0.75	2.39	0.47	1.23	123
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0024	0-15	2.65	5.15	2.65	5.15	10
	15-25	0.89	2.71	0.73	1.72	99
	25-35	1.93	7.5	-1.93	-7.5	5
	35+	-	-	-	-	-
GA05-0025	0-15	3.77	6.23	3.77	6.23	20
	15-25	0.84	2.82	0.7	2.37	54
	25-35	0.71	3.95	-0.71	-3.95	5
	35+	-	-	-	-	-
GA05-0026	0-15	3.12	5.19	3.12	5.14	44
	15-25	0.67	2.48	0.48	1.35	178
	25-35	0.08	1.76	-0.08	-1.14	10
	35+	-	-	-	-	-

Vendor B

Table 5 summarizes the error metrics computed between ground truth (i.e., WRTM) and Vendor B speeds. Average Absolute Speed Error (AASE) and Speed Error Bias (SEB) measures were each within specification for all speed bins when compared to the 1.96 SEM Band, and in all but the >35 MPH bin when compared with the Mean for the SEB.

Table 5– Vendor B data quality measures

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison w/ 1.96 SEM Band	Comparison with Mean	Comparison w/ 1.96 SEM Band	Comparison with Mean	
0-15	1.51	3.12	1.38	2.58	2645
15-25	0.93	2.99	0.3	0.49	4470
25-35	1.22	3.94	-0.88	-2.25	1039
35+	2.96	6.36	-2.86	-5.9	138
All Speeds	1.19	3.21	0.44	0.71	8292

Table 6 shows the percentage of time the Vendor B data fell within 5mph of the mean and 1.96 SEM band for each speed bin.

Table 6– Percent of Vendor B observations meeting data quality criteria

Speed Bin	Data Quality Measures for				Number of 5 Minute Samples.
	1.96 SEM Band		Mean		
	Percent inside band	Percent within 5mph of band	Percent equal to mean	Percent within 5mph of mean	
0-15	42.9	92.6	-	80.0	2645
15-25	61.5	95.2	-	81.4	4470
25-35	62.0	92.5	-	70.0	1039
35+	37.7	73.9	-	42.8	138

Table 7 reports the standard error metrics on individual validation segments. Note that some segments and time bins only have a few observations, and thus may not be representative of the overall performance in each speed bin.

Table 7 – Vendor B data quality measures by validation segment

Path	Speed Bin	Data Quality Measures for				No. of Obs.
		Avg Absolute Speed Error		Speed Error Bias		
		1.96 SEM Band	Mean	1.96 SEM Band	Mean	
GA05-0001A	0-15	1.39	2.99	1.3	2.55	179
	15-25	0.42	2.53	0.02	-0.23	365
	25-35	3.1	7.67	-3.1	-7.44	47
	35+	8.26	14.02	-8.26	-14.02	1
GA05-0001B	0-15	0.47	1.39	0.13	0.06	194
	15-25	1.31	3.46	-0.71	-2.23	24
	25-35	0	11.15	0	-11.15	1
	35+	0.2	2.12	0	0.15	41
GA05-0002A	0-15	1.96	6.08	-1.96	-6.05	70
	15-25	8.07	14.47	-8.07	-14.47	11
	25-35	-	-	-	-	-
	35+	1.26	3.13	1.18	2.84	190
GA05-0002B	0-15	0.62	2.09	-0.13	-0.39	75
	15-25	-	-	-	-	-
	25-35	-	-	-	-	-
	35+	1.53	3.15	1.5	2.92	502
GA05-0003A	0-15	0.81	2.72	0.35	1.07	165
	15-25	3.7	7.03	-3.7	-7.03	2
	25-35	-	-	-	-	-
	35+	0.57	1.79	0.05	-0.02	92
GA05-0004	0-15	3.22	4.65	-3.22	-4.65	21
	15-25	-	-	-	-	-
	25-35	-	-	-	-	-
	35+	0.98	1.97	0.41	0.64	88
GA05-0005	0-15	5.02	5.4	-5.02	-5.26	2
	15-25	-	-	-	-	-
	25-35	-	-	-	-	-
	35+	1.73	3.39	1.73	3.2	31
GA05-0006B	0-15	0.92	2.92	0.23	-0.1	544
	15-25	3.01	5.06	-3.01	-4.4	28
	25-35	18.53	20.75	-18.53	-20.75	1
	35+	0.86	2	0.86	1.88	15
GA05-0007	0-15	0.58	2.2	0.14	0.3	80
	15-25	2.57	6.67	-2.57	-6.67	3
	25-35	-	-	-	-	-
	35+	1.56	3.75	1.56	3.66	22
GA05-0008	0-15	0.69	2.58	0.6	1.26	188
	15-25	0.97	3.12	-0.46	-1.62	71
	25-35	0	8.42	0	-8.42	1
	35+	2.53	4.22	2.5	3.82	48
GA05-0009A	0-15	0.63	2.37	0.02	-0.03	427
	15-25	1.56	4.65	-1.56	-4.56	42
	25-35	-	-	-	-	-
	35+	1.39	2.99	1.3	2.55	179

Path	Speed Bin	Data Quality Measures for				No. of Obs.
		Avg Absolute Speed Error		Speed Error Bias		
		1.96 SEM Band	Mean	1.96 SEM Band	Mean	
GA05-0009B	0-15	1.79	3.8	1.76	3.49	382
	15-25	0.73	3.11	0.36	0.76	141
	25-35	3.47	8.78	-3.47	-8.78	6
	35+	-	-	-	-	-
GA05-0010A	0-15	1.54	3.18	1.46	2.66	125
	15-25	0.87	3.39	0.05	0.07	199
	25-35	4.99	11.08	-4.99	-11.08	4
	35+	-	-	-	-	-
GA05-0010B	0-15	2.2	5.56	2.2	5.56	60
	15-25	0.7	2.94	0.5	1.64	330
	25-35	0.63	3.16	-0.63	-2.68	52
	35+	-	-	-	-	-
GA05-0018	0-15	1.21	2.51	1.04	2.11	85
	15-25	0.72	2.83	-0.02	-0.94	219
	25-35	3.52	7.05	-3.49	-6.46	42
	35+	8.55	13.24	-8.55	-13.24	2
GA05-0019	0-15	4.14	5.77	4.14	5.7	45
	15-25	1.29	3.43	1.23	2.98	549
	25-35	0.7	3.06	-0.16	-0.81	419
	35+	2.6	6.09	-2.44	-5.55	79
GA05-0020	0-15	3.49	5.05	3.49	5.04	195
	15-25	1.75	3.92	1.68	3.35	385
	25-35	0.63	3.08	-0.2	-0.18	186
	35+	2.08	4.98	-2.08	-4.45	37
GA05-0021	0-15	0.9	2.57	0.88	2.48	93
	15-25	0.65	2.35	-0.05	-0.4	220
	25-35	1.29	4.05	-1.22	-3.27	105
	35+	4.8	8.36	-4.8	-8.36	17
GA05-0023	0-15	0.69	1.91	0.34	0.83	182
	15-25	0.78	2.56	-0.52	-1.49	127
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0024	0-15	0.56	1.96	0.24	-0.29	11
	15-25	0.93	2.91	-0.75	-1.63	104
	25-35	1.68	8.91	-1.68	-8.91	5
	35+	-	-	-	-	-
GA05-0025	0-15	1.11	3.08	0.68	0.91	21
	15-25	1.16	2.9	-0.76	-1.92	54
	25-35	1.28	6.16	-1.28	-6.16	5
	35+	-	-	-	-	-
GA05-0026	0-15	1.28	2.88	1.15	2.01	44
	15-25	1.12	3.16	-0.59	-1.82	181
	25-35	2.06	5.93	-1.89	-5.55	10
	35+	-	-	-	-	-

Vendor C

Table 8 summarizes the error metrics computed between ground truth (i.e., WRTM) and Vendor C speeds. Average Absolute Speed Error (AASE) and Speed Error Bias (SEB) measures were each within specification for all speed bins when compared to the 1.96 SEM Band, and in all but the >35 MPH bin when compared with the Mean for the SEB.

Table 8 – Vendor C data quality measures

Speed Bin	Average Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples
	Comparison w/ 1.96 SEM Band	Comparison with Mean	Comparison w/ 1.96 SEM Band	Comparison with Mean	
0-15	0.47	1.66	0.22	0.61	2645
15-25	0.64	2.58	-0.34	-1.26	4470
25-35	1.75	4.9	-1.62	-4.15	1039
35+	3.21	6.7	-3.21	-6.57	138
All Speeds	0.77	2.64	-0.37	-1.12	8292

Table 9 shows the percentage of time the Vendor C data fell within 5 mph of the mean and SEM band for each speed bin.

Table 9 – Percent of Vendor C observations meeting data quality criteria

Speed Bin	Data Quality Measures for				Number of 5 Minute Samples.
	1.96 SEM Band		Mean		
	Percent inside band	Percent within 5mph of band	Percent equal to mean	Percent within 5mph of mean	
0-15	65.1	99.2		96.3	2645
15-25	65.8	98.1		87.5	4470
25-35	52.2	86.7		57.3	1039
35+	39.9	73.9		39.1	138

Table 10 reports the standard error metrics on individual validation segments. Note that some segments and time bins only have a few observations, and thus may not be representative of the overall performance in each speed bin.

Table 10 – Vendor C data quality measures by validation segment

Path	Speed Bin	Data Quality Measures for Avg Absolute Speed Error 1.96 SEM Band	Avg Absolute Speed Error Mean	Speed Error Bias 1.96 SEM Band	Speed Error Bias Mean	No. of Obs.
GA05-0001A	0-15	0.4	1.55	0.18	0.56	179
	15-25	0.4	2.74	-0.35	-2.17	365
	25-35	4.05	9.31	-4.05	-9.31	47
	35+	10.34	16.1	-10.34	-16.1	1
GA05-0001B	0-15	0.25	1.08	-0.06	-0.02	194
	15-25	0.95	2.93	-0.9	-2.77	24
	25-35	0	11.33	0	-11.33	1
	35+	-	-	-	-	-
GA05-0002A	0-15	0.27	1.82	0.13	0.85	41
	15-25	1.1	4.89	-1.1	-4.82	70
	25-35	7.78	14.03	-7.78	-14.03	11
	35+	-	-	-	-	-
GA05-0002B	0-15	0.42	1.62	0.23	0.53	190
	15-25	-	-	-	-	-
	25-35	-	-	-	-	-
	35+	0.95	2.85	-0.94	-2.67	75
GA05-0003A	0-15	0.34	1.39	0.26	0.7	502
	15-25	0.46	1.92	-0.36	-1.34	165
	25-35	1.7	6.73	-1.7	-6.73	2
	35+	-	-	-	-	-
GA05-0004	0-15	0.41	1.51	-0.12	-0.66	92
	15-25	2.51	4.15	-2.51	-4.15	21
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0005	0-15	0.66	1.73	-0.01	-0.01	88
	15-25	6.26	7.08	-6.26	-6.07	2
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0006B	0-15	1.25	2.88	1.25	2.66	31
	15-25	0.49	2.23	-0.04	-0.32	544
	25-35	3.08	6.09	-3.08	-6.09	28
	35+	18.18	20.4	-18.18	-20.4	1
GA05-0007	0-15	0.33	1.08	0.22	0.45	15
	15-25	0.47	1.88	-0.25	-0.92	80
	25-35	4.16	8.51	-4.16	-8.51	3
	35+	-	-	-	-	-
GA05-0008	0-15	1.1	2.96	1.09	2.28	22
	15-25	0.5	2.4	-0.32	-1.26	188
	25-35	1.47	4.17	-1.47	-4.06	71
	35+	0	13.78	0	-13.78	1
GA05-0009A	0-15	0.99	2.49	0.94	2.19	48
	15-25	0.35	1.86	0.01	0.04	427
	25-35	1.87	5.24	-1.87	-4.91	42
	35+	-	-	-	-	-

Path	Speed Bin	Data Quality Measures for				No. of Obs.
		Avg Absolute Speed Error		Speed Error Bias		
		1.96 SEM Band	Mean	1.96 SEM Band	Mean	
GA05-0009B	0-15	0.73	2.32	0.66	1.9	382
	15-25	0.35	2.46	0.01	0.01	141
	25-35	2.46	7.7	-2.46	-7.7	6
	35+	-	-	-	-	-
GA05-0010A	0-15	0.5	1.9	0.25	0.77	125
	15-25	0.57	2.56	-0.42	-1.65	199
	25-35	5.52	11.38	-5.52	-11.38	4
	35+	-	-	-	-	-
GA05-0010B	0-15	0.8	2.87	0.8	2.7	60
	15-25	0.48	2.4	-0.08	-0.61	330
	25-35	1.64	5.06	-1.61	-4.82	52
	35+	-	-	-	-	-
GA05-0018	0-15	0.53	1.51	-0.39	-0.79	85
	15-25	0.99	3.59	-0.95	-3.35	219
	25-35	5.27	9.27	-5.27	-9.27	42
	35+	10.18	14.88	-10.18	-14.88	2
GA05-0019	0-15	0.74	1.79	0.08	0.04	45
	15-25	0.58	2.35	0.2	0.48	549
	25-35	0.86	3.44	-0.55	-1.98	419
	35+	2.33	5.55	-2.33	-5.32	79
GA05-0020	0-15	0.29	1.18	-0.13	-0.34	195
	15-25	0.6	2.44	-0.29	-1.33	385
	25-35	1.14	3.97	-1.1	-3.27	186
	35+	3.05	6.56	-3.05	-6.56	37
GA05-0021	0-15	0.26	1.43	-0.21	-0.6	93
	15-25	1.08	3.25	-0.94	-2.85	220
	25-35	2.73	6.55	-2.73	-6.53	105
	35+	5.69	9.61	-5.69	-9.61	17
GA05-0023	0-15	0.44	1.45	0.15	0.4	182
	15-25	0.53	2.29	-0.43	-1.84	127
	25-35	-	-	-	-	-
	35+	-	-	-	-	-
GA05-0024	0-15	0.03	0.97	-0.03	-0.67	11
	15-25	1.04	2.91	-0.98	-2.48	104
	25-35	1.78	8.3	-1.78	-8.3	5
	35+	-	-	-	-	-
GA05-0025	0-15	0.14	1.29	0.09	0.41	21
	15-25	0.67	2.51	-0.63	-2.02	54
	25-35	1.78	7.06	-1.78	-7.06	5
	35+	-	-	-	-	-
GA05-0026	0-15	0.26	1.5	-0.14	-0.55	44
	15-25	1.68	4.22	-1.6	-4.03	181
	25-35	3.75	7.57	-3.75	-7.57	10
	35+	-	-	-	-	-

Slowdown Analysis Results

The slowdown analysis was initially conceived to evaluate vendor data during major congestion events along high-speed, high-volume suburban arterials (usually 50 mph). However, in this validation, we are evaluating data along highly signalized urban arterials with many access points (local traffic) and speed limits around 25-30 mph. While visual inspection of the data is still informative, we note upfront that this evaluation method and the associated scoring criteria are pushed to their limits, and the results should be interpreted with this in mind.

Table 11 summarizes the classification results, while Figures 2-4 show a representative example for each of the three classification scores. Note that in each of the 13 major slowdowns suitable for analysis, all vendors correctly registered a speed drop in their data feed – even if ultimately the duration or magnitude of the vendor's slowdown did not match the reference data closely enough to be deemed "Fully Captured" or "Partially Captured". Slowdowns were scored based on the stated magnitude and duration criteria, and every effort was made to apply the logic in a manner consistent with recent validation efforts. However, this proved to be challenging, and it is worth noting that most "Failed to Capture" classifications in this dataset look far better than similarly classified events several years ago, when it was common to see vendors completely miss slowdown events.

Table 11: Slowdown Analysis Summary

Vendor	Major Slowdowns	Fully Captured	Partially Captured	Not Captured
A	13	5	4	4
B	13	7	6	0
C	13	13	0	0

Fully Captured Example

Figure 2 shows an example for a "Fully Captured Slowdown". Both duration and magnitude of the vendor's slowdown are within 20% of the reference data.

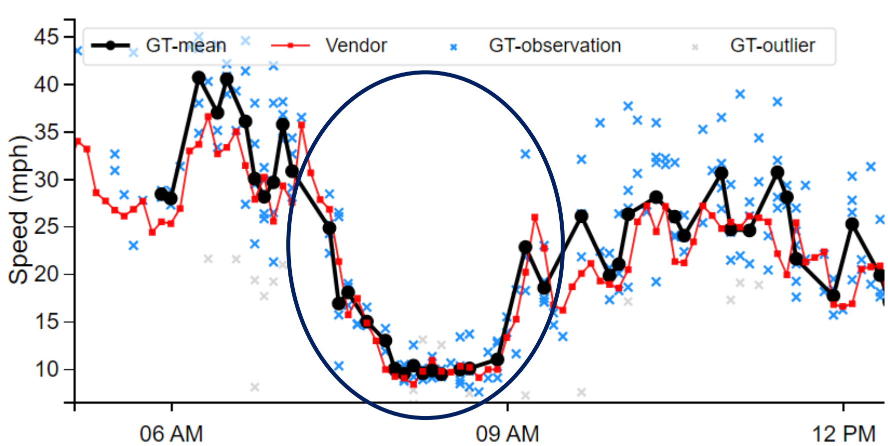


Figure 2: Example of a 'Fully Captured' slowdown classification

Partially Captured Example

Figure 3 shows an example of a "Partially Captured" classification. The duration of the slowdown matches the ground truth data within 20%, but the magnitude is off by more than 20%.

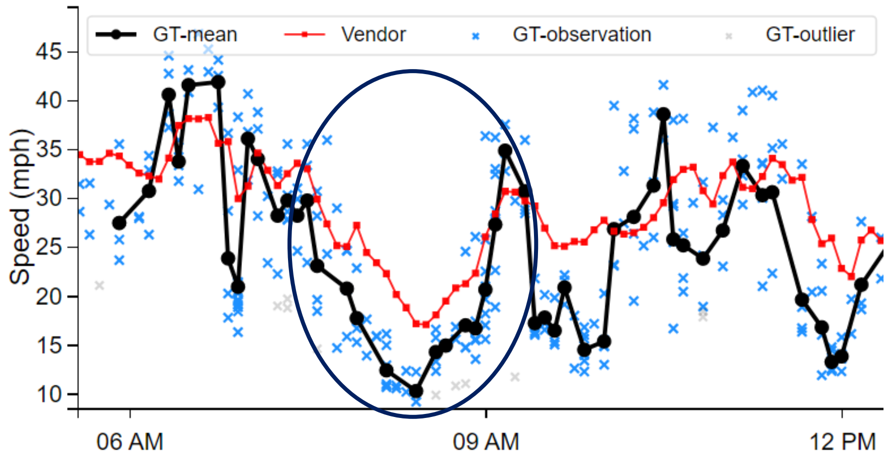


Figure 3: Example of a 'Partially Captured' slowdown classification

Failed to Capture Example

Figure 4 shows an example of a "Failed to Capture" classification. Like the previous example showing a "Partially Captured" scenario, the magnitude of speed reduction is not within 20% of the reduction observed in the reference data, but in this case the duration of the slowdown is also not within 20% because of quite significant delay/latency in registering the event (over 30 minutes). This example is representative of other "Fail to Capture" scenarios in this study, and illustrates the fact that despite the classification, the vendors did register a meaningful drop in speed and did not "flatline" or completely miss the event.

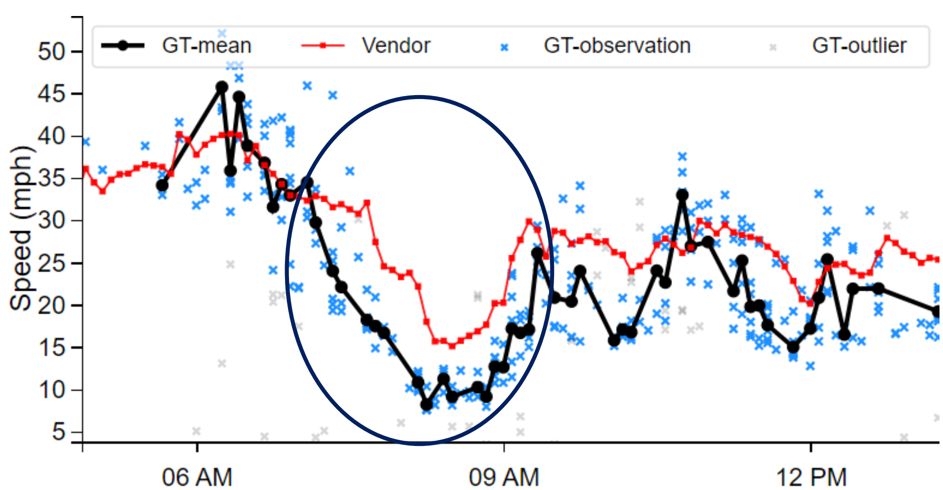


Figure 4: Example of a 'Failed to Capture' slowdown classification