Preliminary Recommendations on Probe Data Processing and Performance Measures Calculation[1]

Table 1 Summary of Preliminary Recommendations on Probe Data Processing

#	Recommendation	Reason	Possible consequence if recommendation not adopted
1	Use Harmonic Mean to calculate average probe speeds	Probe speed is Space Mean Speed	Underestimate congestion
2	Use segment length as a weight to calculate multi-segment, corridor, area or regional averages	Segment length plays a role in the value of certain performance measures	Biased averages (Note: use volume as another weight if available)
3	Use Reference Speed in calculating Travel Time Index (TTI) and constrain TTI >= 1	TTI could <= 1 if observed speed is higher than reference speed (for INRIX data)	Underestimate congestion
4	Use the raw data amalgamated with the same frequency (1-, 5-, 15-, 30-, OR 60-minute) for all performance measures	Data archive frequency could have significant impact on travel time reliability measures	Different values of the same reliability measure from differently archived raw data
5	Use the same calculation sequence to calculate a performance measure	Calculation sequence could have significant impact on travel time reliability measures	Different values of the same reliability measure from different calculation sequences
6	Use instantaneous travel time in calculating multi-segment or corridor travel time (for now)	No significant difference between instantaneous and experienced travel time observed based on limited investigation; experienced travel time is more difficult to calculate than instantaneous travel time	Note: if such multi-segment or corridor travel time will be compared to travel time obtained from re-identification methods, use experienced travel time instead
7	Use all time epochs even there are not enough real-time samples in an epoch (e.g., Score is 10 or 20 for VPP data or data is missing in NPMRDS)	Those epochs are an integral part of traffic operations	Biased results based on only higher volume conditions
8	Document all choices/options in any analysis to facilitate comparison to other analyses	facilitate analyses being comparable, consistent, and repeatable	Results of multiple analyses showing differences which are actually attributable only to inconsistent input assumptions

[1] A Discussion Draft for the May 14, 2015 Joint Meeting of the Vehicle Probe Data Users Group (VPDUG) and the Management, Operations and Intelligent Transportation Systems (MOITS) Subcommittee of the National Capital Region Transportation Planning Board (TPB). **Please send comments to Wenjing Pu** (wpu@mwcog.org).

0. Introduction

Vehicle probe data is different from other speed/travel time data such as those collected from location-fixed traffic detectors. The probe data discussed in this document has the following characteristics[2]:

- Vehicles self-report positions and speed based on GPS equipment
- Individual vehicle data is aggregated to overall traffic
  - Speed samples & point-pair processing
- Third party (INRIX, HERE, TomTom) reports traffic data
  - 24/7/365, in real-time
  - Every minute using TMC codes
- Scales to large networks
- No roadside equipment, and therefore less costly

More specifically, the proposed recommendations are primarily based on experience gained in handling INRIX data provided by the I-95 Corridor Coalition Vehicle Probe Project[3]. While some recommendations could be generic to all probe data (e.g., the true Space Mean Speed nature), others might be vendor- or contract- specific (e.g., TomTom data capped at the speed limit, the National Performance Management Research Data Set – NPMRDS has missing epochs if sample size is too small), which are to be added later to this document once become available.

This document is a **work in progress** with periodical revisions and updates. Any other recommendations and comments are welcome at all time.

1. Use the *Harmonic Mean* to calculate average speeds from probe data

Background

- $Space\ Mean\ Speed = \frac{d}{(\sum_i t_i)/n} = \frac{n}{(\sum_i t_i)/d} = \frac{n}{\sum_i (1/s_i)} = Harmonic\ Mean\ of\ speeds$
- $Time\ Mean\ Speed = \frac{\sum_i d/t_i}{n} = \frac{1}{n}\sum_i s_i = Arithmetic\ Mean\ of\ speeds$

where,

d is the distance traversed,
n is the number of observed vehicles,
t_i is the time for vehicle "i" to traverse the section, and
s_i is the speed for vehicle "i" to traverse the section.

[2] Stanley Young, Use of Probe and Bluetooth data for arterial performance measures in the I-95 Corridor Coalition, Vehicle Probe Data Users Group Meeting, MWCOG, February 12. 2015.
[3] Wenjing Pu, Standardized Data Processing: Where We Need It in Mining Private Sector Probe-Based Traffic Data for Highway Performance Measurement, Transportation Research Record: Journal of the Transportation Research Board, 2338, 44-57, Washington, D.C., 2013. (available upon request)

Reason

- **Speed from vehicle probe data is Space Mean Speed[4] thus it requires Harmonic Mean to average vehicle probe speeds.** This is different from location-fixed detector speeds, which are Time Mean Speed[5] and Arithmetic Mean should be used to average those speeds.
- **The HCM recommends Space Mean Speed for analyses**. Space Mean speed ensures that there is an equivalent travel time along the same road segment and it can be exclusively calculated by the speed and the segment length. It is this Space Mean Speed feature that differentiates the probe data from traffic detector data as the former can provide more direct and accurate travel time measurements for a road segment.
- The difference between the average speeds calculated by Harmonic Mean and Arithmetic Mean could be significant[6].

Example

- If a traveler traveled the same 1-mile segment twice, the first time taking 1 minute with an average speed of 60 mph and the second time taking 2 minutes with an average speed of 30 mph, then, what is the average speed of the two trips: (60+30)/2=45 mph (arithmetic mean is used), or 2/(1/60+1/30) = 40 mph (harmonic mean is used)? The correct answer is 40 mph. A simple check can be done by using the travel time. In this example, the average travel time of the two trips is (1+2)/2 = 1.5 minutes, which correspond to: 1 mile/(1.5 minute/60 minutes per hour) = 40 mph. If 45 mph was the average speed, then the average travel time would be: 1 mile/45 mph * 60 minutes per hour = 1.33 minutes, which obviously is not the actual average travel time (1.5 minutes).

Possible Consequence If Recommendation Not Adopted

- Mathematically, harmonic mean is always equal to or smaller than arithmetic mean. So **if arithmetic mean was used, the calculated average speed could be higher than what it should be**, giving a false and "optimistic" estimation of congestion (as illustrated in the above example).

Alternative

- Use Travel Time instead of Speed in averaging data and calculating performance measures. For example, use $Travel\ Time\ Index = \ (Actual\ Travel\ Time)/(Free\ Flow\ Travel\ Time)$, instead of $Travel\ Time\ Index = \ (Free\ Flow\ Speed)/(Actual\ Speed)$.

[4] According to the Highway Capacity Manual (HCM 2010), Space Mean Speed is a statistical term denoting an average speed based on the average travel time of vehicles to traverse a length of roadway.
[5] According to the Highway Capacity Manual (HCM 2010), Time Mean Speed is the arithmetic average of speeds of vehicles observed passing a point on a highway, also referred to as the Average Spot Speed.
[6] Wenjing Pu, Standardized Data Processing: Where We Need It in Mining Private Sector Probe-Based Traffic Data for Highway Performance Measurement, Transportation Research Record: Journal of the Transportation Research Board, 2338, 44-57, Washington, D.C., 2013. (available upon request)

2. Use segment length as a weight to calculate multi-segment, corridor, area or regional averages

Background

- Vehicle probe data is often geo-referred by Traffic Message Channel (TMC) paths (or segments).
- The length of a TMC segment varies significantly, ranging from less than 0.1 mile to more than 10 miles in the entire Washington region for instance. Out of the 12,000 TMC segments in the region, a large portion (78%) of them are less than 1-mile long, and 34% of which are even less than 0.1 mile. At the same time there are about 3% of the TMC segments with lengths more than 3 miles, a handful of which are more than 10 miles.

Reason

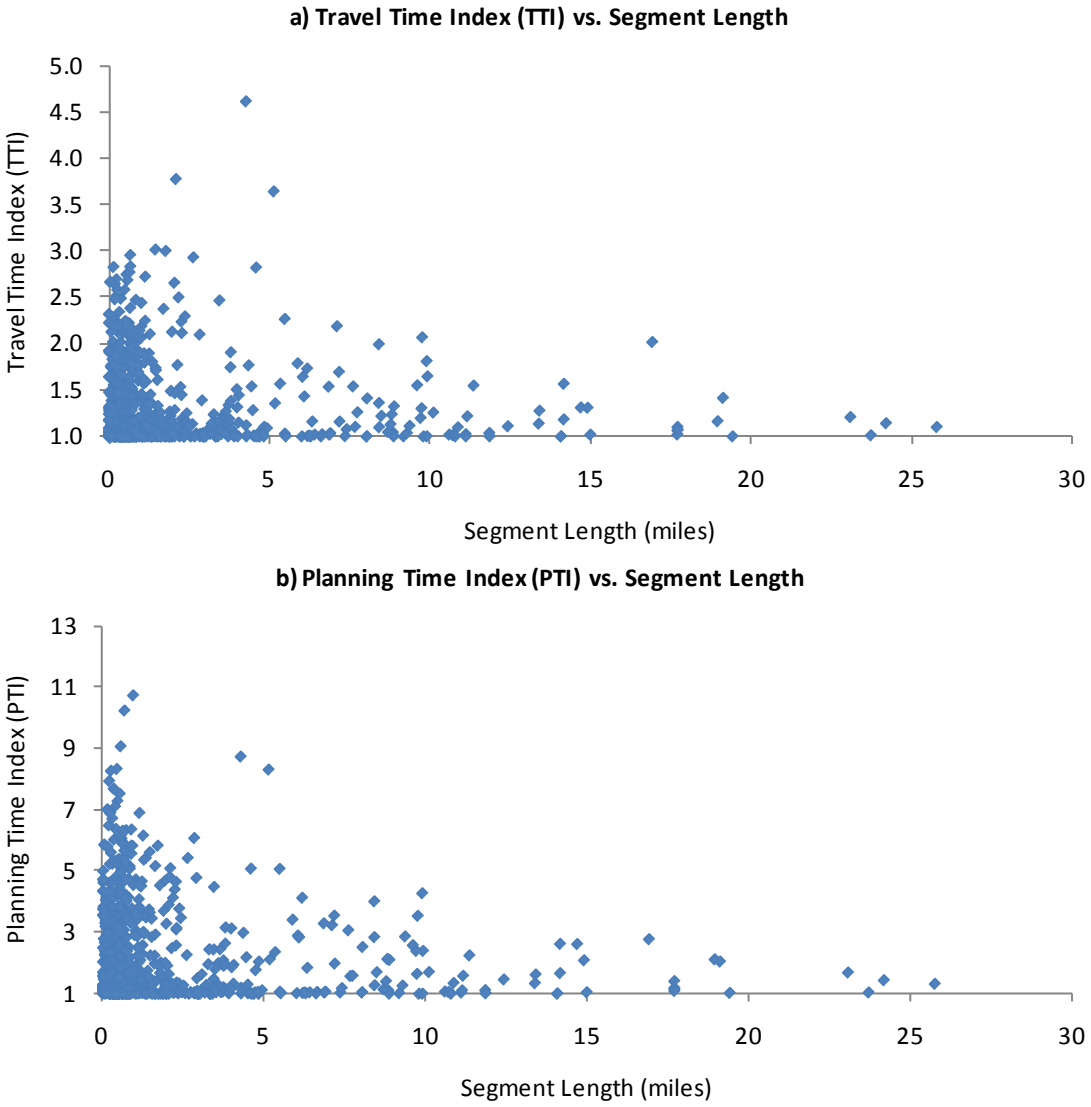

Figure 1 Scatter plots of congestion and reliability measures versus segment length

- The upper limit value of Travel Time Index and Planning Time Index tends to decrease as the segment length increases (as illustrated in Figure 1 above).

Possible Consequence If Recommendation Not Adopted

- Biased results, likely higher than what they should be.

Future Improvement

- If vehicle volume data is available, then Vehicle Miles Traveled (VMT) is a better weight than segment length along as VMT takes into consideration both volume and segment length.

3. Use Reference Speed in calculating Travel Time Index (TTI) and constraint TTI >= 1

Background

- $Travel\ Time\ Index = \frac{Actual\ Travel\ Time}{Free\ Flow\ Travel\ Time} = \frac{Free\ Flow\ Speed}{Actual\ Speed}$
- INRIX "reference speed" capped at 65 mph, reported actual speed could > 65 mph, so TTI = reference speed/actual speed could < 1.00
- INRIX defines Reference Speed as follows[7]: Reference Speed is the calculated "free flow" mean speed for the roadway segment in miles per hour (capped at 65 miles per hour). This attribute is calculated based upon the 85th-percentile point of the observed speeds on that segment for all time periods, which establishes a reliable proxy for the speed of traffic at free-flow for that segment.

Reason

- Reference Speed is often more representative than the Speed Limit of actual traffic operations in unconstrained conditions (this is primarily for freeways; for arterials, further investigation is needed).
- Travel Time Index could be less than 1 if observed speed is higher than Reference Speed in the case of INRIX data.

Possible Consequence If Recommendation Not Adopted

- If constraint TTI >= 1 not imposed, congestion could be underestimated as TTI > 1 conditions and TTI < 1 conditions could be canceled to some extent. For example, TTI1 = 0.9, TTI2 = 1.1, then the average TTI = (TTI1+TTI2)/2 = 1.0; versus TTI1 = 0.9 and impose TTI1 = 1.0, TTI2 = 1.1, then the average TTI = (TTI1+TTI2)/2 = 1.05.

[7] INRIX, Inc. I-95 VPP Interface Guide, Version 4.0, February 2013.

4. Use the raw data amalgamated with the same frequency (1-, 5-, 15-, 30-, OR 60-minute) for all performance measures

Reason

- Data archiving frequency could have significant impacts on travel time reliability measures
- Data archiving frequency usually does not have impacts on congestion measures such as Travel Time Index as long as all calculations are correct (e.g., Harmonic Mean is used in averaging speeds)

Possible Consequence If Recommendation Not Adopted

- Different values of the same travel time reliability measure could exist from differently archived raw data

5. Use the same calculation sequence to calculate a performance measure

Background

- The same performance measure can be calculated by different procedures (or steps).
- Example: to construct a 24-hour profile of a performance measure on a typical weekday for an entire region, four different sequences:
  - Seq. 1: Base data → Performance measures → Regional weekday average
  - Seq. 2: Base data → Weekday average → Performance measures → Regional average
  - Seq. 3: Base data → Regional average → Performance measures → Weekday average
  - Seq. 4: Base data → Regional weekday average → Performance measures

Reason

- Data archiving frequency could have significant impact on travel time reliability measures
- Data archiving frequency usually does not have impact on congestion measures such as Travel Time Index as long as all calculations are correct (e.g., Harmonic Mean is used in averaging speeds)

Possible Consequence If Recommendation Not Adopted

- Different values of the same travel time reliability measure could exist from differently archived raw data

6. Use instantaneous travel time in calculating multi-segment or corridor travel time (for now)

Background

- Instantaneous Travel Time is the travel time that would result if prevailing traffic conditions remained unchanged.
- Experienced Travel Time is the travel time of the user who has just completed the considered trip.

Reason

- No significant difference between instantaneous and experienced travel time observed based on limited investigation
- Experienced travel time is more difficult to calculate than instantaneous travel time

Exception

- If such multi-segment or corridor travel time will be compared to travel time obtained from re-identification methods (such as toll tags, Bluetooth, WiFi matches), use experienced travel time instead.

7. Use all time epochs even there are not enough real-time samples in an epoch (e.g., Score is 10 or 20 for VPP data or data is missing in NPMRDS)

Background

- In INRIX data provided by the VPPI and VPPII, the variable "Confidence Score" indicates if there are enough real-time samples in a reporting epoch to make a sound estimation of traffic conditions for that epoch[8]:
    - Score = 30 Real Time Data. Any segment that has adequate data, at any time of day, will report real time data.
    - Score = 20 Historical Average. Between 4 am and 10 pm, any segment without sufficient real time data will show the historical average for that segment during that day/time period (15 minute granularity).
    - Score = 10 Reference Speed. From 10 pm to 4 am, any segment without sufficient real time data will show the reference speed for that segment. Any segment that does not have calculated historical averages will show the reference speed 24 hours a day if there is not sufficient real time data.
- In HERE data provided by the VPPII, the variable "Confidence" is similar to INRIX data's "Confidence Score" variable. The three possible values are[9]:
    - .90-1.0 – high confidence, based on real-time data for that specific segment.
    - .80-.89 – medium confidence, based on real-time data across multiple segments and/or based on a combination of expected and real-time data.

[8] INRIX, Inc. INRIX Project Interface Guide v1 (Dec 2014).
[9] VPP Suite, Massive Raw Data Downloader

    - Less than .79 – lower confidence, based primarily on historical data.
- In the National Performance Management Research Data Set (NPMRDS) provided by HERE for FHWA, travel times are provided for 288 epochs per day or 5 minute time periods. However, if no observations are recorded, the epoch will not have a data record[10].

Reason

- All epochs, including those without enough samples, are integral part of traffic operations.

Possible Consequence If Recommendation Not Adopted

- Biased results based on only higher volume conditions (with enough samples).

8. Document all choices/options in any analysis to facilitate comparison to other analyses

Reason

- Facilitate analyses being comparable, consistent, and repeatable.

Possible Consequence If Recommendation Not Adopted

- Results of multiple analyses showing differences which are actually attributable only to inconsistent input assumptions.

[10] HERE, Product Specifications, September 16, 2013.