METROPOLITAN WASHINGTON
Council of Governments

National Capital Region
TRANSPORTATION PLANNING BOARD

Item #5

COG/TPB's Use of Probe Data and Lessons Learned

Vehicle Probe Data Users Group Meeting
October 9, 2014

VPDUG

A Brief History

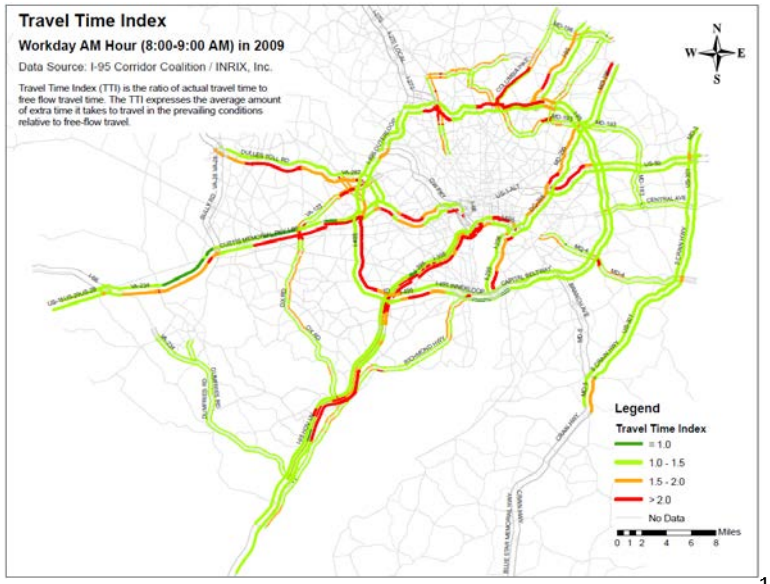
- June 2009, Data Use Agreement signed
- 2010, Congestion Management Process (CMP) Technical Report
- 2011, Congestion Dashboard, with volume data fused
- 2012, CMP Technical Report
- 2013, ICC before and after study
- 2014
  - CMP Technical Report (www.mwcog.org/cmp)
  - Congestion Dashboard (www.mwcog.org/congestion)
  - DUA signed for VPP2
  - License Agreement signed to access FHWA's NPMRDS

Internal, external data & technical support, special event analysis, etc.

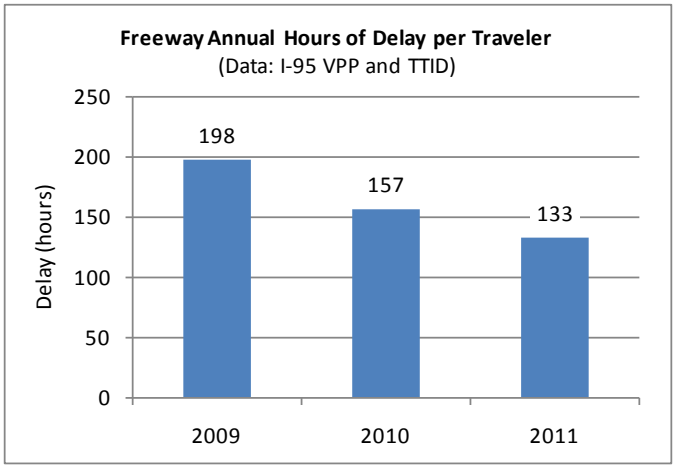
Applications

- Congestion Management Process
  - CMP Technical Report
  - Congestion Dashboard
  - Special event analysis
- Travel demand model validations
- Regional Transportation Data Clearinghouse
- Support internal and member jurisdictions studies

Examples from the CMP Tech Report

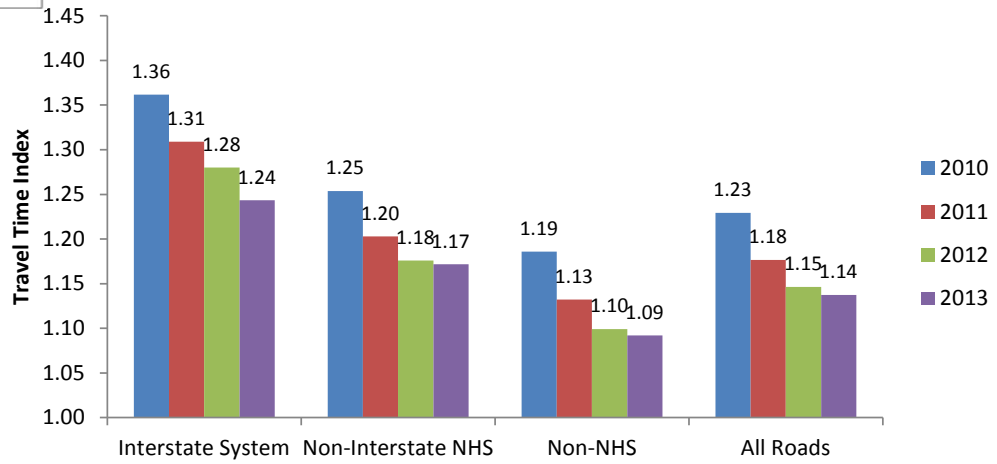


2010 CMP Tech Report



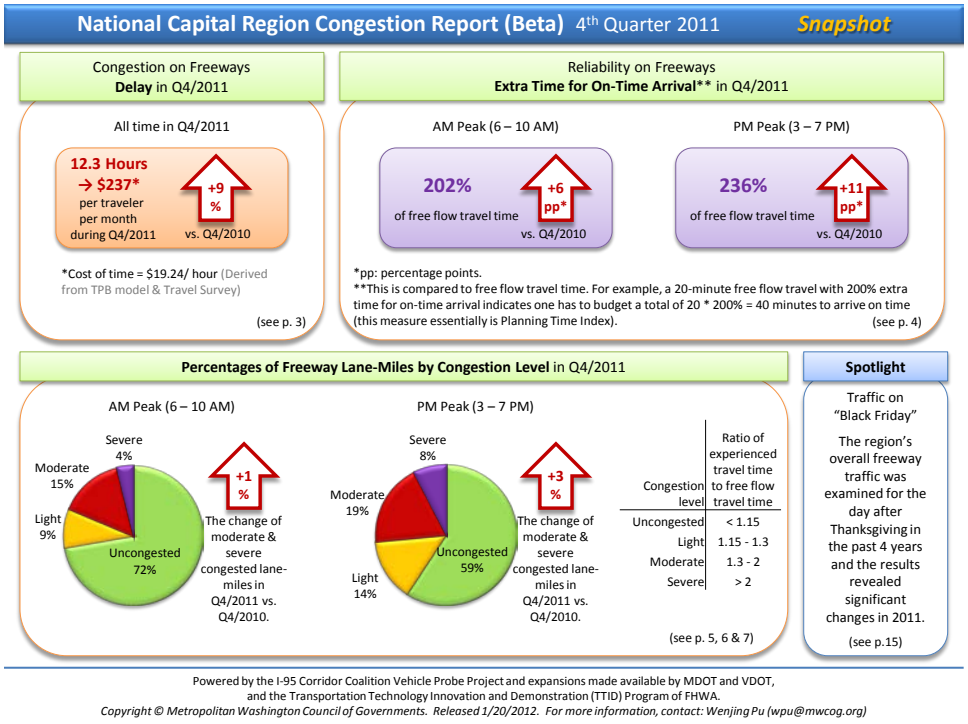
2012 CMP Tech Report

Annual Average Travel Time Index by Highway Category
Total AM and PM Peaks

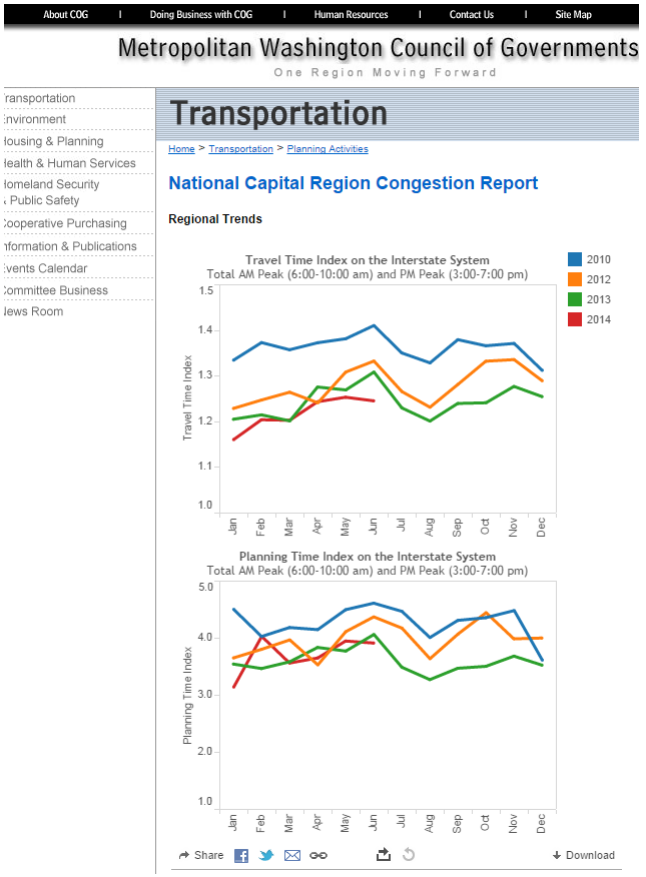


2014 CMP Tech Report

Examples from Congestion Dashboard



2012 Dashboard

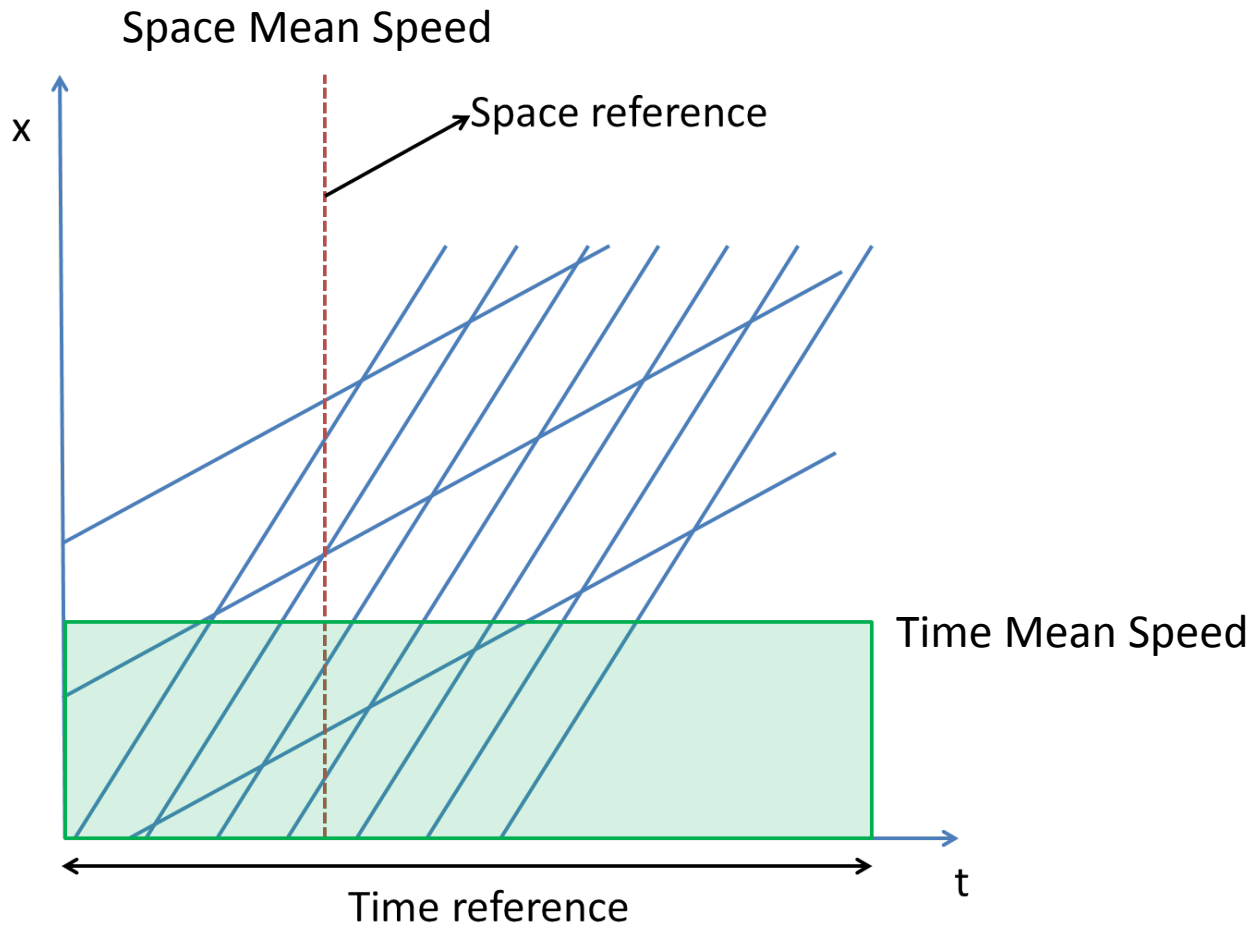


2014 Dashboard

Lessons Learned

1. Harmonic mean should be used to average probe-based speeds
2. Segment length plays a role in the values of performance measures
3. Data archiving frequency impacts reliability measures
4. Performance measure calculating procedure matters
5. Mixed results in comparing instantaneous vs. experienced travel times
6. Travel Time Index (TTI) should be kept >= 1.00

Two Definitions of Speed



Time Mean Speed vs. Space Mean Speed

Mathematics

- Space Mean Speed

$$Space\ Mean\ Speed = \frac{d}{(\sum_i t_i)/n} = \frac{n}{(\sum_i t_i)/d} = \frac{n}{\sum_i (1/s_i)}$$

Harmonic mean

- Time Mean Speed (Spot Speed)

$$Time\ Mean\ Speed = \frac{\sum_i d/t_i}{n} = \frac{1}{n}\sum_i s_i$$

Arithmetic mean

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.

Space Mean Speed ≤ Time Mean Speed

- Mathematically:

  Harmonic mean ≤ Arithmetic mean

- Therefore:

  Space Mean Speed ≤ Time Mean Speed

TMC-based speed: Space Mean Speed

- Based on GPS technologies and vendor's methodologies, **TMC-based speed is Space Mean Speed**, which was confirmed by INRIX, Inc.
- So, vehicle probe speed is a different animal compared to **location-fixed detector speed,** which **is Time Mean Speed**

  (Many detectors claim to report "space mean speed", it is true only within the detection zone)

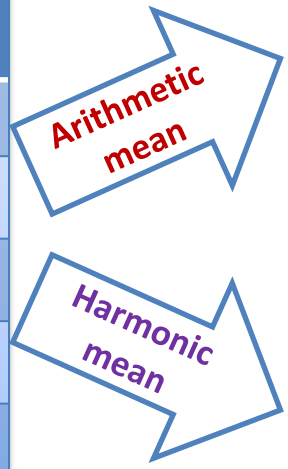
Harmonic Mean Should Be Used in Averaging Probe-based Link Speeds

- If arithmetic mean used (as we normally do in averaging detector speeds, which is correct), two possible consequences:
  - Inconsistent speed and travel time in aggregated data
  - Varying performance measures based on the same data

Inconsistent Travel Time and Speed

Example of 1-minute raw data

TMC	Miles	Time-stamp	Speed (mph)	Travel Time (min)
110+12345	1	16:00	60	1.00
110+12345	1	16:01	55	1.09
110+12345	1	16:02	50	1.20
110+12345	1	16:03	45	1.33
110+12345	1	16:04	40	1.50



Aggregated 5-minute data

Time-stamp	Speed (mph)	Travel Time (min)
16:00	50	1.22

Time-stamp	Speed (mph)	Travel Time (min)
16:00	49	1.22

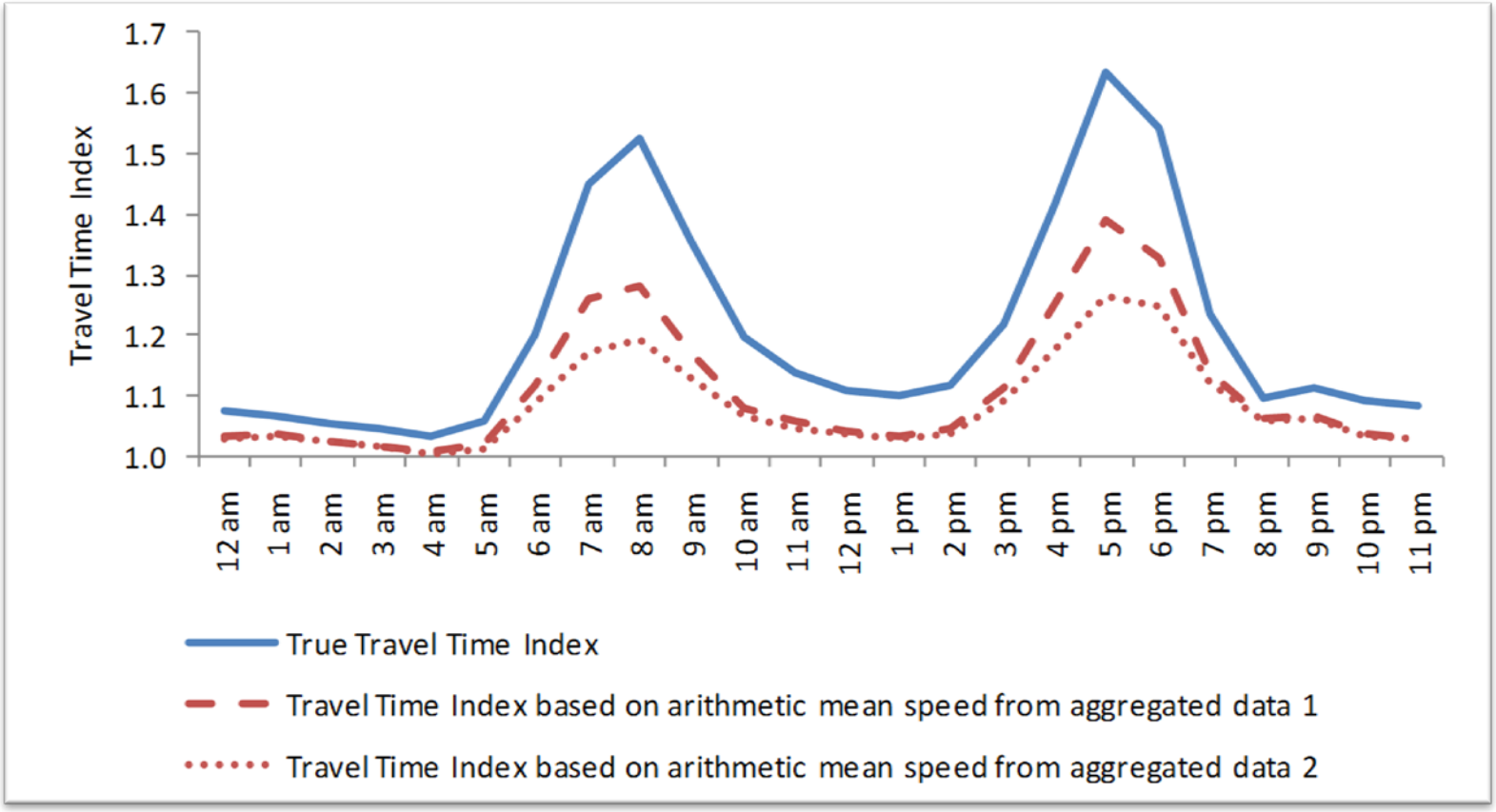
Arithmetic mean >= Harmonic mean, so arithmetic mean could OVERESTIMATE ground truth average speed

Difference between Arithmetic and Harmonic Mean Speeds

Absolute difference in speed			Percentage difference in speed		
Magnitude	Number of records	% of all records	Magnitude	Number of records	% of all records
>= 5mph	52800	8.6940%	>= 30%	25437	4.1884%
>= 10 mph	21660	3.5665%	>= 100%	5968	0.9827%
>= 20 mph	8487	1.3975%	>= 200%	2420	0.3985%

Note: There are total 607,315 valid records in the aggregated 1-hour data

Varying Performance Measures

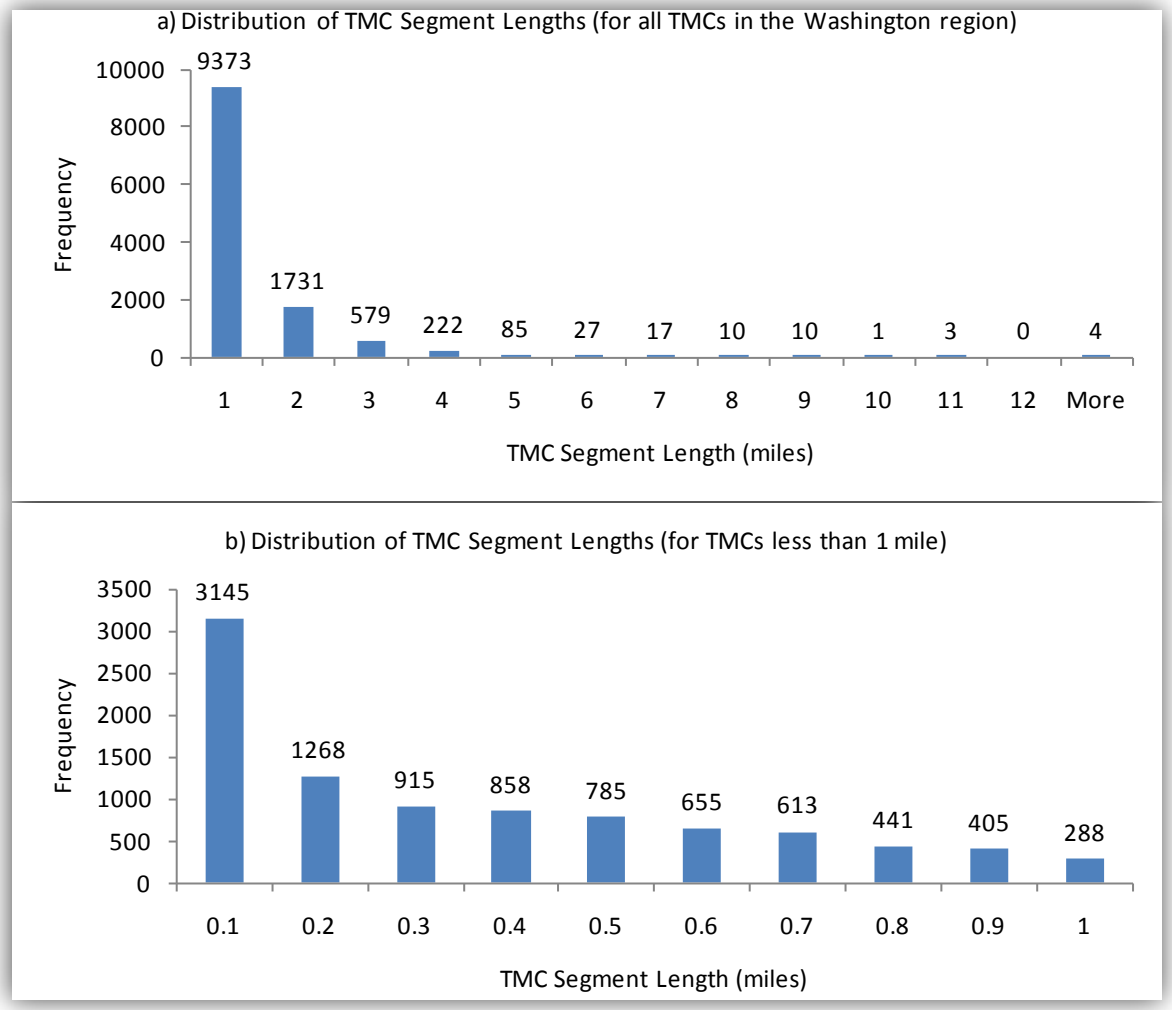


$$Travel\ Time\ Index = \frac{Free\ Flow\ Speed}{Actual\ Speed}$$

Work around Harmonic Mean

- Always use Travel Time instead of Speed in calculations, Arithmetic mean applies for Travel Time, for example:
  - ~~o TTI = Free flow speed/Actual speed~~
  - o TTI = Actual TT/ Free flow TT
  - ~~o Ave. Speed = Sum of speeds/# of Obs.~~
  - o Ave. Speed = Segment Length/Ave. TT

Segment length

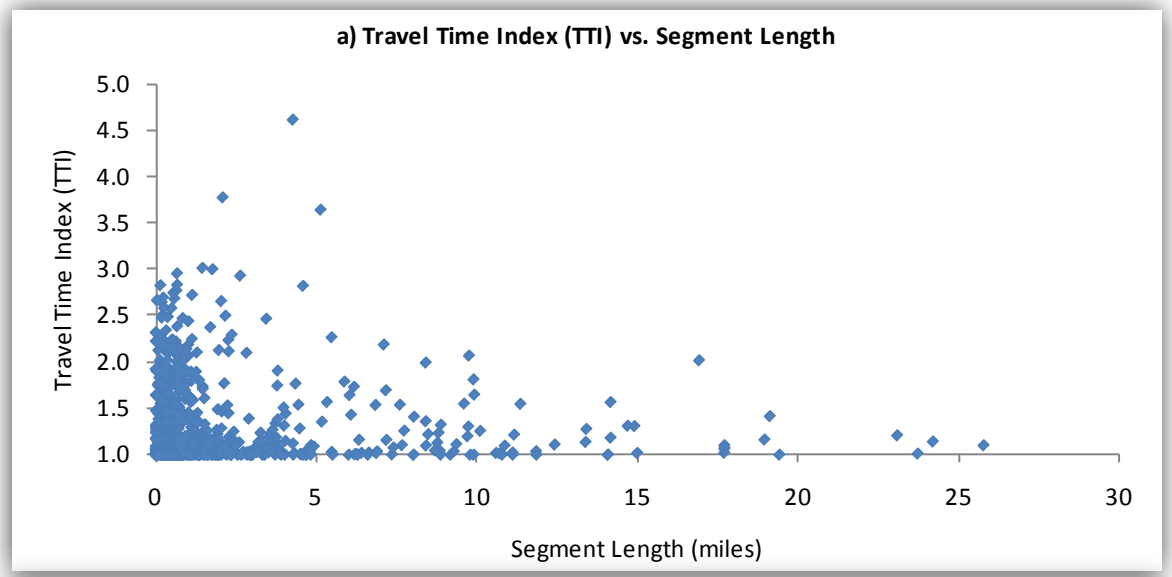


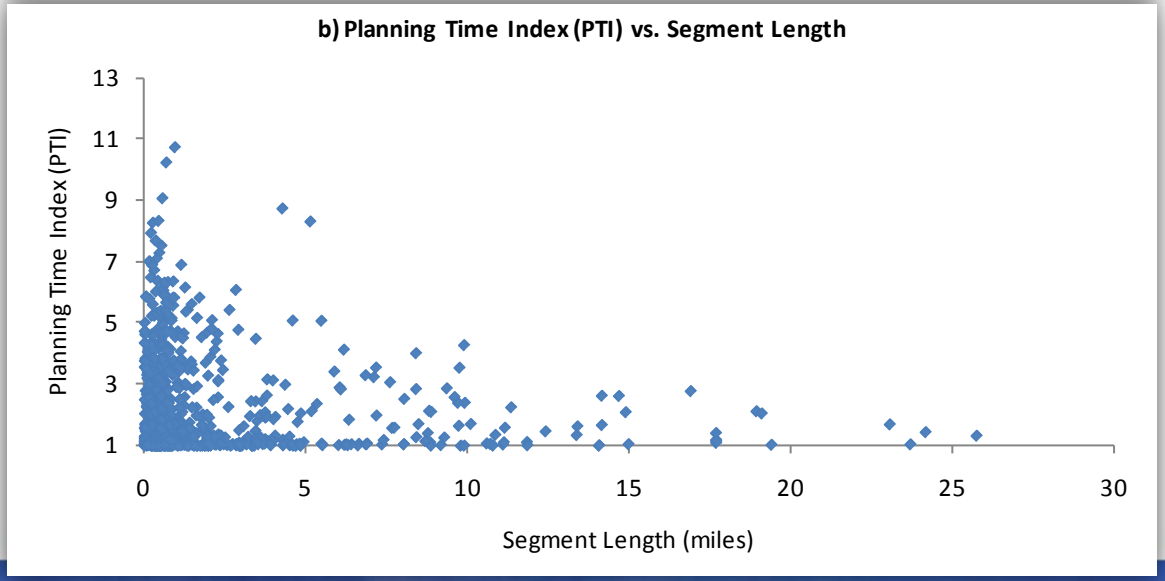
- 78% of all TMCs are shorter than 1 mile, of which 1/3 are shorter than 0.1 mile
- 3% are longer than 3 miles

A total of 12,000 TMCs covering 8,300 route-miles of roads are analyzed in the Washington region.

Impact of segment length

- The upper limit value of Travel Time Index and Planning Time Index tends to decease as the segment length increases
- Take segment length into consideration when comparing performance
- Use segment length as the weight in calculating regional summary of Travel Time Index and Planning Time Index



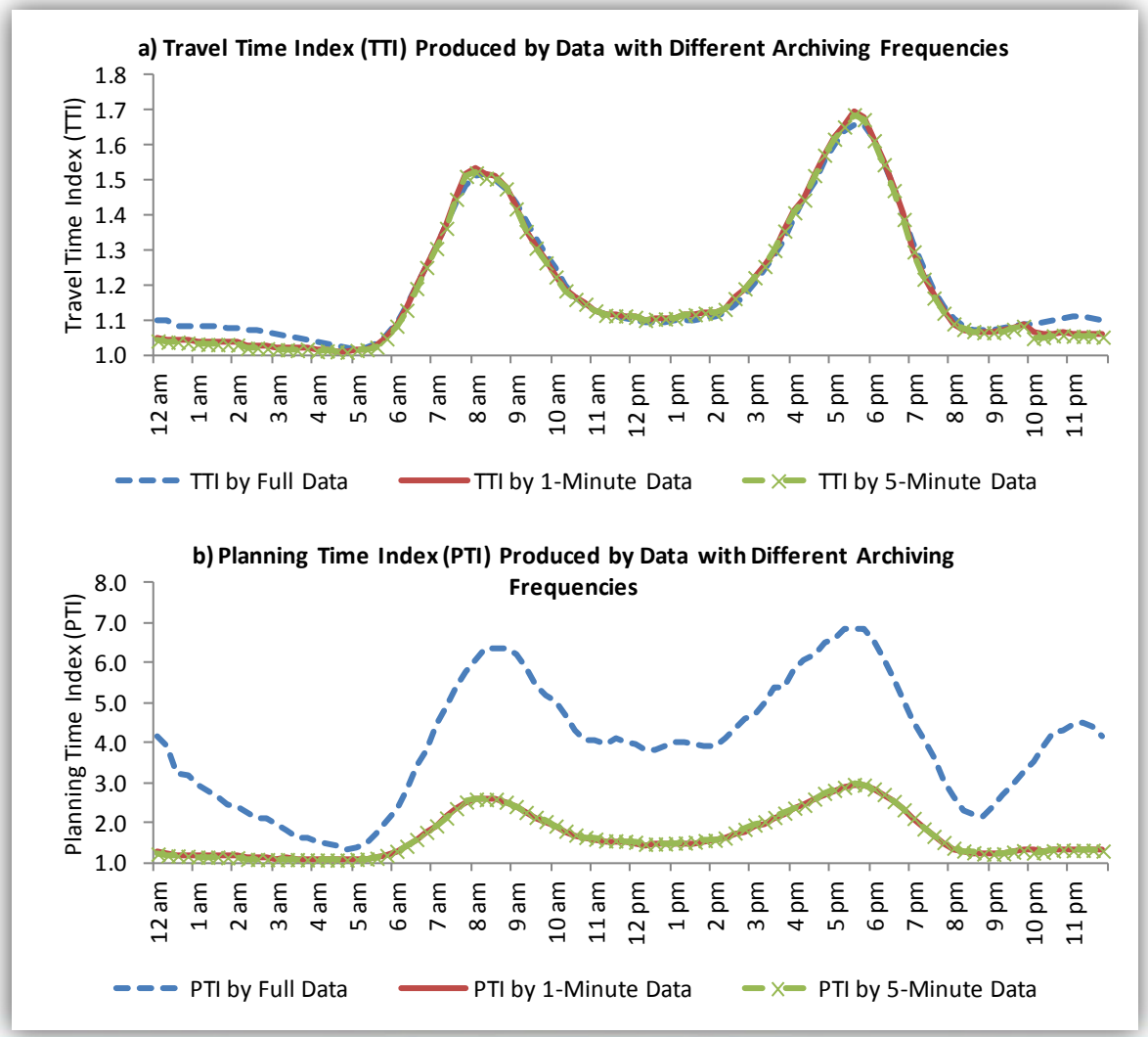


Data archiving frequency

- Probe data can be archived by at least the following three options:
  - Archive all raw probe reports (full data)
  - Take one snapshot of the real-time data stream every 1 minute (1-minute data)
  - Take one snapshot of the real-time data stream every 5 minute (5-minute data)

Impact of data archiving frequency

- 1-minute and 5-minute data produce almost identical performance measures
- Underlying difference between full data and 1-minute (or 5-minute) data requiring different interpretations of reliability measures

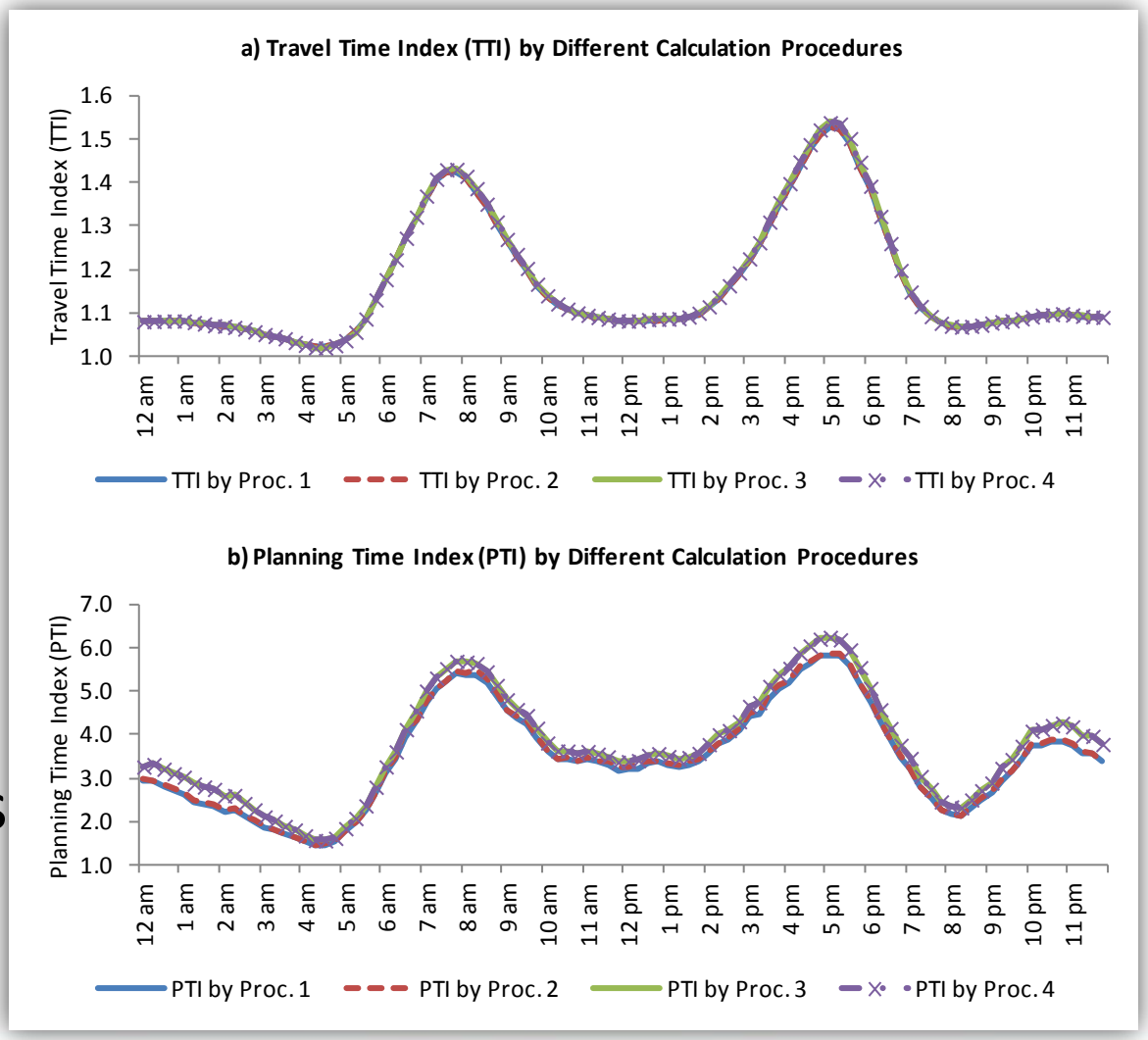


Calculation procedure

- 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:
  - Proc. 1: Base data → Performance measures → Regional weekday average
  - Proc. 2: Base data → Weekday average → Performance measures → Regional average
  - Proc. 3: Base data → Regional average → Performance measures → Weekday average
  - Proc. 4: Base data → Regional weekday average → Performance measures

Impact of calculation procedure

- Performance measures may be impacted by calculation procedures
- Keep consistency in calculation steps

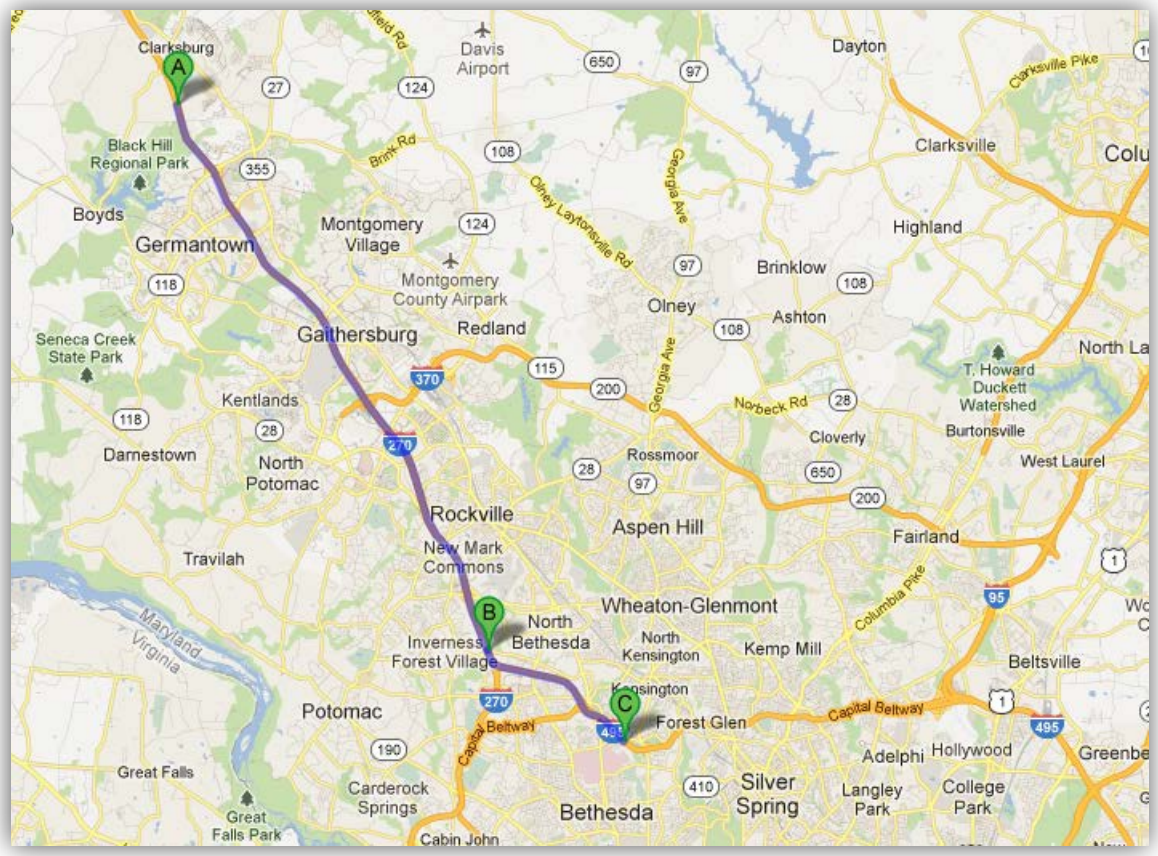


Instantaneous vs. Experienced Travel Time

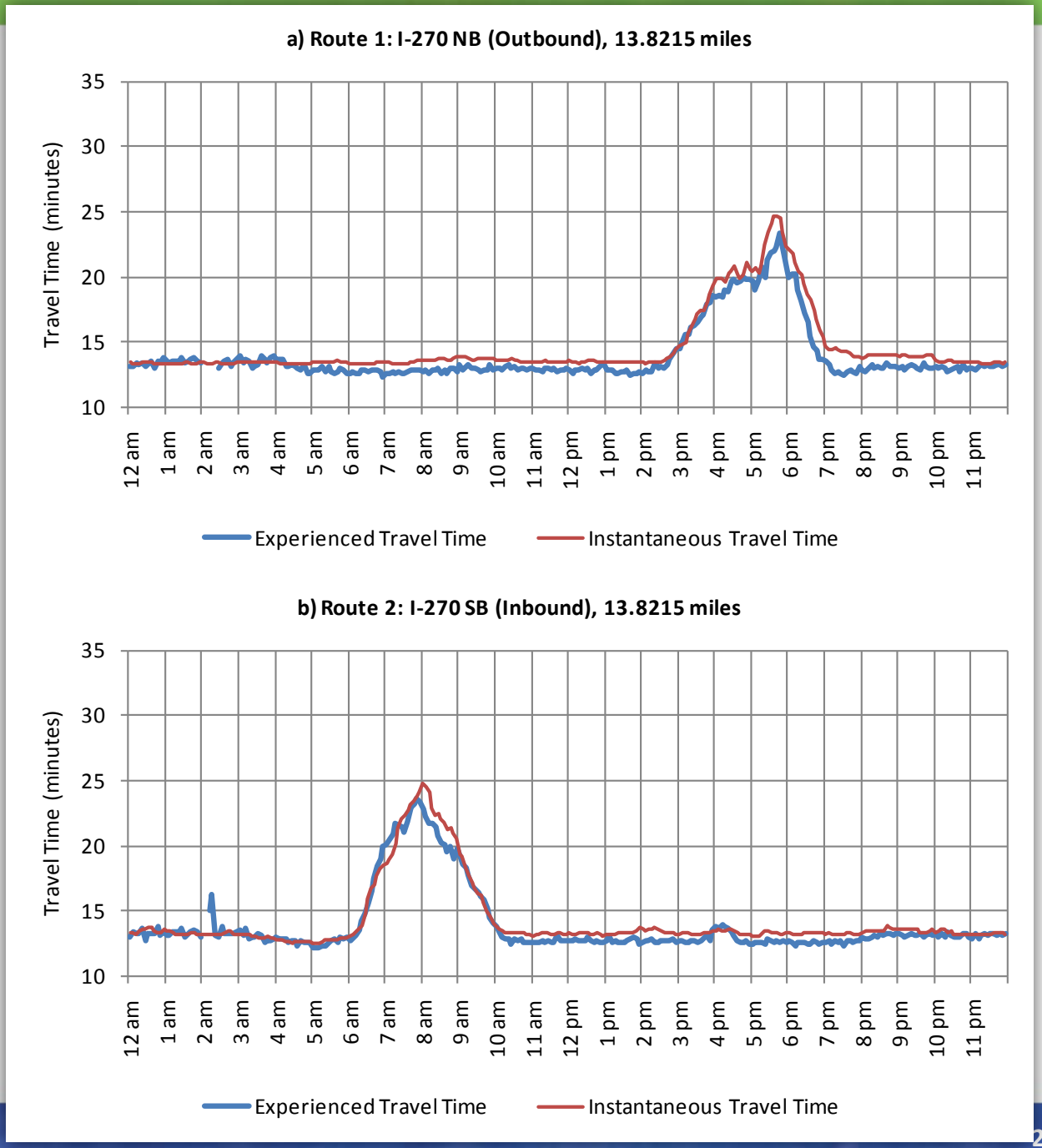
- *Instantaneous Travel Time* is the travel time that would result if prevailing traffic conditions remained unchanged
- *Experienced Travel Time* is the travel time of the user who has just completed the considered trip
- Question: should Experienced Travel Time be used for performance measurement?

Field data

- Study routes:
  - 1: B to A
  - 2: A to B
  - 3: C to A
  - 4: A to C
- INRIX data for instantaneous travel time
- Traffax Bluetooth data for experienced travel time



Courtesy of Google Maps


a) Route 1: I-270 NB (Outbound), 13.8215 miles
Travel Time (minutes)
35
30
25
20
15
10
12 am
1 am
2 am
3 am
4 am
5 am
6 am
7 am
8 am
9 am
10 am
11 am
12 pm
1 pm
2 pm
3 pm
4 pm
5 pm
6 pm
7 pm
8 pm
9 pm
10 pm
11 pm
Experienced Travel Time
Instantaneous Travel Time
b) Route 2: I-270 SB (Inbound), 13.8215 miles
Travel Time (minutes)
35
30
25
20
15
10
12 am
1 am
2 am
3 am
4 am
5 am
6 am
7 am
8 am
9 am
10 am
11 am
12 pm
1 pm
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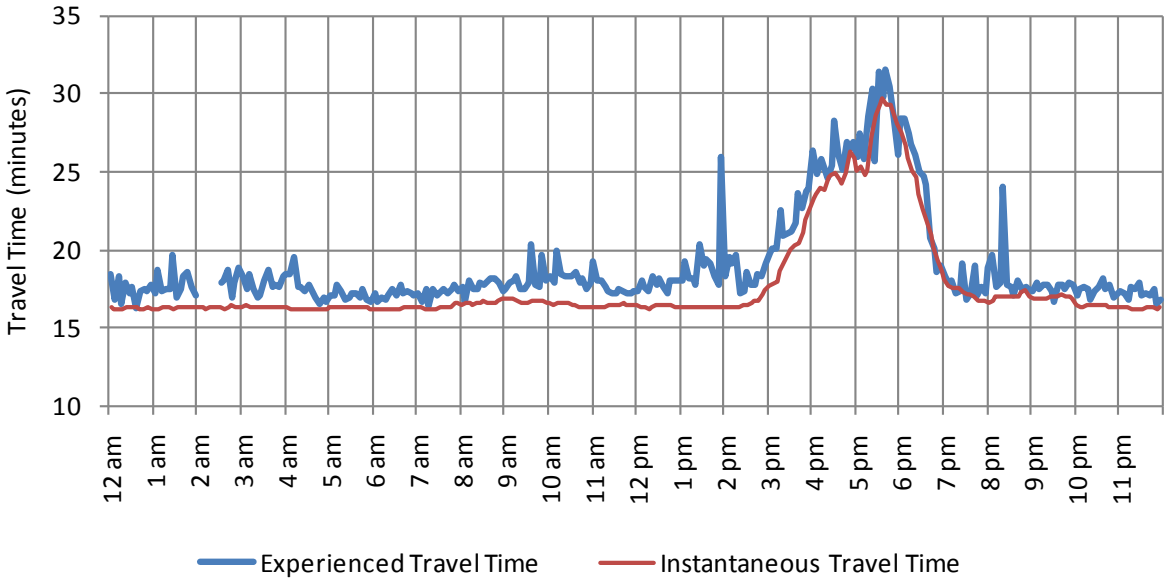
11 pm
Experienced Travel Time
Instantaneous Travel Time


c) Route 3: I-495WB to I-270 NB, 17.7586 miles
Travel Time (minutes)
35
30
25
20
15
10
12 am
1 am
2 am
3 am
4 am
5 am
6 am
7 am
8 am
9 am
10 am
11 am
12 pm
1 pm
2 pm
3 pm
4 pm
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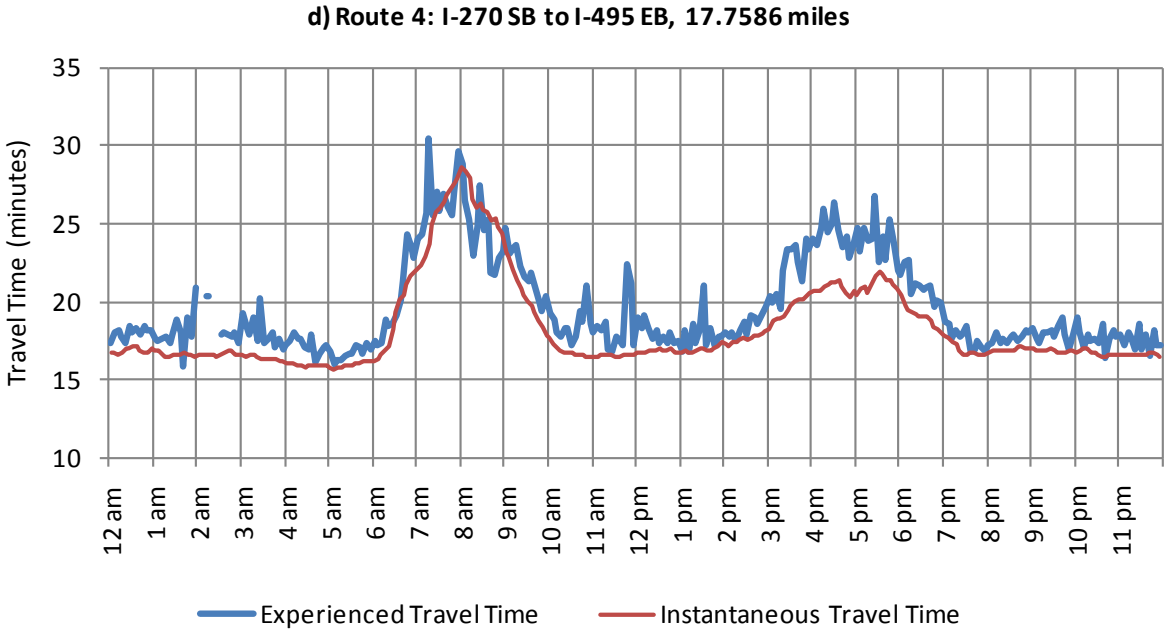
6 pm
7 pm
8 pm
9 pm
10 pm
11 pm
Experienced Travel Time
Instantaneous Travel Time


d) Route 4: I-270 SB to I-495 EB, 17.7586 miles
Travel Time (minutes)
35
30
25
20
15
10
12 am
1 am
2 am
3 am
4 am
5 am
6 am
7 am
8 am
9 am
10 am
11 am
12 pm
1 pm
2 pm
3 pm
4 pm
5 pm
6 pm
7 pm
8 pm
9 pm
10 pm
11 pm
Experienced Travel Time
Instantaneous Travel Time

Mixed results

- The experienced and instantaneous travel times could be very consistent, or noticeably different, depending on the routes and/or time of day
- It could be true that the longer the route the larger the difference, the more mainline diverges/merges the larger the difference
- Further investigation needed

Travel Time Index ≥ 1.00

- INRIX "reference speed" capped at 65 mph, reported actual speed could > 65 mph, so TTI = reference speed/actual speed could < 1.00
- TTI should be kept ≥ 1.00 to avoid underestimate of congestion, e.g.,

  TTI1 = 0.9, TTI2 = 1.1, then

  Ave. TTI = (TTI1+TTI2)/2 = 1.0;

  vs.

  TTI1 = 0.9 and impose TTI1 = 1.0, TTI2 = 1.1, then

  Ave. TTI = (TTI1+TTI2)/2 = 1.05

Re-cap: Lessons Learned

1. Harmonic mean should be used to average probe-based speeds; always use Travel Time instead of speed to avoid harmonic mean
2. Segment length plays a role in the values of performance measures; when comparing performance, select segments with similar length
3. Data archiving frequency impacts reliability measures; use the same raw data (1-, 5-, …, 60-minute data)
4. Performance measure calculating procedure matters; use the same procedure over time
5. Mixed results in comparing instantaneous vs. experienced travel times; use of instantaneous travel time seems fine
6. Travel Time Index (TTI) should be kept ≥ 1.00; there is no need to impose Planning Time Index ≥ 1.00

Other Issues

- Relationship between TMC network and travel forecasting and other networks
- Potentially different free-flow speed definitions from different vendors
- Strengthening the relationship between probe data, performance reporting and travel forecasting