Indirect Validation of Probe Speed Data on Arterial Corridors

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Sepideh Eshragh[1], Stanley E. Young[2], Elham Sharifi[1], Masoud Hamedi[1], Kaveh Farokhi Sadabadi[1]

[1]Center for Advanced Transportation Technology (CATT), University of Maryland, College Park, MD 20742, USA

[2]National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 80401, USA

Abstract

The accuracy of probe speed data on arterial corridors are estimated based on roadway geometric attributes and functional classification. Functional class (medium and low) along with other road characteristics (such as weighted average AADT, average signal density, average access point density, and average speed) are used as correlation factors to estimate probe traffic data accuracy. The proposed models for medium and low type of arterials are validated based on the slowdown analysis results. These models can be used to indirectly predict accuracy of probe data in medium and low class arterial corridor types.

Introduction

- Arterials are interrupted-flow facilities (non-freeway) providing a higher level of throughput mobility compared to collectors/distributors. Many departments of transportation (DOT) are extending performance measure efforts originating from the freeway system to their system of arterial roadways.
- Since 2008 the I-95 Vehicle Probe Project (VPP) started to monitor the performance measures for freeways and major arterials on the East Coast of the United States. From 2013 to the present, the University of Maryland (UMD) Center for Advanced Transportation Technology (CATT) has gathered data from several arterial corridors within the mid-Atlantic region.
- Arterial corridors are classified based on accessibility and mobility:
  - *High classification arterial*
    - Average Annual Daily Traffic (AADT) >= 40,000
    - Average signal density on a corridor <= 1 signal per mile
    - Limited curb cuts and access points to disrupt traffic flow
  - *Medium classification arterial*
    - AADT =>20,000
    - Average signal density on a corridor <= 2 signals per mile
    - Moderate number of curb cuts and access points to disrupt traffic flow
  - *Low classification arterial*
    - AADT < 20,000
    - Average signal density on a corridor >= 2 signals per mile
    - Substantial curb cuts and significant access points to disrupt traffic flow

Methodology

- Two validation methods used in this study defined as follows:

- *Slowdown Analysis Method*
  - The slowdown analysis is effective in assessing the ability of probe data to capture significant disruptions in traffic.
  - The significant disruption is defined as a speed reduction of at least 15 mph from nominal for a period of one hour or more. On slower speed arterials, the threshold may be reduced to 10 mph, and 30 minutes.
  - A slowdown analysis identifies significant disruptions in traffic flow and classifies probe data's ability to accurately capture these disruptions into one of three categories:
    - *Fully Captured:* traffic data reflected a significant disruption to traffic flow, and accurately characterized its magnitude both in time and extent of speed reduction.
    - *Partially Captured:* traffic data reflected a major disruption to the traffic stream, but the traffic data inaccurately reflected either the reduction in speed or extent of time of the slowdown.
    - *Poorly Captured:* a slowdown was either completely missed by the traffic data or the extent of speed reduction and/or duration of the event was significantly underestimated such that it would be mistaken for a minor slowdown or minor traffic disruption.

- *Traditional Analysis*
  - Daily 24-hour data plots contrasting the VPP data with the BTM reference data were generated for each corridor.
  - Average Absolute Speed Error (AASE): The mean absolute value of the difference between the mean speed reported from the VPP and the reference mean speed for a specified time period.
  - Speed Error Bias (SEB): The average speed error in each speed bin. A typical set of speed ranges for an arterial was 0-15 mph, 15-30 mph, 30-45 mph, and >45 mph, though the actual range differs based on the facility.

Case Study

- The probe data accuracy models are based on the results of 17 arterial corridors located in different States (North Carolina, Virginia, Maryland, Pennsylvania, and New Jersey), spanning the nine case studies conducted between 2013 and 2014.
- More than 300,000 Bluetooth observation resulting from 117 days continues data collection is used in data validation.
- In general data has been collected on each road segment used in this study for a period of 10-12 days, and 5 minutes time intervals with less than 3 valid Bluetooth observations were discarded.
- The data used in this study was mixed of real and traditional data and also it did not include any special event such as severe weather.

Arterial Corridor Locations, Attributes, Types, Slowdown Analysis and Traditional Analysis Results

Arterial Corridor	Road Name	Length (mile)	Weighted Average AADT (in 1000)	Average Signal Density (signal/mi)	Average Access Point Density (accesses/mi)	Average Speed Limit (mph)	Arterial Type	Slowdown Analysis				AASE (mph)
								Total Slowdown	% Fully Captured	% Partially Captured	% Failed to Capture	
NC-55	Williams St, or Apex Hwy.	30.3	25	2.1	7.6	42.5	Low	54	15.0%	44.0%	41.0%	11.6
MD-355	Wisconsin Ave, Rockville Pike, Hungerford Dr., Frederick Rd	17.1	44	3.9	12.9	37.5	Low	9	44.4%	22.2%	33.3%	8.2
MD-586	Veirs Mill Rd	5.2	34	3.1	9.0	37.5	Low	8	0.0%	37.5%	62.5%	9.5
US-1	Trenton Fwy., Brunswick Pike	14.2	70	0.7	7.9	55	High	101	63.4%	36.6%	0.0%	7.0
NJ-42	Black Horse Pike	12.5	48	1.8	20.8	47.5	Medium	4	0.0%	100 %	0.0%	10.7
US-130	Burlington Pike	14.3	42	2.0	16.0	50	Medium	4	25.0%	50.0%	25.0%	14.0
NJ-38	Kaighn Ave.	24.5	46	1.8	9.6	50	Medium	57	40.4%	38.6%	21.1%	11.9
NJ-73	Palmyra Bridge Rd	23.9	52	1.7	9.9	50	Medium	89	41.6%	46.1%	12.4%	8.6
US-1	Lincoln Highway, Arterial	30.6	45	4.1	6.5	45	Low	78	28.2%	48.7%	23.1%	8.7
US-322	Colchester Highway	14.3	25	0.5	3.4	40	High	58	50.0%	41.4%	8.6%	8.3
PA-611	Easton Rd, Old York Rd	20.5	27	3.3	11.1	30	Low	18	22.2%	33.3%	44.4%	6.6
	N Broad St	12.5	21	11.5	20.1	32.5	Low	5	0.0%	20.0%	80.0%	4.4
VA-7	Leesburg Pike and Harry Byrd Hwy.	30.5	56	1.9	6.9	45	Medium	75	24.0%	42.7%	33.3%	8.3
US-29	Lee Hwy (S Washington St)	4.4	21	5.0	25.9	30	Low	1	0.0%	0.0%	100.0%	4.3
	Lee Hwy	31.9	33	3.6	9.0	42.5	Low	49	8.2%	42.9%	49.0%	8.6
MD-140	Reisterstown Rd	17.4	31	3.9	12.7	35	Low	20	0.0%	35.0%	65.0%	5.9
	Baltimore Blvd	15.5	42	1.2	3.4	52.5	Medium	18	22.2%	66.7%	11.1%	14.8

Data Analysis

- The results of correlation analysis among the arterial attributes (weighted average AADT, average signal density, average access point density, and average speed) and the accuracy of probe data (AASE) on medium and low type of arterial are summarized in the following table.
- There were only two high type arterials in this case study. Therefore, no meaningful conclusion for high type arterials based on the correlation analysis can be derived.
- The weighted average AADT has strong and negative correlation with accuracy of probe data in medium type of arterial which is marked by asterisk.
- In low type of arterial, the average access point density has a very strong and negative correlation with accuracy of probe data also marked by asterisk.
- This table also indicates that some geometric and traffic attributes are strongly correlated with each other.

The Correlation of Corridor Type with Road Attributes and Probe Data Accuracy

Type of Corridor	Attributes and Probe Data Accuracy	Weighted Average AADT (in 1000)	Average Signal Density	Average Access Point Density	Average Speed Limit (mph)	AASE (mph)
Medium Type of Corridor	Weighted Average AADT (in 1000)	1.00				
	Average Signal Density	0.34	1.00			
	Average Access Point Density	-0.11	0.60	1.00		
	Average Speed (mph)	-0.79	-0.64	-0.28	1.00	
	AASE (mph)	-0.97*	-0.41	-0.05	0.73	1.00
Low Type of Corridor	Weighted Average AADT (in 1000)	1.00				
	Average Signal Density	-0.36	1.00			
	Average Access Point Density	-0.53	0.60	1.00		
	Average Speed (mph)	0.55	-0.39	-0.76.	1.00	
	AASE (mph)	0.41	-0.68	-0.84*	0.79	1.00

Results

- Linear regression models were calibrated to estimate the relationship between probe data accuracy measure (AASE) and other geometric and traffic attributes for each type of arterial corridor.
- Regression results indicated that the weighted average AADT has strong correlation with accuracy of probe data (AASE) on medium type of arterial whereas the average access point density has strong correlation with accuracy of probe data on low type of arterial.
- In slowdown analysis, in order to estimate accuracy of probe speed data on arterial, the fidelity of outsource probe data based on the level of correlation with the re-identification reference data are classified to well performed, mixed performed, and poor performed.
- The classification of the probe data fidelity is performed based on the following criteria:

- *Well Performed*

  If Fully Captured $\geq 50\%$ AND Fully Captured + Partially Captured $\geq 90\%$

- *Poor Performed*

  If Fully Captured $< 50\%$ AND Fully Captured + Partially Captured $< 65\%$

- *Mixed Performed*

  Any slowdowns are not belong to these above criteria's

- By applying these criteria's on the slowdown analysis results, the probe data fidelity on each corridor is classified as either well, mixed, or poor. The results of classification of the fidelity of probe data on each arterial corridor are shown in the following table.
- Result shows arterial probe data performance in capturing slowdowns strongly correlates with the type level in which arterial corridor is classified.
  - Low type arterials almost corresponded with poor performance.
  - Medium type arterials have been almost synonymous with mixed performance.
  - High type arterials without exception correspond with well performance in capturing slowdowns, however there were only two high type arterials in this case study and no meaningful conclusion can be derived.

The Fidelity of Probe Data Classification on Arterials and Arterial Type

Arterial Corridor	Road Name	Arterial Type	Slowdown Analysis				Probe Data Fidelity
			Total Slowdown	% Fully Captured	% Partially Captured	% Failed to Capture	
NC-55	Williams St, or Apex Hwy.	Low	54	15.0%	44.0%	41.0%	Poor Performed
MD-355	Wisconsin Ave, Rockville Pike, Hungerford Dr., Frederick Rd	Low	9	44.4%	22.2%	33.3%	Mixed Performed
MD-586	Veirs Mill Rd	Low	8	0.0%	37.5%	62.5%	Poor Performed
US-1	Trenton Fwy., Brunswick Pike	High	101	63.4%	36.6%	0.0%	Well Performed
NJ-42	Black Horse Pike	Medium	4	0.0%	100 %	0.0%	Mixed Performed
US-130	Burlington Pike	Medium	4	25.0%	50.0%	25.0%	Mixed Performed
NJ-38	Kaighn Ave.	Medium	57	40.4%	38.6%	21.1%	Mixed Performed
NJ-73	Palmyra Bridge Rd.	Medium	89	41.6%	46.1%	12.4%	Mixed Performed
US-1	Lincoln Highway, Arterial	Low	78	28.2%	48.7%	23.1%	Mixed Performed
US-322	Colchester Highway	High	58	50.0%	41.4%	8.6%	Well Performed
PA-611	Easton Rd, Old York Rd	Low	18	22.2%	33.3%	44.4%	Poor Performed
	N Broad St	Low	5	0.0%	20.0%	80.0%	Poor Performed
VA-7	Leesburg Pike and Harry Byrd Hwy.	Medium	75	24.0%	42.7%	33.3%	Mixed Performed
US-29	Lee Hwy (S Washington St)	Low	1	0.0%	0.0%	100.0%	Poor Performed
	Lee Hwy	Low	49	8.2%	42.9%	49.0%	Poor Performed
MD-140	Reisterstown Rd	Low	20	0.0%	35.0%	65.0%	Poor Performed
	Baltimore Blvd	Medium	18	22.2%	66.7%	11.1%	Mixed Performed

Summary

- There are strong correlations between arterial attributes and the accuracy of probe data on medium and low type of arterials.
- The Average Absolute Speed Error (AASE) from traditional analysis is used as an indicator of the accuracy of probe data on these arterials.
- Linear regression models are calibrated in order to estimate the appropriate relationships for medium and low type of arterials.
- The weighted average AADT has strong correlation with accuracy of probe data (AASE) on medium type of arterial whereas the average access point density has strong correlation with accuracy of probe data on low type of arterial. This is in line with the intuition as medium type arterials demonstrate higher mobility (throughput volume) levels while low type arterials provide higher accessibility (number of access points) levels.
- To estimate accuracy of probe speed data on arterials, the fidelity of out-sourced probe data based on the level of correlation with the re-identification reference data are classified to well performed, mixed performed, and poor performed.
- The validation results showed the resulting classification of probe data fidelity on each arterial corridor directly corresponds with the results obtained from classification of arterial corridor types.

Conclusions

- This research can be used to make decisions regarding accuracy and applicability of probe data on medium and low type of arterials.
- Based on existing case studies, error estimates of probe data on arterials are provided.
- The results of analyses reported in this paper provide benefits in terms of time saving and informing the decision makers regarding the expected accuracy of probe data.
- The case study had limited number of corridors. a large number of corridors will be considered in the future work.
- This research used probe data which were mixed data including real time and historical data as provided by the vendors. This study did not collect any special event such as severe weather.

Contact Information

Sepideh Eshragh, Ph.D.
Faculty Research Assistant

5000 College Ave, Suite 2201
College Park, MD 20742

T: 301.405.8192
F: 301.405.5959
E: eshragh@umd.edu