

**White Paper – I-95 Corridor Coalition
Vehicle Probe Project
Confidence Value and Smoothing
April 2010**

Background

The Vehicle Probe Project is a groundbreaking initiative among public, private and academia. Real-time data is provided to the seven contiguous states from New Jersey to South Carolina. In addition, a continuous, comprehensive data validation program is in place to ascertain data quality on a monthly basis. To date, more than 15,000 hours of validation data, gathered in 17 monthly tests across six states by the University of Maryland have determined that the speed/travel time data INRIX provides in the Vehicle Probe Project meets the contract specifications for accuracy.

This paper summarizes two new techniques or tools that have been developed by the Coalition, University of Maryland (UMD) and INRIX that are now available to coalition member agencies to identify and minimize the impact of random errors that can occur in the INRIX data. INRIX has developed a new “C-Value” metric to assist in the assessment of data quality and the UMD has developed a smoothing algorithm to minimize the impacts of random data errors. Using either one, or both in tandem, are possibilities. *These tools are optional and targeted to those using the data in automated real-time applications – either/both can be implemented as part of application/TMC software.*

Action will be required by agencies to utilize these new tools – this paper highlights the issues being addressed, the tools developed, and how they might be used separately or in tandem by agencies.

Data Quality Measures

The vehicle probe data acquired by the I-95 Corridor Coalition from the INRIX Corporation is intended to provide samples of travel time and speeds as frequently as every minute along selected roadways within the I-95 corridor. The accuracy of this data is continuously validated by the University of Maryland (UMD) to verify that it correctly reflects travel conditions along these roadways. The UMD validation is conducted to verify that the INRIX data satisfies the following contractual requirements:

- 1) Average Absolute Speed Error (AASE): Speed data shall have a maximum average absolute error of 10 mph in each of the following speed ranges: 0-30 mph, 30-45 mph, 45-60 mph and >60 mph. This is the primary accuracy metric, measuring the average deviation from ground truth.
- 2) Speed Error Bias (SEB): Speed data shall have a maximum error of +/- 5 mph in each of the same speed ranges as those that are specified for the average absolute speed error. The SEB indicates whether the speed data provided from the project is consistently higher or lower than ground truth.

These specifications have served the Coalition well. They have provided its members with confidence that the INRIX data is of adequate accuracy for use in a variety of applications. It is important to recognize however, that both the AASE and the SEB are long term averages of the data that is collected during the evaluation period. As such, they do not capture significant short term deviations that might be present in the INRIX data. These types of errors could be the result of anomalies such as data captured from a vehicle whose speed is not representative of the overall traffic stream.

Figure 1 below provides an example of a short term deviation of this nature. In this figure, the blue plot is the mean of the speed recorded by the Bluetooth validation equipment. The red and yellow lines are the INRIX data with and without smoothing (explained below) respectively. The data highlighted by the oval is a period during which the INRIX data unexpectedly deviates from the Bluetooth data; the latter of which has been shown to be an accurate representation of “ground-truth”. During this period of time, the INRIX data is indicating speeds between 60 mph and 70+ mph, while the Bluetooth speeds for the same time period are between 45 mph and 55mph. These are significant differences since they represent speed errors of approximately 30%, with corresponding travel time errors greater than 20%. Thus if one were to use this particular INRIX data to post DMS travel times on a roadway segment for which the normal travel time is 15 minutes, the posted travel time would be in error by 3 minutes (20% of 15 minutes).

Coalition members will have to determine for themselves whether errors of this magnitude are adequate to justify the modest investments in additional processing described by this paper.

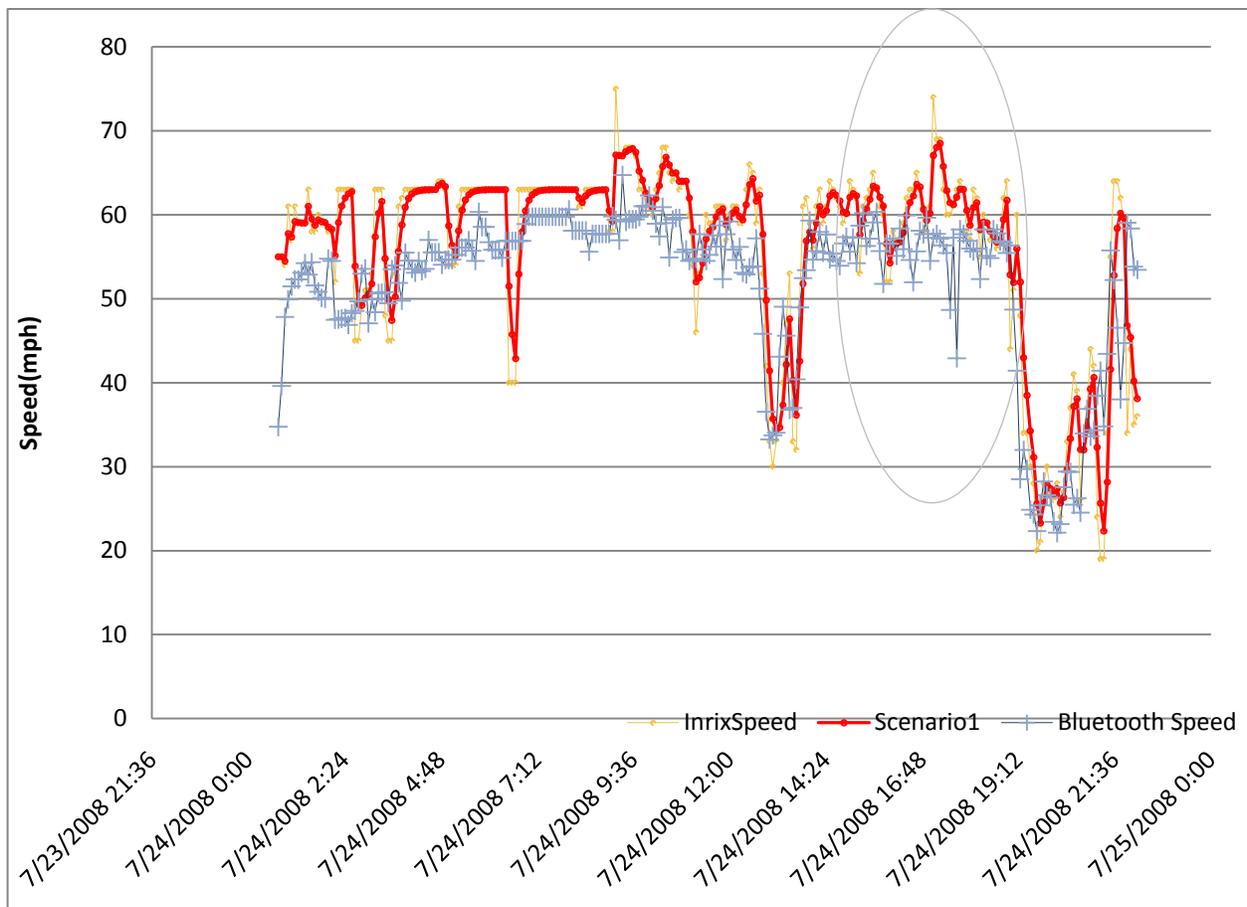


Figure 1. Representative Plot Showing Sudden Deviation in Speed Data

Purpose of this Paper

The purpose of this paper is to present two new techniques that have been developed by the Coalition, UMD and INRIX that are now available to coalition member agencies to assess data quality and deal with random deviations that can occur in the INRIX data.

Two complimentary techniques have been developed that offer the potential to reduce the impact of short term deviations. The first technique, developed by INRIX is based on a continuous self-analysis of the data quality that produces a numerical score called a **Confidence Value**.

The second technique that was developed is based on the use of a **smoothing equation**. The purpose of the smoothing equation is to eliminate sudden changes in the data.

These two techniques are complimentary in that the Confidence Value provides users with the ability to “turn off” the data stream if its quality appears questionable while the smoothing is used to continuously prevent abrupt changes in the data stream which could have been caused by the momentary appearance of bad data as opposed to a disruption of the traffic flow. If the two techniques are used together, smoothing would always be in use even though the use of the data stream for posting messages may occasionally be discontinued due to a drop in the confidence value.

This paper provides a description of these two techniques and an evaluation of their effectiveness. In addition it provides recommended default parameters that may be used both as thresholds for the confidence value and for determining the degree of smoothing to be employed.

Confidence Value

Initial Implementation: From the onset of their contract with the I-95 Corridor Coalition, INRIX has provided (and continues to provide) a data parameter known as the “Score” along with the speed information on every segment and for every time period. The Score is not to be confused with the Confidence Value.

The Concept: Two broad categories of data are used by INRIX when they generate real-time data; historic data (i.e. what was traffic like under similar conditions for previous days?), and current real-time data received from a variety of sources including fleet operations (GPS data), TMCs etc. The Score provides an indication of the relative amount of data utilized from each of these sources. If the Score has a value of 30, the INRIX data is exclusively generated from current real-time sources. If the score has a value of 10, the INRIX data is exclusively generated using historical data. A score of 20 indicates that a mix of the two sources is being used. The original intent of the Score was to provide an indication of data quality. However, the data validation demonstrated that the Score was not a reliable indicator of data accuracy. The result was that the Confidence Value (C-Value) was developed.

The C-Value provides an added degree of detail to the real-time data and is only applied to those data that have a score of 30 thus allowing the score and C-value to be used in tandem. The C-Value is based on a number of additional factors including the degree to which the current traffic matches historic conditions, the rate of change of the data that is being produced, and the length of time that the same speeds are being computed. A detailed discussion of the C-Value is presented here.

In December 2009 INRIX began publishing a C-Value to I-95 users in the API data feed (it has been available since May 2009 within the archive data that is accessed via the I-95 Monitoring Site). The C-

Value is designed to provide added information to the “Score” attribute to best identify the confidence of the data being sent by INRIX. When used in conjunction with the “Score, the C-Value allows agencies to make an independent determination as to the type and confidence of the data based on individual use cases. It is important to remember that the “Score” is used to determine the type of data (a score of “30” represents real-time data), and the C-Value should be used to add commentary to the score, or a confidence of the real-time data (note: the “C-Value” is produced only when the “Score” is 30). The bullets below are important to consider when using the C-Value:

Real-time speeds have variability which is a function of driver behavior and congestion state

A model of confidence must capture this variability and identify speed estimates which are inconsistent with “expectations”

Our model of “expectations” is based on three time-scales which are used within the INRIX calculation to produce the single C-Value, it is a blended calculation based on all three time-scales:

Short-Term:

(a) Probe data is a reliable estimator of current speeds if their density is sufficient:

(b) If sufficient real-time data points, then C-value is 100

Mid-Term:

(a) Compute a model of speed distributions within the last 45 minutes

(b) Is the current speed probable given mid-term speeds?

C-Value is proportional to probability

Long-Term:

(a) Historic data can be used to create a very dense model of average behavior. Within a broader range, these speeds can validate current speeds

(b) If current speed is within confidence interval about the historic average, then C-Value is 100

C-Value of 100 represents that there was: high data density + the current data is very consistent with the data over the past 45 minutes + current data is very consistent with the historical data.]

The challenge faced by the user is to select an appropriate threshold for C-Value to use in their applications. If the C-Value falls below the selected threshold, the respective data would not be used in the application. A detailed analysis was conducted of the relationship between the percentage of times that the INRIX data points exceeded the AASE of 10 mph on a point-by-point basis. This analysis was performed on roadway segments in the States of Delaware, New Jersey and North Carolina. Using the objective that the AASE of 10 mph should be exceeded less than 1% of the time (corresponding to one significant error greater than 10 mph per day), it was concluded that a Confidence Value threshold of 30 would achieve this objective. These tests also confirmed the effectiveness of the technique, in that there was a strong relationship between the percent of time that the INRIX data points exceeded the AASE of 10 mph, and the Confidence Value threshold. (Please see the appendix for graphical illustrations of data from these states.) Note that if a C-Value threshold is selected as a basis for filtering, any data points with a Score of either 10 or 20 will not have a C-Value reported. A C-Value of 0 can be assumed for such data points, and should also be filtered.

In practice the C-Value will drop from at or near 100 primarily when a sharp, unexpected change in speed/travel time occurs, as shown in Figure 2 where “low confidence speeds” are indicated. If the sudden change is accurate, and reported speed values continue to be higher or lower than normal, it is

likely indicative of actual conditions, and the C-Value will move back towards 100. So to be clear, initial data points associated with actual traffic flow anomalies may initially be flagged with low confidence values for a short period of time.

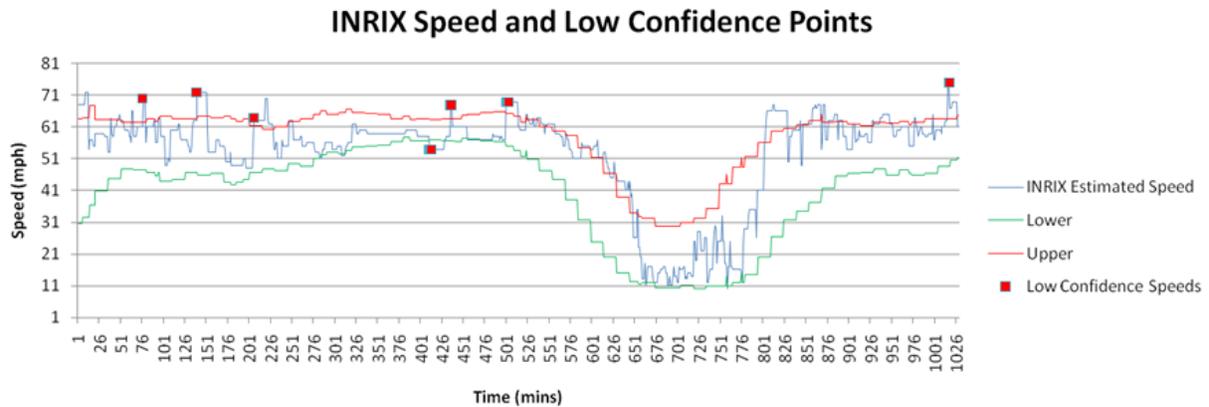


Figure 2. Conceptual Operation of the Confidence Value

Implementation: Figure 3 is a conceptual flow diagram of the Confidence Value implementation. As indicated by the figure, the Confidence Value is continuously monitored as speed data is received by INRIX. If the Confidence Value is greater than the user-selected threshold, speed and travel time data is processed without interruption. If the Confidence Value drops below the user-selected threshold, a default mode of operation should be activated. This activation should be defined by the user, and may include actions such as:

- Blanking travel time displays on DMS and Websites
- Inserting default travel times on these displays
- Requiring manual operator intervention

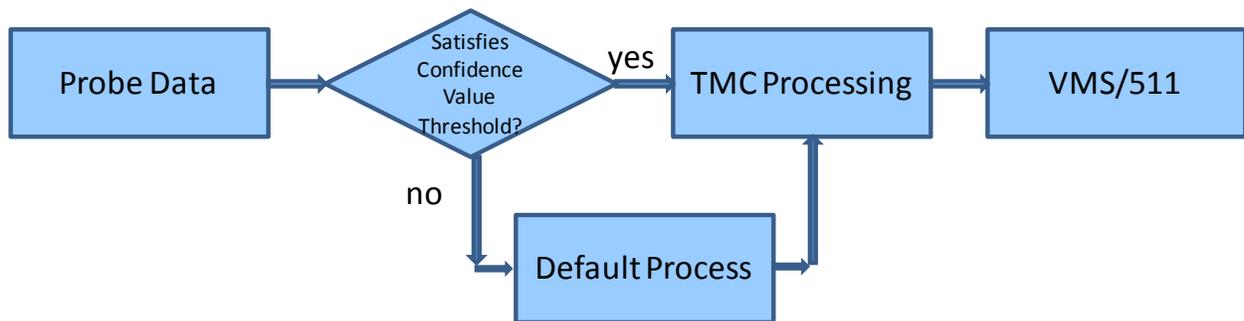


Figure 3. Confidence Value Processing

In summary, the implementation of the Confidence Value processing requires users to (1) select the confidence value threshold to be used, and (2) determine a default operation to be activated in the event that the Confidence Value falls below the selected threshold.

Smoothing

Smoothing can be used in conjunction with the Confidence Value technique described in the previous section. Smoothing is intended to prevent sudden deviations in the data, by changing a sudden jump in speed to a more gradual transition. The theory of the smoothing is based on the fact that sudden deviations between two distinctly different speeds for the overall traffic stream rarely occur in practice.

The following equation is used for smoothing the speed data:

$$SV(t) = SV(t-1) + K * (V(t) - SV(t-1))$$

Where:

SV(t) = Smoothed value of speed calculated for the current time

SV(t-1) = Smoothed value of speed calculated for the previous time (this could be two minutes ago)

V(t) = The value of speed that has just been received from INRIX for the current time

K = Smoothing constant (a value of 0.5 is recommended)

This is a very simple equation. Its function is to update the value of smoothed speed that was previously calculated with the difference between that value and the current unsmoothed speed measurement (received from INRIX) multiplied by the factor “K”. If the recommended value of 0.5 is used for K, the updated value of smoothed speed will then be influenced by ½ the difference between the current INRIX speed measurement and the previous value of smoothed speed.

If Travel Time data is to be smoothed, the previous, current and smoothed values of travel time should be substituted for speed. However, if smoothing is applied to the speed data, and smoothed speed data is utilized for the calculation of travel time, the resulting travel time should not be smoothed, since this would be equivalent to smoothing the data twice.

The equation and the recommended K value of 0.5 are based on an evaluation of the relative effectiveness of a number of alternative smoothing techniques and K values, which concluded that they produced the most effective techniques.

Implementation: Smoothing would be performed within the traffic management computer as part of the overall processing that produces the travel time displays on DMS, 511 and websites. The smoothing equation is inserted in the processing stream, prior to the calculation of travel times and prior to its use for real-time displays. This information flow is shown in Figure 4.

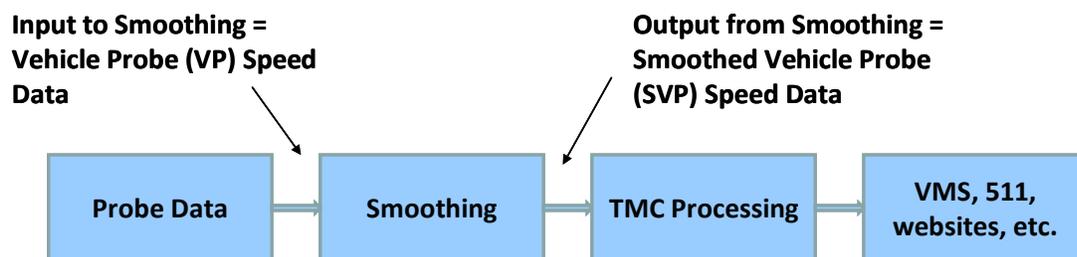


Figure 4. Incorporating Smoothing Into the TMC Data Processing Stream

Conclusions

Sudden abrupt changes in the INRIX speed data are rare, but occur often enough that users should consider the implementation of appropriate countermeasures. Two techniques that have been developed and tested are the Confidence Value and smoothing. When used together, these techniques have been demonstrated to reduce both the frequency and severity of the abrupt changes that have been observed. The two techniques can be readily implemented in the software of the traffic management center computer.