Probe Vehicle Data Comparative Validation Study

New Jersey and New York

FINAL REPORT

NJIT New Jersey's Science & Technology University

Prepared for
TRANSCOM

Revised: June 6, 2013

Probe Vehicle Data Comparative Validation Study

New Jersey and New York

FINAL REPORT

Submitted to:

TRANSCOM
Newport Financial Center
111 Town Square Place - 6th Fl,
Jersey City, NJ 07310

Submitted by:

New Jersey Institute of Technology
Department of Civil & Environmental Engineering
University Heights
Newark, NJ 07102-1983

Authors:
Dr. Lazar N. Spasovic (Principal Investigator)
Branislav Dimitrijevic
Dr. Kitae Kim

June 6, 2013.

Table of Contents

List of Tables

List of Figures

Executive Summary

Background

This report summarizes the results of a validation study for the probe-vehicle speed data provided by three commercial traffic data providers. The providers were INRIX Inc., NAVTEQ and TrafficCast Dynaflow™. All three vendors provided estimates of prevailing vehicle speeds in real time by tracking the movement of participating commercial fleet vehicles equipped with global positioning systems (GPS). The sample of traffic data used for validation purposes was obtained from TRANSCOM and it included complete datasets from all three vendors for a three-week period between Sunday, October 16 and Saturday, November 5, 2011. The validation was conducted by comparing the speeds estimated by each data provider to the corresponding speeds estimated using stationary TRANSMIT[1] readers, which were considered to represent the "ground truth" for validation purposes. For this reason, validation was conducted along select roadway sections equipped with TRANSMIT readers. The roadways selected included:

1. I-287 in New Jersey: 20.51 miles between NJ Turnpike (MP 0.93) and I-78 (MP 21.44)
2. I-78 in New Jersey: 17.5 miles between Drift Road (MP 42.2) and Doremus Avenue (MP 59.7)
3. Long Island Expressway (LIE) in New York: 14.26 miles between Shelter Rock Road and Route 110
4. Northern State Parkway (NSP) in New York: 17.24 miles between Route 106/7 and Veterans Highway

Overall, the data sample covered approximately 69.51 freeway miles.

Validation Methodology

The speed data validation was based on the methodology developed and utilized by the I-95 Corridor Coalition's Vehicle Probe Project (VPP). The speed estimates were compared in 5-minute intervals for each freeway section between two consecutive TRANSMIT readers

[1] TRANSMIT readers are stationary roadside vehicle detectors that use vehicles equipped with E-ZPass tags as anonymous probes to determine prevailing traffic speeds. As tags are detected by successive readers, the TRANSMIT system compiles aggregate data on average speeds, travel times, and the number of non-arriving vehicles (vehicles expected but not yet detected by the next reader downstream). The E-ZPass tag ID's are scrambled by the TRANSMIT system to protect motorist privacy. The scrambled ID information is deleted after the vehicle has left the highway segment. The TRANSMIT system and the readers are operated by TRANSCOM, www.xcm.org.

(constituting a total of 43 freeway sections in both directions). Two performance measures were used to ascertain the quality and accuracy of the speed data:

- Average Absolute Speed Error (AASE), which represented the average absolute difference between estimated speeds and the "ground truth"; and
- Speed Error Bias (SEB), which ascertained the prevailing sign (positive or negative) of the difference between the estimated speeds and the "ground truth".

The data accuracy was considered to be acceptable if the AASE $\leq$ 10 mph and the |SEB| $\leq$ 5 mph. Both the AASE and SEB were calculated with respect to the mean estimated speed, as well as the 95% confidence interval around the mean speed (referred to as the Standard Error of the Mean Band, or the SEM Band).

For the purpose of this validation study, the speed data points were stratified into four categories, referred to as "speed bins":

- < 30 mph
- 30 – 45 mph
- 45 – 60 mph
- > 60 mph

The AASE and SEB were calculated for each traffic data provider (i.e., technology) and each speed bin.

Results

The results of the speed data validation for each evaluated vendor are summarized in **Tables 1 through 3**. The results were based on the cumulative analysis of the data samples for all four analyzed freeway sections during the three-week analysis period. As shown, **all three technologies were within the acceptance limits for the average absolute speed error (AASE ≤ 10 mph) and the speed error bias (|SEB| ≤ 5 mph), with the following two exceptions:**

- INRIX's SEB with respect to the mean in the 30 to 45 mph speed bin: value 5.21 > 5
- NAVTEQ's SEB with respect to the mean in the speed bin > 60 mph: value (-5.31) < (-5).

Table 1. INRIX Validation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.87	5.48	4.42	4.79	3,251
30 – 45	5.60	6.70	4.56	**5.21**	4,787
45 – 60	3.45	4.37	2.31	2.87	21,584
>60	2.44	3.15	(1.48)	(1.81)	115,088
All Speeds	**2.75**	**3.50**	**(0.58)**	**(0.73)**	**144,710**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table 2. NAVTEQ Validation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.18	4.84	3.90	4.39	3,513
30 – 45	3.91	5.06	2.60	3.14	5,112
45 – 60	3.18	4.02	(0.96)	(0.94)	25,931
>60	4.99	5.74	(4.71)	**(5.31)**	122,303
All Speeds	**4.64**	**5.41**	**(3.66)**	**(4.09)**	**156,859**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table 3. DynaFlow Validation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	6.27	6.93	4.51	4.76	4,229
30 – 45	5.08	6.25	1.81	2.16	5,722
45 – 60	3.87	4.71	(1.02)	(1.15)	27,757
>60	4.32	5.07	(3.87)	(4.42)	124,206
All Speeds	**4.32**	**5.10**	**(2.96)**	**(3.38)**	**161,914**

* Negative numbers are displayed in parentheses

It was observed that all of the studied technologies ***consistently overestimated*** the speed in the lowest speed bin (0-30 mph), and ***consistently underestimated*** the speed in the highest speed bin (> 60 mph). In the case of NAVTEQ, the speed bias in the [>60] mph speed bin was largely due to capped maximum reported speeds on the LIE and NSP (which were capped at the speed limit of 55 mph).

It was also observed that all three evaluated technologies provided inaccurate (and therefore unreliable) estimates of speeds during incidents, especially on the weekends. This can be explained by an insufficient number of probes on weekends and during off-peak time periods (especially night time), as all three evaluated vendors obtain speed data largely from commercial vehicle fleets (which operate mostly on weekdays, during regular business hours).

The following are the details of the validation findings focusing on each studied freeway section:

- **I-287 speed data validation**: The validation analysis showed that the speed estimates provided by all three evaluated vendors (technologies) satisfied both the AASE and SEB data quality criteria in all of the speed bins.
- **I-78 speed data validation**: The estimates from all three evaluated vendors met the AASE validation criteria, but did not satisfy the SEB acceptance thresholds in the following cases:

  (a) NAVTEQ's overall SEB, with respect to Mean, was below the minimum acceptance threshold (SEB = -5.06 <- 5 mph). This was largely driven by poor performance in the [> 60] mph speed bin (SEB = -5.46 mph), which indicated a significant underestimation of speed, as explained earlier. The SEB, with respect to both the Mean and SEM Band for the [0-30] mph speed bin, were also outside the validation acceptance range with anSEB (Mean) =

7.34 and SEB(SEM Band) = 6.54 mph, both of which were greater than the threshold of 5 mph. This indicated a significant overestimation of speed in the lowest speed bin.

(b) INRIX's SEB was outside the validation acceptance range with respect to the SEM Band in the [0-30] mph speed bin (SEB = 5.41 > 5 mph), and with respect to the Mean in the [0-30] mph speed bin (SEB = 6.02 mph) and the [30-45] mph speed bin (SEB = 5.68 mph).

(c) DynaFlow's SEB was outside the acceptance thresholds in the [0-30] mph speed bin, both with respect to the SEM Band and Mean (5.04 mph and 5.56 mph respectively, both >5 mph).

- **LIE speed data validation**: The speed estimates by all three evaluated vendors met the AASE validation criteria. When it came to the SEB, NAVTEQ failed the validation in the [>60] mph speed bin by a significant margin (-8.13 mph with respect to the SEM Band and -8.94 mph with respect to the Mean, both of which were significantly higher the threshold of $\pm$5 mph). This in turn caused the overall SEB statistics in both categories to fail the validation test. The apparent bias in the highest speed bin was due to capped maximum speeds in NAVTEQ's reporting for the LIE. NAVTEQ'S highest reported speed was equivalent to the speed limit of 55 mph, whereas ground truth top speeds went well above this cap during times of uncongested traffic. Therefore, it is recommended that the overall SEB values for the LIE not be used as a validation reference in this analysis.

- **NSP speed data validation**: The results of the speed data validation for the studied section of the NSP were the most problematic. Overall, the datasets for the NSP, from all three vendors, seemed to exhibit lower accuracy (and hence lower reliability in real time) as compared to other evaluated freeway segments. This was illustrated by the following:

  (a) Of the three evaluated datasets, only NAVTEQ met the AASE validation criteria in all speed bins. However, it failed the SEB test in the [0-30] mph speed bin, as well as in the [>60] mph speed bin. In the [0-30] mph bin, the SEB indicated a slight, but consistent, ***overestimation*** of speed (5.79 mph with respect to the SEM Band and 6.45 mph with respect to the Mean). In the top speed bin the SEB indicated a significant, and consistent, ***underestimation*** of speed ((-9.23) with respect to the SEM Band, and (-9.71) with respect to the Mean). As in the case of the LIE, the result in the [>60] mph speed bin can be explained by the fact that NAVTEQ was capping the maximum speed in their reporting to a speed limit of 55 mph. With actual speeds largely exceeding this limit during uncongested times, discrepancies between the actual and estimated speed reflected in the SEB were not surprising.

(b) Both the INRIX and DynaFlow datasets failed both the AASE and the SEB validation tests in the lower two speed bins ([0-30] and [30-45] mph), with respect to both the SEM Band and the Mean. However, the overall validation statistics across all speed bins were within the acceptance ranges for both datasets. This result was facilitated by relatively small speed estimation errors in the two upper speed bins and the fact that most of the sampled speeds (95%) in each dataset were in these two speed bins. In other words, in the case of INRIX and DynaFlow, the more accurate estimates of speeds higher than 45 mph more than offset the inaccuracies identified in lower speed bins. This was due to the much bigger share of the validation sample falling in the higher two speed bins.

It was assumed that poor performance of the speed estimates on the NSP was due to an insufficient number of probe vehicles on this roadway. Commercial vehicles are not allowed on the NSP, yet they represent the largest portion of the probe fleet all three vendors use to collect and aggregate vehicle speeds in real time. Therefore, the evaluated data sample is largely based on historical and synthetic speed estimates, rather than actual speeds collected from the probe vehicles.

Introduction

This report summarizes the results of a validation study for the probe-vehicle speed data provided by three commercial traffic data providers. The providers were INRIX Inc., NAVTEQ and TrafficCast Dynaflow™. All three vendors provided estimates of prevailing vehicle speeds in real time by tracking the movement of participating commercial fleet vehicles equipped with global positioning systems (GPS). The sample of traffic data used for validation purposes was obtained from TRANSCOM and it included complete datasets from all three vendors for a three-week period between Sunday, October 16 and Saturday, November 5, 2011.

The validation was conducted by comparing the speeds estimated by each data provider to the corresponding speeds estimated using stationary TRANSMIT readers, which were considered to represent the "ground truth" for validation purposes. TRANSMIT readers are stationary roadside vehicle detectors that use vehicles equipped with E-ZPass tags as anonymous probes to determine prevailing traffic speeds. As tags are detected by successive readers, the TRANSMIT system compiles aggregate data on average speeds, travel times, and the number of non-arriving vehicles (vehicles expected but not yet detected by the next reader downstream). The E-ZPass tag ID's are scrambled by the TRANSMIT system to protect motorist privacy. The scrambled ID information is deleted after the vehicle has left the highway segment. The TRANSMIT system and the readers are operated by TRANSCOM, www.xcm.org.

The validation was conducted along select roadway sections equipped with TRANSMIT readers. The roadways selected included:

1. I-287 in New Jersey: 20.51 miles between NJ Turnpike (MP 0.93) and I-78 (MP 21.44)
2. I-78 in New Jersey: 17.5 miles between Drift Road (MP 42.2) and Doremus Avenue (MP 59.7)
3. Long Island Expressway (LIE) in New York: 14.26 miles between Shelter Rock Road and Route 110
4. Northern State Parkway (NSP) in New York: 17.24 miles between Route 106/7 and Veterans Highway

Overall, the data sample covered approximately 69.51 freeway miles, containing a total of 43 freeway sections between two consecutive TRANSMIT readers in both directions (referred to as '*TRANSMIT links*').

Validation Methodology

The speed data validation was based on the methodology developed and utilized by the I-95 Corridor Coalition's Vehicle Probe Project (VPP). The speed estimates were compared in 5-minute intervals for each TRANSMIT link. A statistical analysis was conducted to evaluate the degree of variability between the TRANSMIT speeds and speeds estimated by each vendor.

Before the statistical analysis could be performed, substantial data processing and integration was required. This was due to differences in the linear referencing of highway links and reporting intervals among the three evaluated datasets, as well as the TRANSMIT dataset. An overview of the validation methodology is illustrated in Figure 1:

1. The first step was a comprehensive review of the previous travel time validation study[2] by the I-95 Corridor Coalition, which was adopted as the basis of the statistical analysis for this study.
2. Next, with the assistance of TRANSCOM, the speed data for the selected freeway sections was obtained and stored in an SQL Server database for further processing and analysis.
3. In the next step, the link definitions and reporting intervals were unified among the datasets so as to allow for an unbiased comparison with the TRANSMIT reported speeds. The datasets were then processed to conform to the common reporting interval and TRANSMIT link definitions.
4. Finally, the statistical analysis was performed and validation statistics were calculated for each evaluated dataset.

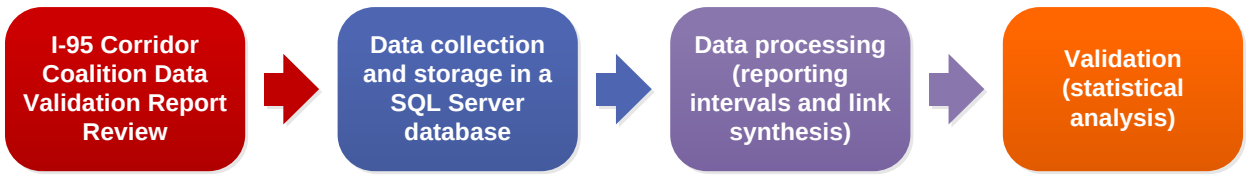

Figure 1. Validation Study Methodology

[2] Vehicle Probe Project *Data Use and Application Guide*, University of Maryland and KMJ Consulting Inc., April 2011.

Study Database

A comparative statistical analysis for travel time data provided by the three companies started with data processing. As the link travel speed data of each technology was archived using a different format, a computer program was developed to retrieve the link travel speed data from the four technologies (i.e., TRANSMIT, INRIX, NAVTEQ, and DynaFlow) and process the data in preparation for the statistical analysis. The processed speed data was loaded into the SQL database for each data source (e.g., technology and confidence level) by link and timestamp.

Reporting (Time) Interval Synthesis

The TRANSMIT and INRIX data were reported every minute, while the NAVTEQ and DynaFlow data were reported every 2 and 1.5 minutes, respectively. To facilitate the analysis on a minute-by-minute basis, additional data fill-in was required for the NAVTEQ and DynaFlow data. Additionally, the time of the first speed reporting of a day varied between the sources and dates. To ensure consistency, all speeds were analyzed relative to the common one-minute time interval. A detailed procedure of speed data recording has been illustrated using sample data in Appendix A.

TRANSMIT and TMC Link Synthesis

INRIX, NAVTEQ, and DynaFlow speed estimates were reported for freeway segments defined by the so-called Traffic Message Channel (TMC) network. The TMC segmentation was developed in order to provide a basis for delivering traffic and travel information to motor vehicles via FM radio broadcast. Upon a review of the documentation for each evaluated dataset, it was found that the TMC links they used as a basis for speed reporting did not 'line up' (i.e. had different endpoints and lengths). In addition, the location of the TRANSMIT readers did not match the endpoints of the TMC links, and the TRANSMIT links were comparatively much longer than the TMC links of any of the three commercial data providers.

Due to the lack of correspondence between the TMC coordinates, a mapping procedure was implemented that matched each TRANSMIT link with multiple TMC links contained along the corresponding freeway sections. To that end, the TRANSMIT reader locations on the studied freeway segments were identified and coded into a geographical information system (GIS) map, as well as the TMC links for each evaluated dataset (INRIX, NAVTEQ, and DynaFlow). Then, the TMC links located in-between consecutive TRANSMIT links were measured and merged to form '*path segments*', which were equivalent to TRANSMIT links. In this process every effort

was made to minimize the differences between the TRANSMIT link length and the combined TMC link length.

Statistical Analysis

The statistical analysis was a pair-wise comparison in which the speed estimates from each of the three commercial companies were compared to the ground truth data (TRANSMIT). Using the reporting format adopted in the I-95 Corridor Coalition speed data validation reports, the speed data points were stratified into four categories, referred to as "***speed bins***":

- < 30 mph
- 30 – 45 mph
- 45 – 60 mph
- > 60 mph

A series of data validation statistics were calculated for each vendor dataset and each speed bin. The validation statistics and corresponding validation criteria will be explained next.

Speed Estimate Validation Statistics

The ground truth standard error of the mean (SEM) band and the mean were calculated for the four speed bins in order to evaluate the accuracy of the INRIX, NAVTEQ and DynaFlow data. The SEM band was a surrogate for the 95% confidence interval of the ground truth data. The errors of the mean and SEM band between TRANSMIT and three technologies for each 5-minute interval were calculated using the following formulae:

- The error of the mean between TRANSMIT vs. INRIX, NAVTEQ, and DynaFlow

$$e_M = \overline{S_\tau} - \overline{S_T}$$

where, e_M : corresponding error of the estimated mean speed between TRANSMIT and each of the other three technologies in a given time interval

$\overline{S_\tau}$: mean of the speed during the evaluation time period from the commercial technologies (τ = INRIX, NAVTEQ, and DynaFlow)

$\overline{S_T}$: mean of the speed during the evaluation time period from TRANSMIT

- The error of the SEM band between TRANSMIT vs. INRIX, NAVTEQ, and DynaFlow

$$e_{SEM} = \begin{cases} e_{SEM} = [\overline{S_\tau} - (\overline{S_T} - 1.96 \times SE_T)], \; if \; [\overline{S_\tau} \le (\overline{S_T} - 1.96 \times SE_T)] \\ e_{SEM} = [\overline{S_\tau} - (\overline{S_T} + 1.96 \times SE_T)], \; if \; [\overline{S_\tau} \ge (\overline{S_T} + 1.96 \times SE_T)] \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad , \; otherwise \end{cases}$$

where, e_{SEM} : corresponding error of the estimated SEM band between TRANSMIT and each of the other three technologies in a given time interval

SE_T : SEM of TRANSMIT in a given time interval

$$SE_T = \frac{\sigma}{\sqrt{N}}$$

σ : standard deviation of TRANSMIT in a given time interval

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_{T_i} - \overline{S_T})^2}$$

S_{T_i} : i^{th} recorded speed during the evaluation time period from TRANSMIT

n : number of speed data per time interval (n =5)

Two performance measures were used to ascertain the quality and accuracy of the speed data:

1. **Average Absolute Speed Error (AASE)**, which represented the average absolute difference between estimated speeds and the “ground truth”; and
2. **Speed Error Bias (SEB)**, which ascertained the prevailing sign (positive or negative) of the difference between the estimated speeds and the “ground truth”.

The AASE was defined as the absolute value of the difference between the INRIX, NAVTEQ, and DynaFlow speed estimates and speed estimates based on TRANSMIT readers. The AASE values compared with the mean and SEM band were estimated based on the following:

(a) The average absolute speed error (AASE) compared with the Mean

$$AASE_{Mean} = \frac{1}{N}\sum_{j=1}^{N}|e_M|$$

where, N : number of 5-minute intervals with calculated e_M (or e_{SEM})

(b) The average absolute speed error (AASE) compared with the SEM band

$$AASE_{SEM\,Band} = \frac{1}{N}\sum_{j=1}^{N}|e_{SEM}|$$

The speed error bias (SEB) was calculated using the same procedure used for the AASE, with the exception that the absolute value was not taken. Thus, if there was a consistent positive or negative error, it would appear in the result of the calculation. The SEB values compared with the mean and SEM band were also estimated based on the following:

(a) The speed error bias (SEB) compared with the mean

$$SEB_{Mean} = \frac{1}{N}\sum_{j=1}^{N} e_M$$

(b) The speed error bias (SEB) compared with the SEM band

$$SEB_{SEM\ Band} = \frac{1}{N}\sum_{j=1}^{N} e_{SEM}$$

Validation (Data Accuracy) Criteria

The data accuracy was considered to be acceptable if the ***AASE*** $\leq$ ***10 mph*** and ***|SEB| ≤ 5 mph***. Both the AASE and SEB were calculated with respect to the Mean estimated speed, as well as the 95% confidence interval around the mean speed (SEM Band). The AASE and SEB were calculated for each traffic data provider (i.e., technology) and each speed bin.

Data Set (Confidence Level)

TRANSMIT and DynaFlow provided travel time data without defining data confidence levels. However, INRIX and NAVTEQ reported link speeds in three different ways, each labeled with a different confidence level, as follows:

(a) High Confidence: speed estimates based mostly on real-time readings from the probe vehicles.

(b) Medium Confidence: a synthetic speed estimate based on a combination of real-time readings from the probe vehicles and historical speed data for the corresponding location and time interval. This usually occurred at times when the probe vehicle fleet was small or insufficient to calculate the prevailing speeds with confidence.

(c) Low Confidence: speed estimates almost entirely based on the historical data.

To perform a more in-depth quality comparison, the available data sample for each evaluated dataset was divided into two qualitative data subsets:

Subset 1: Included the data points for all 5-minute intervals in which TRANSMIT consistently reported speed data (i.e., speed information was available for

every minute during a 5-minute interval), regardless of the confidence level reported for the INRIX and NAVTEQ data.

Subset 2: Included the speed data from Subset #1, excluding the 5-minute intervals in which at least one data point in either the INRIX or NAVTEQ data was reported with a confidence level of “LOW” (i.e. considered only “HIGH” and “MEDIUM” confidence data points).

Study Locations

I-287 (between New Jersey Turnpike and I-78)

The first study location in New Jersey was the section of I-287 between the New Jersey Turnpike (MP 0.93) and I-78 (MP 21.44). This section covered a total length of 20.51 freeway miles. Figure 2 presents a snapshot of I-287 over which TRANSMIT readers were deployed. Table 4 presents a list of the TRANSMIT links that were selected as the validation sample on I-287 (From NJ Turnpike to I-78).

Figure 2. TRANSMIT link segments selected for validation on I-287 in New Jersey

Table 4. TRANSMIT link segments selected for validation on I-287

LINK ID	STARTING AT	ENDING AT	DIRECTION	LENGTH (mi)
5361673	Exit 1 - US 1	Exit 7 - Randolphville Rd.	North	6.78
5361674	Exit 7 - Randolphville Rd.	Exit 13 - (NJ 28)	North	5.79
5361675	Exit 13 - (NJ 28)	Exit 17 - (US 202/6)	North	4.16
5361676	Exit 17 - (US 202/6)	Exit 21 - (I-78)	North	3.78
Total Freeway Miles			**North**	**20.51**
5361676	Exit 17 - (US 202/6)	Exit 21 - (I-78)	South	3.78
5361675	Exit 13 - (NJ 28)	Exit 17 - (US 202/6)	South	4.16
5361674	Exit 7 - Randolphville Rd.	Exit 13 - (NJ 28)	South	5.79

LINK ID	STARTING AT	ENDING AT	DIRECTION	LENGTH (mi)
5361673	Exit 1 - US 1	Exit 7 - Randolphville Rd.	South	6.78
Total Freeway Miles			**South**	**20.51**

I-78 (between Drift Road and Doremus Avenue)

The second study location in New Jersey was the section of I-78 between Drift Road (MP 42.2) and Doremus Avenue (MP 59.7). This section covered a 17.5-mile long highway segment. Travel speed validation on I-78 was performed for both local and express lanes. Figure 3 presents a snapshot of the I-78 corridor over which eight TRANSMIT readers were previously deployed for eastbound local lanes and five TRANSMIT readers were already deployed for westbound local lanes. For the express lanes, there were five TRANSMIT readers previously installed for both directions. **Error! Reference source not found.** shows a list of TRANSMIT links that were selected as the validation sample on I-78.

Figure 3. TRANSMIT link segments selected for validation on I-78 in New Jersey

Table 5. TRANSMIT link segments selected for validation on I-78 (Local and Express Lanes)

LINK ID	STARTING AT	ENDING AT	DIRECTION	LENGTH (mi)
5361722	Drift Rd (MP 42.2)	Glenside Ave (MP 46.5)	East (Local)	4.30
5361678	Glenside Ave (MP 46.5)	Loc/Exp Split (MP 48.4)	East (Local)	1.90
5361715	Loc/Exp Split (MP 48.4)	Springfield Ave (50.5)	East (Local)	2.10
5361717	Springfield Ave (50.5)	Halsey St (MP 52.2)	East (Local)	1.70
5361695	Halsey St (MP 52.2)	Lyons Ave (MP 54.9)	East (Local)	2.70
5361697	Lyons Ave (54.9)	US 1&9 (MP 58.4)	East (Local)	3.50
4329514	US 1&9 (MP 58.4)	HBE Doremus Ave (59.7)	East (Local)	1.30
Total Freeway Miles (Local Roadway)			**East**	**17.50**
5361714	Loc/Exp Split (MP 48.4)	Springfield Ave. (MP 50.5)	East (Express)	2.10
5361716	Springfield Ave. (MP 50.5)	Halsey St. (MP 52.2)	East (Express)	1.70
5361696	Halsey St. (MP 52.2)	Lyons Ave. (MP 54.9)	East (Express)	2.70
5361698	Lyons Ave. (54.9)	US 1&9 (MP 58.4)	East (Express)	3.50
Total Freeway Miles (Express Roadway)			**East**	**10.00**
5361703	US 1&9 (MP 58.4)	Lyons Ave. (MP 54.9)	West (Local)	3.50
5361705	Lyons Ave. (MP 54.9)	Halsey St. (MP 52.2)	West (Local)	2.70
5361679	GSP Exit 52 (MP 52.2)	Exit 48-NJ 24 (MP 49.6)	West (Local)	2.60
5361723	Exit 48-NJ 24 (MP 49.6)	Glenside Ave. (MP 46.5)	West (Local)	3.10
Total Freeway Miles (Local Roadway)			**West**	**11.90**
5361704	US 1&9 (MP 58.4)	Lyons Ave. (MP 54.9)	West (Express)	3.50
5361706	Lyons Ave. (MP 54.9)	Halsey St. (MP 52.2)	West (Express)	2.70
5361718	Halsey St. (MP 52.2)	Springfield Ave. (50.5)	West (Express)	1.70
5361719	Springfield Ave. (50.5)	Exit 48-NJ 24 (MP 49.6)	West (Express)	0.90
Total Freeway Miles (Express Roadway)			**West**	**8.80**

Long Island Expressway (I-495, between Shelter Rock Road and NY Route 110)

The roadway segments on the Long Island Expressway (LIE, I-495) were located between Shelter Rock Road and Route 110. This section covered a 14.26-mile long highway segment. Figure 4 presents a snapshot of the LIE corridor over which five TRANSMIT readers were previously deployed. Table 6 shows a list of TRANSMIT links that were selected as the validation sample on the LIE.

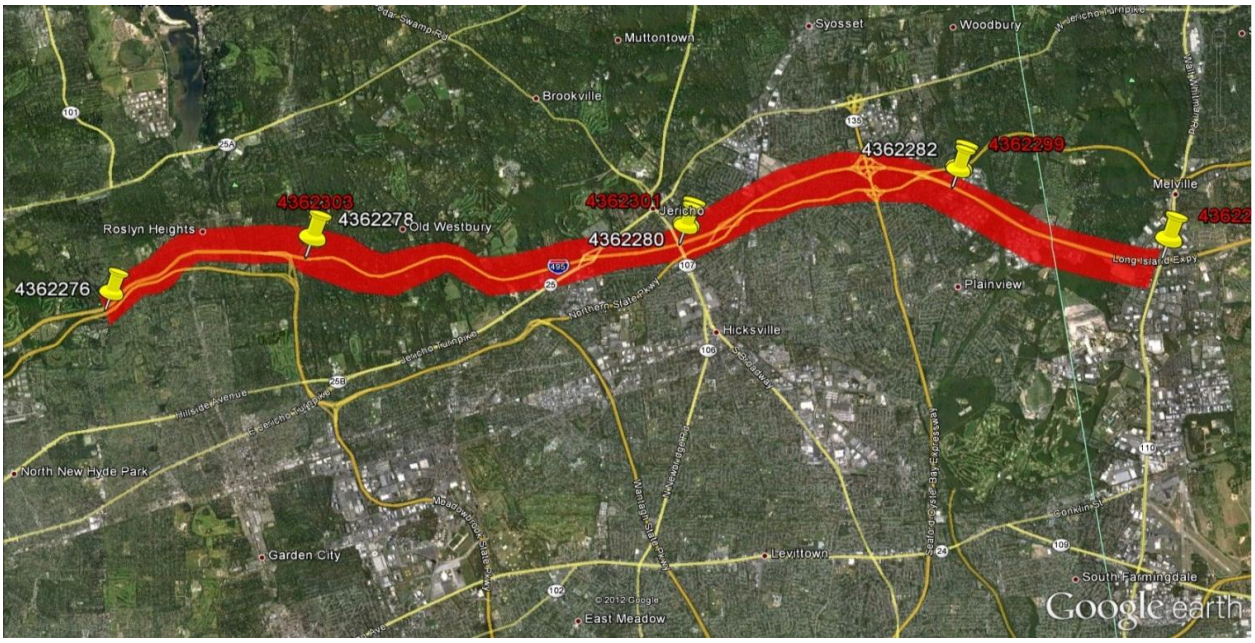

Figure 4. TRANSMIT link segments selected for validation on LIE in New York

Table 6. TRANSMIT link segments selected for validation on Long Island Expressway (LIE)

LINK ID	STARTING AT	ENDING AT	DIRECTION	LENGTH (mi)
4362276	Shelter Rock Road	Glen Cove Road	East	2.76
4362278	Glen Cove Road	Route 106/7	East	4.93
4362280	Route 106/7	Sunnyside Blvd	East	3.43
4362276	Shelter Rock Road	Glen Cove Road	East	3.14
Total Freeway Miles			**East**	**14.26**
4362297	Route 110	Sunnyside Blvd	West	3.14
4362299	Sunnyside Blvd	Route 106/7	West	3.43
4362301	Route 106/7	Glen Cove Road	West	4.93
4362303	Glen Cove Road	Shelter Rock Road	West	2.76
Total Freeway Miles			**West**	**14.26**

Northern State Parkway (between Route 106/7 and Veterans Highway)

The roadway segments on the Northern State Parkway (NSP) were located between Route 106/7 and Veterans Highway. This section covered a total length of 17.24 freeway miles (14.63-mile EB, 17.24 WB). Figure 5 presents a snapshot of the NSP over which TRANSMIT readers were previously deployed. Table 7 presents a list of TRANSMIT links that were selected as the validation sample on the NSP.

Figure 5. TRANSMIT link segments selected for validation on NSP in New York

Table 7. TRANSMIT link segments selected for validation on Northern State Parkway (NSP)

LINK ID	STARTING AT	ENDING AT	DIRECTION	LENGTH (mi)
4362264	NY Route 106/7	Sunnyside Blvd.	East	3.44
4362265	Sunnyside Blvd.	NY Route 110	East	3.46
4362266	NY Route 110	Deer Park Ave.	East	4.53
4362267	Deer Park Ave.	Sagtikos State Pkwy.	East	3.20
Total Freeway Miles			**East**	**14.63**
4362253	Veterans Highway	Sagtikos State Pkwy.	West	2.58
4362254	Sagtikos State Pkwy.	NY Route 110	West	7.75
4362255	NY Route 110	Sunnyside Blvd.	West	3.46
4362341	Sunnyside Blvd.	NY Route 106/7	West	3.45
Total Freeway Miles			**East**	**17.24**

Validation Results

This chapter summarizes the results of the speed data validation. The summaries were organized by study location (freeway section) and presented in tables and graphs for each evaluated data provider (technology). It should be noted that the validation results presented herein were for the data sample ***Subset 1***. This data sample included the data points for all 5-minute intervals in which TRANSMIT consistently reported speed data (i.e., speed information was available for every minute during a 5-minute interval), ***regardless of the confidence level*** reported for the INRIX and NAVTEQ data.

The results of the validation for the ***Subset 2*** dataset are provided in Appendix B of this report. Subset 2 excluded the 5-minute intervals in which at least one data point in either the INRIX or NAVTEQ dataset was reported with a "low confidence" level (i.e. only considered the data points reported with ***"high confidence"*** or ***"medium confidence"***).

I-287 (between New Jersey Turnpike and I-78)

Table 8 through Table 10 summarize the AASE and SEB statistics calculated for the studied segment of I-287 between the New Jersey Turnpike and I-78 for all three evaluated traffic data providers. The results showed that **INRIX, NAVTEQ, and DynaFlow met the validation criteria** for the AASE and SEB in all speed bins with respect to both the SEM Band and Mean. The same results are also shown in Figure 6 through Figure 11. Table 11 through Table 13 show the percentages of the sampled intervals that met the validation criteria, distinguishing between INRIX, NAVTEQ, and DynaFlow estimates equal to the TRANSMIT estimates, and those falling within the validation range.

Table 8. INRIX Evaluation Summary for I-287

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	2.40	2.98	1.80	2.11	733
30 – 45	3.28	4.51	2.37	3.07	950
45 – 60	3.43	4.71	2.52	3.29	2,236
>60	2.48	3.23	(2.03)	(2.54)	29,423
All Speeds	**2.35**	**3.12**	**(0.21)**	**(0.75)**	**33,342**

* Negative numbers are displayed in parentheses

Table 9. NAVTEQ Evaluation Summary for I-287

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	4.21	4.82	3.99	4.51	781
30 – 45	2.85	4.03	1.41	1.90	973
45 – 60	2.98	4.12	(1.68)	(1.76)	2,289
>60	3.97	4.76	(3.91)	(4.65)	30,064
All Speeds	**3.55**	**4.36**	**(0.39)**	**(1.55)**	**34,107**

* Negative numbers are displayed in parentheses

Table 10. DynaFlow Evaluation Summary for I-287

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	3.86	4.45	0.67	0.63	726
30 – 45	4.71	5.93	(0.45)	(0.41)	947
45 – 60	4.11	5.29	(0.19)	(0.22)	2,223
>60	4.02	4.80	(3.72)	(4.37)	29,022
All Speeds	**4.01**	**4.81**	**(0.42)**	**(1.60)**	**32,918**

* Negative numbers are displayed in parentheses

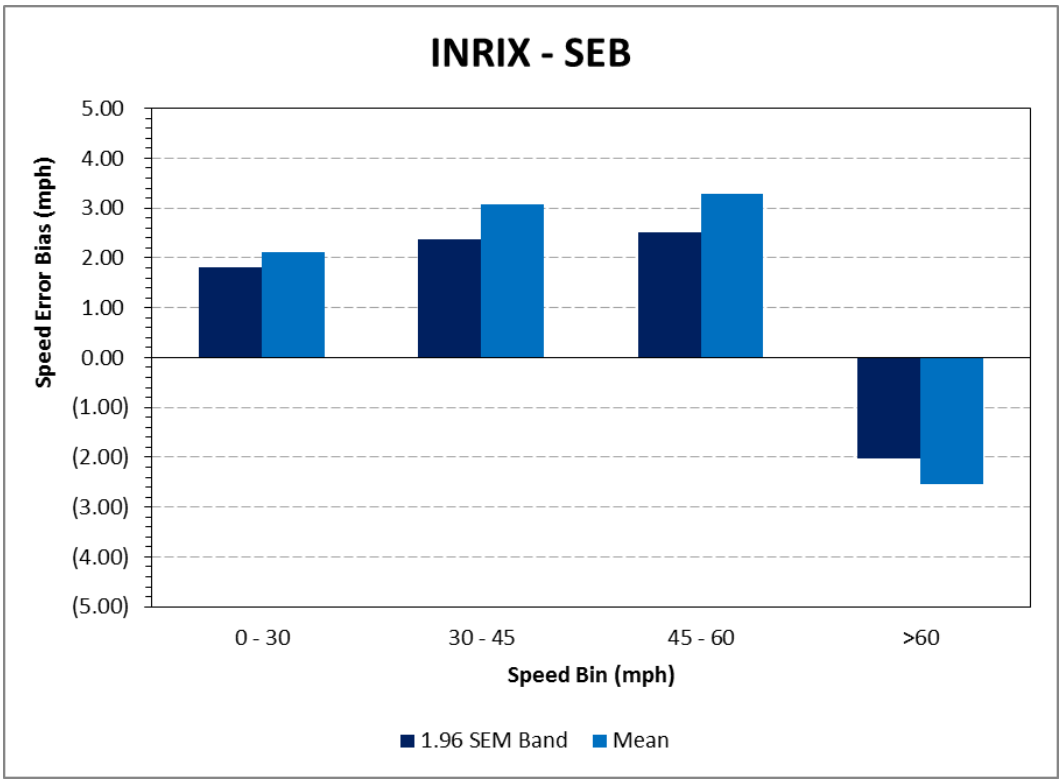

Figure 6. Speed Error Bias (SEB) for INRIX on I-287

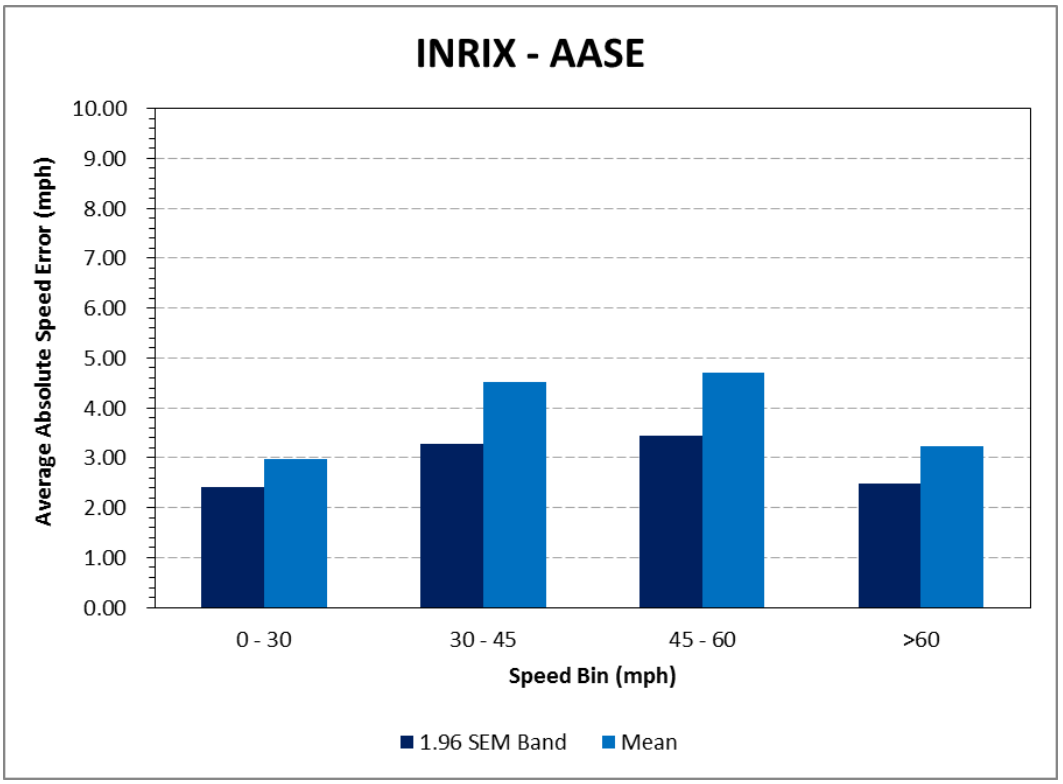

Figure 7. Average Absolute Speed Error (AASE) for INRIX on I-287

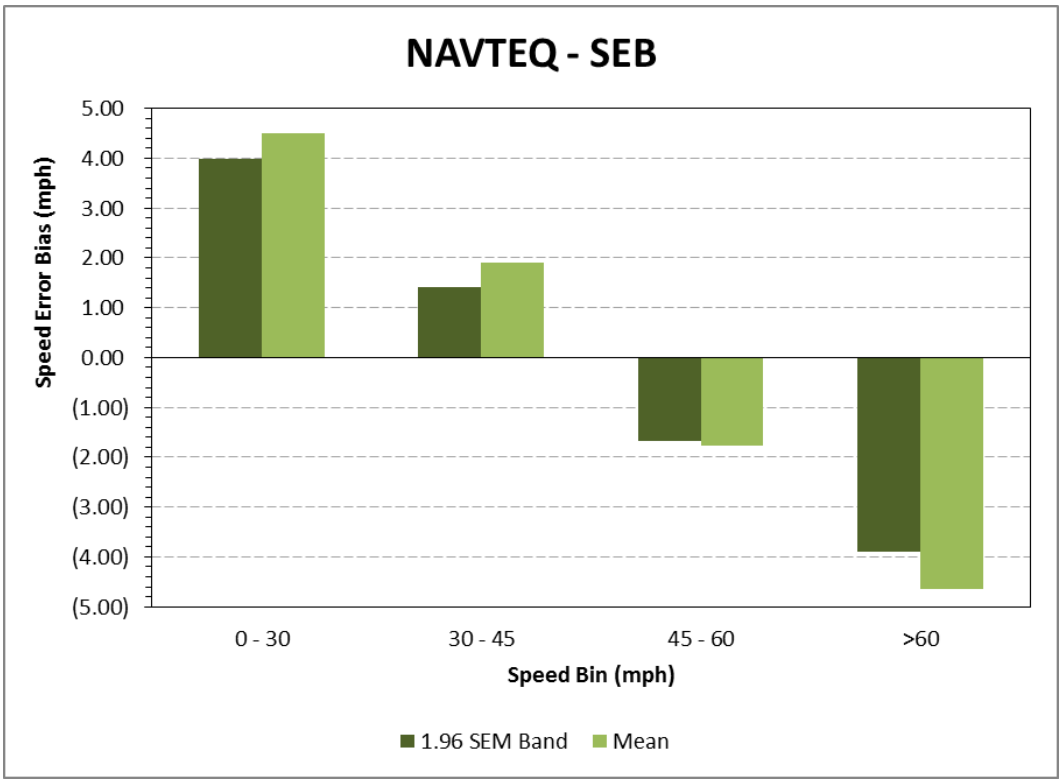

Figure 8. Speed Error Bias (SEB) for NAVTEQ on I-287

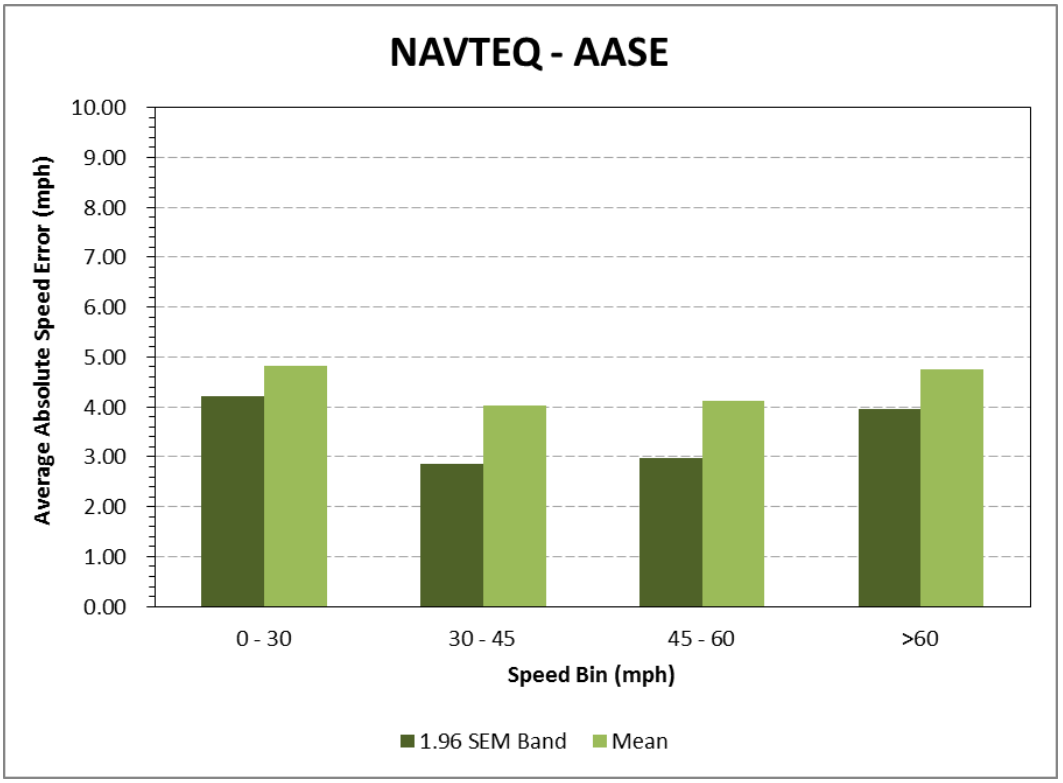

Figure 9. Average Absolute Speed Error (AASE) for NAVTEQ on I-287

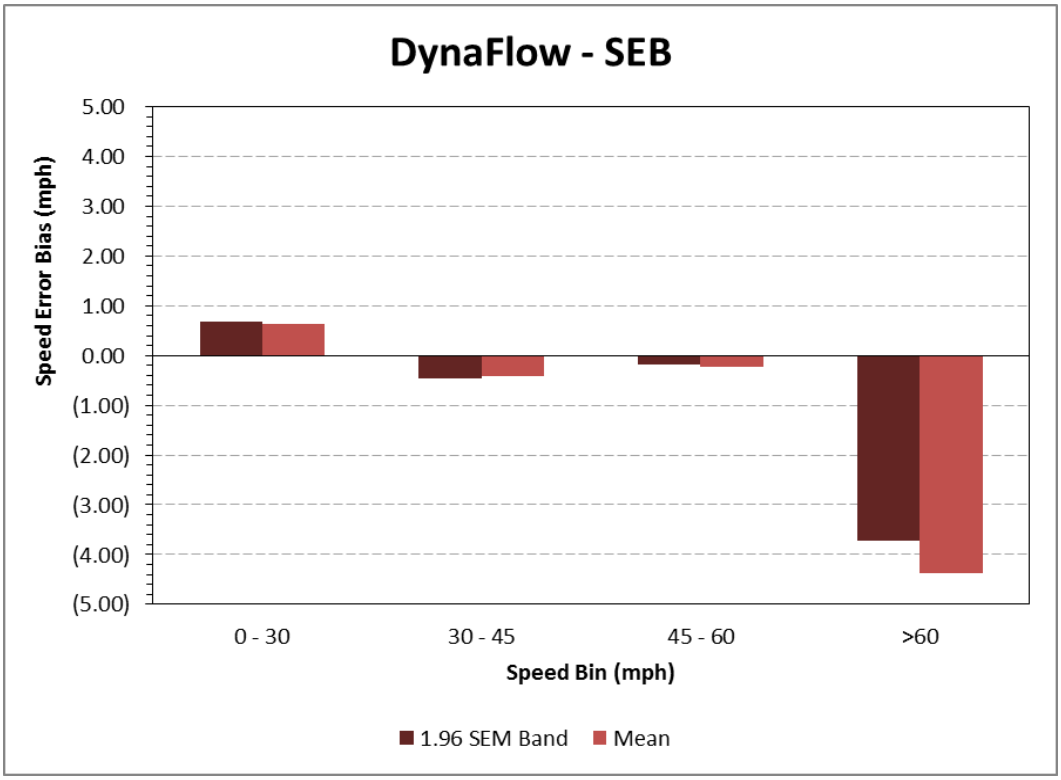

Figure 10. Speed Error Bias (SEB) for DynaFlow on I-287

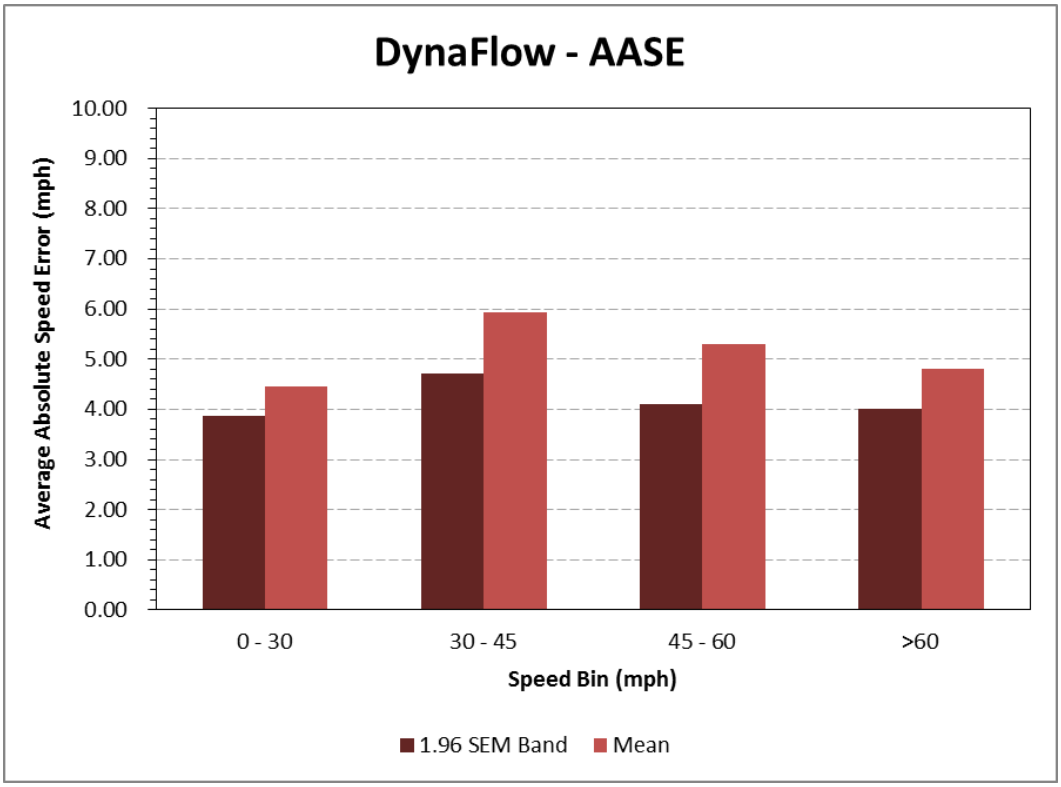

Figure 11. Average Absolute Speed Error (AASE) for DynaFlow on I-287

Table 11. INRIX Percent Observations Meeting Data Quality Criteria for I-287

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	18%	92%	5%	89%	733
30 – 45	19%	76%	3%	68%	950
45 – 60	17%	73%	1%	59%	2,236
>60	14%	87%	2%	80%	29,470

Table 12. NAVTEQ Percent Observations Meeting Data Quality Criteria for I-287

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	9%	72%	1%	68%	781
30 – 45	22%	81%	3%	71%	973
45 – 60	24%	80%	2%	71%	2,289
>60	7%	72%	1%	61%	30,064

Table 13. DynaFlow Percent Observations Meeting Data Quality Criteria for I-287

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	11%	79%	2%	75%	726
30 – 45	14%	64%	1%	54%	947
45 – 60	18%	69%	2%	57%	2,223
>60	9%	68%	1%	58%	29,022

I-78 (between Drift Road and Doremus Avenue)

Table 14 through
Table 16 summarize the AASE and SEB statistics calculated for the studied segment of I-78 between Drift Road and Doremus Avenue for all three evaluated traffic datasets. Note that negative numbers are displayed in parentheses, and numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow. The results showed that INRIX, NAVTEQ, and DynaFlow met the validation criteria for the AASE in all speed bins with respect to both the SEM Band and Mean. However, all three datasets exhibited error bias reflected in the SEB values outside of the acceptance ranges:

- INRIX's SEB was outside the validation acceptance threshold: (a) with respect to the SEM Band in the [0-30] mph speed bin (SEB = 5.41 > 5.00 mph), and (b) with respect to the Mean in the [0-30] mph speed bin (SEB = 6.02 mph) and the [30-45] mph speed bin (SEB = 5.68 mph).

- NAVTEQ's overall SEB, with respect to Mean, was outside the acceptance threshold (SEB = -5.06 ><- 5 mph). This was largely driven by poor performances in the [0-30] mph speed bin (SEB = 7.34 mph) and the [> 60] mph speed bin (SEB = -5.46 mph). This indicated a significant underestimation of speed, again due to NAVTEQ's capping by the speed limit. The SEB, with respect to both the Mean and SEM Band for NAVTEQ in the [0-30] mph speed bin, was also outside the validation acceptance threshold: (SEB (Mean) = 7.34 and SEB (SEM Band) = 6.54 mph, both of which were greater than the threshold of > 5 mph). This indicated a significant overestimation of speed in the lowest speed bin.

- DynaFlow's SEB was outside the acceptance thresholds in the [0-30] mph speed bin, both with respect to the SEM Band and Mean (5.04 mph and 5.56 mph respectively, both >5 mph). Overall, DynaFlow's SEB satisfied the validation criteria.

The same results are also shown in Figure 12 through Figure 17. Table 17 through

Table 19 show the percentage of the sampled intervals that met the validation criteria, distinguishing between INRIX, NAVTEQ, and DynaFlow estimates equal to the TRANSMIT estimates, and those falling within the validation range.

Table 14. INRIX Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 - 30	6.01	7.04	**5.41**	**6.02**	256
30 - 45	6.45	8.25	4.67	**5.68**	532
45 - 60	3.34	4.27	0.45	0.79	5,337
>60	2.92	3.76	(1.71)	(2.09)	40,253
All Speeds	**3.02**	**3.89**	**(1.34)**	**(1.63)**	**46,378**

Table 15. NAVTEQ Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 - 30	6.76	7.75	**6.54**	**7.34**	308
30 - 45	4.05	5.61	1.80	2.35	666
45 - 60	4.14	5.08	(3.18)	(3.59)	6,436
>60	4.83	5.72	(4.68)	**(5.46)**	46,267
All Speeds	**4.75**	**5.65**	**(4.36)**	**(5.06)**	**53,677**

Table 16. DynaFlow Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 - 30	6.89	7.97	**5.04**	**5.56**	258
30 - 45	6.73	8.45	2.00	2.50	549
45 - 60	6.04	6.97	(4.17)	(4.49)	5,423
>60	4.63	5.51	(4.08)	(4.75)	43,148
All Speeds	**4.82**	**5.72**	**(3.98)**	**(4.58)**	**49,378**

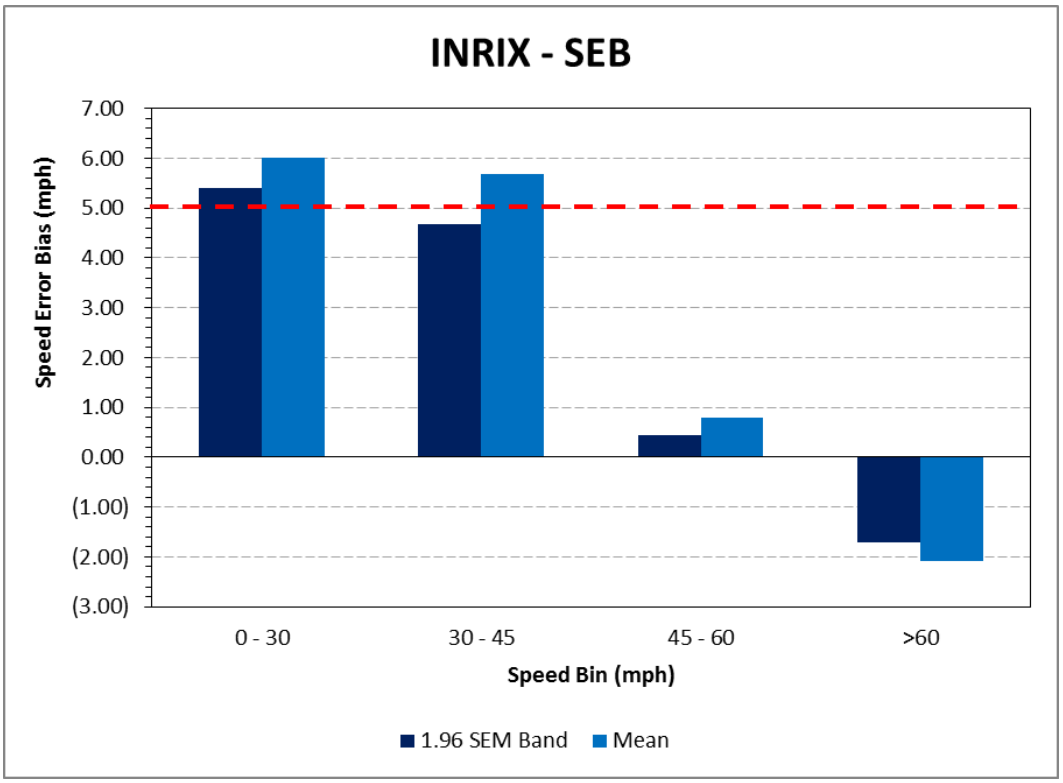

Figure 12. Speed Error Bias (SEB) for INRIX on I-78

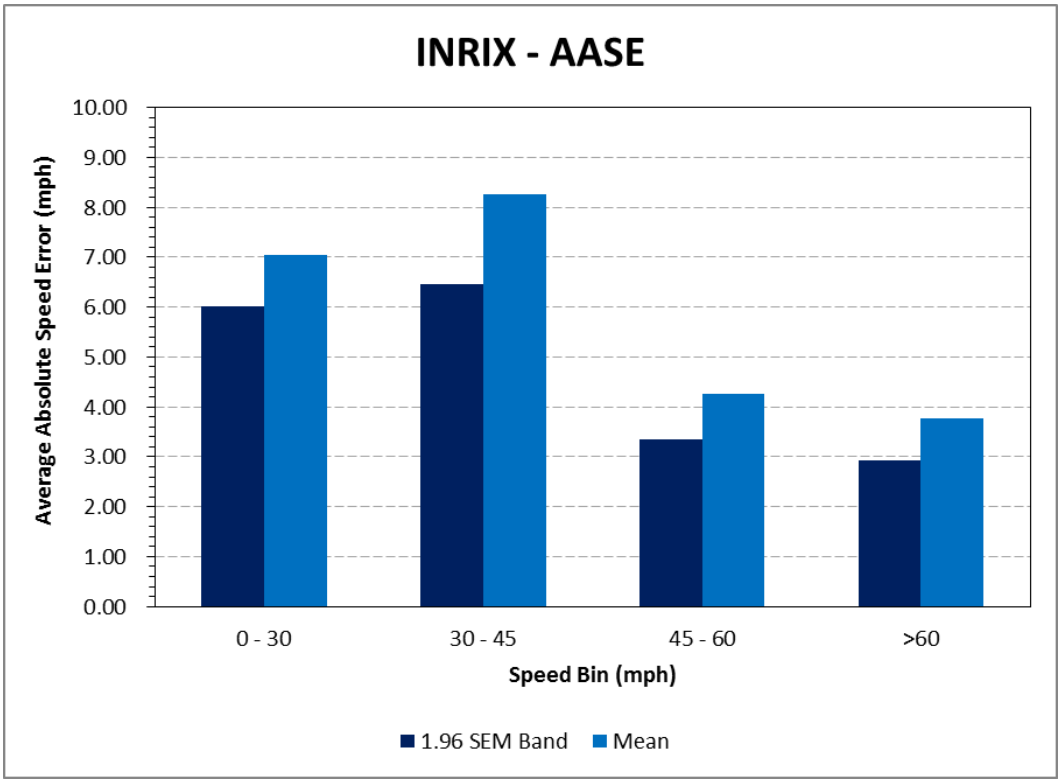

Figure 13. Average Absolute Speed Error (AASE) for INRIX on I-78

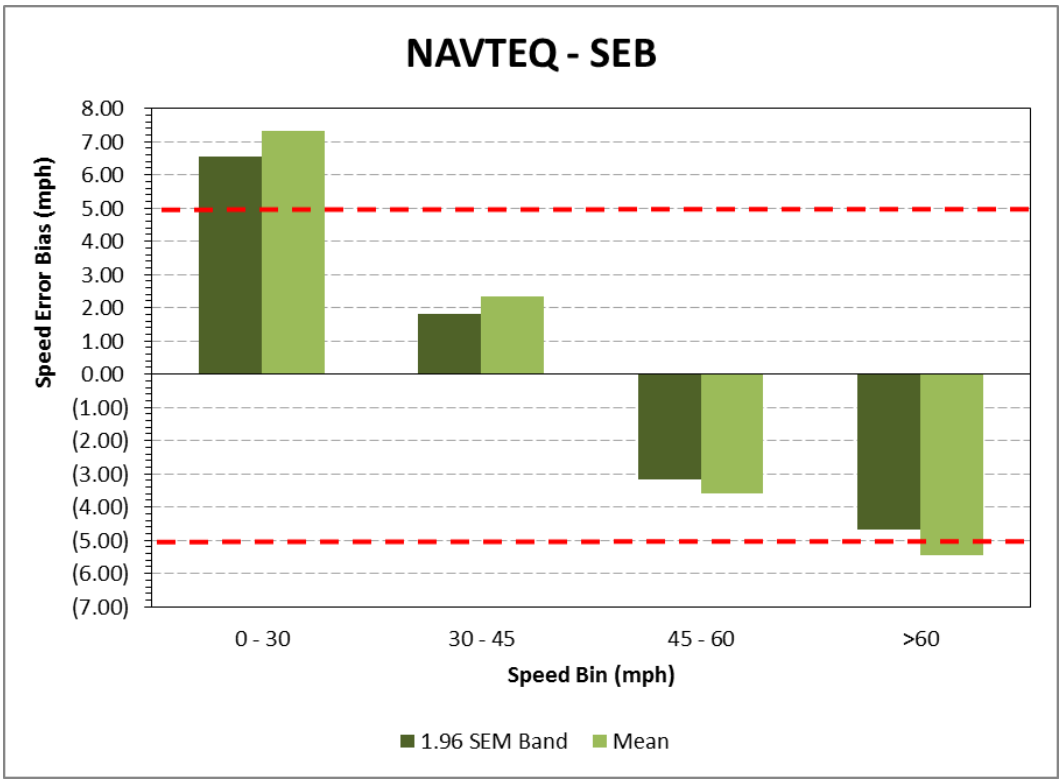

Figure 14. Speed Error Bias (SEB) for NAVTEQ on I-78

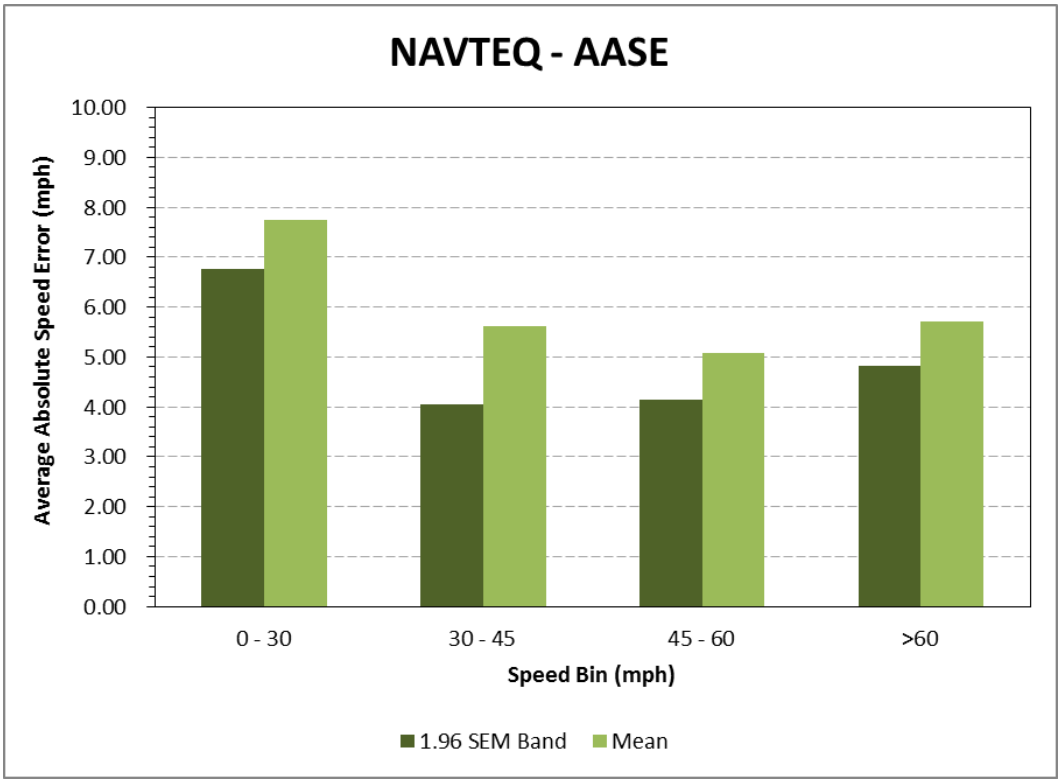

Figure 15. Average Absolute Speed Error (AASE) for NAVTEQ on I-78

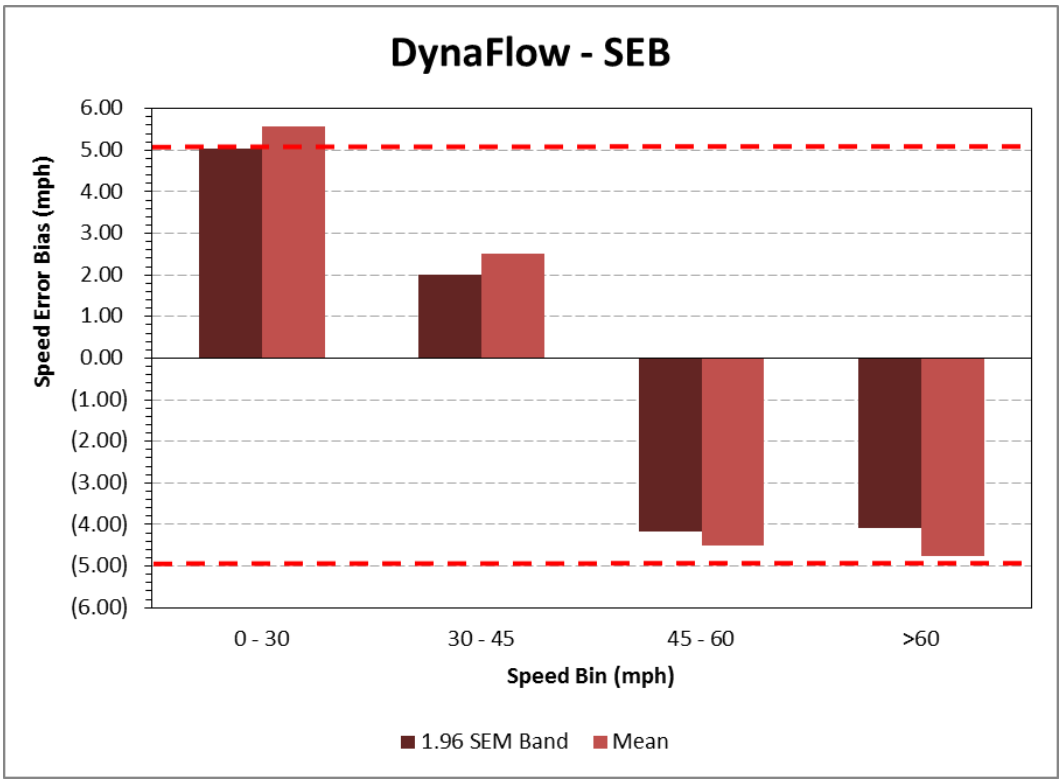

Figure 16. Speed Error Bias (SEB) for DynaFlow on I-78

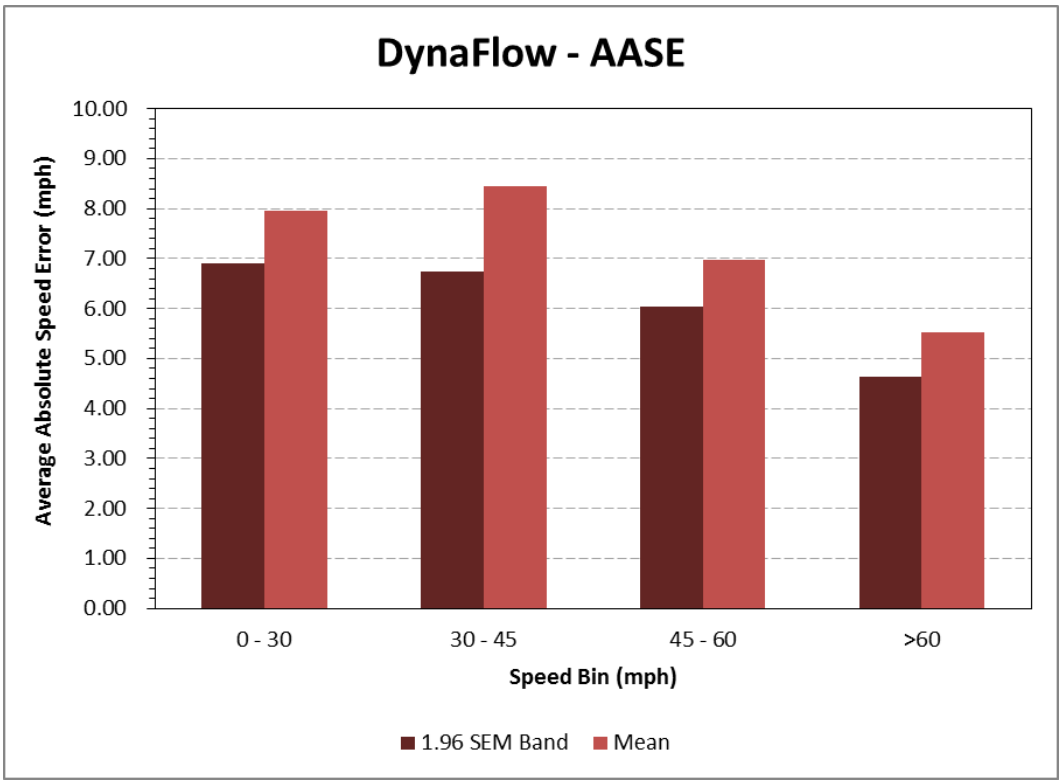

Figure 17. Average Absolute Speed Error (AASE) for DynaFlow on I-78

Table 17. INRIX Percent Observations Meeting Data Quality Criteria for I-78

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 -– 30	14%	61%	1%	55%	256
30 -– 45	15%	51%	10%	50%	532
45 -– 60	14%	78%	2%	68%	5,337
>60	15%	79%	2%	70%	40,253

Table 18. NAVTEQ Percent Observations Meeting Data Quality Criteria for I-78

SPEED BIN(mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 -– 30	11%	49%	1%	40%	308
30 -– 45	21%	69%	2%	57%	666
45 -– 60	14%	67%	2%	58%	6,436
>60	10%	57%	1%	47%	46,267

Table 19. DynaFlow Percent Observations Meeting Data Quality Criteria for I-78

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 -– 30	12%	53%	2%	46%	258
30 -– 45	15%	52%	1%	40%	549
45 -– 60	12%	56%	2%	49%	5,423
>60	10%	62%	1%	52%	43,148

Long Island Expressway (between Shelter Rock Rd. and NY Route 110)

Table 20 through

Table 22 summarize the AASE and SEB statistics calculated for the studied segment of the Long Island Expressway (LIE) between Shelter Rock Road and Route 110 in Long Island, New York, for all three evaluated traffic datasets. Note that negative numbers are displayed in parentheses, and numbers outside of the validation acceptance range in

Table 21 are shown in underlined bold face and highlighted in yellow.

The results show that all three evaluated vendors met the AASE validation criteria. When it came to the SEB, **NAVTEQ failed the validation in the [>60] mph** speed bin by a significant margin (8.13 mph with respect to the SEM Band, and 8.94 mph with respect to the Mean, both of which were significantly higher than the threshold of 5 mph). This in turn caused the overall SEB statistics in both categories to fail the validation test. The apparent bias in the highest speed bin was **due to capped maximum speeds in NAVTEQ's reporting** for the LIE. NAVTEQ's highest reported speed was equivalent to the speed limit of 55 mph, whereas ground truth top speeds went well above this cap during times of uncongested traffic. Therefore, the overall SEB values for the LIE **should not be used as a validation reference** in this analysis. Instead, one would draw better conclusions about the accuracy of the NAVTEQ speed estimates from the LIE sample by considering validation statistics for the lower three speed bins.

The same results are also shown in Figure 18 through Figure 23.
Table 23 through

Table 25 show the percentage of the sampled intervals that met the validation criteria, distinguishing between INRIX, NAVTEQ, and DynaFlow estimates equal to the TRANSMIT estimates, and those falling within the validation range.

Table 20. INRIX Evaluation Summary for LIE

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	2.82	3.40	2.38	2.72	1,686
30 – 45	4.63	5.59	3.74	4.28	2,464
45 – 60	2.82	3.81	2.33	3.05	8,951
>60	1.77	2.44	(0.56)	(0.71)	21,414

All Speeds	**2.29**	**3.06**	**0.64**	**0.79**	**34,515**

Table 21. NAVTEQ Evaluation Summary for LIE

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.67	5.27	4.25	4.70	2,477
30 – 45	3.29	4.22	2.25	2.71	3,221
45 – 60	2.21	3.19	(1.86)	(2.53)	11,814
>60	8.13	8.94	**(8.13)**	**(8.94)**	27,139
All Speeds	**6.02**	**6.88**	**(5.04)**	**(5.65)**	**44,651**

Table 22. DynaFlow Evaluation Summary for LIE

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	3.76	4.34	2.32	2.51	2,461
30 – 45	3.70	4.62	0.99	1.15	3,198
45 – 60	2.64	3.60	(0.72)	(0.93)	11,708
>60	2.99	3.71	(2.33)	(2.76)	26,882
All Speeds	**2.99**	**3.78**	**(1.41)**	**(1.70)**	**44,249**

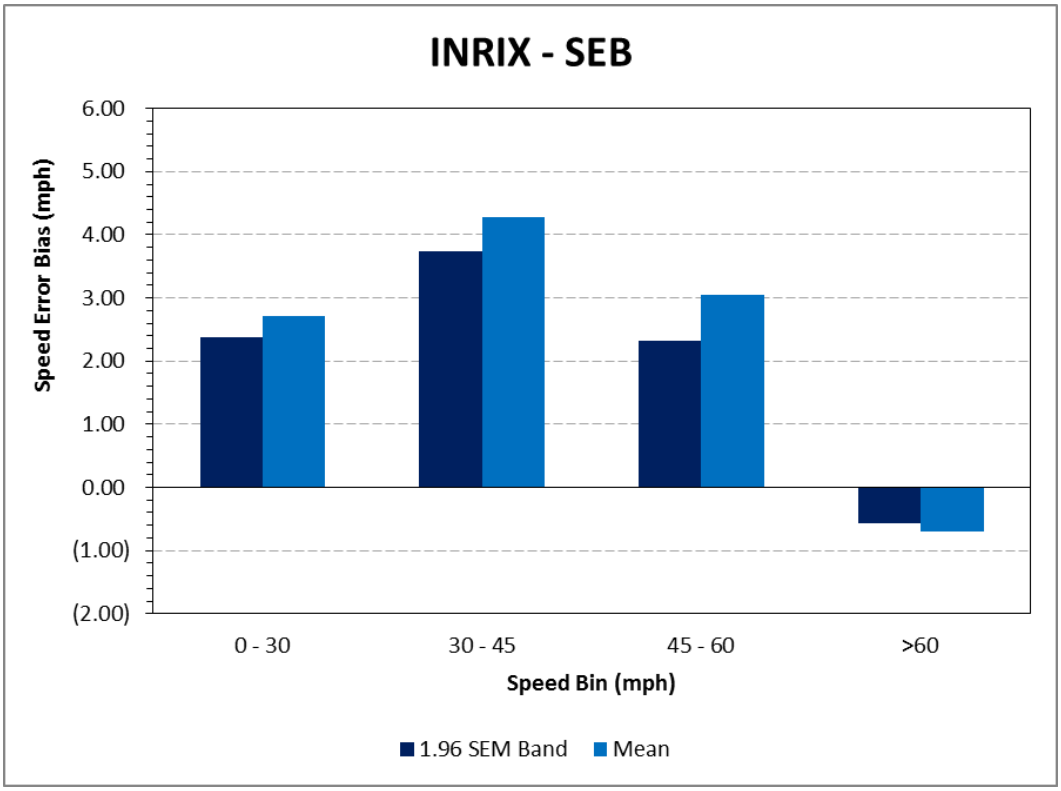

Figure 18. Speed Error Bias (SEB) for INRIX on LIE

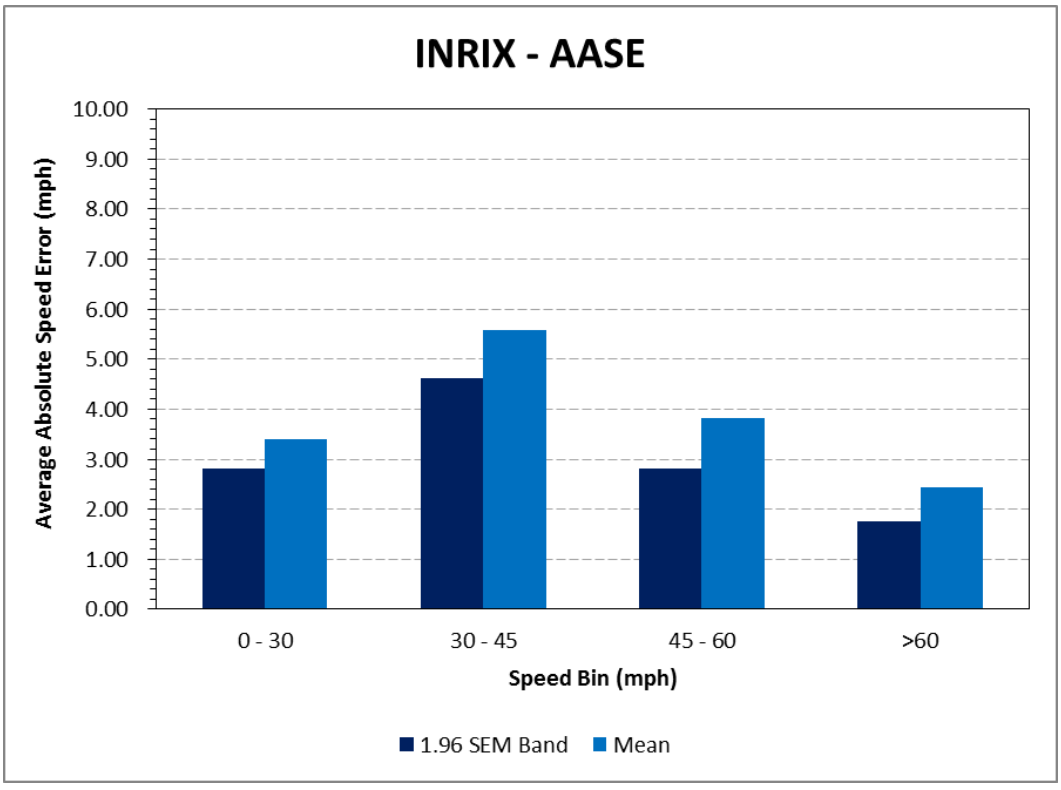

Figure 19. Average Absolute Speed Error (AASE) for INRIX on LIE

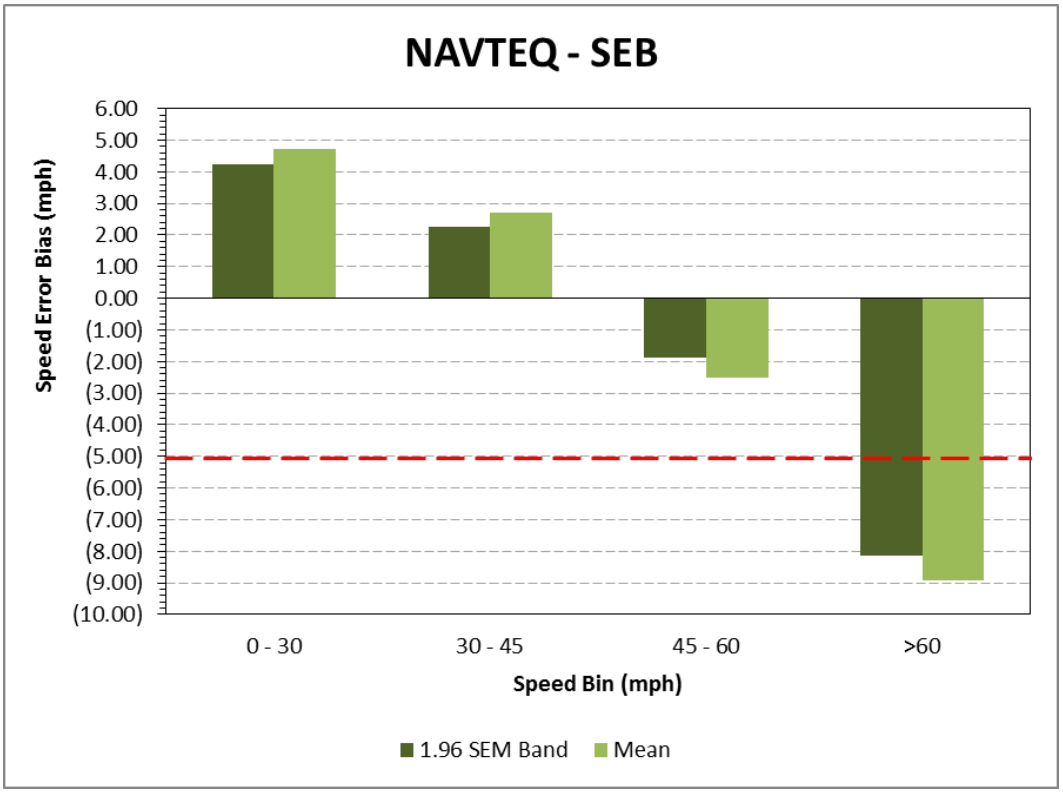

Figure 20. Speed Error Bias (SEB) for NAVTEQ on LIE

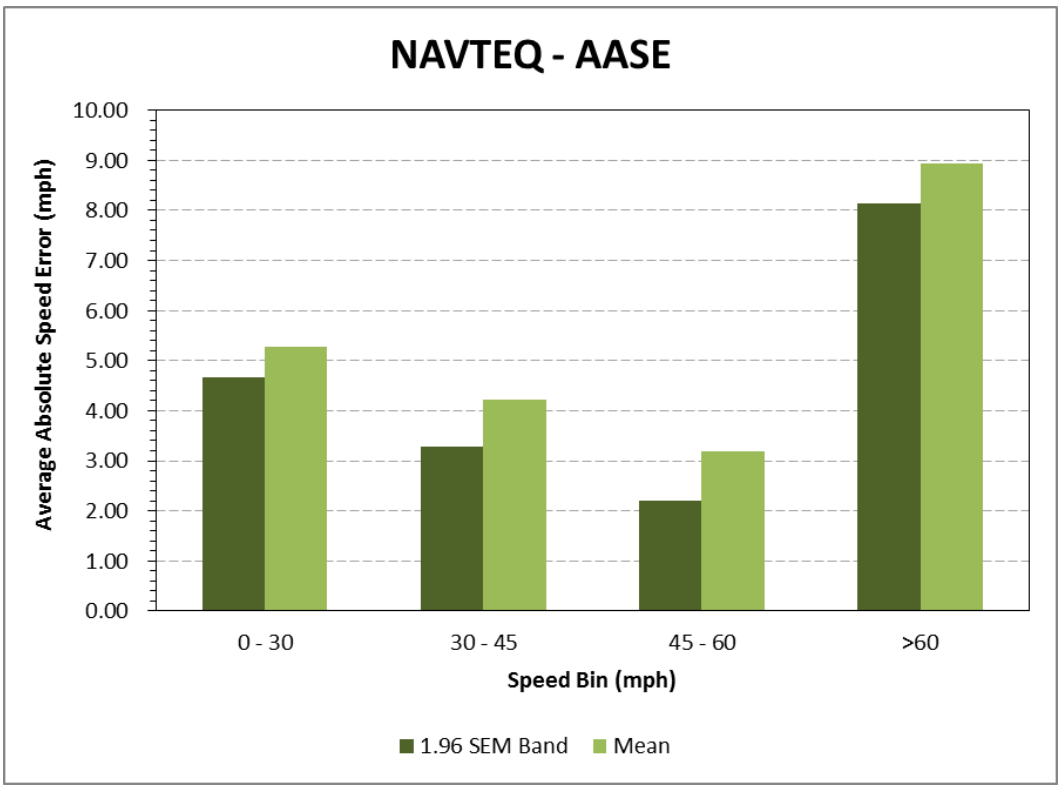

Figure 21. Average Absolute Speed Error (AASE) for NAVTEQ on LIE

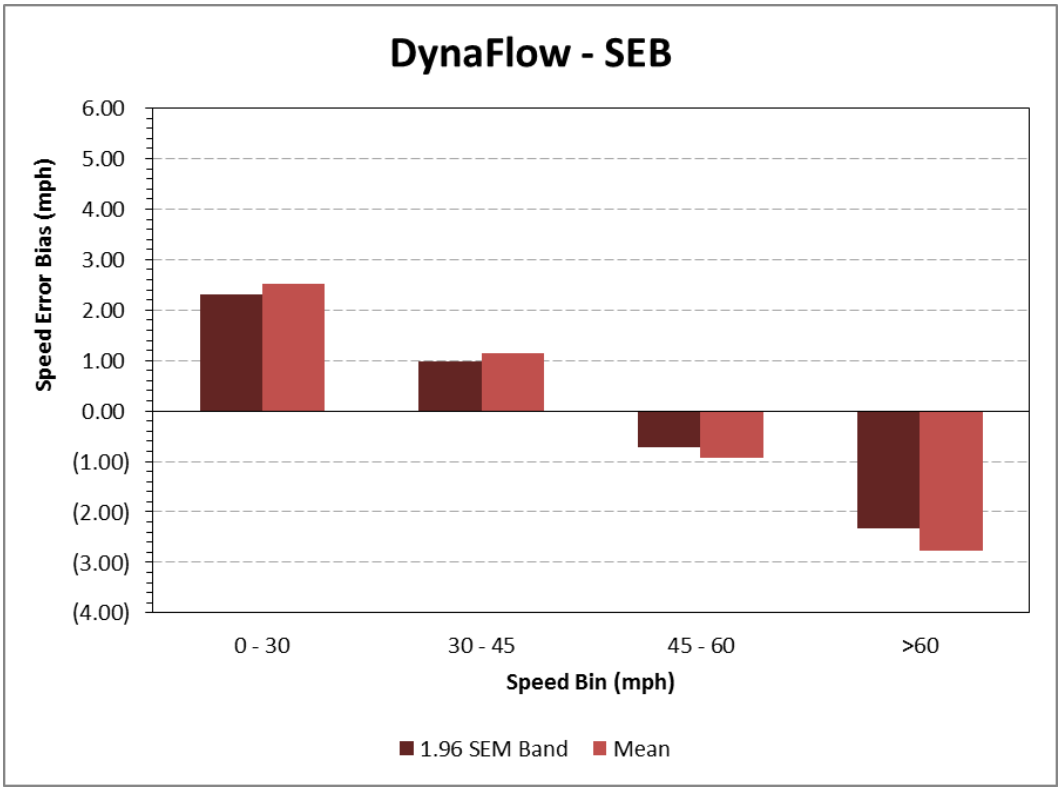

Figure 22. Speed Error Bias (SEB) for DynaFlow on LIE

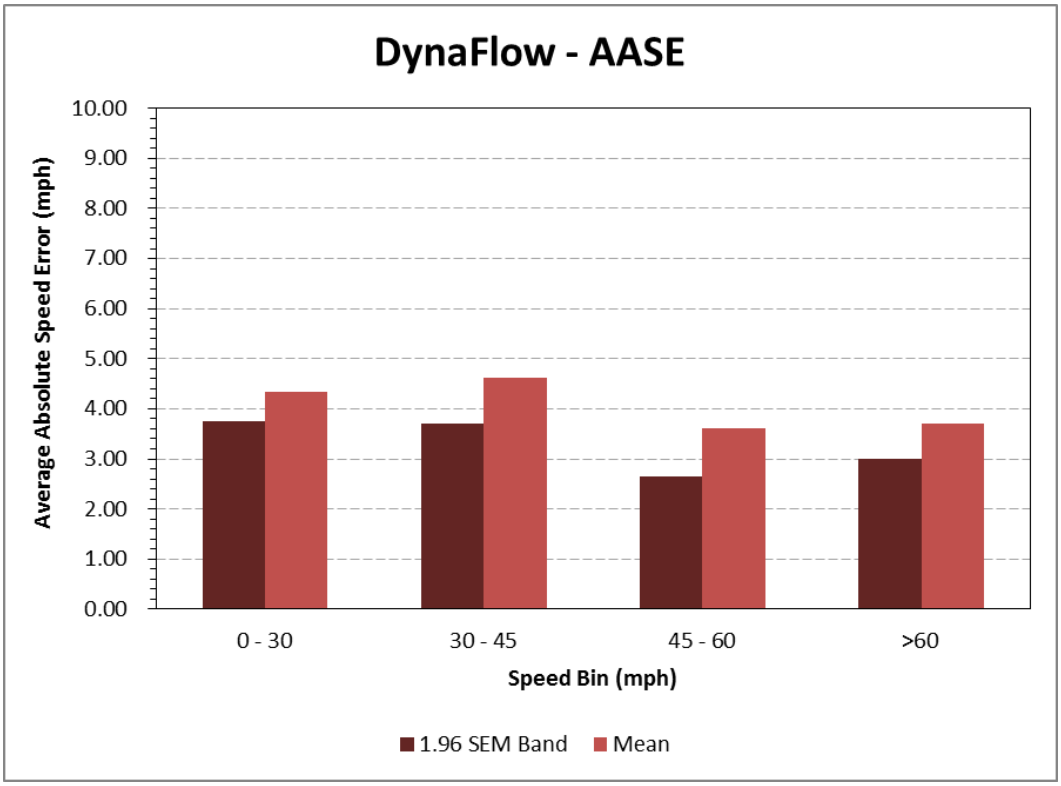

Figure 23. Average Absolute Speed Error (AASE) for DynaFlow on LIE

Table 23. INRIX Percent Observations Meeting Data Quality Criteria for LIE

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	27%	89%	3%	86%	1,686
30 – 45	22%	91%	3%	86%	2,464
45 – 60	24%	90%	3%	84%	8,951
>60	19%	86%	2%	80%	21,414

Table 24. NAVTEQ Percent Observations Meeting Data Quality Criteria for LIE

SPEED BIN(mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	6%	73%	1%	66%	2,477
30 – 45	13%	75%	1%	64%	3,221
45 – 60	19%	92%	2%	85%	11,814
>60	0%	8%	0%	0%	27,139

Table 25. DynaFlow Percent Observations Meeting Data Quality Criteria for LIE

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	18%	85%	2%	78%	2,461
30 – 45	20%	84%	2%	78%	3,198
45 – 60	20%	84%	2%	78%	11,708
>60	16%	78%	2%	71%	26,882

Northern State Parkway (between NY Route 106/7 and Veterans Highway)

Table 26 through

Table 28 summarize the AASE and SEB statistics calculated for the studied segment of the Northern State Parkway (NSP) between Route 106/7 and Veterans Highway in Long Island, New York, for all three evaluated traffic datasets. As in the previous analysis, the negative numbers in these three tables are displayed in parentheses, and numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow. The results of the speed data validation for the studied section of the NSP were the most problematic. Overall, the datasets for the NSP from all three vendors seemed to exhibit lower accuracy (and hence lower reliability in real time) as compared to other evaluated freeway segments. This has been illustrated as follows:

- Of the three evaluated datasets, only NAVTEQ met the AASE validation criteria in all speed bins.
- However, NAVTEQ failed the SEB test in the [0-30] mph speed bin, as well as in the [>60] mph speed bin:

  (a) In the [0-30] mph bin, the SEB indicated a slight, but consistent, ***overestimation*** of speed (5.79 mph with respect to the SEM Band and 6.45 mph with respect to the Mean).

  (b) In the top speed bin the SEB indicated a significant and consistent ***underestimation*** of speed ((-9.23) with respect to SEM Band, and (-9.71) with respect to the Mean). As in the case of the LIE, the result in the [>60] mph speed bin can be explained by the fact that NAVTEQ was capping the maximum speed in their reporting to a speed limit of 55 mph. With actual speeds largely exceeding this limit during uncongested times, discrepancies between the actual and estimated speed reflected in the SEB were not surprising.

- Both the ***INRIX and DynaFlow*** datasets ***failed both the AASE and the SEB validation tests in the lower two speed bins ([0-30] and [30-45] mph)***, with respect to the SEM Band and the Mean. However, the overall validation statistics across all speed bins were within the acceptance ranges for both datasets. This result was facilitated by relatively small speed estimation errors in the two upper speed bins and the fact that most of the sampled speeds (95%) in each dataset were in these two speed bins. In other words, in the case of INRIX and DynaFlow, the more accurate estimates of speeds higher than 45 mph more than offset the inaccuracies identified in lower speed bins due to the much bigger share of the validation sample falling in the higher two speed bins.

It was assumed that the ***poor performance*** of the speed estimates on the NSP was ***due to an insufficient number of probe vehicles on this roadway***. Commercial vehicles are not allowed on the NSP, yet they represent the largest portion of the probe fleet that all three vendors use to collect and aggregate vehicle speeds in real time. Therefore, the evaluated data sample was largely based on historical and synthetic speed estimates, rather than actual speeds collected from the probe vehicles.

The same results are also shown in Figure 24 through Figure 29. Table 29 through Table 31 show the percentage of the sampled intervals that met the validation criteria, distinguishing between INRIX, NAVTEQ, and DynaFlow estimates equal to the TRANSMIT estimates, and those falling with within the validation range.

Table 26. INRIX Evaluation Summary for NSP

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	**13.45**	**14.02**	**13.20**	**13.68**	578
30 – 45	**10.52**	**11.44**	**9.39**	**10.08**	841
45 – 60	4.70	5.30	4.14	4.57	5,060
>60	2.21	2.66	(1.25)	(1.43)	23,998
All Speeds	**3.07**	**3.55**	**0.21**	**0.17**	**30,477**

Table 27. NAVTEQ Evaluation Summary for NSP

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	5.94	6.68	**5.79**	**6.45**	787
30 – 45	3.14	4.46	1.50	2.07	1,030
45 – 60	2.87	3.39	(2.59)	(2.95)	8,305
>60	9.23	9.71	**(9.23)**	**(9.71)**	25,227
All Speeds	**7.48**	**8.01**	**(7.02)**	**(7.42)**	**35,349**

Table 28. DynaFlow Evaluation Summary for NSP

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	**16.10**	**16.92**	**14.52**	**15.12**	784
30 – 45	8.89	**10.51**	**6.22**	**7.40**	1,028
45 – 60	4.11	4.65	0.37	0.47	8,403
>60	5.50	5.96	**(5.21)**	**(5.57)**	25,156
All Speeds	**5.50**	**6.03**	**(3.11)**	**(3.30)**	**35,371**

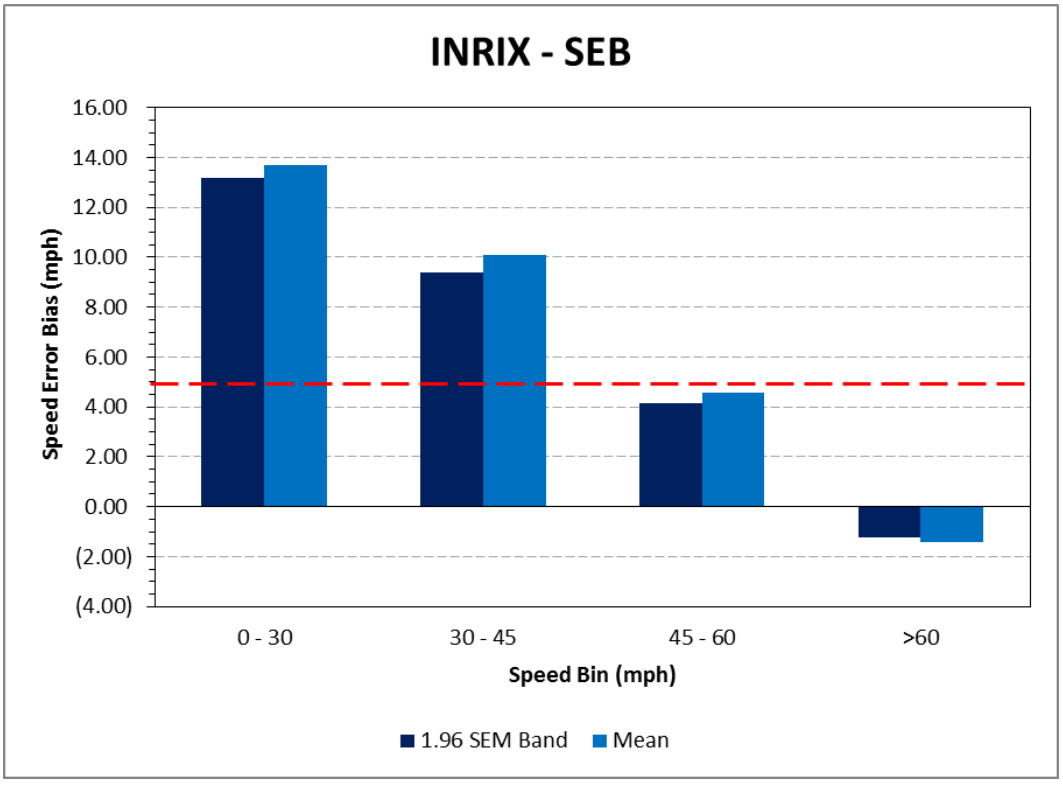

Figure 24. Speed Error Bias (SEB) for INRIX on NSP

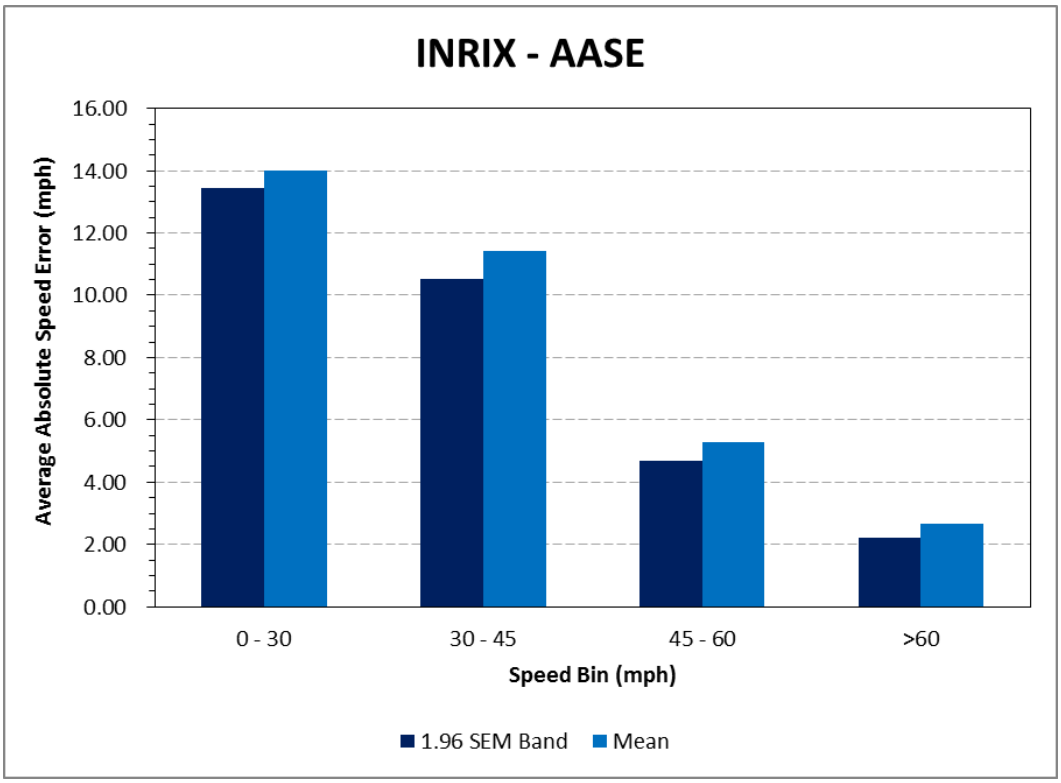

Figure 25. Average Absolute Speed Error (AASE) for INRIX on NSP

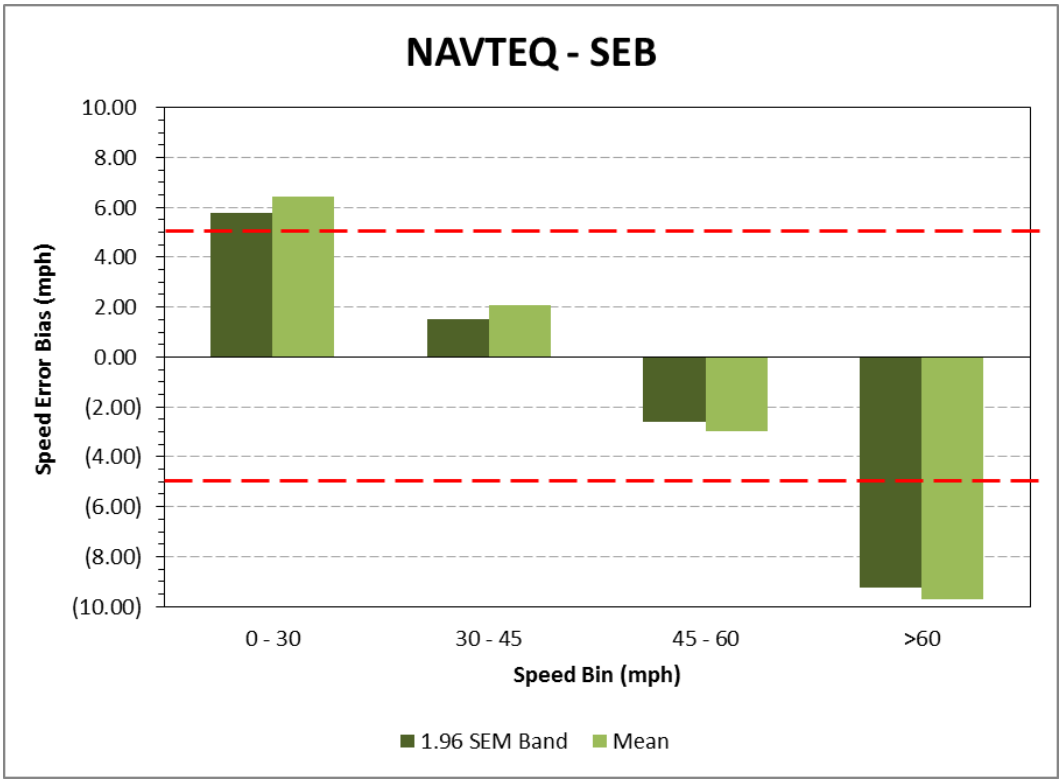

Figure 26. Speed Error Bias (SEB) for NAVTEQ on NSP

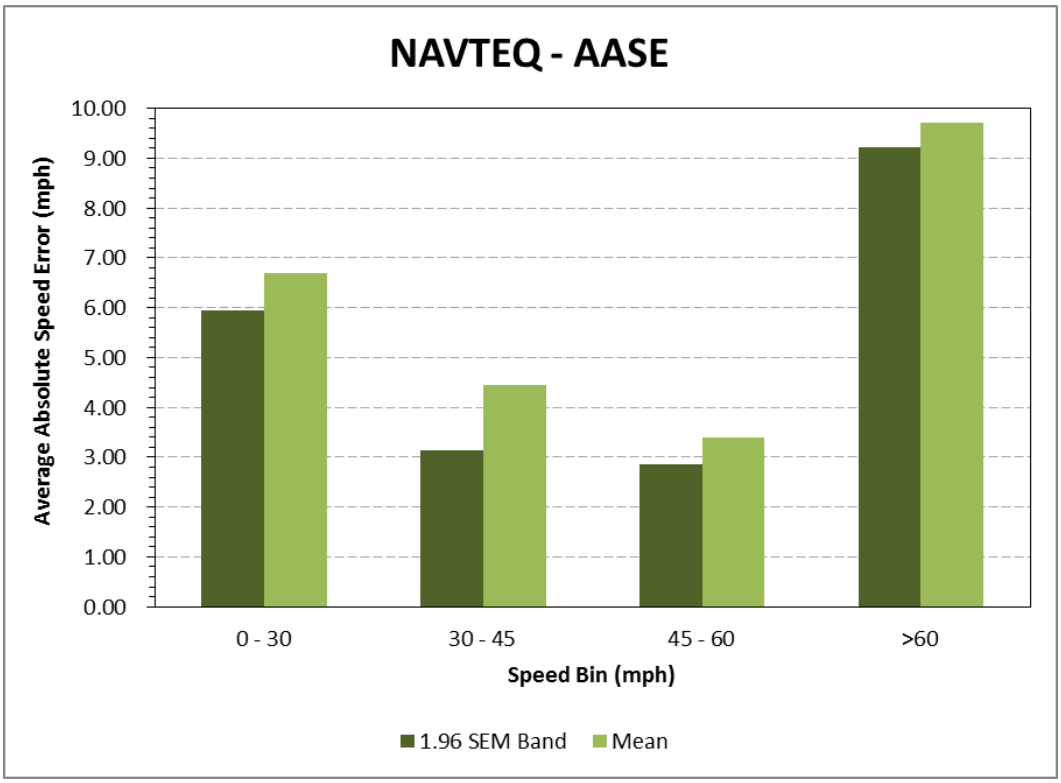

Figure 27. Average Absolute Speed Error (AASE) for NAVTEQ on NSP

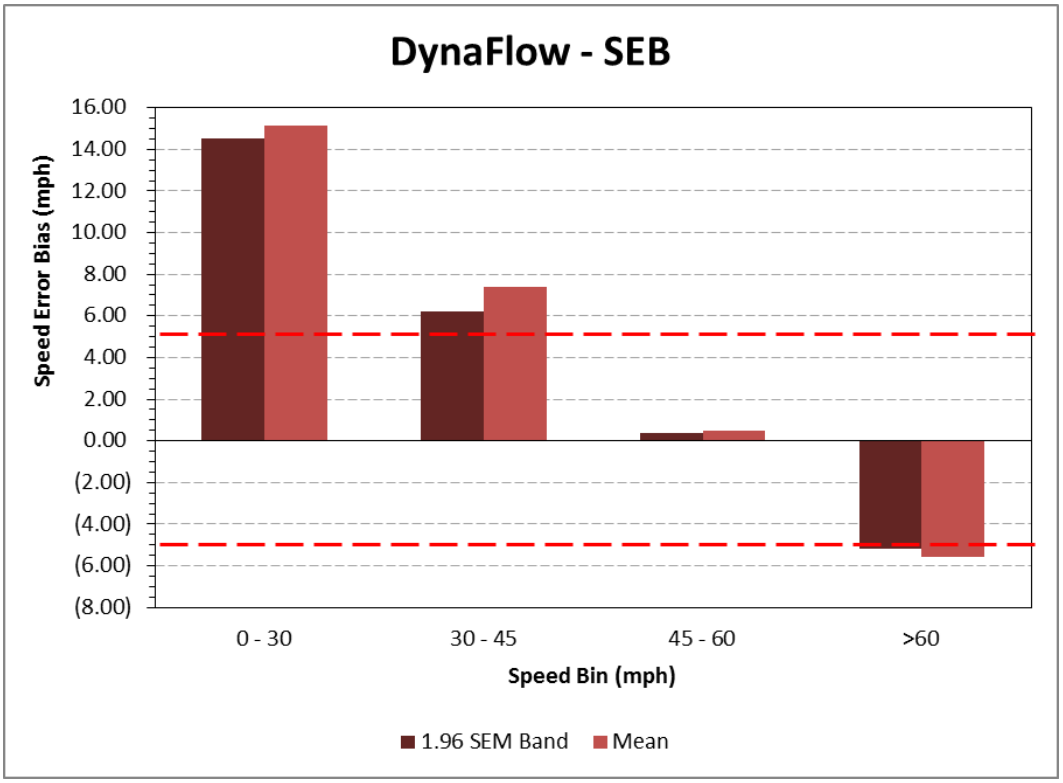

Figure 28. Speed Error Bias (SEB) for DynaFlow on NSP

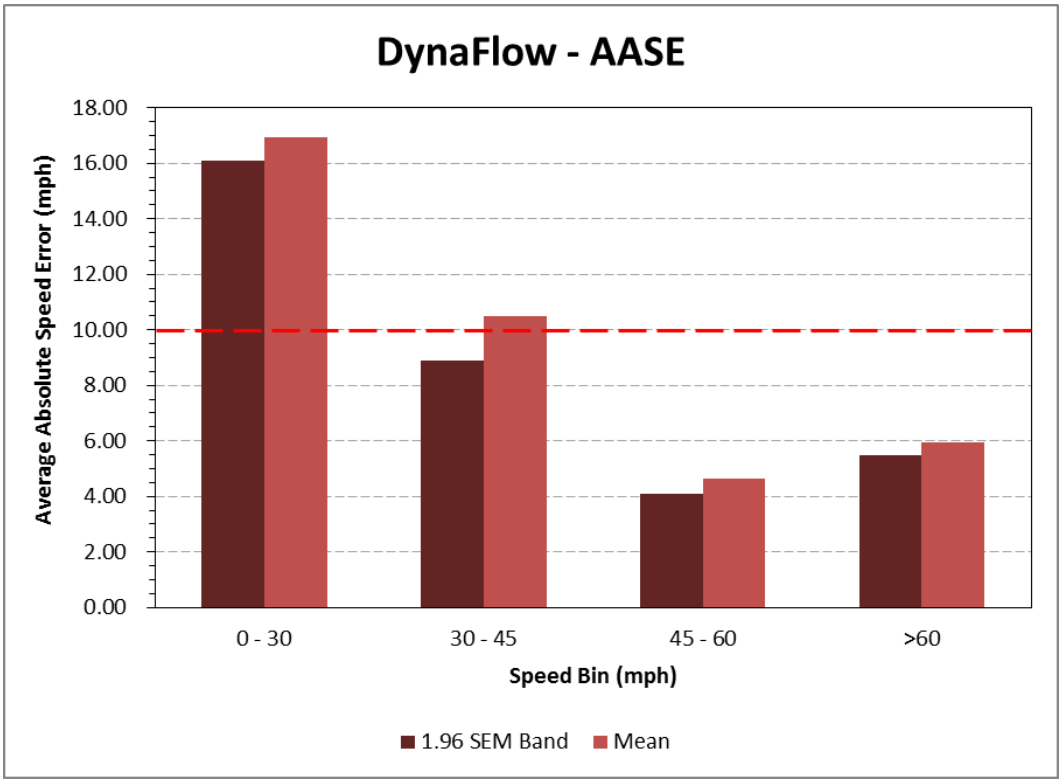

Figure 29. Average Absolute Speed Error (AASE) for DynaFlow on NSP

Table 29. INRIX Percent Observations Meeting Data Quality Criteria for NSP

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	4%	38%	1%	36%	578
30 – 45	5%	32%	1%	26%	841
45 – 60	10%	68%	2%	63%	5,060
>60	14%	90%	4%	87%	23,998

Table 30. NAVTEQ Percent Observations Meeting Data Quality Criteria for NSP

SPEED BIN(mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	6%	57%	1%	52%	787
30 – 45	18%	77%	2%	65%	1,030
45 – 60	11%	83%	3%	67%	8,305
>60	0%	2%	0%	0%	25,227

Table 31. DynaFlow Percent Observations Meeting Data Quality Criteria for NSP

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	3%	30%	0%	27%	784
30 – 45	6%	35%	1%	28%	1,028
45 – 60	7%	44%	1%	36%	8,403
>60	8%	63%	2%	59%	25,156

Overall Validation Results

This section presents the results of the data validation for all four studied freeway sections combined. In total, data from 43 TRANSMIT links (eight links on I-287, 19 links on I-78, eight links on the LIE, and eight links on the NSP) were aggregated. As shown in Table 32 through Table 34 and Figure 30 through Figure 35, the following can be concluded:

- Overall, all three technologies met the validation criteria for the Average Absolute Speed Error (AASE ≤ 10 mph) and the Speed Error Bias (|SEB| ≤ 5 mph).
- They were also within the validation (acceptance) range for the AASE in all speed bins.
- INRIX's SEB exceeded the validation limit with respect to the mean in the [30-45] mph speed bin: value 5.21 > 5.00.

- NAVTEQ's SEB exceeded the validation limit with respect to mean in the speed bin [>60] mph: value (-5.31) < (-5.00).
- It was observed that all of the studied technologies ***consistently overestimated*** the speed in the lowest speed bin ([0-30] mph), and ***consistently underestimated*** the speed in the highest speed bin (> 60 mph). In the case of NAVTEQ, the speed bias in the [>60] mph speed bin on the LIE and NSP sections was largely due to the capped maximum speeds, as explained earlier.

Note that the negative numbers in Table 32 through
Table 34 are displayed in parentheses, and numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow. Table 35 through

Table 37 show the percentage of the time intervals that fall within 5 mph of the SEM band and the mean for each speed bin for all TRANSMIT link segments on the two highway segments.

Table 32. INRIX Evaluation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.87	5.48	4.42	4.79	3,251
30 – 45	5.60	6.70	4.56	**5.21**	4,787
45 – 60	3.45	4.37	2.31	2.87	21,584
>60	2.44	3.15	(1.48)	(1.81)	115,088
All Speeds	**2.75**	**3.50**	**(0.58)**	**(0.73)**	**144,710**

Table 33. NAVTEQ Evaluation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	4.18	4.84	3.90	4.39	3,513
30 – 45	3.91	5.06	2.60	3.14	5,112
45 – 60	3.18	4.02	(0.96)	(0.94)	25,931
>60	4.99	5.74	(4.71)	**(5.31)**	122,303
All Speeds	**4.64**	**5.41**	**(3.66)**	**(4.09)**	**156,859**

Table 34. DynaFlow Evaluation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		Number of 5-Minute Samples
	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	
0 – 30	6.27	6.93	4.51	4.76	4,229
30 – 45	5.08	6.25	1.81	2.16	5,722
45 – 60	3.87	4.71	(1.02)	(1.15)	27,757
>60	4.32	5.07	(3.87)	(4.42)	124,206
All Speeds	**4.32**	**5.10**	**(2.96)**	**(3.38)**	**161,914**

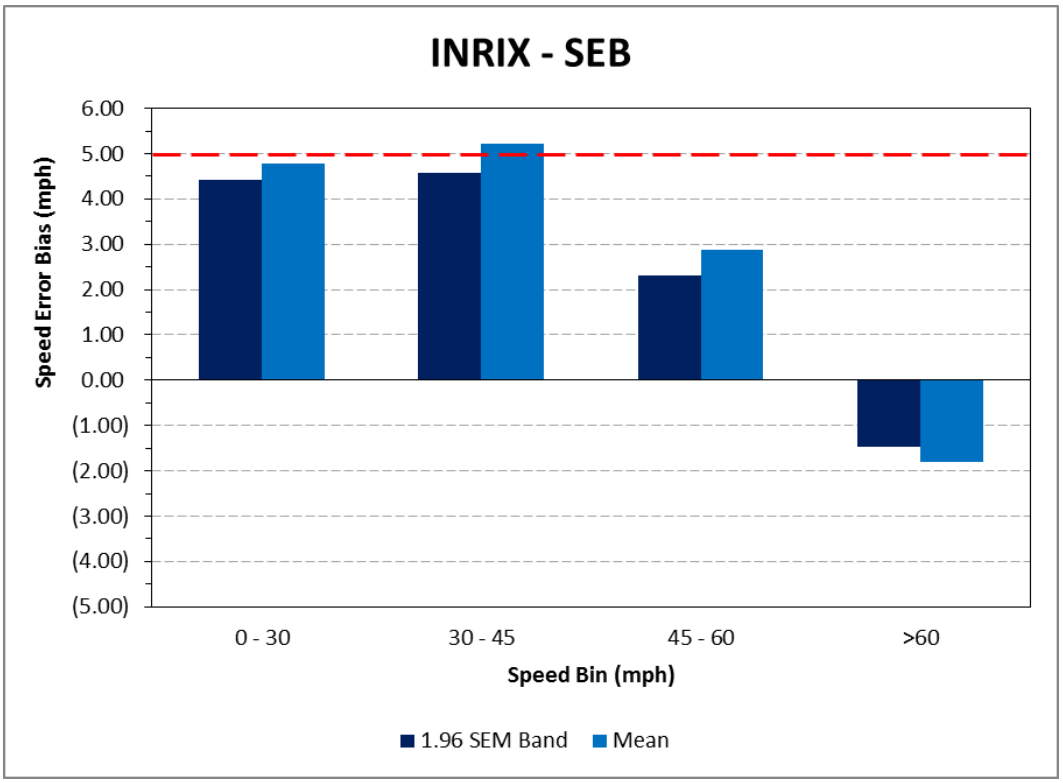

Figure 30. Speed Error Bias (SEB) for INRIX (Overall)

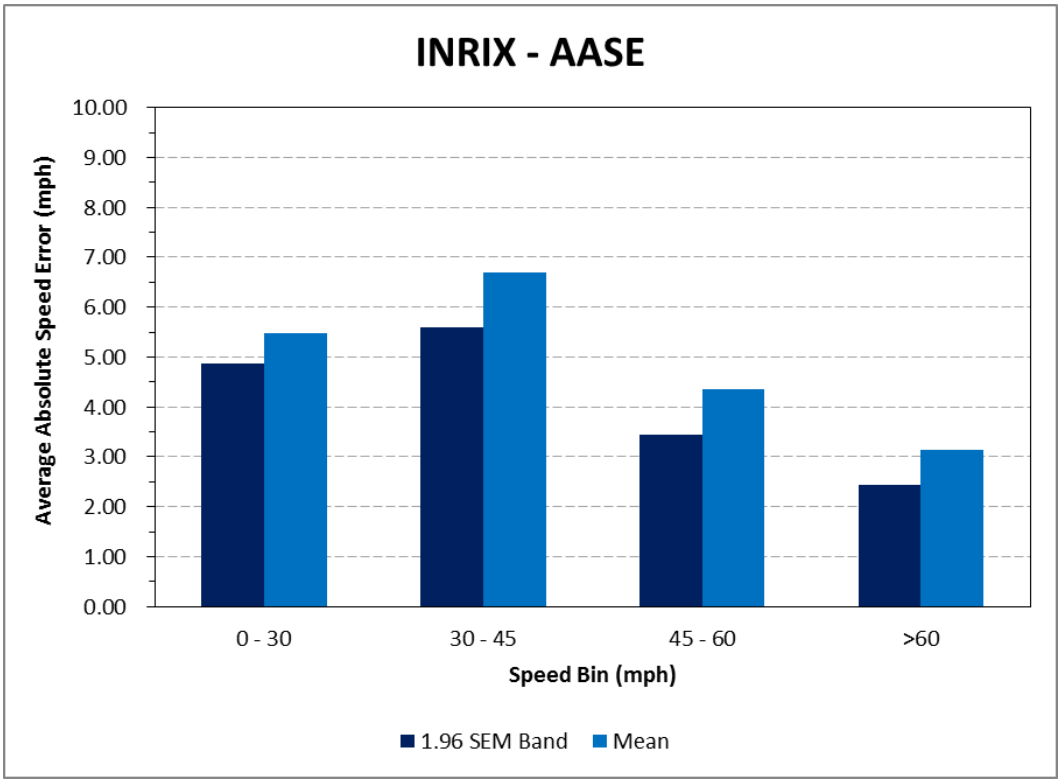

Figure 31. Average Absolute Speed Error (AASE) for INRIX (Overall)

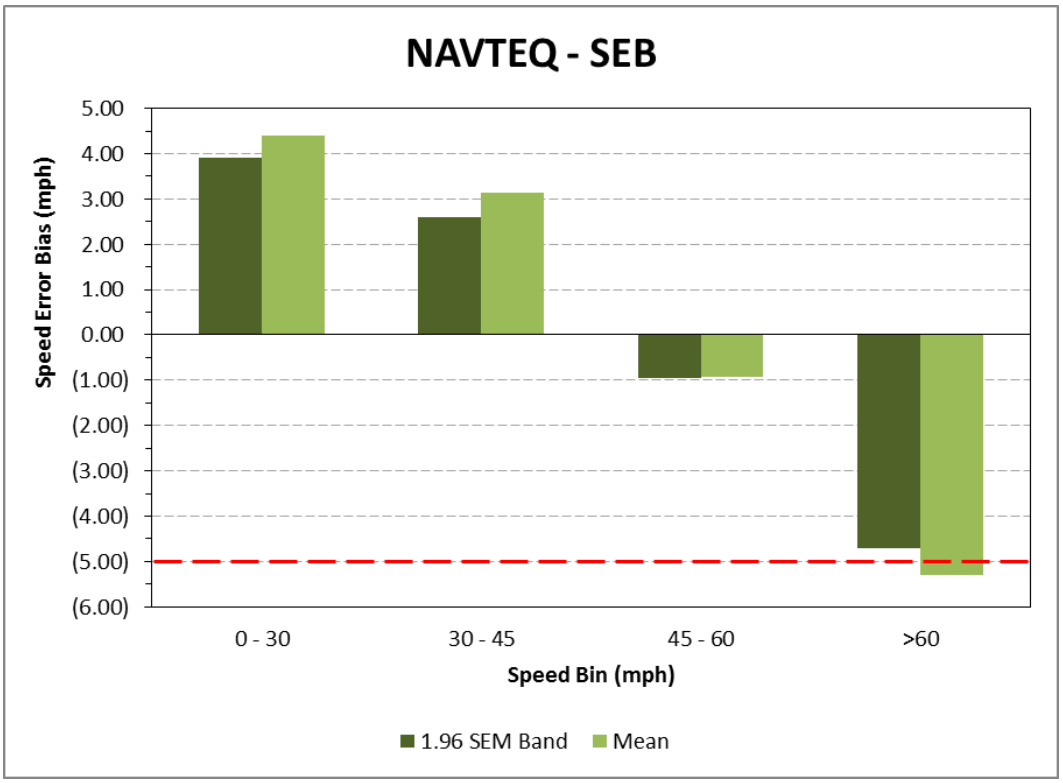

Figure 32. Speed Error Bias (SEB) for NAVTEQ (Overall)

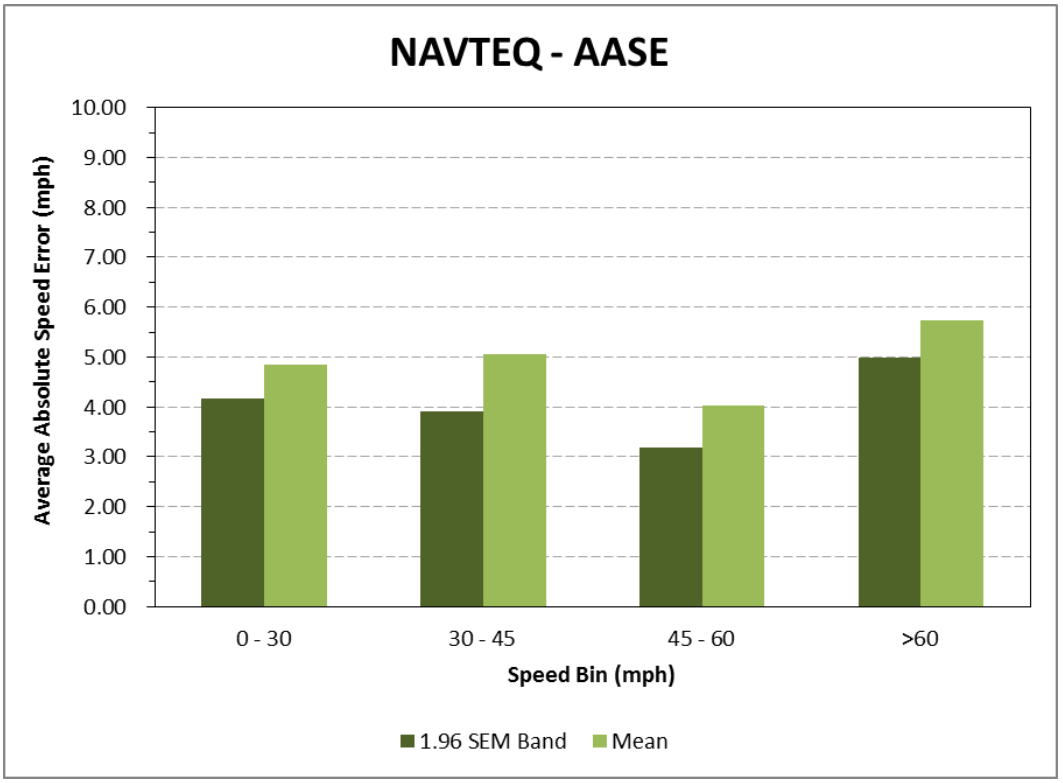

Figure 33. Average Absolute Speed Error (AASE) for NAVTEQ (Overall)

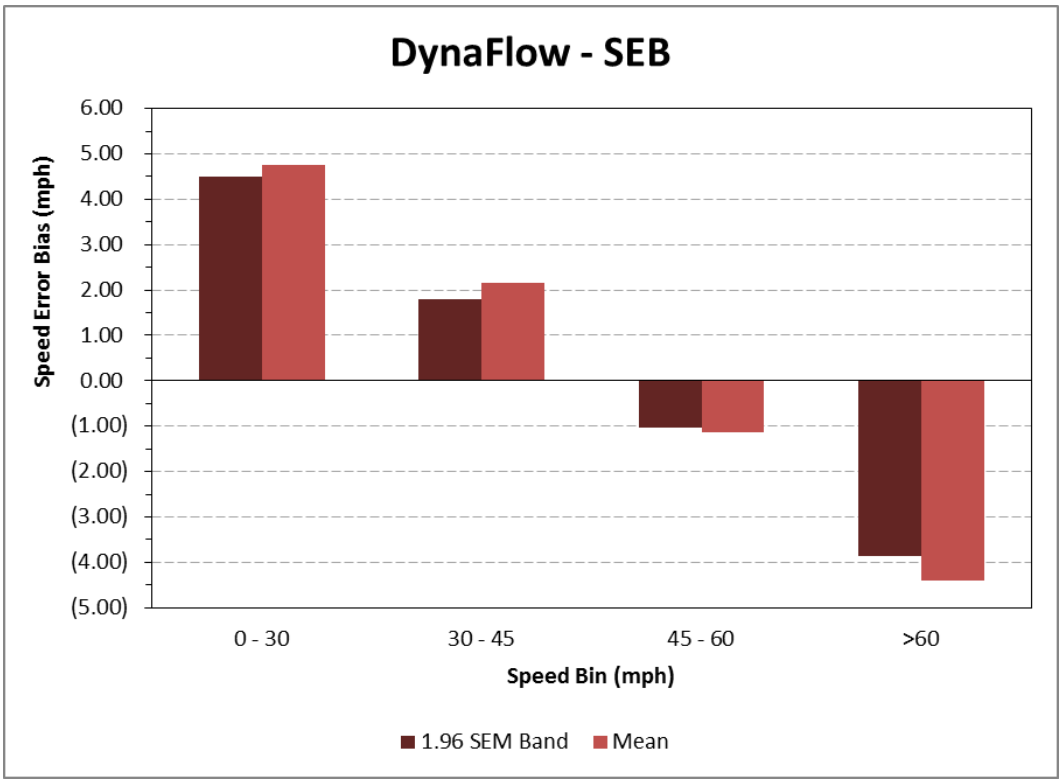

Figure 34. Speed Error Bias (SEB) for DynaFlow (Overall)

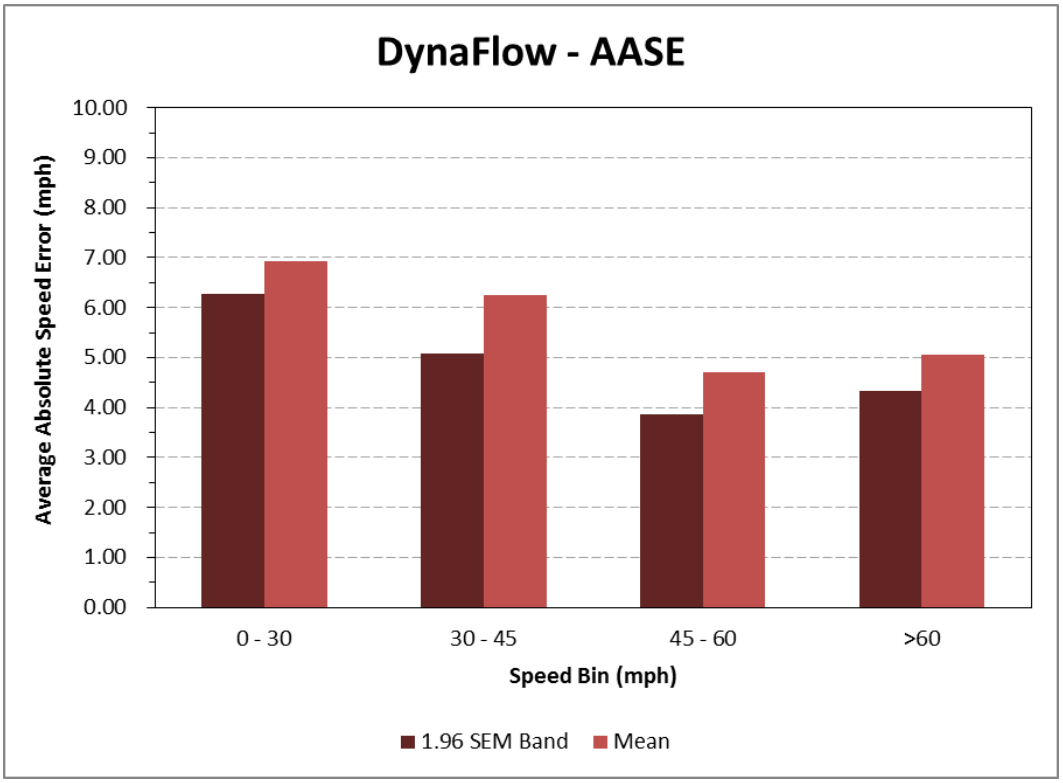

Figure 35. Average Absolute Speed Error (AASE) for DynaFlow (Overall)

Table 35. INRIX Percent Observations Meeting Data Quality Criteria (Overall)

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	17%	84%	4%	80%	3251
30 – 45	17%	67%	2%	58%	4787
45 – 60	15%	76%	1%	65%	21584
>60	15%	83%	2%	74%	115,088

Table 36. NAVTEQ Percent Observations Meeting Data Quality Criteria (Overall)

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	10%	64%	1%	59%	3513
30 – 45	22%	77%	2%	66%	5112
45 – 60	16%	70%	2%	61%	25931
>60	8%	63%	1%	52%	122,303

Table 37. DynaFlow Percent Observations Meeting Data Quality Criteria (Overall)

SPEED BIN (mph)	Data Quality Measures for				Number of 5-Minute Samples
	1.96 SEM Band		Mean		
	Percentage falling inside the band	Percentage within 5 mph of the band	Percentage equal to the mean	Percentage within 5 mph of the mean	
0 – 30	12%	72%	2%	67%	4229
30 – 45	14%	60%	1%	49%	5722
45 – 60	14%	60%	2%	51%	27757
>60	1%	99%	1%	54%	124,206

Analysis of Speed Data Accuracy in Incident Conditions

The speed data samples were analyzed for several time intervals during the three-week analysis period when major incidents occurred, each causing significant disruptions in traffic operations. These disruptions resulted in traffic congestion and travel delays, which should have been reflected as sharp drops in speed recorded by INRIX, NAVTEQ, and DynaFlow for the corresponding time intervals. With assistance from TRANSCOM, seven incidents were identified that occurred on the studied roadway segments during the analysis period between October 16 and November 5, 2011. Detailed information about these incidents is summarized in

Table 38.

Table 38. Incident Information Summary

	Incident Type	Incident Location	Date (mm/dd/yy)	Start Time (hh:mm)	End Time (hh:mm)
Weekdays	Accident	NSP (between Exit 36 S and South Oyster Bay Rd.)	10/17/11	15:51	16:42
	Accident	I-78 (between Exit 52 and GSP)	10/18/11	12:35	13:03
	Truck Fire	I-287 (between Exit 22 and US 202)	10/19/11	12:43	12:52
	Accident	LIE (between Exit 49 S and NY 110)	11/02/11	09:06	09:43
	Accident	NSP (between Exit 35S and NY 106)	11/03/11	18:53	19:05
Weekends	Weather	I-287 (between NJTPKE ramp and Exit 4, Durham Rd.)	10/29/11	12:21	15:58
	Downed Tree	NSP (between Exit 44 and Sagtikos State Parkway)	10/30/11	01:31	03:04

Accident on Northern State Parkway, Eastbound, between Exit 36S and South Oyster Bay Rd. (Monday, Oct 17, 2011, 15:51-16:42)

- Figure 36 illustrates the speed variation in each evaluated dataset before, during, and after the accident. The reported incident duration was from 3:51 PM to 4:42 PM.

- During the incident, all three data providers reported speeds that were consistently higher than the speeds reported by TRANSMIT. At times Dynaflow was more than 30 mph higher and INREX was more than 40 mph higher than TRANSMIT.
- The speed estimates reported by NAVTEQ had a trend (pattern) similar to TRANSMIT (exhibited by a similar shape of the curve in Figure 36) and also had a smaller amplitude of error when compared to INRIX and DynaFlow.
- The discrepancies continued after the incident was cleared, which might have been due to the backup of vehicles and the time it took the queue to dissipate.
- Overall, the evaluated probe vehicle technologies did not accurately estimate the speed variations during this incident.
- It should be noted that INRIX, NAVTEQ, and DynaFlow reported speeds during this time interval with a "high confidence" level, which was all the more peculiar given the exhibited data inaccuracies.

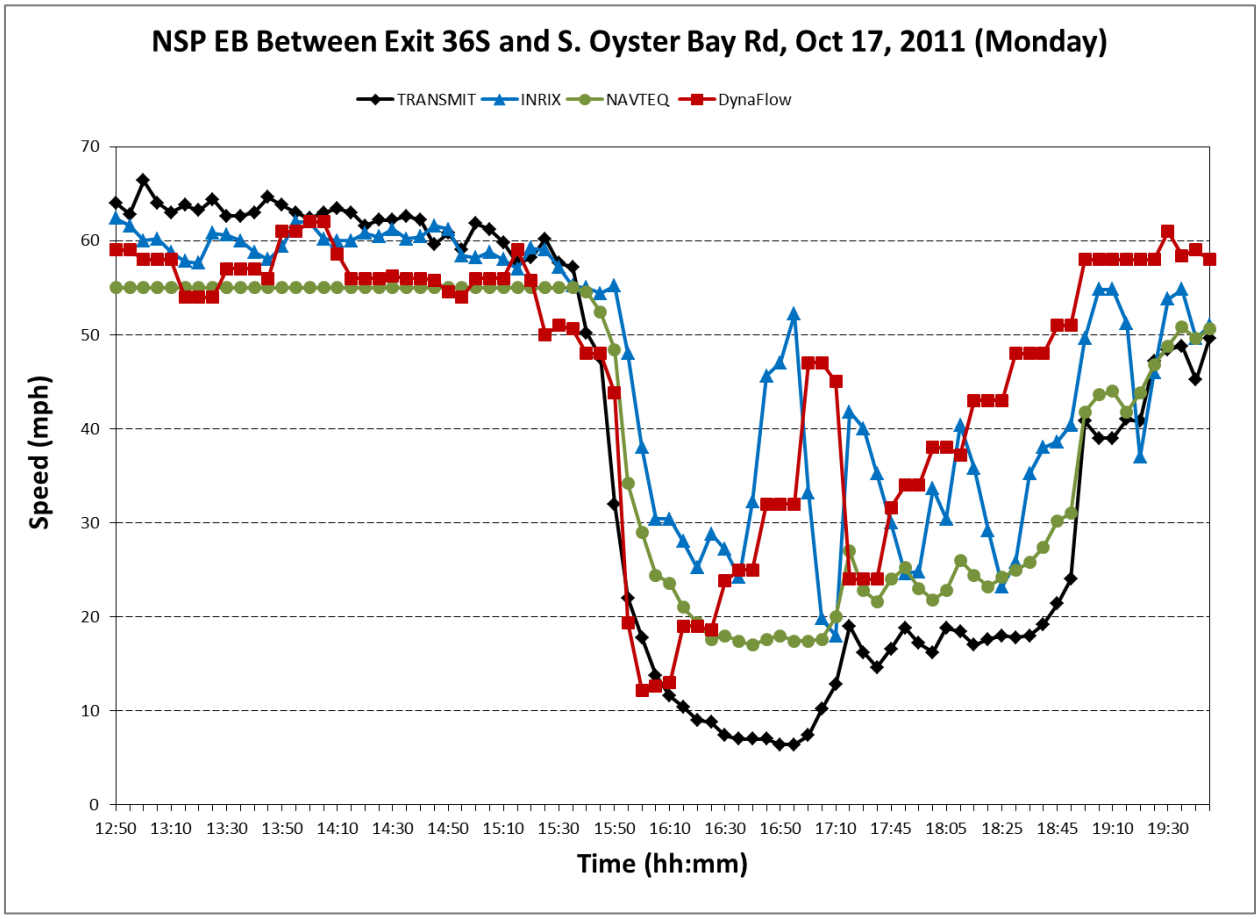

Figure 36. Reported speeds on the NSP between Exit 36S and South Oyster Bay Road on Oct 17, 2011.

Accident on I-78, Westbound, between Exit 52 and the Garden State Parkway (Tuesday, Oct 18, 2011, 12:35-13.03)

- Figure 37 shows the speeds reported by each technology before and during the accident, as well as following the accident clearance.
- Although there were discrepancies in the reported speeds, the general trend in terms of decrease and increase in speed over time was fairly consistent between TRANSMIT and the three evaluated datasets.
- A significant latency in speed reporting was observed in the NAVTEQ and DynaFlow datasets. Their reporting needed between 15 and 30 minutes to catch up with the speeds reported by TRANSMIT. This time lag resulted in a more than 20 mph speed difference between TRANSMIT and these two datasets in real time.
- INRIX estimates were lagging behind TRANSMIT in recording the drop in speed, but showed recovery of speeds even before this was recorded by TRANSMIT.
- It should be noted that the confidence level of the reported data for this incident was “high” for INRIX and DynaFlow, and “high and medium” for NAVTEQ.

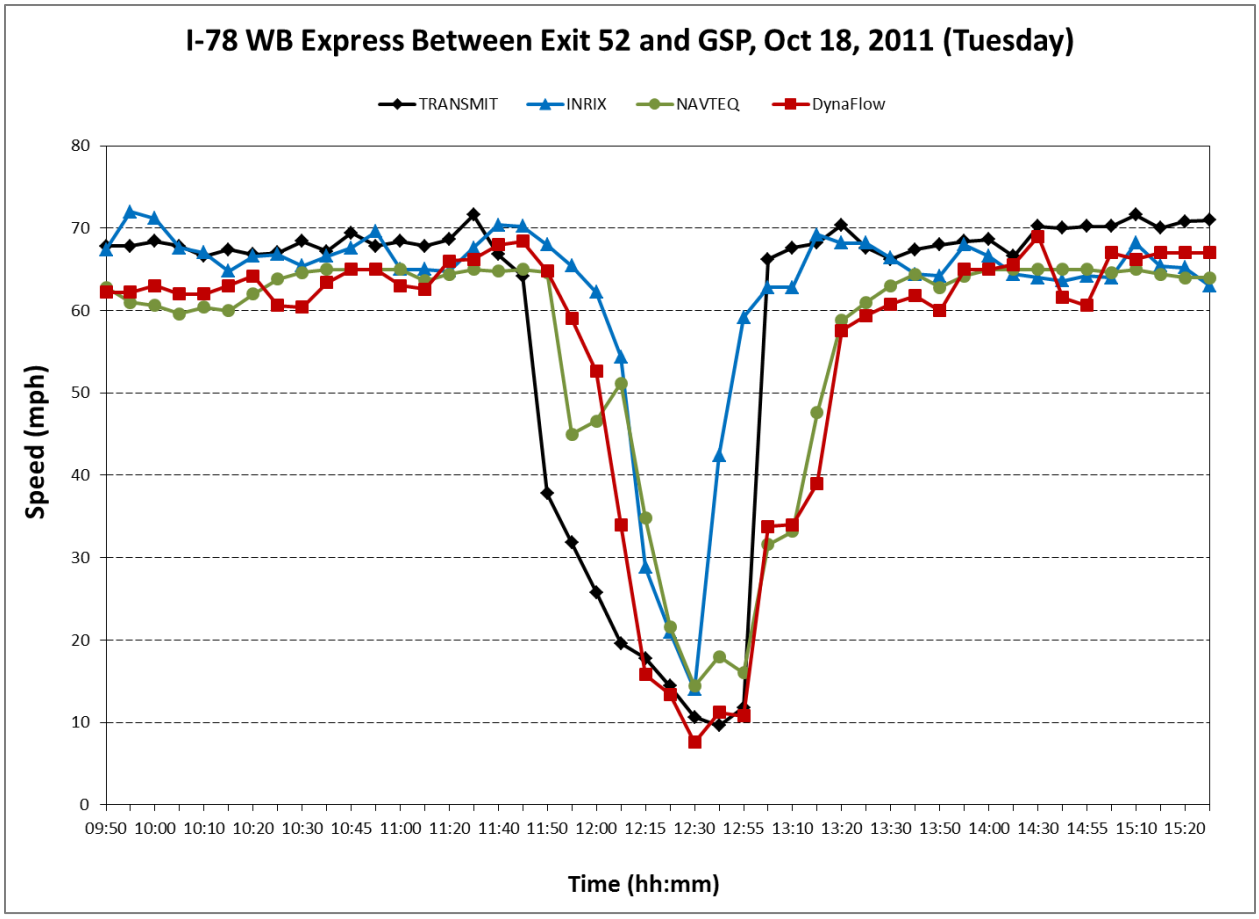

Figure 37. Reported speeds on I-78 between Exit 52 and the Garden State Parkway on Oct 18, 2011.

Truck Fire Incident on I-287, Northbound, between Exit 22 and US 202 (Wednesday, Oct 19, 2011, 12:43-12.52)

- Figure 38 shows the speeds reported before, during, and after the incident.
- Although the incident was reported at 12:43 and lasted only about 10 minutes, the actual drop in prevailing vehicle speed was observed from 11:55 to 13:30.
- During this interval, the speed estimates reported by the three technologies fluctuated around the TRANSMIT speed, with DynaFlow and NAVTEQ exhibiting greater discrepancies and latency than INRIX.
- However, all three technologies seemed to have 'picked-up' the amplitude of the drop in speed due to the incident, with NAVTEQ overestimating the minimum speed by about 10 mph.

- The confidence level of the reported data for this incident was “high” for INRIX and DynaFlow, and “high and medium” for NAVTEQ. .

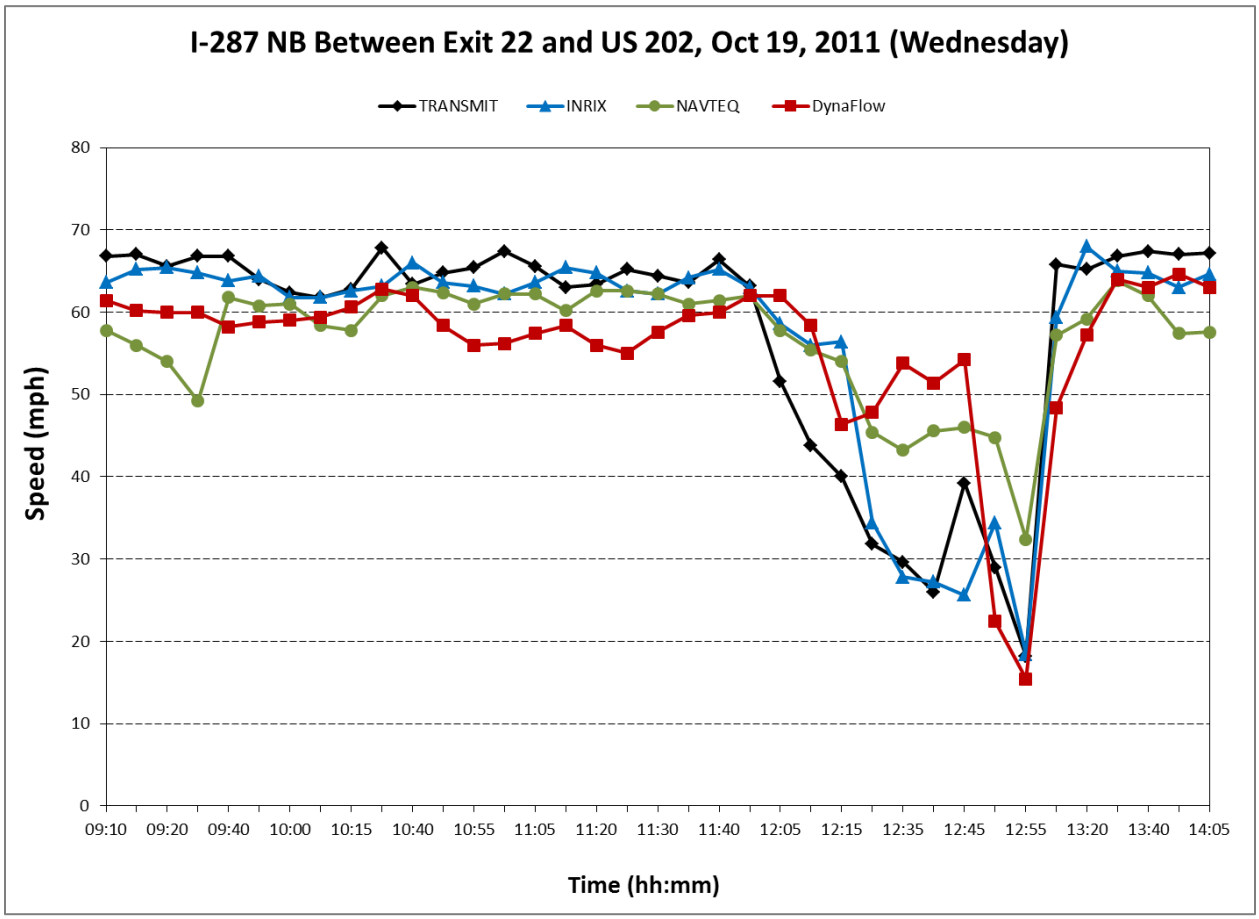

Figure 38. Reported speeds on I-287 between Exit 22 and US 202 on Oct 19, 2011.

Accident on the Long Island Expressway, Eastbound, between Exit 49S and NY Route 110 (Wednesday, Nov 2, 2011, 09:06-09:43)

- The speeds reported by each technology prior to, during, and after the accident clearance are shown in Figure 39.
- The speeds reported by all three data providers were very consistent with TRANSMIT speeds. The DynaFlow data exhibits variability with a bigger amplitude than NAVTEQ and INRIX.
- It can be observed that NAVTEQ capped the maximum speed at 55 mph, equivalent to the speed limit on this section of the LIE.
- The confidence level of the reported data for this incident was "high" for INRIX and DynaFlow, and "high and medium" for NAVTEQ.

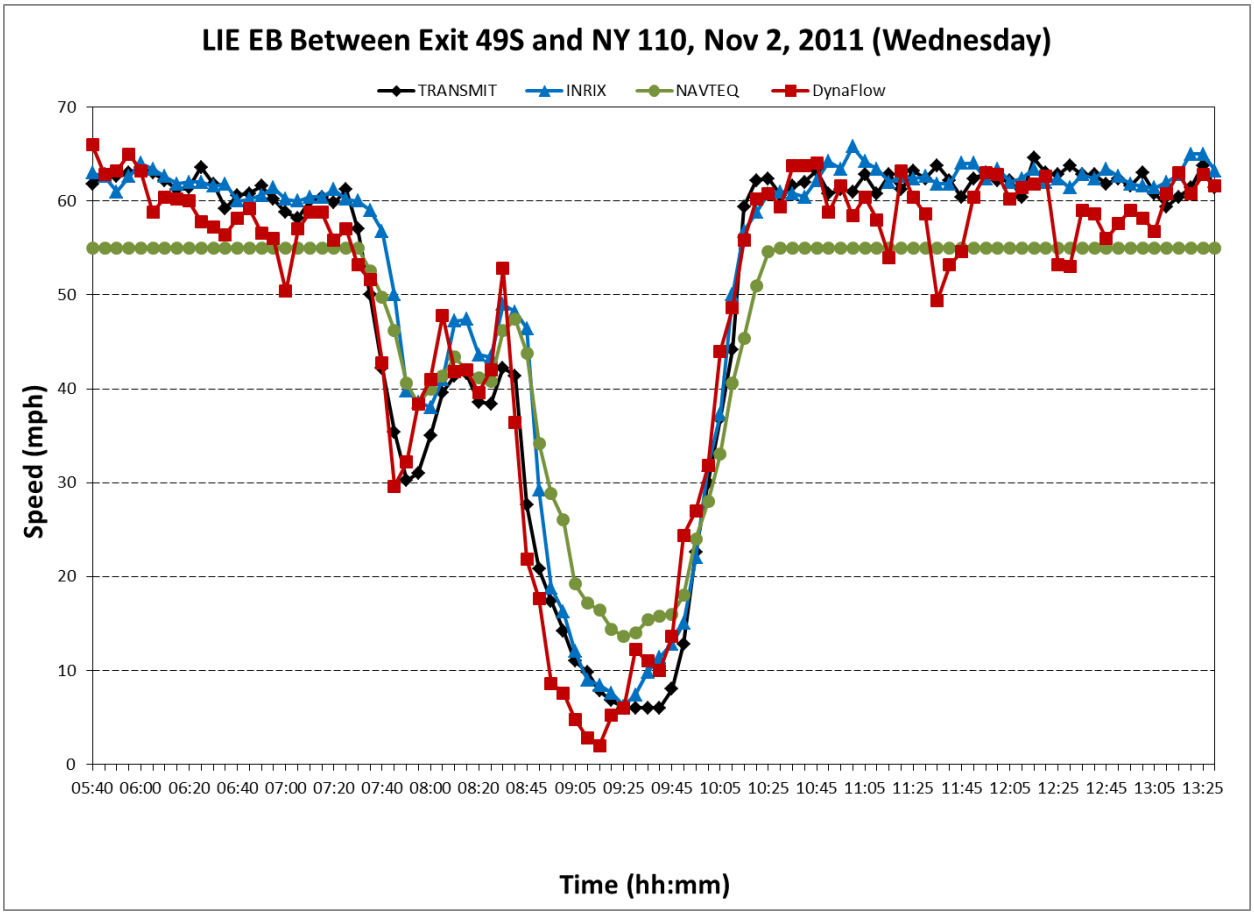

Figure 39. Reported speeds on the LIE between Exit 49S and NY Route 110, on Nov 2, 2011.

Accident on the Northern State Parkway, Eastbound, between Exit 35S and NY Route 106 North Broadway (Thursday, Nov 3, 2011, 18:53-19:05)

- Figure 40 shows the reported speeds between 16:35 and 21:25 hours.
- As shown, all three evaluated technologies exhibit latency in reporting the accident-related drop in speed.
- Otherwise, it seems that all three datasets followed the trend observed in the TRANSMIT speed reporting, with INRIX data exhibiting intermittent changes in speed with amplitudes of up to 20 mph.
- The confidence level of the reported speed data during this incident was "high" for DynaFlow and NAVTEQ, and "high and medium" for INRIX.

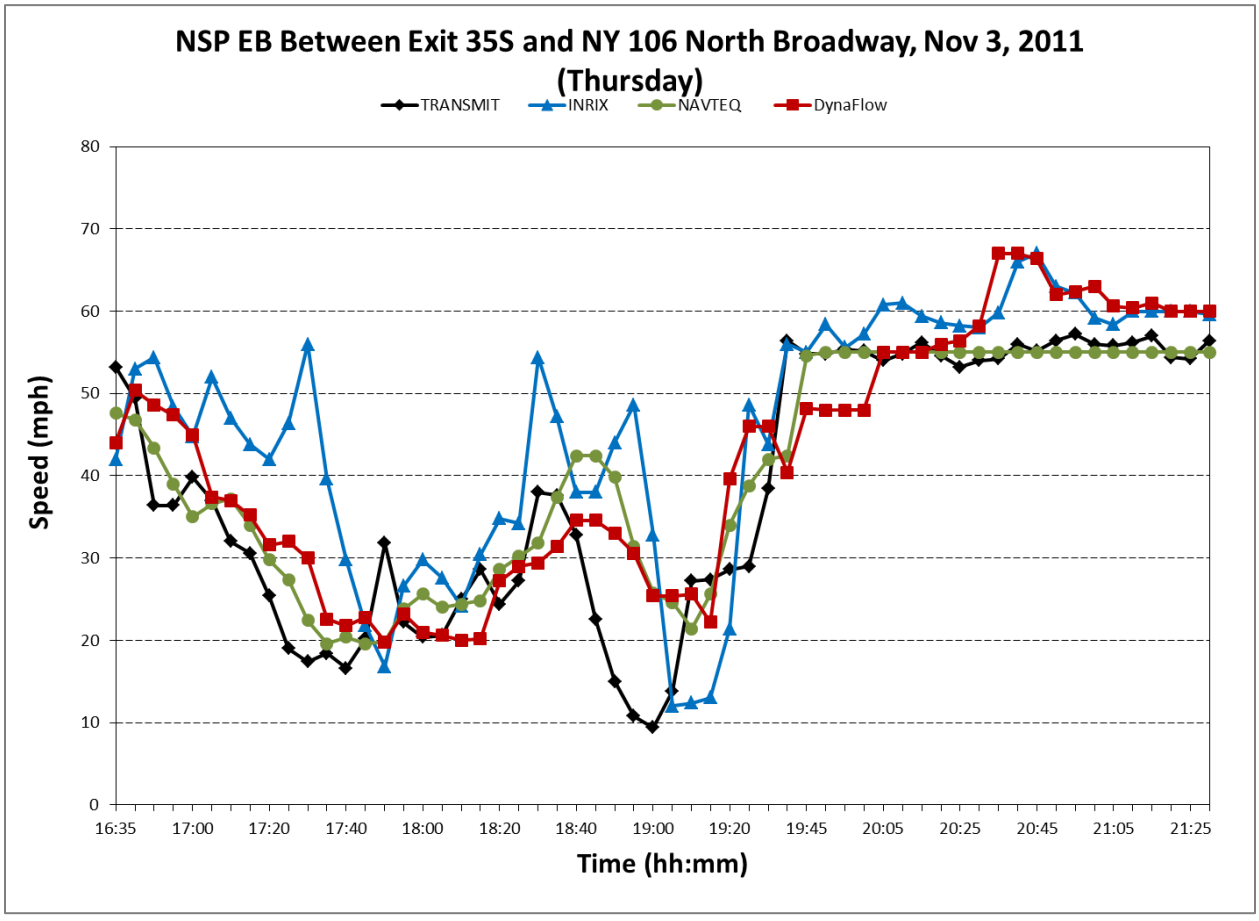

Figure 40. Reported speeds on the NSP EB between Exit 35S and NY Route 106, on Nov 3, 2011**.**

Weather-related Congestion on I-287, Northbound, between the New Jersey Turnpike and Exit 4 (Saturday Oct 29, 2011, 12:21-15:58)

- A review of the speed validation statistics for I-287 revealed that there were significant discrepancies between TRANSMIT speeds and the speeds reported by all three evaluated technologies in the early afternoon on Saturday October 29, 2011. While TRANSMIT reported prevailing speeds between 5 and 10 mph, INRIX, NAVTEQ and DynaFlow estimated speeds to be in the 30-45 mph range during the same time interval.
- The speed plots are shown in Figure 41. The circled, highlighted area on the far right side of the graph denotes the differences in speed reporting.
- According to the incident records obtained from the New Jersey Department of Transportation and TRANSCOM, there were stop-and-go delays due to the weather on October 29, 2011 between 12:21 and 15:58. The speed graph in Figure 41 shows that only TRANSMIT successfully detected the corresponding reduction in traffic speed.

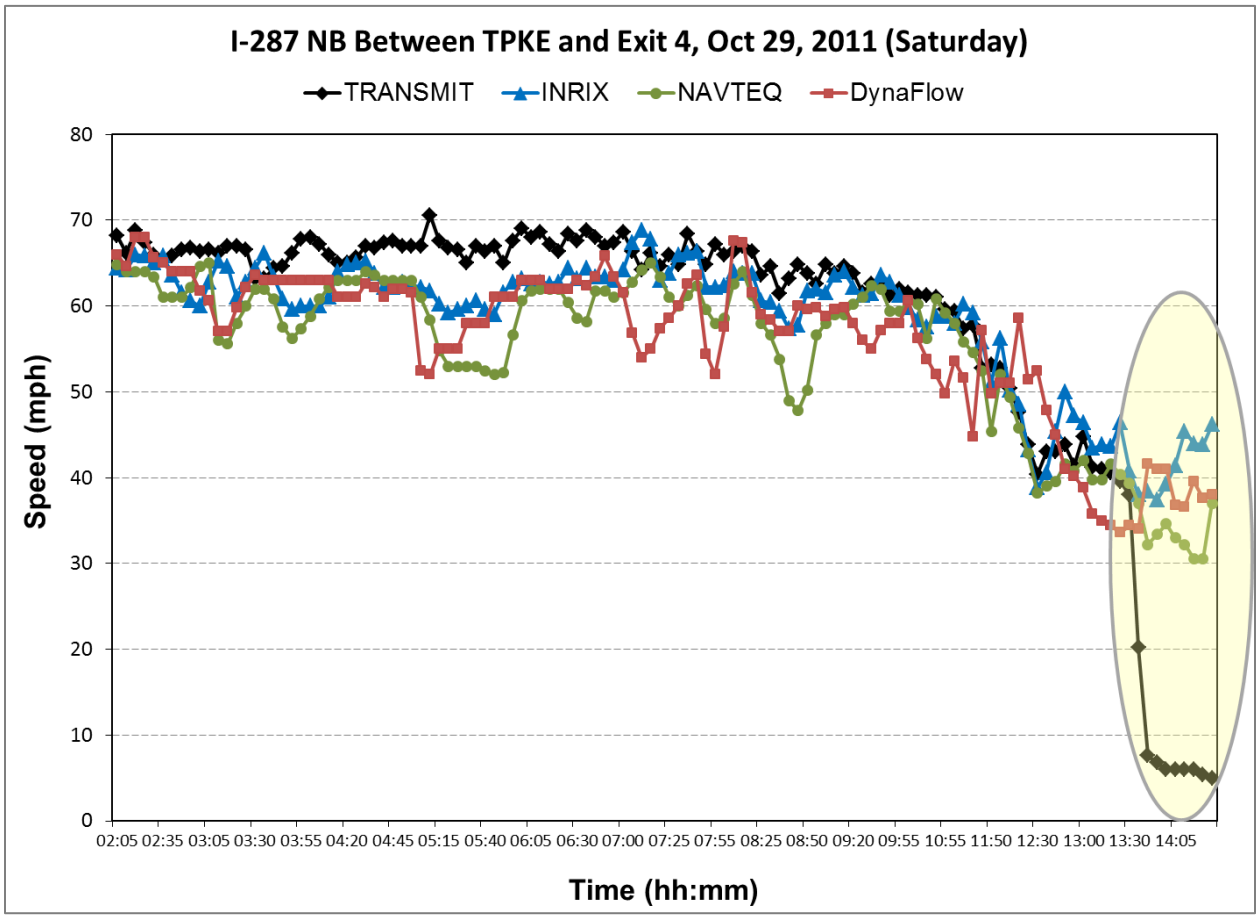

Figure 41. Reported speeds on I-287 NB between Exit 35S and NY Route 106, on Nov 3, 2011.

- Given that this was a Saturday, it is suspected that the inaccuracies in speed estimates by the three vendors were due to insufficient probe vehicle samples. However, it should be noted that INRIX and DynaFlow reported the speed estimates with "high" confidence, while the confidence level for the NAVTEQ data was a mix of "high" and "medium" for the duration of this incident.

Downed Tree on the Northern State Parkway, Eastbound, between Exit 44 and Sagtikos State Parkway (Sunday, Oct 30, 2011, 01:31-03:04)

- The speed plots for the time interval prior to, during, and after the incident clearance are shown in Figure 42.
- The effect of the incident on traffic speed was not significant during the incident, according to speed readings reported by TRANSMIT.
- Overall, NAVTEQ seems to have reported the speed variance over time accurately, illustrated by almost identical speed plots as compared to TRANSMIT. The only discrepancies were observed at times when TRANSMIT reported speeds greater than 55 mph, which was the maximum speed NAVTEQ reports for this section of the Northern State Parkway.
- INRIX and DynaFlow consistently overestimated the speed on the same link, with errors at times reaching 20 mph when compared to TRANSMIT (e.g., see the speeds reported at 05:05).
- It should be noted that INRIX reported a constant speed of 65 mph between midnight and 07:00, with an abrupt drop in speed before the incident occurred (i.e., between 00:50 and 01:10). A similar drop in speed was observed in DynaFlow dataset as well.
- Note that the confidence level of the reported data for the time period shown in Figure 42 was "high" for DynaFlow and NAVTEQ, and "high and medium" for INRIX. It should also be noted that this was a Sunday, between midnight and early morning, a time when the number of probe vehicles is scarce, if at all existent. It is therefore plausible that the majority of reported speed estimates was based on historical data, or simply represented speed limits or maximum speeds defined for this section of the Northern State Parkway.

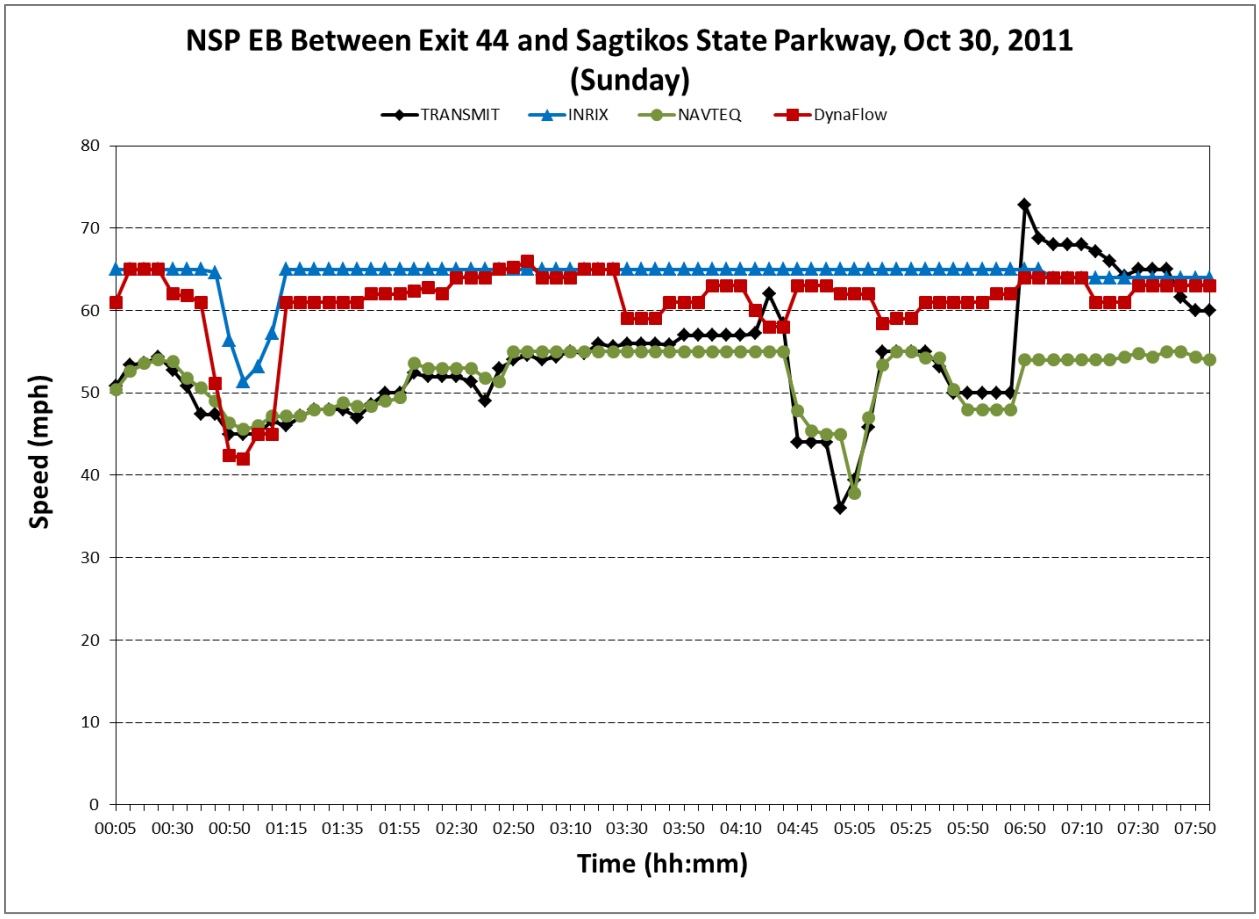

Figure 42. Reported speeds on the NSP EB between Exit 44 and Sagtikos State Parkway, on Oct 30, 2011.

Conclusions

This report summarized the results of a validation study for the probe-vehicle speed data provided by three commercial traffic data providers. The providers were INRIX Inc., NAVTEQ and TrafficCast Dynaflow™. The validation was conducted by comparing the speeds estimated by each data provider to the corresponding speeds estimated using stationary TRANSMIT readers, which were considered to represent the "ground truth" for validation purposes. The validation was conducted using a sample of speed data for four freeway sections, including sections on I-287 and I-78 in New Jersey, as well as sections of the Long Island Expressway and the Northern State Parkway in New York. Overall, the data sample covered approximately 69.51 freeway miles, and was collected for a three-week period between Sunday, October 16 and Saturday, November 5, 2011.

The speed data validation was based on the methodology developed and utilized by the I-95 Corridor Coalition's Vehicle Probe Project (VPP). Two performance measures were used to ascertain the quality and accuracy of the speed data:

- Average Absolute Speed Error (AASE), which represented the average absolute difference between estimated speeds and the "ground truth"; and
- Speed Error Bias (SEB), which ascertained the prevailing sign (positive or negative) of the difference between the estimated speeds and the "ground truth".

The data accuracy was considered to be acceptable if the AASE ≤ 10 mph and |SEB| ≤ 5 mph.

The results of the speed data validation, including all four analyzed freeway sections, showed that all three evaluated technologies (INRIX, NAVTEQ, and DynaFlow) **met the validation criteria** with the **following two exceptions**:

(a) INRIX 's SEB with respect to the mean in the 30 to 45 mph speed bin: value 5.21 > 5.00

(b) NAVTEQ's SEB with respect to the mean in the speed bin '> 60 mph': value (-5.31) < (-5.00).

It was observed that all of the studied technologies consistently overestimated the speed in the lowest speed bin ([0-30] mph), and consistently underestimated the speed in the highest speed bin (> 60 mph). In the case of NAVTEQ, the speed bias in the [>60] mph speed bin on the LIE and NSP sections was largely due to capped maximum speeds, as explained earlier.

It was also observed that all three evaluated technologies provided inaccurate (and therefore unreliable) estimates of speeds during incidents, especially on weekends. This can be explained by an insufficient number of probes on weekends and during off-peak time periods (especially

night time), as all three evaluated vendors obtain speed data largely from commercial vehicle fleets (which operate mostly on weekdays during regular business hours).

The summary of the validation findings, focusing on each studied freeway section, are as follows:

- **I-287 speed data validation**: The validation analysis showed that the speed estimates provided by all three evaluated vendors (technologies) satisfied both the AASE and SEB data quality criteria in all of the speed bins.
- **I-78 speed data validation**: The estimates from all three evaluated vendors met the AASE validation criteria, but did not satisfy the SEB acceptance thresholds in the following cases:

  (a) NAVTEQ's overall SEB, with respect to the Mean, was slightly below the acceptance threshold. This was largely driven by the poor performance in the [>60] mph speed bin. This result indicated a consistent underestimation of speeds in the highest speed bin. On the other hand, the NAVTEQ SEB with respect to both the Mean and SEM Band in the [0-30] mph speed bin were above the validation acceptance threshold. This indicated a consistent overestimation of speeds in the lowest speed bin.

  (b) INRIX's SEB was outside the validation acceptance range with respect to the SEM Band in the [0-30] mph speed bin, and with respect to the Mean in the [0-30] and [30-45] mph speed bins. However, the overall SEB values, with respect to both the Mean and SEM, were within the acceptance range. This was due to a very good performance in the [45-60] mph and [>60] mph speed bins.

  (c) DynaFlow's SEB was outside the acceptance thresholds in the [0-30] mph speed bin, both with respect to the SEM Band and Mean. Overall, the DynaFlow SEB satisfied the validation criteria.

- **LIE speed data validation**: The speed estimates by all three evaluated vendors met the AASE validation criteria. When it came to the SEB, NAVTEQ failed the validation in the [>60] mph speed bin by a significant margin. It was found that this was due to capped maximum speeds in NAVTEQ's reporting for the LIE. NAVTEQ's highest reported speed was equivalent to the speed limit of 55 mph, whereas ground truth top speeds went well above this cap during times of uncongested traffic. Therefore, the overall SEB values for the LIE should not be used as a validation reference in this analysis. Instead, one would draw better conclusions about the accuracy of the NAVTEQ speed estimates from the LIE sample by considering validation statistics for the lower three speed bins.
- **NSP speed data validation**: The results of the speed data validation for the studied section of the NSP were the most problematic. Overall, the datasets for the NSP from all

three vendors seemed to exhibit lower accuracy (and hence lower reliability in real time) as compared to other evaluated freeway segments. This was illustrated by the following:

(a) Of the three evaluated datasets, only NAVTEQ met the AASE validation criteria in all speed bins. However, it failed the SEB test in the [0-30] mph speed bin, as well as in the [>60] mph speed bin. In the [0-30] mph bin, the SEB indicated a slight but consistent ***overestimation*** of speed. In the top speed bin the SEB indicated a significant and consistent ***underestimation*** of speed. As in the case of the LIE, the result in the [>60] mph speed bin can be explained by the fact that NAVTEQ was capping the maximum speed in their reporting to a speed limit of 55 mph, when actual speeds largely exceeded this limit during uncongested times.

(b) Both INRIX and DynaFlow datasets failed both the AASE and the SEB validation tests in the lower two speed bins ([0-30] and [30-45] mph), with respect to both the SEM Band and the Mean. However, the overall validation statistics across all speed bins were within the acceptance ranges for both datasets.

- It was assumed that the poor performance of the speed estimates on the NSP was due to an insufficient number of probe vehicles on this roadway. Commercial vehicles are not allowed on the NSP, yet they represent the largest portion of the probe fleet all three vendors use to collect and aggregate vehicle speeds in real time. Therefore, the evaluated data sample was largely based on historical and synthetic speed estimates, rather than actual speeds collected from the probe vehicles.

Future Research

The developed methodology can be applied to validate probe vehicle speed data estimated by other technologies and in different locations. The evaluation conducted in this study suggested that the speed data estimated by the three technologies was comparable and generally of acceptable accuracy. The immediate extensions of this study should include, but not be limited to the following tasks:

1. Investigate the probe vehicle data quality under various conditions by considering the time of day, roadway type and location (e.g., Interstate highway, arterial, etc.).
2. Investigate the accuracy of the probe vehicle data in incident conditions considering only “high confidence” data.
3. Identify, if possible, the data collection resources of each commercial technology so that the advantages and disadvantages of each technology can be assessed.
4. Provide a guide (e.g., the accuracy of data by time period, location, and incident condition (or type)) for utilizing the speed data from the three technologies to assist the end users as they design particular applications for the data.

Appendix A

Unified Speed Recording (Reconciliation) Method

Figure A-1 illustrates the speed data reported by each of the four technologies on one highway link as archived in the XML file compiled for this study. Each technology had a different speed-reporting interval (e.g., TRANSMIT and INRIX every minute, DynaFlow every 1.5 minutes, NAVTEQ every 2 minutes). In addition, the speed-reporting times, referred to as time stamps, differed for each technology. They also differed from one day to another, and the first speed reporting of a day for each technology was observed at different times each day.

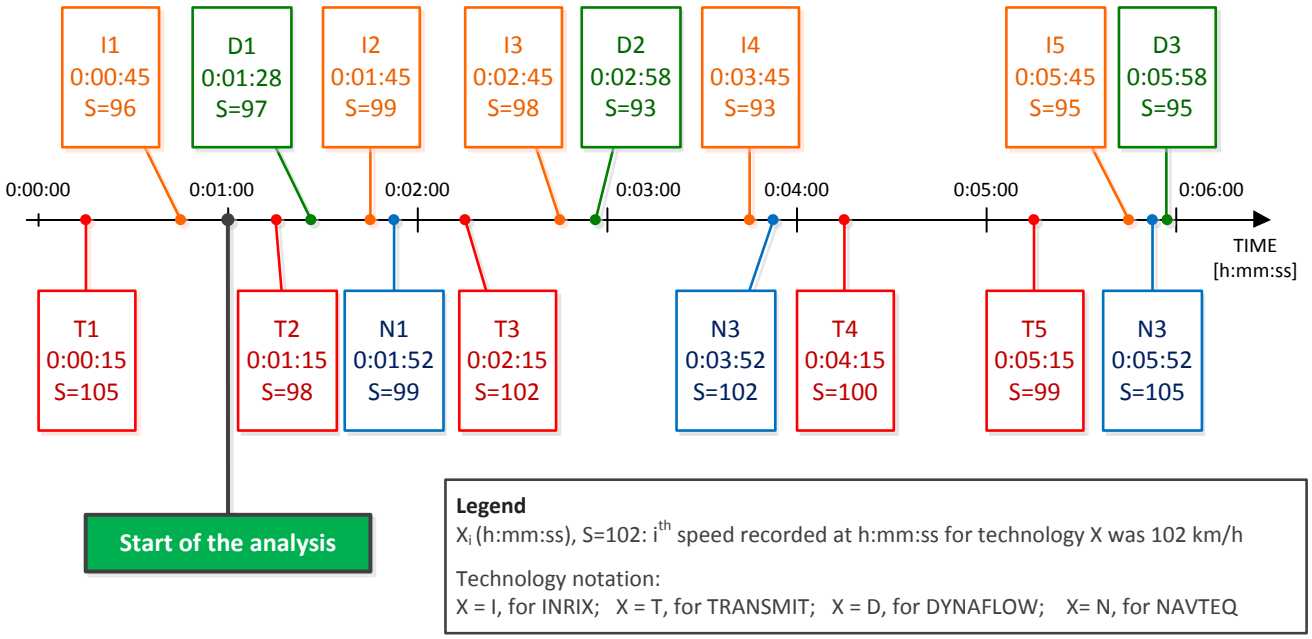

Figure A-1. Example of Data Archive Timestamp

To conduct a precise comparative analysis of the speed estimates, a speed "reconciliation" table (Table A-1) was used to reconcile the overlapping speed-reporting intervals among the four technologies. It is worth noting that the second minute of the day (e.g., the time between the time stamps 0:01:00 and 0:02:00) was determined to be the first 1-minute analysis interval of each day because the first speed of the day for each of the four technologies was recorded by the time this period ends.

In Table A-1, the first column defines 1-minute intervals. For each interval, the most recent reported speed was recorded in the reconciliation table for each technology, with the condition that the elapsed time between the speed reporting time stamp and the interval end time was:

- less or equal to 1 minute (60 seconds) for TRANSMIT and INRIX
- less or equal to 1.5 minutes (90 seconds) for DynaFlow
- less or equal to 2 minutes (120 seconds) for NAVTEQ.

Table A-1. Sample of the Speed Reconciliation Table for the Studied Technologies

Time period	Link ID	Speed (km/h)			
		TRANSMIT	INRIX	NAVTEQ	DynaFlow
0:01:00-0:01:59	16806156	98	99	99	97
0:02:00-0:02:59	16806156	102	98	**99***	93
0:03:00-0:03:59	16806156	NULL	93	102	**93***
0:04:00-0:04:59	16806156	100	NULL	**102***	NULL
0:05:00-0:05:59	16806156	99	95	105	95

** Carry-over speed from the preceding reporting interval that satisfies elapsed time condition.*

If, for any of the technologies, the most recently reported speed did not satisfy this condition, a NULL value was recorded in the reconciliation table. This means that the technology failed to report the speed for that particular 1-minute interval. Note that the same speed may be recorded more than once for DynaFlow and NAVTEQ because of the difference between the speed-reporting intervals for these two technologies (every 1.5 and every 2 minutes respectively) and the speed-recording interval (every minute).

For example, the TRANSMIT speed T_2 = 98 km/h is reported at 0:01:15, and it was recorded for the time interval ending at 0:01:59. Similarly, speed T3 = 102 km/h (time stamp 0:02:15) was recorded for the interval ending at 0:02:59. The next was the interval ending at 0:03:59; the most recent reported TRANSMIT speed was T3, but the elapsed time between the T3 time stamp and the interval end time was 104 seconds, which was more than 60 seconds. Therefore, the TRANSMIT speed for this time interval was recorded as NULL. The same procedure was applied in the following 1-minute intervals for the rest of day.

DynaFlow speeds were recorded in a similar fashion. As shown in Figure 1, at the end of the first analyzed interval (time 0:01:59) the latest reported DynaFlow speed was D1 = 97 km/h, with a time stamp of 0:01:28. The elapsed time was 31 seconds (less than 90 seconds) and this speed was recorded in Table 3 for the interval ending at 0:01:59. At the end of the next interval, the last reported DynaFlow speed was D2 = 93 km/h (time stamp 0:02:58), the elapsed time was 1 second, and the speed was recorded for the interval ending 0:02:59. At the end of the

next interval, the latest reported DynaFlow speed was still D2 = 93 km/h and the elapsed time was 61 seconds (less than 90 seconds). This speed was recorded again, but this time for the interval ending at 0:03:59. At the end of the next interval, ending at 0:04:59, the most recent reported DynaFlow speed was still D2 = 93 km/h; however, the elapsed time was now 121 seconds, which was more than 90 seconds. Therefore, the DynaFlow speed for this time interval was recorded as NULL. Note that speed data for INRIX and NAVTEQ were recorded using the same method, as illustrated for TRANSMIT and DynaFlow.

Appendix B

Evaluation Summary of the High Confidence Level Data

Appendix B provides a summary of data validation for all three evaluated technologies considering the Subset 2 dataset, which **excluded** the 5-minute intervals in which at least one data point in either the INRIX or NAVTEQ dataset was reported with a **"low confidence**" level (i.e. only considered the data points reported with "high confidence" or "medium confidence"). The summaries start on the next page.

Table B-1. INRIX High-Confidence Only Evaluation Summary for I-287

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	2.35	2.92	1.77	2.08	725
30 – 45	3.28	4.50	2.39	3.07	939
45 – 60	3.30	4.70	2.31	3.13	1944
>60	2.49	3.28	(2.04)	(2.59)	25,973
All Speeds	**2.56**	**3.40**	**(1.52)**	**(1.92)**	**29,581**

* Negative numbers are displayed in parentheses

Table B-2. NAVTEQ High & Medium-Confidence Only Evaluation Summary for I-287

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.33	4.94	4.26	4.78	732
30 – 45	2.80	3.98	1.41	1.90	952
45 – 60	2.99	4.13	(1.73)	(1.82)	2,221
>60	3.97	4.77	(3.92)	(4.67)	29,068
All Speeds	**3.88**	**4.70**	**(3.44)**	**(4.08)**	**32,973**

* Negative numbers are displayed in parentheses

Table B-3. DynaFlow High-Confidence Only Evaluation Summary for I-287

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	3.86	4.45	0.67	0.63	726
30 – 45	4.71	5.93	(0.45)	(0.41)	947
45 – 60	4.11	5.29	(0.19)	(0.22)	2,223
>60	4.02	4.80	(3.72)	(4.37)	29,022
All Speeds	**4.01**	**4.81**	**(0.42)**	**(1.60)**	**32,918**

* Negative numbers are displayed in parentheses

Table B-4. INRIX High-Confidence Only Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	5.36	6.28	4.75	**5.24**	249
30 – 45	6.45	8.21	4.67	**5.62**	530
45 – 60	3.41	4.44	0.48	0.88	4,459
>60	2.87	3.77	(1.63)	(2.03)	35,398
All Speeds	**2.61**	**3.47**	**(0.65)**	**(0.70)**	**40,636**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-5. NAVTEQ High & Medium-Confidence Only Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	6.75	7.74	**6.52**	**7.32**	307
30 – 45	4.05	5.61	1.80	2.35	666
45 – 60	4.15	5.08	(3.17)	(3.59)	6,373
>60	4.80	5.69	(4.65)	**(5.43)**	45,142
All Speeds	**3.54**	**4.25**	**(3.21)**	**(3.71)**	**52,488**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-6. DynaFlow High-Confidence Only Evaluation Summary for I-78

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean	Speed Error Bias* SEB (<5 mph) Comparison with SEM	Speed Error Bias* SEB (<5 mph) Comparison with Mean	Number of 5-Minute Samples

	Band [mph]	[mph]	Band [mph]	[mph]	
0 – 30	6.89	7.97	**5.04**	**5.56**	258
30 – 45	6.73	8.45	2.00	2.50	549
45 – 60	6.04	6.97	(4.17)	(4.49)	5,423
>60	4.63	5.51	(4.08)	(4.75)	43,148
All Speeds	**4.82**	**5.72**	**(3.98)**	**(4.58)**	**49,378**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-7. INRIX High-Confidence Only Evaluation Summary for LIE

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	2.72	3.30	2.28	2.62	1,683
30 – 45	4.55	5.51	3.66	4.19	2,443
45 – 60	2.66	3.67	2.15	2.88	8,490
>60	1.76	2.45	(0.52)	(0.66)	19,155
All Speeds	**2.27**	**3.06**	**0.66**	**0.83**	**31,771**

* Negative numbers are displayed in parentheses

Table B-8. NAVTEQ High & Medium-Confidence Only Evaluation Summary for LIE

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.22	4.82	3.79	4.24	2,440
30 – 45	3.22	4.15	2.17	2.63	3,199
45 – 60	2.21	3.19	(1.86)	(2.53)	11,729
>60	8.14	8.94	**(8.14)**	**(8.94)**	26,975
All Speeds	**6.00**	**6.85**	**(5.08)**	**(5.69)**	**44,343**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-9. DynaFlow High-Confidence Only Evaluation Summary for LIE

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	3.76	4.34	2.32	2.51	2,461
30 – 45	3.70	4.62	0.99	1.15	3,198
45 – 60	2.64	3.60	(0.72)	(0.93)	11,708
>60	2.99	3.71	(2.33)	(2.76)	26,882
All Speeds	**2.99**	**3.78**	**(1.41)**	**(1.70)**	**44,249**

* Negative numbers are displayed in parentheses

Table B-10. INRIX High-Confidence Only Evaluation Summary for NSP

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	**12.96**	**13.50**	**12.70**	**13.16**	570
30 – 45	**10.44**	**11.28**	**9.29**	**9.91**	831
45 – 60	4.03	4.67	3.35	3.79	4,199
>60	2.34	2.82	(1.50)	(1.73)	17,067
All Speeds	**3.22**	**3.74**	**0.15**	**0.09**	**22,667**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-11. NAVTEQ High & Medium-Confidence Only Evaluation Summary for NSP

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples

0 – 30	5.29	6.02	**5.14**	**5.78**	767
30 – 45	3.05	4.38	1.41	1.97	1,024
45 – 60	2.87	3.39	(2.59)	(2.96)	8,288
>60	9.23	9.72	**(9.23)**	**(9.72)**	25,131
All Speeds	**7.47**	**7.99**	**(7.05)**	**(7.45)**	**35,210**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-12. DynaFlow High-Confidence Only Evaluation Summary for NSP

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	**16.10**	**16.92**	**14.52**	**15.12**	784
30 – 45	8.89	**10.51**	**6.22**	**7.40**	1,028
45 – 60	4.11	4.65	0.37	0.47	8,403
>60	5.50	5.96	**(5.21)**	**(5.57)**	25,156
All Speeds	**5.50**	**6.03**	**(3.11)**	**(3.30)**	**35,371**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-13. INRIX High-Confidence Only Evaluation Summary (Overall)

	Average Absolute Speed Error AASE (< 10 mph)		Speed Error Bias* SEB (<5 mph)		
SPEED BIN (mph)	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Comparison with SEM Band [mph]	Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	3.12	3.78	2.53	2.89	974
30 – 45	4.43	5.84	3.22	3.99	1,469
45 – 60	3.38	4.52	1.04	1.56	6,403
>60	2.71	3.56	(1.81)	(2.27)	61,371
All Speeds	**2.61**	**3.47**	**(1.38)**	**(1.72)**	**70,217**

* Negative numbers are displayed in parentheses

Table B-14. NAVTEQ High & Medium-Confidence Only Evaluation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	5.04	5.76	4.93	**5.53**	1039
30 – 45	3.32	4.65	1.57	2.09	1618
45 – 60	3.85	4.84	(2.80)	(3.13)	8594
>60	4.48	5.33	(4.36)	**(5.13)**	74,210
All Speeds	**3.56**	**4.36**	**(3.98)**	**(4.66)**	**85,461**

* Negative numbers are displayed in parentheses

** Numbers outside of the validation acceptance range are shown in underlined bold face and highlighted in yellow

Table B-15. DynaFlow High-Confidence Only Evaluation Summary (Overall)

SPEED BIN (mph)	Average Absolute Speed Error AASE (< 10 mph) Comparison with SEM Band [mph]	Average Absolute Speed Error AASE (< 10 mph) Comparison with Mean [mph]	Speed Error Bias* SEB (<5 mph) Comparison with SEM Band [mph]	Speed Error Bias* SEB (<5 mph) Comparison with Mean [mph]	Number of 5-Minute Samples
0 – 30	4.74	5.45	2.01	2.12	984
30 – 45	5.42	6.83	0.52	0.74	1,496
45 – 60	5.49	6.48	(3.02)	(3.26)	7,646
>60	4.41	5.26	(3.97)	(4.63)	72,170
All Speeds	**4.53**	**5.40**	**(3.73)**	**(4.32)**	**82,296**

* Negative numbers are displayed in parentheses

Appendix C

Speed Reporting Quality by Technology (% reported 1-minute intervals)

Hourly Percent Speed Reported (1-minute increments)								
Period (1-minute)	TRANSMIT	INRIX-HIGH	INRIX-MED	INRIX-LOW	INRIX-TOTAL	NAVTEQ-HIGH	NAVTEQ-MED	NAVTEQ-LOW	NA
0:59	**89.83%**	73.02%	0.00%	26.98%	**100.00%**	48.39%	51.50%	0.11%	
1:59	**98.33%**	79.92%	0.00%	20.08%	**100.00%**	48.39%	50.91%	0.70%	
2:59	**96.67%**	73.61%	0.00%	26.39%	**100.00%**	48.39%	49.62%	1.99%	
3:59	**100.00%**	80.28%	0.00%	19.72%	**100.00%**	48.39%	50.22%	1.40%	
4:59	**93.33%**	60.33%	0.00%	39.67%	**100.00%**	48.39%	49.14%	2.47%	
5:59	**95.00%**	60.69%	39.31%	0.00%	**100.00%**	48.39%	49.79%	1.83%	
6:59	**95.00%**	82.28%	16.05%	0.00%	**98.33%**	48.39%	51.61%	0.00%	
7:59	**93.33%**	90.95%	5.72%	0.00%	**96.67%**	48.39%	49.57%	2.04%	
8:59	**100.00%**	91.36%	8.64%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
9:59	**91.67%**	96.11%	2.22%	0.00%	**98.33%**	38.71%	61.29%	0.00%	
10:59	**95.00%**	98.89%	1.11%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
11:59	**90.00%**	96.69%	3.31%	0.00%	**100.00%**	50.75%	49.25%	0.00%	
12:59	**90.00%**	99.22%	0.78%	0.00%	**100.00%**	61.18%	38.82%	0.00%	
13:59	**93.33%**	99.39%	0.61%	0.00%	**100.00%**	61.29%	38.71%	0.00%	
14:59	**91.67%**	99.69%	0.31%	0.00%	**100.00%**	61.29%	38.71%	0.00%	
15:59	**88.33%**	99.64%	0.36%	0.00%	**100.00%**	58.93%	41.07%	0.00%	
16:59	**88.33%**	99.64%	0.36%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
17:59	**86.67%**	99.69%	0.31%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
18:59	**91.67%**	99.36%	0.64%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
19:59	**93.33%**	96.83%	3.17%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
20:59	**88.33%**	99.47%	0.53%	0.00%	**100.00%**	48.39%	51.61%	0.00%	
21:59	**91.67%**	98.25%	1.75%	0.00%	**100.00%**	48.39%	51.24%	0.38%	
22:59	**98.33%**	91.75%	0.00%	8.25%	**100.00%**	48.39%	50.48%	1.13%	
23:59	**91.67%**	82.89%	0.00%	17.11%	**100.00%**	48.39%	51.51%	0.11%	

October 16-November 5, 2011
I-287 NB & SB, MP 0.93-21.44 (NJ Turnpike to I-78, both directions)
4
41.02 miles (20.51 miles in each direction)

Figure C-1. Speed Reporting Quality for I-287

Hourly Percent Speed Reported (1-minute increments							
TRANSMIT	INRIX-HIGH	INRIX-MED	INRIX-LOW	INRIX-TOTAL	NAVTEQ-HIGH	NAVTEQ-MED	NAVTEQ-
89.83%	87.85%	0.00%	8.76%	**96.61%**	5.44%	93.76%	0
98.33%	53.11%	0.00%	43.50%	**96.61%**	5.26%	93.86%	0
96.67%	62.51%	0.00%	34.10%	**96.61%**	5.35%	92.90%	1
100.00%	78.70%	0.00%	17.91%	**96.61%**	5.70%	87.72%	6
93.33%	72.71%	0.00%	23.90%	**96.61%**	4.21%	93.82%	1
95.00%	84.07%	12.54%	0.00%	**96.61%**	4.91%	92.81%	2
95.00%	81.89%	13.11%	0.00%	**95.00%**	5.35%	93.55%	1
93.33%	88.31%	5.09%	0.00%	**93.39%**	5.53%	94.12%	0
100.00%	92.32%	4.29%	0.00%	**96.61%**	5.53%	91.97%	2
91.67%	92.03%	2.97%	0.00%	**95.00%**	4.30%	95.57%	0
95.00%	84.29%	12.32%	0.00%	**96.61%**	5.44%	93.64%	0
90.00%	93.98%	2.63%	0.00%	**96.61%**	5.35%	94.34%	0
90.00%	95.99%	0.62%	0.00%	**96.61%**	5.61%	94.25%	0
93.33%	94.27%	2.34%	0.00%	**96.61%**	5.53%	94.34%	0
91.67%	92.74%	3.87%	0.00%	**96.61%**	5.70%	94.04%	0
88.33%	95.93%	0.68%	0.00%	**96.61%**	5.35%	94.65%	0
88.33%	90.40%	6.21%	0.00%	**96.61%**	5.70%	93.77%	0
86.67%	93.33%	3.28%	0.00%	**96.61%**	5.61%	94.12%	0
91.67%	95.65%	0.96%	0.00%	**96.61%**	5.53%	94.47%	0
93.33%	89.35%	7.26%	0.00%	**96.61%**	6.01%	93.11%	0
88.33%	88.84%	7.77%	0.00%	**96.61%**	5.83%	93.68%	0
91.67%	82.51%	14.10%	0.00%	**96.61%**	5.53%	93.64%	0
98.33%	82.91%	0.00%	13.70%	**96.61%**	5.44%	90.92%	3
91.67%	77.43%	0.00%	19.18%	**96.61%**	5.97%	92.32%	1

October 16-November 5, 2011
-78 EB & WB, MP 42.2-59.7 (from Drift Rd to Doremus Ave, fro
18
17.5

Figure C-2. Speed Reporting Quality for I-78

Hourly Percent Speed Reported (1-minute increments)							
TRANSMIT	INRIX-HIGH	INRIX-MED	INRIX-LOW	INRIX-TOTAL	NAVTEQ-HIGH	NAVTEQ-MED	NAVTEQ-L
88.77%	66.07%	0.00%	10.13%	**76.19%**	95.80%	3.96%	0.
89.10%	67.95%	0.00%	8.24%	**76.19%**	94.74%	4.30%	0.
92.55%	68.89%	0.00%	7.30%	**76.19%**	95.50%	4.34%	0.
93.38%	70.51%	0.00%	5.60%	**76.11%**	95.99%	3.85%	0.
92.67%	70.86%	0.00%	5.33%	**76.19%**	95.96%	3.89%	0.
94.37%	71.57%	4.54%	0.00%	**76.11%**	97.06%	2.78%	0.
95.67%	74.34%	1.85%	0.00%	**76.19%**	98.52%	1.47%	0.
97.76%	74.81%	1.30%	0.00%	**76.11%**	99.57%	0.43%	0.
97.39%	75.70%	0.49%	0.00%	**76.19%**	99.77%	0.23%	0.
99.36%	75.92%	0.20%	0.00%	**76.11%**	98.89%	1.11%	0.
98.31%	75.67%	0.44%	0.00%	**76.11%**	99.55%	0.13%	0.
98.46%	75.95%	0.16%	0.00%	**76.11%**	99.85%	0.07%	0.
98.29%	75.23%	0.64%	0.00%	**75.87%**	99.68%	0.01%	0.
98.95%	75.69%	0.18%	0.00%	**75.87%**	98.97%	0.00%	0.
99.34%	75.52%	0.27%	0.00%	**75.79%**	99.84%	0.00%	0.
98.84%	75.91%	0.05%	0.00%	**75.95%**	99.37%	0.63%	0.
98.15%	75.85%	0.18%	0.00%	**76.03%**	96.35%	2.46%	0.
98.33%	75.99%	0.20%	0.00%	**76.19%**	95.24%	1.90%	2.
97.58%	78.69%	0.44%	0.00%	**79.13%**	95.08%	2.06%	2.
98.09%	79.98%	0.97%	0.00%	**80.95%**	92.46%	4.78%	2.
99.10%	80.33%	0.62%	0.00%	**80.95%**	95.23%	4.77%	0.
98.01%	79.43%	1.52%	0.00%	**80.95%**	94.82%	5.18%	0.
96.06%	74.60%	0.02%	6.33%	**80.95%**	97.27%	2.58%	0.
93.88%	71.82%	0.00%	9.13%	**80.95%**	94.03%	5.76%	0.

October 16-November 5, 2011
LIE, Shelter Rock Rd - Rt 110
8
28.52

Figure C-3. Speed Reporting Quality for the LIE

Hourly Percent Speed Reported (1-minute increments)							
TRANSMIT	INRIX-HIGH	INRIX-MED	INRIX-LOW	INRIX-TOTAL	NAVTEQ-HIGH	NAVTEQ-MED	NAVTEQ-L
86.29%	18.33%	0.00%	78.93%	**97.26%**	69.52%	29.23%	0.
81.89%	11.06%	0.00%	86.10%	**97.16%**	64.15%	32.76%	1.
82.53%	9.52%	0.00%	87.55%	**97.07%**	64.01%	31.75%	3.
83.99%	9.06%	0.00%	87.63%	**96.69%**	64.20%	32.41%	2.
89.47%	12.32%	0.00%	84.75%	**97.07%**	69.69%	28.06%	1.
94.55%	29.12%	67.66%	0.00%	**96.79%**	73.17%	25.93%	0.
96.47%	57.64%	39.56%	0.00%	**97.21%**	78.88%	20.89%	0.
97.66%	64.30%	33.11%	0.00%	**97.41%**	80.18%	19.77%	0.
98.16%	75.40%	21.96%	0.00%	**97.36%**	81.34%	18.66%	0.
99.16%	81.12%	16.29%	0.00%	**97.41%**	80.34%	19.66%	0.
98.82%	79.97%	17.35%	0.00%	**97.32%**	81.62%	18.00%	0.
98.75%	74.37%	22.99%	0.00%	**97.36%**	81.65%	18.30%	0.
97.93%	72.11%	24.64%	0.00%	**96.75%**	81.22%	18.44%	0.
98.67%	71.03%	26.28%	0.00%	**97.31%**	80.94%	18.37%	0.
99.20%	78.32%	18.81%	0.00%	**97.13%**	81.46%	18.35%	0.
98.89%	79.64%	17.67%	0.00%	**97.31%**	81.37%	18.63%	0.
98.17%	77.96%	18.12%	0.00%	**96.08%**	79.61%	19.57%	0.
98.06%	74.36%	23.05%	0.00%	**97.41%**	79.29%	19.65%	1.
97.03%	70.18%	27.04%	0.00%	**97.22%**	78.99%	19.95%	1.
97.20%	58.04%	39.38%	0.00%	**97.41%**	75.15%	23.64%	1.
97.80%	50.24%	47.17%	0.00%	**97.41%**	74.62%	24.47%	0.
97.43%	41.00%	56.41%	0.00%	**97.41%**	73.23%	26.35%	0.
95.49%	27.98%	0.00%	69.43%	**97.41%**	74.87%	24.39%	0.
93.98%	23.68%	0.00%	73.73%	**97.41%**	70.69%	28.03%	0.

October 16-November 5, 2011
Northern State Parkway, Route 106/7 - Veterans Hwy
8
31.87

Figure C-4. Speed Reporting Quality for the NSP

Hourly Percent Speed Reported (1-minute increments)							
TRANSMIT	INRIX-HIGH	INRIX-MED	INRIX-LOW	INRIX-TOTAL	NAVTEQ-HIGH	NAVTEQ-MED	NAVTEQ-LO
89.83%	87.85%	0.00%	8.76%	**96.61%**	5.44%	93.76%	0.8
98.33%	53.11%	0.00%	43.50%	**96.61%**	5.26%	93.86%	0.8
96.67%	62.51%	0.00%	34.10%	**96.61%**	5.35%	92.90%	1.7
100.00%	78.70%	0.00%	17.91%	**96.61%**	5.70%	87.72%	6.5
93.33%	72.71%	0.00%	23.90%	**96.61%**	4.21%	93.82%	1.9
95.00%	84.07%	12.54%	0.00%	**96.61%**	4.91%	92.81%	2.2
95.00%	81.89%	13.11%	0.00%	**95.00%**	5.35%	93.55%	1.1
93.33%	88.31%	5.09%	0.00%	**93.39%**	5.53%	94.12%	0.3
100.00%	92.32%	4.29%	0.00%	**96.61%**	5.53%	91.97%	2.5
91.67%	92.03%	2.97%	0.00%	**95.00%**	4.30%	95.57%	0.1
95.00%	84.29%	12.32%	0.00%	**96.61%**	5.44%	93.64%	0.9
90.00%	93.98%	2.63%	0.00%	**96.61%**	5.35%	94.34%	0.3
90.00%	95.99%	0.62%	0.00%	**96.61%**	5.61%	94.25%	0.1
93.33%	94.27%	2.34%	0.00%	**96.61%**	5.53%	94.34%	0.1
91.67%	92.74%	3.87%	0.00%	**96.61%**	5.70%	94.04%	0.2
88.33%	95.93%	0.68%	0.00%	**96.61%**	5.35%	94.65%	0.0
88.33%	90.40%	6.21%	0.00%	**96.61%**	5.70%	93.77%	0.5
86.67%	93.33%	3.28%	0.00%	**96.61%**	5.61%	94.12%	0.2
91.67%	95.65%	0.96%	0.00%	**96.61%**	5.53%	94.47%	0.0
93.33%	89.35%	7.26%	0.00%	**96.61%**	6.01%	93.11%	0.8
88.33%	88.84%	7.77%	0.00%	**96.61%**	5.83%	93.68%	0.4
91.67%	82.51%	14.10%	0.00%	**96.61%**	5.53%	93.64%	0.8
98.33%	82.91%	0.00%	13.70%	**96.61%**	5.44%	90.92%	3.6
91.67%	77.43%	0.00%	19.18%	**96.61%**	5.97%	92.32%	1.7

October 16-November 5, 2011
I-287 NB & SB, I-78 EB & WB
19
38.01

Figure C-5. Speed Reporting Quality (Overall)