I-95 Corridor Coalition

I-95 Corridor Coalition Vehicle Probe Project: Validation of INRIX Data

Estimation of Travel Times for Multiple TMC Segments

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Estimation of Travel Times for Multiple TMC Segments

Prepared for:

I-95 Corridor Coalition

Sponsored by:

I-95 Corridor Coalition

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February 2010

Introduction

The data validation effort for the Vehicle Probe Project optimally studies TMC segments of greater that one mile in length. However, not all TMC segments are greater than one mile. In fact, more than half of the TMC segments in the project study area are less than one mile in length. Therefore, it became necessary to develop a process to validate data along roadways comprised of these shorter TMC segments. It was determined that multiple TMC segments would be studied together by estimating the equivalent travel time based on a path of multiple TMC segments. The following is a discussion of the process developed along with examples to illustrate the method used.

Estimation of the equivalent path-based speeds

In order to compare INRIX speed feeds with the Bluetooth dataset, for each pair of Bluetooth observations at two endpoints of a path comprised of multiple TMC segments, one equivalent travel time estimate based on INRIX data should be estimated. The estimation is based on the observed exit time of the vehicle from the path segment. Therefore, the initial example given here and the proposed algorithm are based on the exit times.

However, in the final example provided with real data, both forward and backward procedures are applied and results are reported.

First, the time interval to which the end time of a Bluetooth match belongs should be identified. Given the distances and speeds of each segment in that time interval an average travel time for each segment can be calculated. Backtracking based on these travel times we can determine where the vehicle has been at the beginning of the current time interval. Obviously, in the case that the vehicle has been midway on the path the procedure can be repeated with data from the previous interval until it is determined that the vehicle has entered the path during the current time interval. The concept is illustrated through an example.

Figure A-1 shows the aggregated space-time diagram of a path segment comprised of four smaller segments. The segments are 0.4, 0.3, 0.2 and 0.1 mile long (shown on the Y-axis) which together form a one mile path. Time intervals are each five minutes long (X-axis). Sample INRIX speeds (mph) and average travel time (in minutes), respectively are shown for each segment and time interval cell. Two Bluetooth sensors are placed at either end of this longer path. If we have a Bluetooth match with an exit time at 8:11:00 (indicated with the arrow in this figure) then we know it belongs to the 8:15 time interval. In the one minute time that this vehicle has spent in the fourth time interval it has covered the last two segments and parts of the second one:

1-0.24>=0, thus our vehicle has totally covered the fourth segment during this interval,
1-0.24-0.27>=0, thus our vehicle has totally covered the third segment during this interval,
1-0.24-0.27-0.72<0, thus our vehicle has spent 1-0.24-0.27=0.49 min. on the second segment during this interval. This translates to 0.3*0.49/0.72=0.2 mile of the second segment. In other

words, at the beginning of 8:15 interval, our vehicle has already covered 0.3-0.2=0.1 mile of the second segment.

Given the average speed on the second segment in the 8:10 time interval, our vehicle would have required 0.1/0.3*0.4=0.13 min. to cover 0.1 mile on the second segment, 5-0.13>=0, thus our vehicle has covered the 0.1 mile on the second segment during the 8:10 interval, 5-0.13-0.8>=0, thus our vehicle has totally covered the first segment during the 8:10 interval.

In total, our vehicle has spent 1+0.13+0.8=1.93 min. to go through the segments. This is the equivalent travel time estimated using average reported speeds on each segment which results in an average travel speed equal to (0.4+0.3+0.2+0.1)/1.93*60=31.0 mph for our sample vehicle.

Figure A-1 -Aggregated space-time diagram of an example path segment

TMC Segments	0.1	45(0.13)	30(0.2)	40(0.15)	25(0.24)
	0.2	30(0.4)	40(0.3)	25(0.48)	45(0.27)
	0.3	15(1.2)	30(0.6)	45(0.4)	25(0.72)
	0.4	25(0.96)	15(1.6)	30(0.8)	45(0.53)
		8:00	8:05	8:10	8:15
		Time Interval			

In summary, to estimate the equivalent travel times the following algorithm is proposed:

Given a sequence of segments $i = 1, \dots, N$ forming a path, each with a length, $l(i)$, and speed $S(i,t)$ at time interval t:

For each valid Bluetooth observation pair $(StTime, EndTime)$ ending at the same time interval $\{T: (T-1)*5 < EndTime \leq T*5\}$, let: $TE = mod(EndTime, 5); n = N; t = T; PTT = 0;$

While (Ture)

If $TE \geq \sum_{i=1}^{n} TT(i,t)$ then

$PTT = PTT + \sum_{i=1}^{n} TT(i,t)$; Break.

Find segment j for which, $TE \geq \sum_{i=j+1}^{n} TT(i,t)$ and $TE < \sum_{i=j}^{n} TT(i,t)$

$PTT = PTT + TE;$

$$TT(j,t-1) = TT(j,t-1) * \frac{\sum_{i=j}^{n} TT(i,t) - TE}{TT(j,t)}$$

$TE = 5min; n = j; t = t-1;$

Loop while, Repeat.

Compute the equivalent average path travel time, $\overline{PTT}$

Compute the equivalent average speed for comparison with Bluetooth speed:

$$S_{INRIX}(T) = \frac{\sum_{i=1}^{N} l(i)}{\overline{PTT}}$$

The following is a worked out example using real Bluetooth and INRIX data from the September 2009 validation deployments in New Jersey. This example specifically illustrates the application of the proposed algorithm to estimate equivalent path-based speeds from INRIX data for each Bluetooth travel time observation. Two consecutive short TMCs (103-04311 and 103N04311) on southbound NJ-55 are considered. INRIX reported speeds and average travel times (minutes) on these two segments are shown in Figure A-2. Please note that times are in UTC.

Figure A-2 - Aggregated space-time diagram of a real path segment

TMC Segments	0.19	49(0.24)	49(0.24)	46(0.25)	7(1.65)	6(1.93)
	0.57	49(0.70)	49(0.70)	46(0.74)	7(4.89)	6(5.70)
		21:25	21:30	21:35	21:40	21:45
		Time Interval				

To account for deviation from standard TMC lengths during Bluetooth deployments, adjusted travel times reported in the following table will be used in all ensuing calculations.

Figure A-3 - Adjusted aggregate space-time diagram of a real path segment

TMC Segments	(0.23)	49(0.28)	49(0.28)	46(0.30)	7(1.97)	6(2.30)
	(0.52)	49(0.64)	49(0.64)	46(0.68)	7(4.46)	6(5.20)
		21:25	21:30	21:35	21:40	21:45
		Time Interval				

Table A-1 shows the outcomes of applying the method on a Bluetooth sample and summarizes the procedure to estimate equivalent INRIX speeds when the proposed algorithm is utilized.

Conclusion

The data validation effort for the Vehicle Probe Project optimally studies TMC segments of greater that one mile in length. However, not all TMC segments are greater than one mile. A method has been developed to validate data along roadways comprised of these shorter TMC segments by estimating the equivalent travel time based on a path of multiple TMC segments. The method developed utilizes an algorithm that has been found to calculate the equivalent average travel times and equivalent average speeds. Application of this method yields average travel times that are acceptable for validation efforts.

Table A-1 - Summary calculations for a real path segment

Time Interval	MAC ID	Start Time	End Time	Bluetooth			INRIX Equivalent		
				Travel Time (sec)	**Speed (mph)**	**Average Speed (mph)**	**Travel Time (sec)**	**Speed (mph)**	**Average Speed (mph)**
	00:22:65:F2:90:87	212456	212537	41	66		55	49	
	00:23:7A:C1:7D:84	212624	212709	45	60		55	49	
21:30	00:13:6C:4B:95:D8	212639	212725	46	59	**61**	55	49	**49**
	00:0E:9F:22:4A:42	212807	212857	50	54		55	49	
	00:25:67:DF:56:0A	212848	212928	40	68		55	49	
21:35	00:1D:F6:9E:70:83	213200	213426	146	18	**18**	59	46	**46**
	00:1C:43:09:1B:C0	213252	213502	130	21		61	44	
21:40	00:1F:CD:66:AF:7C	213359	213629	150	18	**16**	134	20	**17**
	00:13:6C:95:CB:11	**1.1.1** 213430	**1.1.2** 213746	**1.1.3** 196	**1.1.4** 14		200	14	
	00:0F:E4:53:82:10	213542	213842	180	15		247	11	
21:45	00:05:4F:42:37:AD	213817	214020	123	22	**22**	389	7	**7**