FROST & SULLIVAN

Real-Time Traffic Flow Ground Truth Testing Methodology Validation and Accuracy Measurement

Prepared for: Inrix, Inc.

Privileged and Confidential

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Real-Time Traffic Flow Ground Truth Testing Methodology Validation and Accuracy Measurement

Executive Summary

Frost & Sullivan has performed an independent evaluation of the data accuracy, breadth of coverage within specific metropolitan markets, and nationwide coverage footprints of two providers of real-time traffic information, Inrix and Traffic.com.

The two companies use very different methodologies for collecting traffic information. While Traffic.com combines data principally from state DOT induction-loop sensor networks and its own proprietary networks of radar-based detectors, Inrix fuses data from over 625,000 GPS-enabled probe vehicles with static sensor data from public and private sources in its Smart Dust Network.

Inrix claims to be able to produce real-time traffic flow information of equal or significantly better accuracy than stationary physical (induction loop or radar) sensor networks, as offered by Traffic.com, while offering near ubiquitous coverage in almost all major metropolitan areas across the United States.

In performing this study, Frost & Sullivan has analyzed data collected by a team of drivers measuring actual travel times on identical key routes for Philadelphia, PA, Providence, RI, and Washington, DC, for which Inrix and Traffic.com both provide real-time travel time information derived from measurements of traffic flow speed, and compared the actual data with data available from the Internet sites of Inrix and Traffic.com for the stated travel time at the start of the traversal of each route.

Through this study, Frost & Sullivan concludes that data generated from the Inrix Smart Dust Network, including data from a large number of GPS-enabled probe vehicles, on balance has on-par accuracy, and in some cases superior accuracy compared with the current state-of-the-art static sensor networks. Furthermore, in terms of both coverage within the markets evaluated independently in this study, and the nationwide footprint of markets in the United States currently live with real-time traffic flow information, Inrix is substantially ahead of Traffic.com.

Frost & Sullivan concludes that Inrix is currently the leading provider of real-time traffic information in the three metropolitan areas studied, based on coverage and accuracy, and that the Inrix Smart Dust Network provides the first truly scalable approach to providing ubiquitous, high-quality, real-time traffic information in the United States.

Introduction

The increasing amount of personal and business time and fuel wasted in congested traffic, intersected with the sharp rise in gasoline prices over the past several years, has stimulated renewed interest in both the public and private sectors in Intelligent Transportation Systems (ITS) in general, and particularly in the provision of rich traffic information to consumers, businesses, and federal, state and local governments.

Until recently, traffic information has been confined to media-friendly incident reporting (common method of reporting traffic on radio and television broadcasts) combined in a limited number of markets (22 as of September 2006) with a DOT-installed and maintained infrastructure of induction loop detectors embedded in roadways, able to capture real-time traffic flow and speed information. In the case of flow and speed information, maintaining a significant sensor infrastructure requires substantial capital and on-going investment in maintenance. As a result, public loop sensor deployments are limited to only the most major roads, and to low densities along those roads.

Over the past five years in the commercial sector, Traffic.com (formerly Mobility Technologies) has worked closely with state DOTs to enhance publicly available traffic information by installing traffic-sensor infrastructure through an exclusive program of federally-funded matching money earmarked for supporting state ITS infrastructure installations (the ITIP Program). Traffic.com has offered state DOTs low-cost installations of radar detector-based traffic flow sensors, measuring speed, flowcount, and occupancy, in exchange for exclusive commercial rights to the data generated. Such radar-based traffic flow sensors are widely believed to yield state-of-the-art information in terms of accuracy and latency. Similar to public deployments of physical sensor networks, Traffic.com's deployment of its own sensor infrastructure is limited in coverage by cost, averaging from 40 to 100 roadside detectors per market. Traffic.com combines data from its own sensor network with data from public loop-detector sources to provide real-time traffic flow and speed information in 29 markets to businesses and consumers.

Within the last year, Inrix, spurred by proprietary technology licensed exclusively from Microsoft Research, has focused on providing both real-time and, uniquely, predictive traffic information nationwide. Inrix traffic data is derived from the fusion of data from over 625,000 GPS vehicle probes nationwide with available public and private sensor network data. This "Inrix Smart Dust Network" represents a paradigm shift in the approach to traffic data aggregation.

The use of GPS vehicle probes and indeed cellular phone network-based probes to generate real-time traffic information is not new, but GPS vehicle probe approaches have historically suffered from lack of probe vehicle density, while cell phone probes suffer from a lack of precision in determining location, and much higher statistical noise in the data. Using its own proprietary technology in combination with exclusive intellectual property licensed from Microsoft Research, Inrix claims to be able to produce real-time traffic flow information of equal or significantly better accuracy than solutions primarily based upon stationary physical (induction loop or radar) sensor networks, while offering near ubiquitous coverage in almost all major metropolitan areas across the United States.

The goal of this study is to evaluate Inrix and Traffic.com with respect to data accuracy, breadth of coverage within specific metropolitan markets, and nationwide coverage footprints.

To realize this goal, in August 2006, Frost & Sullivan analyzed the accuracy and coverage of real-time traffic flow information from Inrix and Traffic.com. A third-party drive-testing company was engaged to provide actual travel time data by driving key routes in three metropolitan areas for which both Inrix and Traffic.com provide real-time traffic flow information; Philadelphia, PA, Providence, RI, and Washington, DC. Simultaneously, Frost & Sullivan extracted available traffic information for those key routes from the Inrix and Traffic.com websites for comparative analysis.

In the following sections, we describe our detailed testing methodology, describe summary and detailed results of the analysis by market, and evaluate the relative accuracy and coverage of the two competitors.

METHODOLOGY

In August 2006, Inrix Inc. contracted with Octagon Data Services and Frost & Sullivan to analyze the accuracy of Inrix's real-time traffic flow information relative to the data reported by its competitor, Traffic.com. Octagon provided actual travel time data by driving key routes in three metropolitan areas for which both Inrix and Traffic.com provide traffic flow data. This is called "ground truth" (GT) data. Traffic.com and Inrix gather traffic flow data from a variety of sources, as described below. These input data are combined to estimate the average speed of traffic on specific road segments. Since average speed differs on various parts of a road segment and from lane to lane, there inevitably will be discrepancies between the actual time that a specific vehicle takes to travel a route (GT) and the estimated time based on traffic flow data.

The three covered metropolitan areas are:

- Philadelphia, Pennsylvania
- Providence, Rhode Island
- Washington, DC

Drivers were instructed to drive in any lane that they wished, but not to seek out either the slowest or the fastest lane. Testing was conducted between 6:00 AM and 8:00 PM to cover commute times, when traffic is heaviest and travel times are more difficult to estimate. The analysis is done in terms of fairly short route segments, since on long routes, segment-by-segment overestimates and underestimates would offset one another, favorably biasing the testing. The average GT route time was 10.6 minutes, the shortest time was 5.0 minutes, and the longest time was 31.0 minutes.

Vehicles were equipped with GPS-enabled Pocket PCs running track-logging software. These devices captured the vehicle's location (in terms of latitude and longitude to within 30 meters) and speed every two seconds. These data were then matched to routes and to sensor data for comparison of estimated and actual (GT) data. For the analysis below, travel times per segment were used, rather than speed data. The conversion of average speed to travel time on a segment of known length is straightforward.

Chart 1 illustrates the onboard hardware.

Chart 1

Onboard Hardware (U.S.), August 2006

Source: Inrix

Inrix worked with Frost & Sullivan on a methodology that simultaneously captured travel time estimates from the Inrix and Traffic.com websites at intervals of about five minutes. Frost & Sullivan used this methodology during the hours that GT trials were conducted on the key routes. An Excel workbook that aligned the GT data and the Inrix and Traffic.com estimates was created. Inrix and Traffic.com estimates then were compared to the GT data. Estimates captured immediately preceding the start time of each GT run were used to reflect how consumers use Inrix and Traffic.com data – to predict drive time before setting out on a route.

The Inrix and Traffic.com estimates are based on inputs from one or more of the following sources:

- Loop sensors – Embedded in roadways, maintained by local Departments of Transportation. Traffic speed is inferred on the basis of 'occupancy' (proportion of the time that a vehicle is above the sensor) and 'flow' (how frequently the sensor is activated).

- Radar – Radar guns measure the speed of traffic at certain locations.

- Toll tags – Some vehicles carry radio frequency identification (RFID) tags for the purpose of toll collection. These tags transmit identification numbers specific to the vehicle. Traffic flow can be measured by the times at which a particular vehicle passes two fixed points.

- Probe vehicles – Probe vehicles are equipped with GPS devices and transmit location, heading and speed data to a data center.

• Cell-phone probes – Location and speed data can be derived from cell phones in use on a specific roadway, based either on the built-in GPS receiver with which some cell phones are equipped or on signal strength as picked up by multiple cell towers.

Chart 2 presents a sample of the Excel workbook with the GT, Traffic.com, and Inrix data.

Chart 2

Raw Data (Washington, DC), August 2006

Microsoft Excel - Inrix_Route_Analysis 08312006 Raw Data

Route: I-66 Eastbound From RT-50/Lee Jackson Hwy (#57) to I-495 Capital Beltway (#64)

Start Timestamp	End TimeStamp	Start Time in UTC	Start Time Local	GT Driver Travel Time	Traffic.Com Travel Time	Inrix Travel Time (min)	TCOM Route Times Capture
1156427163	1156427548	8/24/2006 13:46	8/24/2006 9:46 AM	6	12	6	8/24/2006 13:45
1156427213	1156427655	8/24/2006 13:46	8/24/2006 9:46 AM	7	12	6	8/24/2006 13:45
1156442866	1156443220	8/24/2006 18:07	8/24/2006 2:07 PM	6	8	6	8/24/2006 18:07
1156447175	1156447529	8/24/2006 19:19	8/24/2006 3:19 PM	6	8	6	8/24/2006 19:15
1156450600	1156451528	8/24/2006 20:16	8/24/2006 4:16 PM	15	10	6	8/24/2006 20:13
1156504405	1156504766	8/25/2006 11:13	8/25/2006 7:13 AM	6	8	8	8/25/2006 11:12
1156515378	1156515756	8/25/2006 14:16	8/25/2006 10:16 AM	6	8	7	8/25/2006 14:12
1156521787	1156522163	8/25/2006 16:03	8/25/2006 12:03 PM	6	8	8	8/25/2006 16:03
1156531393	1156531818	8/25/2006 18:43	8/25/2006 2:43 PM	7	8	10	8/25/2006 18:39
1156538807	1156539187	8/25/2006 20:46	8/25/2006 4:46 PM	6	8	6	8/25/2006 20:45

Route: I-66 Westbound From I-495 Capital Beltway (#64) to RT-50/Lee Jackson Hwy (#57)

Start Timestamp	End TimeStamp	Start Time in UTC	Start Time Local	GT Driver Travel Time	Traffic.Com Travel Time	Inrix Travel Time (min)	TCOM Route Times Capture
1156425925	1156426306	8/24/2006 13:25	8/24/2006 9:25 AM	6	8	7	8/24/2006 13:21
1156426667	1156427064	8/24/2006 13:37	8/24/2006 9:37 AM	7	8	7	8/24/2006 13:35
1156446440	1156447083	8/24/2006 19:07	8/24/2006 3:07 PM	11	19	15	8/24/2006 19:05
1156450058	1156450505	8/24/2006 20:07	8/24/2006 4:07 PM	7	8	9	8/24/2006 20:04
1156455634	1156456034	8/24/2006 21:40	8/24/2006 5:40 PM	7	8	7	8/24/2006 21:36
[illegible]	[illegible]	[illegible]	[illegible]	6	7	7	[illegible]

PHL / PVD / WDC

Source: Inrix and Frost & Sullivan

A number of statistics were computed to measure the accuracy of the Traffic.com and Inrix estimates, relative to the GT data. Root mean square error (RMSE) can be taken as a single comprehensive measure that indicates both the average accuracy and the consistency of the estimates. RMSE gives equal weight to overestimates and underestimates, and gives disproportionately large weight to larger errors (a result of the squaring step).

RMSEs were computed as follows:

- For each segment of a route, the difference between the reported and actual (GT) time was computed:
  - o Traffic.com-reported time minus actual GT time
  - o Inrix-reported time minus actual GT time
- Each difference was squared to eliminate negative numbers
- The average (mean) of the squared differences was computed
- The root of the mean square was taken, offsetting the squaring and putting the result into the same units as the original dataset

Thus, the RMSEs indicate how much reported travel times differ from actual travel times, on average. The lower an RMSE is, the better.

RMSEs for all of the trials were then tabulated for comparison, to evaluate whether Traffic.com or Inrix readings are better on average.

Additionally, the Traffic.com and Inrix differences across all trials were graphed. For this purpose, negative numbers were left as negative numbers, and straight averages of differences were computed to indicate if there is a systematic bias (tendency to over- or under-estimate travel times) in either Traffic.com or Inrix data. Statisticians typically compute standard deviations of datasets in cases such as this, and thus, standard deviations are shown with these graphs. Standard deviation is a measure of how "spread out" the observations in a dataset are – in this case, how much the differences between Traffic.com/ Inrix and GT data are spread out around zero. This measure is similar to RMSE, with the difference being that standard deviation compares a dataset to its own mean value and RMSE compares a dataset to outside values that are regarded as "truth".

Mean absolute errors, mean percent errors, root mean square percent errors, and mean absolute percent errors were also computed for each metropolitan area across all trials on all routes. The computed measures all are standard, widely used statistical measures.

RESULTS

Overall

Figure 1 summarizes results across the three metropolitan areas.

Figure 1

Data Comparison (Total), 2006

	Philadelphia		Providence		Washington		Overall	
	Traffic	Inrix	Traffic	Inrix	Traffic	Inrix	Traffic	Inrix
Mean Error (minutes)	**-0.2***	**-1.9**	**0.9**	**0.5***	**1.2**	**-0.5***	**0.7**	**-0.6***
Standard Deviation (minutes)	3.6*	5.7	2.5	2.0*	3.3*	4.0	3.2*	4.2
Root Mean Square Error (minutes)	3.6*	6.0	2.6	2.0*	3.5*	4.0	3.2*	4.2
Mean Absolute Error (minutes)	2.6*	4.1	1.8	1.2*	2.7	2.3*	2.3*	2.5
Mean Percent Error (%)	4.7*	-9.5	13.6	6.0*	23.7	2.2*	14.4	-0.2*
Percent Standard Deviation (%)	18.2*	28.4	21.4	19.9*	29.6*	29.8	24.8*	27.0
Root Mean Square Percent Error (%)	**18.6***	**29.7**	**25.2**	**20.6***	**37.7**	**29.5***	**28.6**	**26.9***
Accuracy (%) (100-RMSPE)	**81.4***	**70.3**	**74.8**	**79.4***	**62.3**	**70.5***	**71.4**	**73.1***
Mean Absolute Percent Error (%)	16.0*	23.3	20.0	13.7*	31.9	21.4*	22.9	19.4*
*** Advantage:**	**Traffic.com**		**Inrix**		**Mixed**		**Mixed**	
Memo: Number of trials	44		48		49		141	
Number of routes	5		4		6		15	

Note: In all rows except Accuracy, lower numbers are better.

Key: Mean error – Average of errors in minutes. Positive and negative errors offset one another.
Standard deviation – A statistical measure of how spread-out a dataset is. Positive and negative errors do not offset one another.
Root mean square error – Square root of the average of squared errors. Positive and negative errors do not offset one another.
Mean absolute error – The average of the absolute values of the errors. Positive and negative errors do not offset one another.
Mean percent error – The mean error calculation based on percent errors rather than errors in minutes.
Percent standard deviation – The standard deviation calculation based on percent errors rather than errors in minutes.
Root mean square percent error – The root mean square error calculation based on percent errors rather than errors in minutes.
Mean absolute percent error – The mean absolute error calculation based on percent errors rather than errors in minutes.

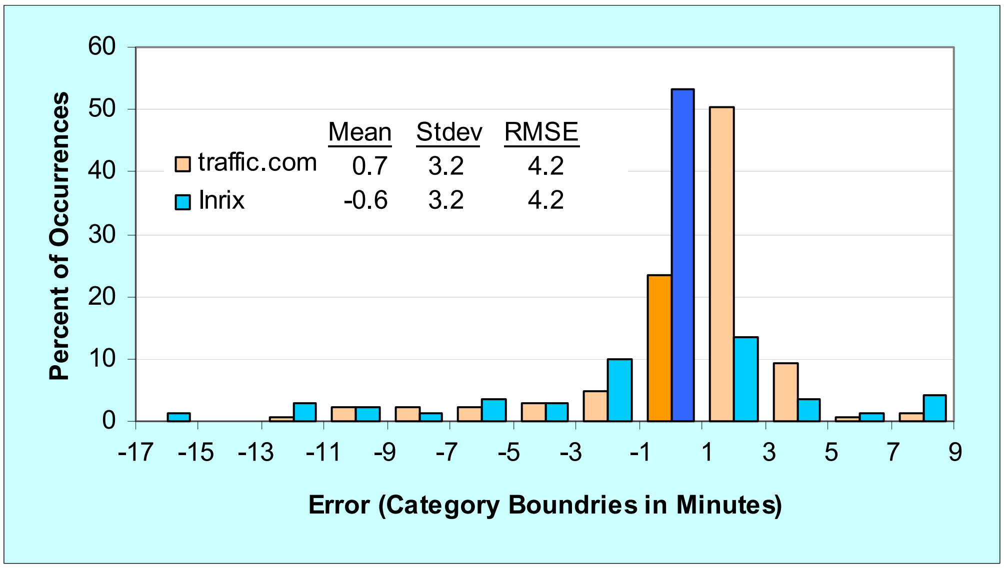
Source: Inrix and Frost & Sullivan

Of the eight measures computed for this study, looking at all 141 trials on 15 routes in three metropolitan areas, Traffic.com comes out ahead on four measures and Inrix comes out ahead on four measures. Thus, neither provider of traffic data can be said to have a clear advantage. From an accuracy standpoint, the two providers are on par with one another.

Chart 3 presents errors – Traffic.com estimates versus GT data and Inrix estimates versus GT data. Data are grouped into two-minute intervals. Inrix has more outcomes in the +/- one-minute category, but has more outliers on both the low and the high ends. Thus, Inrix has a lower mean error, but a higher standard deviation and RMSE in the total dataset.

Chart 3

Comparison of Raw Errors (Total), August 2006

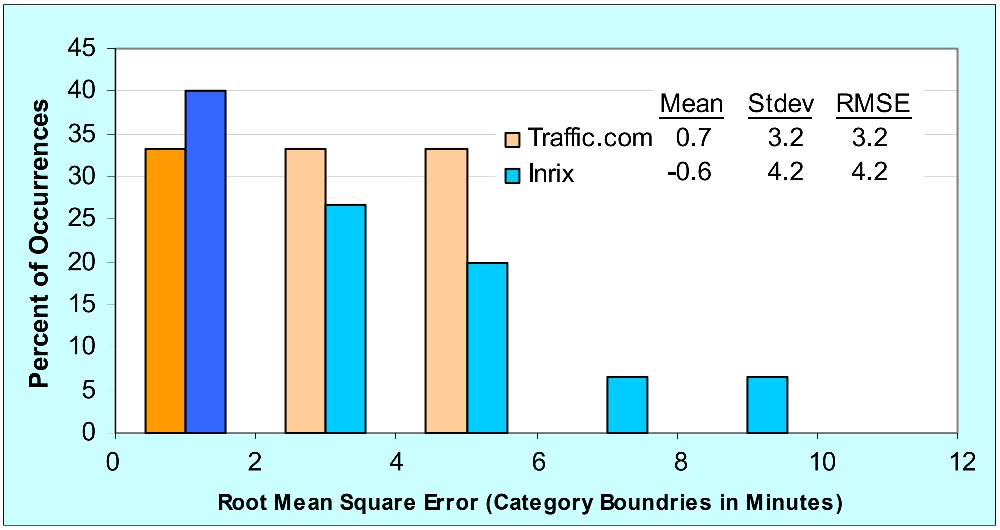


Based on 141 trials on 15 routes. Source: Inrix and Frost & Sullivan

Chart 4 graphs the results in terms of RMSE across all trials in all three metropolitan areas. Inrix has more outcomes in the zero-to-two-minute error group than does Traffic.com, but Inrix also has two outliers – outcomes with RMSEs of more than 6 minutes. These outliers raise measures like standard deviation and RMSE for Inrix.

Chart 4

Comparison of Root Mean Square Errors (Total), August 2006



Based on 141 trials on 15 routes. Source: Inrix and Frost & Sullivan

Neither Traffic.com nor Inrix comes out clearly ahead in these trials. Traffic.com has the better results in Philadelphia and Inrix has the better results in Providence. In Washington, each company comes out ahead on some measures, as is the case when the results are combined across the three metropolitan areas.

Miles of road covered is another key criterion to consider in comparing Traffic.com and Inrix. On this score, Inrix is ahead by far, as detailed below. Thus, being competitive on accuracy and offering greater coverage, Inrix must be regarded as the leading provider of traffic information.

Traffic Coverage

In looking at traffic coverage, there are a number of factors to inspect, including markets covered and number of miles within a market for which speed and flow data are reported.

In looking across the country at specific markets, Inrix has many more markets for both incident data and traffic flow data than Traffic.com. Based upon its partnership with Clear Channel Total Traffic Network, Inrix reports incident data for 135 markets and Traffic.com provides such data for 50 markets across the United States. Inrix currently reports real-time traffic flow data for 43 markets and Traffic.com reports such data for 29 markets. Appendix 2 lists the specific markets covered by Inrix and Traffic.com for incident and flow data.

Figure 2 presents the miles of roadway covered with real-time flows and speed by Traffic.com and by Inrix in the three metropolitan areas under consideration. In each metropolitan area, Inrix covers significantly more miles.

Figure 2

Coverage (Total), August 2006

	Traffic.com (Miles)	Inrix (Miles)
Philadelphia, PA	~276	1,550
Providence, RI	~135	368
Washington, DC	~170	1,537

Source: Inrix

Analysis by Metropolitan Area

Philadelphia, PA

Appendix Figure A1 presents the raw data from the GT trials in Philadelphia. Means, standard deviations, RMSEs, and the other statistics presented in this study were computed from these data.

Figure 3 lists the key routes that were covered in Philadelphia and indicates the RMSEs for Traffic.com and Inrix time estimates across the trials that were run on each route.

Figure 3

Key Routes (Philadelphia), August 2006

Key Route	Length (miles)	Trials (number)	Traffic.com RMSE (min)	Inrix RMSE (min)
I-76/Schuylkill Exwy Eastbound From I-476 Blue Route to I-676 Vine Exwy	12.7	11	3.5	6.0
I-476/Blue Route Southbound From I-76/Schuylkill Exwy to I-95	15.7	12	4.1	4.6
I-76/Schuylkill Exwy Eastbound From I-676 Vine Exwy to Walt Whitman Brg	5.3	9	1.1	1.5
I-76/Schuylkill Exwy Westbound From I-676 Vine Exwy to I-476 Blue Route	12.7	11	4.4	9.0
Overall	**51.5**	**44**	**3.6**	**6.0**

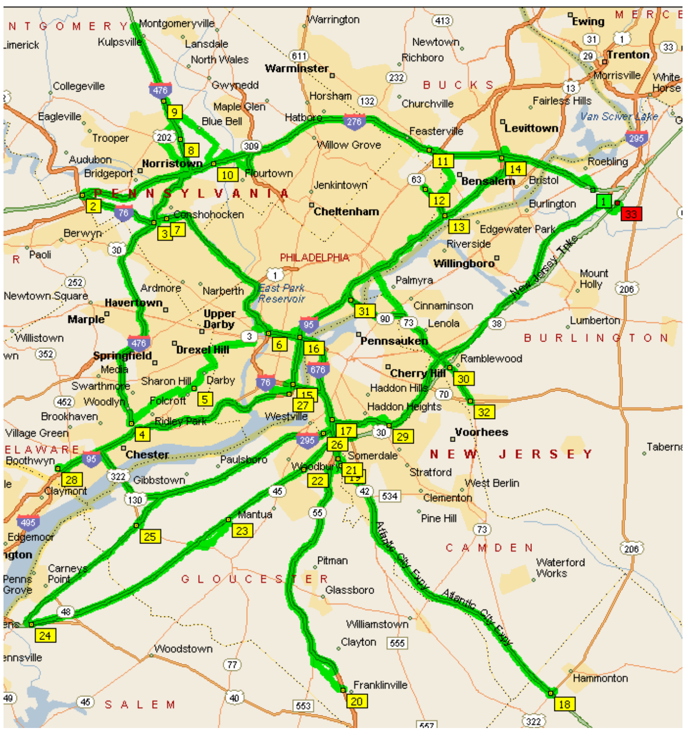
Source: Inrix and Frost & Sullivan

Chart 5 presents maps of the road segments with real-time traffic flow (actual reported speed information) covered by Traffic.com and by Inrix in Philadelphia.

Chart 5

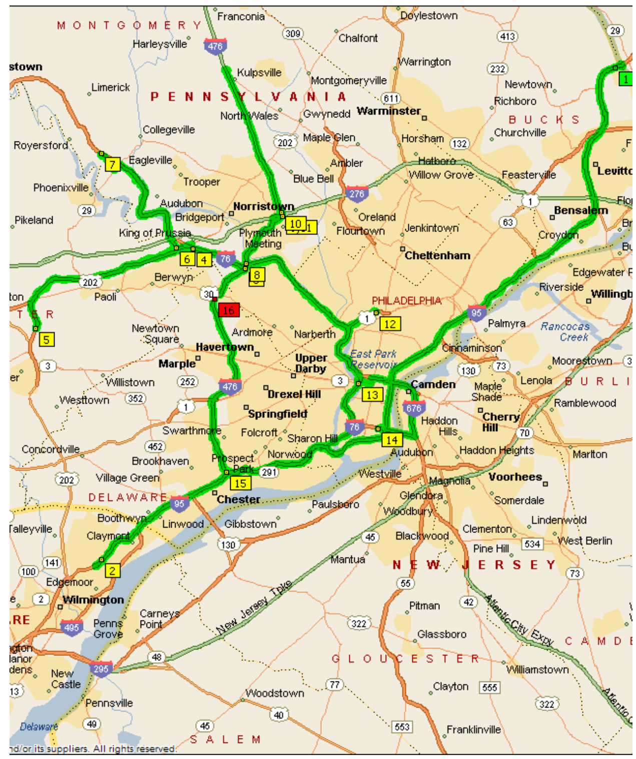
Real-Time Traffic Flow Road Segment Coverage (Philadelphia), August 2006

Inrix



Miles of Road: 1,550

Traffic.com



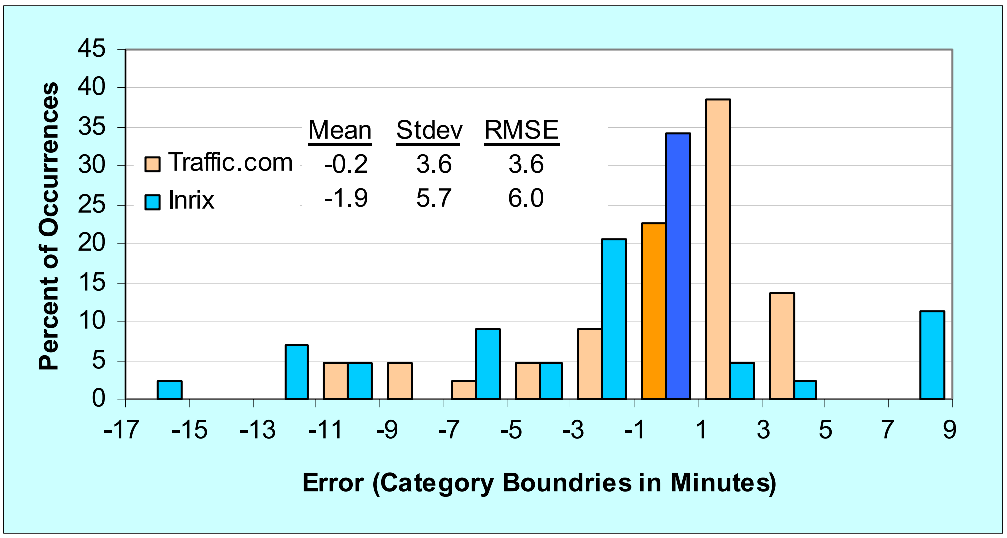
Miles of Road: ~276

Source: Inrix and Traffic.com

Chart 6 graphs the differences between GT and Traffic.com data, and between GT and Inrix data. Traffic.com's average result is essentially exact at -0.2 minutes (with the minus sign indicating an underestimate, on average). Inrix's average result is somewhat poorer, with an underestimate of 1.9 minutes. Inrix is seen to have more results in the +/- one-minute category (essentially no error) than Traffic.com, but Inrix has a number of outliers on both the low and the high ends (underestimates of 11 to 17 minutes and overestimates of 7 to 9 minutes) of the scale. Thus, Inrix's standard deviation and RMSE are higher than Traffic.com's results.

Chart 6

Data Comparison (Philadelphia), August 2006



Based on 44 trials on 5 routes. Source: Inrix and Frost & Sullivan

Traffic.com has the better results in the Philadelphia trials (near the company's headquarters), leveraging the significant public investment in that area that enabled Traffic.com to deploy roadside radar sensors in Philadelphia.

Providence, RI

Appendix Figure A2 presents the raw data from the GT trials in Providence. Means, standard deviations, RMSEs, and other statistics were computed from these data.

Figure 4 lists the key routes that were covered in Providence and indicates the RMSEs for Traffic.com and Inrix time estimates across the trials that were run on each route.

Figure 4

Key Routes (Providence), August 2006

Key Route	Length (miles)	Trials (number)	Traffic.com RMSE (min)	Inrix RMSE (min)
I-95 Northbound From I-295 (#11) to I-195 (#20)	8.9	15	2.8	2.6
I-195 Westbound From Massachusetts State Line to I-95	4.9	6	4.8	3.3
I-295 Northbound From I-95 to RT-6 East (#6A)	7.8	13	1.6	0.9
I-295 Southbound From RT-6 East (#6A) to I-95	8.7	14	1.6	0.9
Overall	**30.3**	**48**	**2.6**	**2.0**

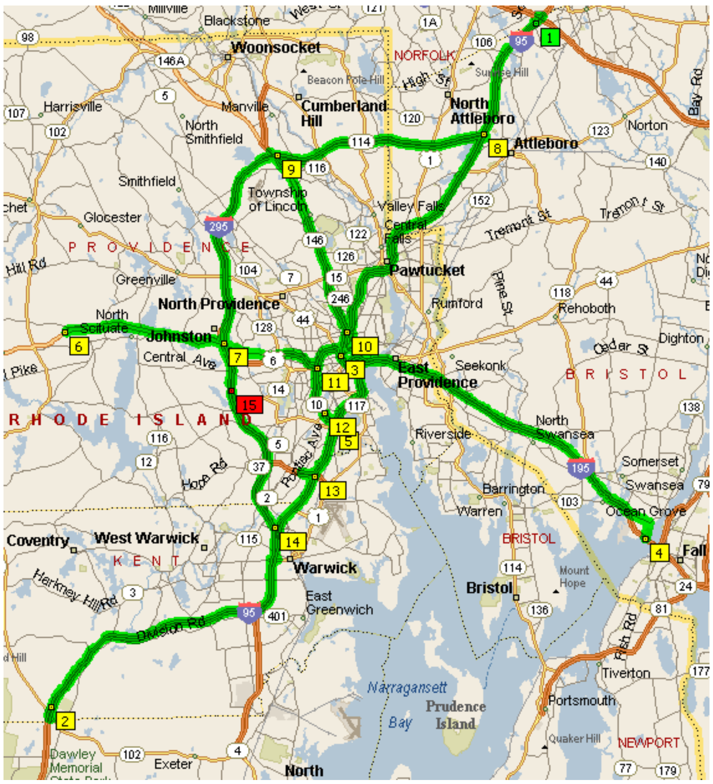
Source: Inrix and Frost & Sullivan

Chart 7 presents maps of the road segments with real-time traffic flow (actual reported speed information) covered by Traffic.com and by Inrix in Providence.

Chart 7

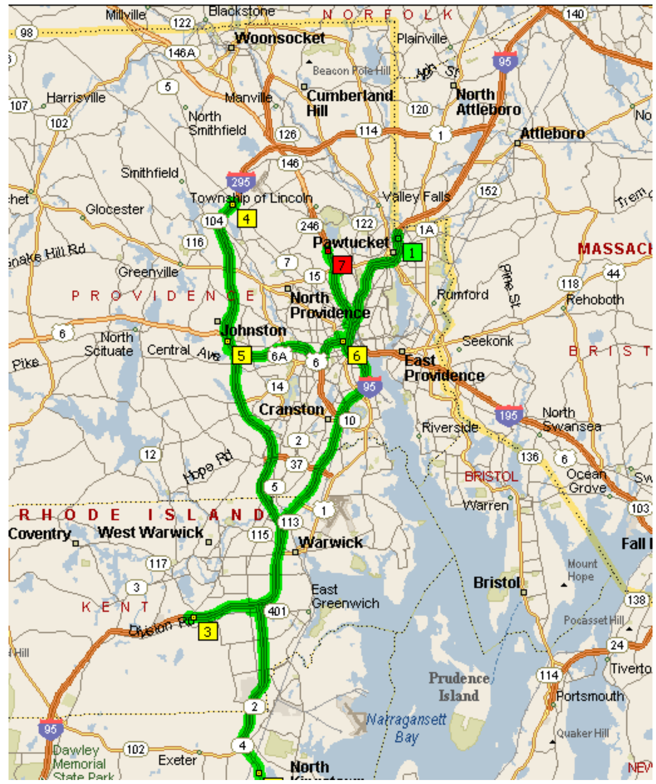
Real-Time Traffic Flow Road Segment Coverage (Providence), August 2006

Inrix



Miles of Road: 368

Traffic.com



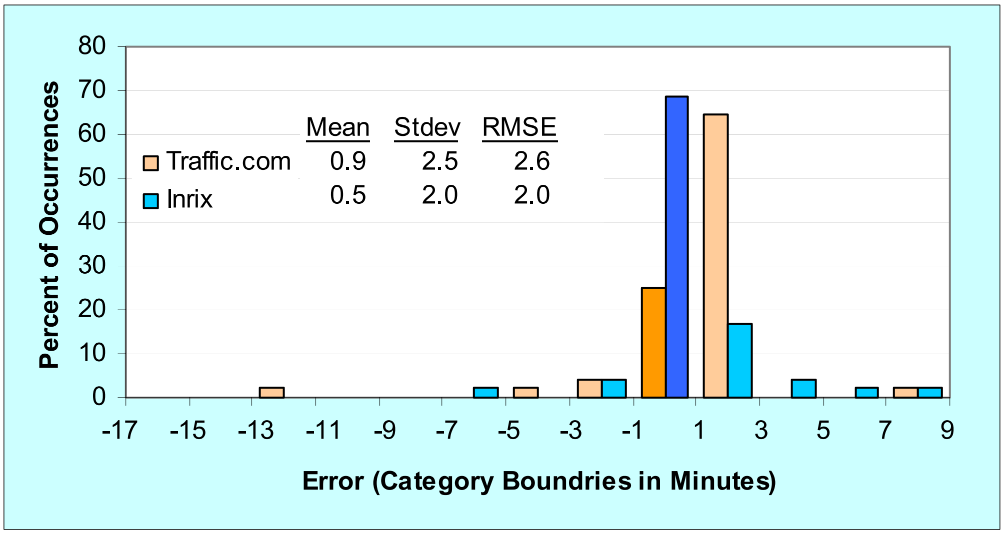
Miles of Road: ~135

Source: Inrix and Traffic.com

Chart 8 graphs the differences between GT and Traffic.com sensor data, and between GT and Inrix sensor data. Inrix comes out ahead on all three of the statistics computed for this metropolitan area – Inrix has the lower mean, standard deviation, and RMSE. Inrix has far more results in the +/- one-minute category. One outlier in the 11 to 13 minute underestimate category hurts Traffic.com's standard deviation and RMSE, but partially offsets the large number of outcomes in the plus one-to-three-minute category.

Chart 8

Data Comparison (Providence), August 2006



Based on 48 trials on 4 routes. Source: Inrix and Frost & Sullivan

Inrix comes out ahead in the Providence trials.

Washington, DC

Appendix Figure A3 presents the raw data from the GT trials in Washington. Means, standard deviations, RMSEs, and other statistics were computed from these data.

Figure 5 lists the key routes that were covered in Washington and indicates the RMSEs for Traffic.com and Inrix time estimates across the trials that were run on each route.

Figure 5

Key Routes (Washington), August 2006

Key Route	Length (miles)	Trials (number)	Traffic.com RMSE (min)	Inrix RMSE (min)
I-66 Eastbound From RT-50/Lee Jackson Hwy (#57) to I-495 Capital Beltway (#64)	6.9	10	3.2	3.3
I-66 Westbound From I-495 Capital Beltway (#64) to RT-50/Lee Jackson Hwy (#57)	7.1	9	2.9	1.8
RT-267 Dulles Toll Rd / Greenway Eastbound From Hunter Mill Rd (#14) to I-66	8.6	6	2.4	2.9
I-495 Capital Beltway Inner Loop From I-95/I-395 to I-66 (#49)	8.7	13	4.1	5.1
I-495 Capital Beltway Inner Loop From I-66 (#49) to American Legion Brg	6.3	7	4.7	6.1
I-495 Capital Beltway Outer Loop From American Legion Brg to I-66 (#49)	6.2	4	1.4	0.5
Overall	**43.8**	**49**	**3.5**	**4.0**

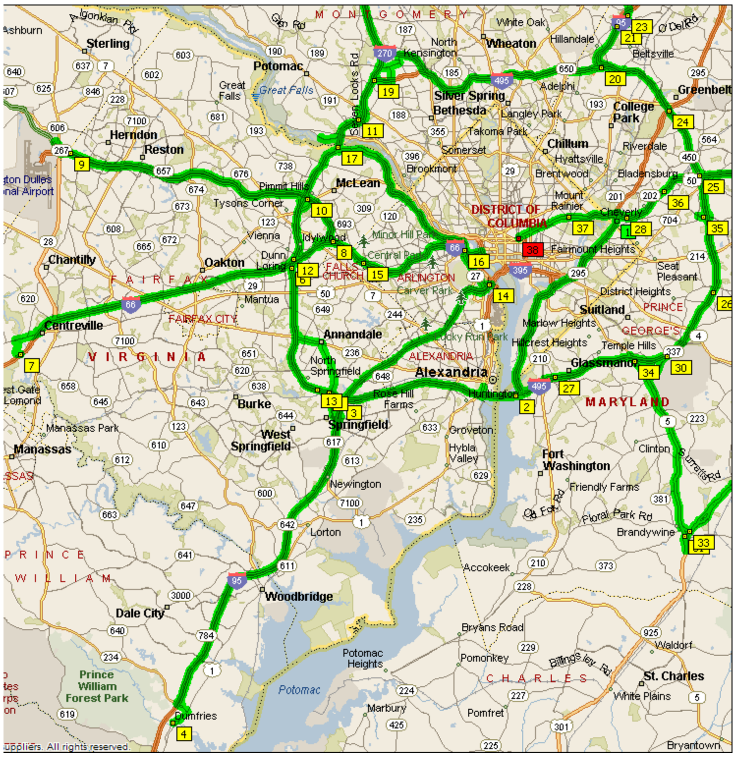
Source: Inrix and Frost & Sullivan

Chart 9 presents maps of the road segments with real-time traffic flow (actual reported speed information) covered by Traffic.com and by Inrix in Washington.

Chart 9

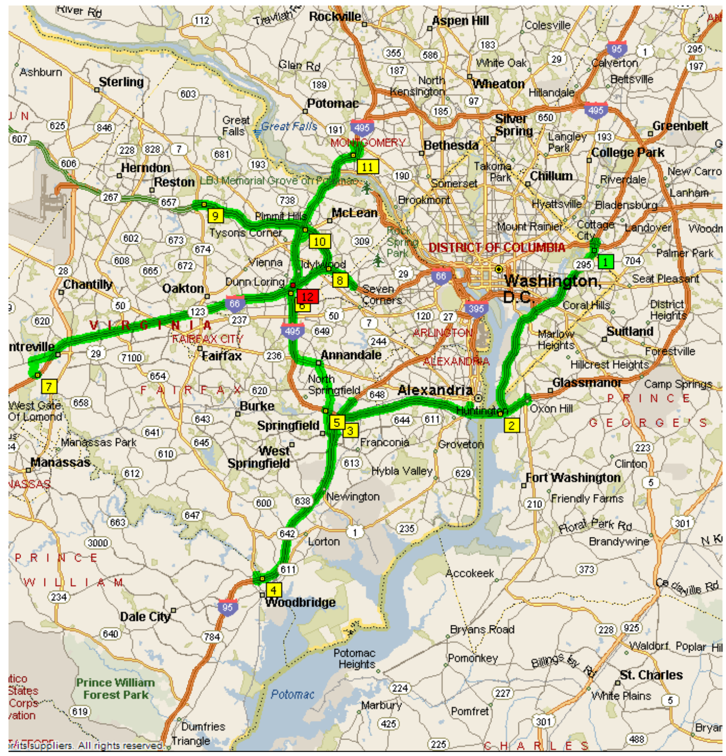
Real-Time Traffic Flow Road Segment Coverage (Washington), August 2006

Inrix



Miles of Road: 1.537

Traffic.com



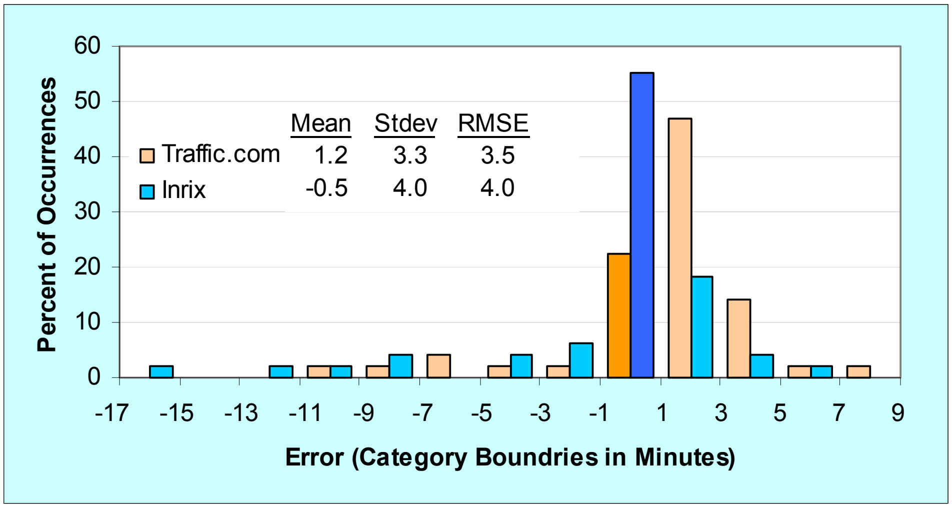
Miles of Road: ~170

Source: Inrix and Traffic.com

Chart 10 graphs the differences between GT and Traffic.com sensor data, and between GT and Inrix sensor data. Inrix's average error is less than Traffic.com's average error. However, Traffic.com's results have a lower standard deviation and a lower RMSE than do Inrix's results. Inrix has substantially more results in the +/- one-minute category, but two outliers in the -11 to -17 minute range spoil its standard deviation and RMSE statistics.

Chart 10

Data Comparison (Washington), August 2006



Based on 49 trials on 6 routes. Source: Inrix and Frost & Sullivan

There is no clear "winner" in this set of trials.

CONCLUSION

The goal of this study has been to evaluate the traffic services of both Inrix and Traffic.com with respect to data accuracy, breadth of coverage within specific metropolitan markets, and nationwide coverage footprints.

Through this independent comparative study of traffic service offerings, we have discovered that data generated from the Inrix Smart Dust Network, including data from a large number of GPS-enabled probe vehicles, on balance has on-par accuracy, and in some cases superior accuracy, compared with the current state-of-the-art static sensor networks.

The GPS-enabled probe vehicles leveraged by Inrix provide superior traffic flow coverage in terms of both miles of road covered within the markets evaluated in this study, and the nationwide footprint of markets in the United States currently live with real-time traffic flow information. Within the three markets chosen as the focus of this study, Inrix covers a total of 3,450 miles while Traffic.com covers a total of about 600 miles. Nationwide, Inrix covers 43 markets with real-time traffic flow information, while Traffic.com covers 29 markets with such information.

Given the quantitative results of this limited study, Frost & Sullivan judges Inrix to currently be the leading provider of real-time traffic information in the United States, and that the Inrix Smart Dust Network provides the first truly scalable approach to providing ubiquitous, high-quality, real-time traffic information in the United States.

Appendix 1 – Raw Data

Raw data on which this study's analysis is based appear in the following figures.

Figure A1

Data Comparison (Philadelphia), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-76/Schuylkill Exwy Eastbound From I-476 Blue Route to I-676 Vine Exwy					
8/22/2006 12:56	15.9	19.0	15.0	3.1	-0.9
8/22/2006 16:10	21.8	15.0	12.0	-6.8	-9.8
8/22/2006 17:04	13.4	16.0	17.0	2.6	3.6
8/22/2006 19:24	16.2	16.0	16.0	-0.1	-0.1
8/22/2006 20:32	16.8	16.0	12.0	-0.8	-4.8
8/23/2006 12:23	20.9	21.0	28.0	0.1	7.1
8/23/2006 13:36	24.6	17.0	12.0	-7.6	-12.6
8/23/2006 14:30	13.8	16.0	12.0	2.2	-1.8
8/23/2006 15:54	14.1	16.0	14.0	1.9	-0.1
8/23/2006 19:34	17.8	16.0	13.0	-1.8	-4.8
8/23/2006 21:55	17.1	16.0	12.0	-1.1	-5.1
I-76/Schuylkill Exwy Eastbound From PA Tpk Toll Plaza to I-476 Blue Route *					
8/22/2006 14:11	5.0	6.0	5.0	1.0	0.0

(continued)

Figure A1 (continued)

Data Comparison (Philadelphia), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-476/Blue Route Southbound From I-76/Schuylkill Exwy to I-95					
8/22/2006 11:26	15.0	17.0	15.0	2.0	0.0
8/22/2006 12:47	15.3	17.0	15.0	1.7	-0.3
8/22/2006 13:46	27.6	17.0	15.0	-10.6	-12.6
8/22/2006 15:14	14.6	18.0	16.0	3.4	1.4
8/22/2006 17:51	14.2	17.0	22.0	2.8	7.8
8/22/2006 19:16	20.3	23.0	15.0	2.7	-5.3
8/22/2006 21:33	14.0	17.0	14.0	3.0	0.0
8/23/2006 11:26	16.3	18.0	14.0	1.7	-2.3
8/23/2006 12:37	14.4	18.0	15.0	3.6	0.6
8/23/2006 13:19	14.2	18.0	15.0	3.8	0.8
8/23/2006 14:35	15.9	17.0	15.0	1.2	-0.9
8/23/2006 16:40	13.7	17.0	15.0	3.3	1.3
I-76/Schuylkill Exwy Eastbound From I-676 Vine Exwy to Walt Whitman Brg					
8/22/2006 14:42	6.2	7.0	5.0	0.8	-1.2
8/22/2006 16:32	5.6	7.0	5.0	1.4	-0.6
8/22/2006 17:18	5.5	7.0	5.0	1.6	-0.5
8/22/2006 19:41	7.8	7.0	5.0	-0.8	-2.8
8/22/2006 20:48	6.6	7.0	5.0	0.4	-1.6
8/23/2006 12:44	5.6	7.0	5.0	1.4	-0.6
8/23/2006 16:08	5.7	7.0	5.0	1.3	-0.7
8/23/2006 19:52	7.9	9.0	6.0	1.1	-1.9
8/23/2006 20:57	7.2	8.0	5.0	0.8	-2.2

(continued)

Figure A1 (continued)

Data Comparison (Philadelphia), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-76/Schuylkill Exwy Westbound From I-676 Vine Exwy to I-476 Blue Route					
8/22/2006 12:24	21.9	20.0	29.0	-1.9	7.1
8/22/2006 13:28	17.5	16.0	12.0	-1.5	-5.5
8/22/2006 14:59	14.2	15.0	12.0	0.8	-2.2
8/22/2006 17:32	19.0	18.0	12.0	-0.9	-7.0
8/22/2006 19:56	31.0	24.0	14.0	-7.0	-17.0
8/22/2006 21:06	25.4	21.0	13.0	-4.4	-12.4
8/23/2006 12:59	19.6	20.0	30.0	0.4	10.4
8/23/2006 14:21	13.5	15.0	23.0	1.5	9.5
8/23/2006 16:26	13.0	14.0	12.0	1.0	-1.0
8/23/2006 20:11	29.9	19.0	27.0	-10.9	-2.9
8/23/2006 21:13	22.3	18.0	12.0	-4.3	-10.3

* The driver only followed the prescribed route correctly on one trial on this route.

Source: Inrix and Frost & Sullivan

Figure A2

Data Comparison (Providence), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-95 Northbound From I-295 (#11) to I-195 (#20)					
8/21/2006 11:23	8.8	10.0	8.0	1.2	-0.8
8/21/2006 12:55	8.5	10.0	8.0	1.6	-0.4
8/21/2006 14:21	9.0	10.0	9.0	1.0	0.0
8/21/2006 19:30	9.4	10.0	9.0	0.6	-0.4
8/21/2006 20:55	8.6	10.0	8.0	1.4	-0.6
8/21/2006 22:24	7.7	10.0	8.0	2.3	0.3
8/22/2006 11:18	8.8	17.0	8.0	8.2	-0.8
8/22/2006 12:38	16.0	11.0	10.0	-5.0	-6.0
8/22/2006 14:07	8.1	10.0	10.0	2.0	2.0
8/22/2006 17:42	10.2	10.0	10.0	-0.2	-0.2
8/22/2006 18:58	8.4	10.0	11.0	1.7	2.7
8/25/2006 11:18	8.6	10.0	9.0	1.4	0.4
8/25/2006 12:58	8.5	10.0	9.0	1.5	0.5
8/25/2006 14:06	8.1	10.0	10.0	1.9	1.9
8/25/2006 18:21	10.9	11.0	18.0	0.1	7.1
I-195 Westbound From Massachusetts State Line to I-95					
8/22/2006 12:00	8.0	6.0	12.0	-2.0	4.0
8/22/2006 13:33	5.7	5.0	6.0	-0.7	0.3
8/22/2006 18:21	8.4	8.0	14.0	-0.4	5.6
8/22/2006 19:36	5.2	5.0	5.0	-0.2	-0.2
8/25/2006 14:49	9.4	9.0	13.0	-0.4	3.6
8/25/2006 19:11	20.6	9.0	23.0	-11.6	2.4

(continued)

Figure A2 (continued)

Data Comparison (Providence), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-295 Northbound From I-95 to RT-6 East (#6A)					
8/21/2006 12:29	7.9	9.0	7.0	1.1	-0.9
8/21/2006 13:55	7.2	9.0	8.0	1.8	0.8
8/21/2006 19:08	6.8	9.0	7.0	2.2	0.2
8/21/2006 20:35	7.8	9.0	7.0	1.2	-0.8
8/21/2006 22:03	7.8	9.0	7.0	1.2	-0.8
8/22/2006 10:59	7.2	9.0	7.0	1.8	-0.2
8/22/2006 12:17	7.8	9.0	10.0	1.2	2.2
8/22/2006 13:48	6.9	9.0	8.0	2.1	1.1
8/22/2006 18:38	7.1	9.0	7.0	1.9	-0.1
8/22/2006 19:50	7.9	9.0	7.0	1.2	-0.9
8/25/2006 10:59	7.4	9.0	7.0	1.6	-0.4
8/25/2006 13:42	7.0	9.0	7.0	2.1	0.0
8/25/2006 18:01	7.0	7.0	8.0	0.0	1.0
I-295 Southbound From RT-6 East (#6A) to I-95					
8/21/2006 12:41	8.4	10.0	8.0	1.6	-0.4
8/21/2006 14:07	10.1	9.0	8.0	-1.1	-2.1
8/21/2006 19:16	8.9	9.0	8.0	0.1	-0.9
8/21/2006 20:45	7.8	9.0	8.0	1.2	0.2
8/21/2006 22:13	7.5	9.0	8.0	1.5	0.5
8/22/2006 11:09	7.7	10.0	8.0	2.4	0.4
8/22/2006 12:27	7.8	10.0	8.0	2.2	0.2
8/22/2006 13:57	7.4	9.0	9.0	1.6	1.6
8/22/2006 18:48	7.5	9.0	9.0	1.5	1.5
8/22/2006 20:03	9.1	9.0	8.0	-0.1	-1.1
8/25/2006 11:09	7.3	10.0	8.0	2.7	0.7
8/25/2006 12:20	8.4	10.0	8.0	1.6	-0.4
8/25/2006 13:54	8.1	9.0	8.0	0.9	-0.1
8/25/2006 20:01	8.1	10.0	8.0	1.9	-0.1

Source: Inrix and Frost & Sullivan

Figure A3

Data Comparison (Washington), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-66 Eastbound From RT-50/Lee Jackson Hwy (#57) to I-495 Capital Beltway (#64)					
8/24/2006 13:46	6.4	12.0	6.0	5.6	-0.4
8/24/2006 13:46	7.4	12.0	6.0	4.6	-1.4
8/24/2006 18:07	5.9	8.0	6.0	2.1	0.1
8/24/2006 19:19	5.9	8.0	6.0	2.1	0.1
8/24/2006 20:16	15.5	10.0	6.0	-5.5	-9.5
8/25/2006 11:13	6.0	8.0	8.0	2.0	2.0
8/25/2006 14:16	6.3	8.0	7.0	1.7	0.7
8/25/2006 16:03	6.3	8.0	8.0	1.7	1.7
8/25/2006 18:43	7.1	8.0	10.0	0.9	2.9
8/25/2006 20:46	6.3	8.0	6.0	1.7	-0.3
I-66 Westbound From I-495 Capital Beltway (#64) to RT-50/Lee Jackson Hwy (#57)					
8/24/2006 13:25	6.4	8.0	7.0	1.7	0.7
8/24/2006 13:37	6.6	8.0	7.0	1.4	0.4
8/24/2006 19:07	10.7	19.0	15.0	8.3	4.3
8/24/2006 20:07	7.5	8.0	9.0	0.6	1.6
8/24/2006 21:40	6.7	8.0	7.0	1.3	0.3
8/25/2006 12:22	6.5	7.0	7.0	0.5	0.5
8/25/2006 14:08	6.6	7.0	9.0	0.4	2.4
8/25/2006 15:40	6.5	7.0	6.0	0.5	-0.5
8/25/2006 20:37	7.2	8.0	6.0	0.8	-1.2
RT-267 Dulles Toll Rd / Greenway Eastbound From Hunter Mill Rd (#14) to I-66					
8/24/2006 13:17	9.9	11.0	9.0	1.1	-0.9
8/24/2006 14:40	8.4	11.0	9.0	2.7	0.7
8/24/2006 18:50	8.2	11.0	15.0	2.8	6.8
8/25/2006 13:46	8.3	11.0	9.0	2.7	0.7
8/25/2006 15:10	8.8	11.0	8.0	2.2	-0.8
8/25/2006 20:09	8.3	11.0	9.0	2.7	0.7

(continued)

Figure A3 (continued)

Data Comparison (Washington), August 2006

Start Time in UTC	Ground Truth Driver Travel Time (min)	Traffic.Com Travel Time (min)	Inrix Travel Time (min)	Traffic.com error (min)	Inrix error (min)
I-495 Capital Beltway Inner Loop From I-95/I-395 to I-66 (#49)					
8/24/2006 12:02	24.9	16.0	9.0	-8.9	-15.9
8/24/2006 14:08	7.4	10.0	8.0	2.6	0.6
8/24/2006 16:33	6.4	11.0	8.0	4.6	1.6
8/24/2006 18:29	7.5	11.0	8.0	3.5	0.5
8/24/2006 18:48	6.4	11.0	8.0	4.6	1.6
8/24/2006 19:41	17.2	14.0	9.0	-3.2	-8.2
8/25/2006 11:35	11.0	10.0	8.0	-1.0	-3.0
8/25/2006 13:10	7.0	11.0	8.0	4.1	1.1
8/25/2006 14:38	8.1	12.0	8.0	3.9	-0.1
8/25/2006 15:33	6.4	10.0	8.0	3.7	1.7
8/25/2006 16:49	7.3	10.0	8.0	2.7	0.7
8/25/2006 18:48	7.1	10.0	8.0	2.9	0.9
8/25/2006 21:08	7.4	10.0	8.0	2.6	0.6
I-495 Capital Beltway Inner Loop From I-66 (#49) to American Legion Brg					
8/24/2006 12:27	9.3	9.0	6.0	-0.3	-3.3
8/24/2006 14:16	6.6	8.0	6.0	1.4	-0.6
8/25/2006 11:46	7.3	8.0	12.0	0.7	4.7
8/25/2006 13:17	7.6	8.0	6.0	0.4	-1.6
8/25/2006 14:46	6.1	8.0	6.0	1.9	-0.1
8/25/2006 16:56	18.7	8.0	6.0	-10.7	-12.7
8/25/2006 18:55	13.9	8.0	6.0	-5.9	-7.9
I-495 Capital Beltway Outer Loop From American Legion Brg to I-66 (#49)					
8/24/2006 11:39	6.2	7.0	6.0	0.8	-0.2
8/24/2006 13:19	6.0	7.0	6.0	1.0	0.0
8/24/2006 15:52	5.3	7.0	6.0	1.8	0.8
8/25/2006 14:57	5.3	7.0	6.0	1.7	0.7

Source: Inrix and Frost & Sullivan

Appendix 2 – Markets Covered

Specific U.S. markets[1] covered by Inrix and Traffic.com for Incident data (i.e., reporting of accidents, construction, and road events) and traffic flow data (i.e., the relative or absolute speed of transportation on segments of roadway) are listed below:

Figure A2-1

Provision of Incident Data by Inrix and Traffic.com (United States), August 2006

Inrix (135)				**Traffic.com (50)**	
Akron, OH Albany, NY Albuquerque, NM Alexandria, LA Allentown, PA Anchorage, AK Asheville, NC Ashtabula, OH Atlanta, GA Augusta, GA Austin, TX Bakersfield, CA Baltimore, MD Battle Creek, MI Biloxi-Gulfport, MS Binghamton, NY Birmingham, AL Bismarck, ND Boston, MA Buffalo-Niagara Falls, NY Burlington, VT Casper, WY Charleston, SC Charlotte, NC Chattanooga, TN Cheyenne, WY Chicago-Gary, IL Cincinnati, OH Cleveland-Akron, OH Colorado Springs, CO Columbia, SC Columbus, OH Dallas-Ft. Worth, TX Dayton, OH	Defiance-Napoleon, OH Denver-Boulder, CO Des Moines, IA Detroit-Flint, MI El Paso, TX Eugene-Springfield, OR Fairbanks, AK Fargo-Moorhead, ND-MN Findlay-Tiffin, OH Frederick, MD Fresno, CA Ft. Collins, CO Ft. Myers, FL Grand Forks, ND-MN Grand Rapids, MI Greensboro-Winston-Salem, NC Greenville, SC Harrisburg, PA Hartford, CT Honolulu, HI Houston-Galveston, TX Huntsville, AL Indianapolis, IN Jackson, MS Jacksonville, FL Kansas City, MO Lancaster, PA Laramie, WY Las Vegas, NV Lebanon, NH Lexington, KY Lima, OH Lincoln, NE Little Rock, AR Los Angeles Metro, CA	Louisville, KY Madison, WI Manchester, NH Melbourne, FL Memphis, TN Miami-Ft. Lauderdale, FL Milwaukee, WI Minneapolis-St. Paul, MN Minot, ND Mobile, AL Modesto, CA Monterey, CA Muskegon, MI Nashville, TN Nassau-Suffolk, NY New Haven, CT New Orleans, LA New York Metro (NY, NJ) Newburgh, NY Norfolk-Va Beach-Newport News, VA Oklahoma City, OK Omaha, NE Orlando, FL Parkersburg, WV Pensacola, FL Philadelphia, PA Phoenix-Mesa, AZ Pittsburgh, PA Portland-Salem, OR Portsmouth, NH Poughkeepsie, NY Providence, RI Raleigh-Durham, NC	Reading, PA Richmond-Petersburg, VA Rochester, MN Rochester, NY Sacramento, CA Salt Lake City, UT San Antonio, TX San Diego, CA San Francisco Metro, CA Sandusky, OH Santa Barbara, CA Sarasota, FL Savannah, GA Seattle-Tacoma, WA Spokane, WA Springfield, MA St. Louis, MO Stockton, CA Sussex, NJ Syracuse, NY Tampa-St. Pete, FL Toledo, OH Tucson, AZ Tulsa, OK Utica-Rome, NY Victor Valley, CA Visalia-Tulare, CA Washington, DC West Palm Beach, FL Wheeling, WV Wichita, KS Wilmington, DE Worcester, MA Youngstown, OH Yuma, AZ	Albany, NY Atlanta, GA Austin, TX Baltimore, MD Birmingham, AL Boston, MA Charlotte, NC Chicago-Gary, IL Cincinnati, OH Cleveland-Akron, OH Columbus, OH Dallas-Ft. Worth, TX Denver-Boulder, CO Detroit-Flint, MI Greensboro-Winston-Salem, NC Hartford, CT Houston-Galveston, TX Indianapolis, IN Jacksonville, FL Kansas City, MO Las Vegas, NV Los Angeles Metro, CA Louisville, KY Miami-Ft. Lauderdale, FL Milwaukee, WI	Minneapolis-St. Paul, MN Nashville, TN New Orleans, LA New York Metropolitan Area (NY, NJ) Norfolk-Via Beach-Newport News, VA Oklahoma City, OK Orlando, FL Philadelphia, PA Phoenix-Mesa, AZ Pittsburgh, PA Portland-Salem, OR Providence, RI Raleigh-Durham-Chapel Hill, NC Richmond-Petersburg, VA Sacramento, CA Salt Lake City, UT San Antonio, TX San Diego, CA San Francisco Metropolitan Area, CA Seattle-Tacoma, WA St. Louis, MO Tampa-St. Pete, FL Tucson, AZ Tulsa, OK Washington, DC

Source: Inrix and Traffic.com

[1] Markets are classified by Core Based Statistical Area (CBSA), the primary unit of metropolitan classification used by the US Census bureau

Figure A2-2

Provision of Flow Data by Inrix and Traffic.com (United States), August 2006

Inrix (43)		**Traffic.com (29)**	
Atlanta, GA	New York Metro (NY, NJ)	Atlanta, GA	Pittsburgh, PA
Austin, TX	Norfolk-Va Beach, VA	Baltimore, MD	Providence, RI
Baltimore, MD	Orlando, FL	Boston, MA	Riverside, CA
Boston, MA	Oxnard-Thousand Oaks, CA	Chicago-Gary, IL	Sacramento, CA
Chicago-Gary, IL	Philadelphia, PA	Denver-Boulder, CO	Salt Lake City, UT
Columbus, OH	Phoenix-Mesa, AZ	Detroit, MI	San Diego, CA
Dallas-Ft. Worth, TX	Portland-Salem, OR	Flint, MI	San Francisco Metro, CA
Denver-Boulder, CO	Providence, RI	Houston, TX	San Jose, CA
Detroit, MI	Richmond-Petersburg, VA	Los Angeles Metro Area, CA	Santa Rosa, CA
Flint, MI	Riverside, CA	Milwaukee, WI	Seattle-Tacoma, WA
Grand Rapids, MI	Sacramento, CA	Minneapolis-St. Paul, MN	St. Louis, MO
Hartford, CT	Salt Lake City, UT	New York Metro Area (NY, NJ)	Tampa-St. Pete, FL
Houston, TX	San Antonio, TX	Oklahoma City, OK	Vallejo, CA
Indianapolis, IN	San Diego, CA	Philadelphia, PA	Washington, DC
Jacksonville, FL	San Francisco Metro, CA	Phoenix-Mesa, AZ	
Las Vegas, NV	San Jose, CA		
Los Angeles Metro, CA	Santa Rosa, CA		
Louisville, KY	Seattle-Tacoma, WA		
Miami-Ft. Lauderdale, FL	Tampa-St. Pete, FL		
Milwaukee, WI	Vallejo, CA		
Minneapolis-St. Paul, MN	Washington, DC		
	West Palm Beach, FL		

Source: Inrix and Traffic.com

Appendix 3 – Additional Metropolitan Areas

Figure A3-1 presents a summary of Inrix data for eleven additional metropolitan areas. These data, based on the same methodology as the Philadelphia, Providence, and Washington data presented above, were provided by Inrix, but have not been validated by Frost & Sullivan. They are computed in terms of speed (miles per hour) rather than travel time, and are available only for Inrix, not Traffic.com. Data are presented as 100 minus root mean square percent error (making these numbers indications of accuracy rather than indications of error), and as root mean square errors in miles per hour.

Figure A3-1

Data Comparison (U.S.), August 2006

Metropolitan Area	100-RMSPE (%) (miles per hour)	RMSE (miles per hour)	Urban Area Real-Time Flow Coverage (miles)
Atlanta	73.2	14.0	305
Baltimore	82.2	12.7	635
Los Angeles / Orange County	80.7	11.6	
Los Angeles / San Bernadino / Riverside	76.8	14.6	
Los Angeles / Total			1,306
Miami	72.9	16.1	514
Minneapolis / St. Paul	72.8	10.7	418
Phoenix	75.9	14.6	167
Sacramento	81.9	11.0	125
San Diego	84.9	10.0	587
Seattle	75.7	12.0	917
Tampa	77.7	14.1	616
Memo: Philadelphia	70.3	---	1,550
Providence	79.4	---	368
Washington	70.5	---	1,537

Key: 100-RMSPE = 100 minus the root mean square percent error
RMSE = root mean square error

Source: Inrix

The memo item presents results from the present study, converted from RMSPE to 100 minus RMSPE for comparison to the other data presented. The additional data are seen to be somewhat more accurate, on balance, than the data computed for Philadelphia, Providence, and Washington.

Appendix 4 – Definitions

Certain terms used in this study are defined below.

- Difference – Error (discrepancy between sensor/ probe data and ground truth data).

- Global positioning system (GPS) – A network of satellites that allows ground-based observers to determine their locations with substantial precision.

- Ground truth (GT) – Results from actual on-the-road driving trials.

- Key route – Major route for which traffic flow information is provided.

- Mean – Average.

- Root mean square error (RMSE) – A measure of average error that gives greater weight to outliers than does mean absolute error. RMSE is computed as the square root of the average of the squared errors (differences).

- Standard deviation – A measure of how "spread out" the values in a dataset are. In a normal distribution, about two-thirds of observations are within one standard deviation of the mean.

- Universal time, coordinated (UTC) – Also called Greenwich Mean Time (GMT), because this is the time that applies on the prime meridian (0 degrees latitude), which runs through Greenwich, England. UTC is five hours ahead of Eastern Standard Time and four hours ahead of Eastern Daylight Time.

Appendix 5 – Hardware and Vehicles Used

Specifics on the data capture devices used in ground truth testing are:

• Hardware:

o HP Ipaq Pocket PC

o Pharos GPS device

• Software:

o Windows 2003 SE

o GPS Tuner from Megalith (www.gpstuner.com)

The following vehicles were used in ground truth testing:

- Philadelphia, Pennsylvania
  - 1996 Toyota Camry
  - 1997 BMW 328 IS
  - 2002 Chevy pickup
- Providence, Rhode Island
  - 2002 Chrysler PT Cruiser
- Washington, DC
  - 2002 Pontiac Grand Prix
  - 1994 Nissan Sentra