Evaluating the Use of Bus-based Video Imagery to Monitor VMT on an Urban Network

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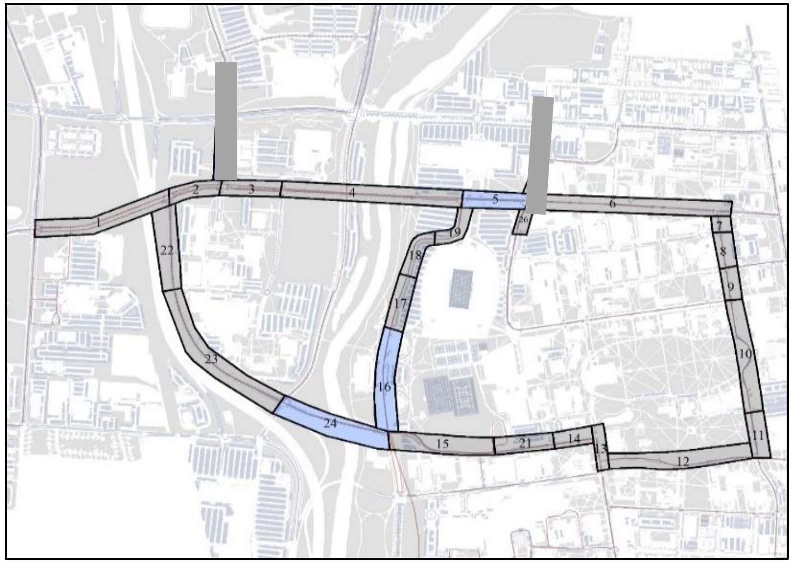
Background: Vehicle Miles Traveled

- Vehicle miles travelled (VMT) is the fundamental measure used to monitor aggregate vehicular travel on a roadway network during a specified time period (e.g., average day) over time (e.g., years)



- Can be calculated by:

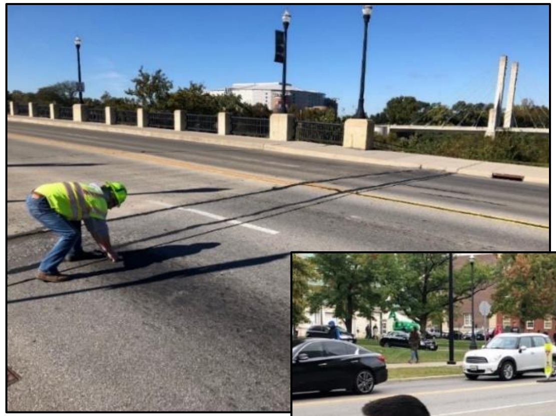
$$VMT = \sum_{\forall i} L_i \times V_i$$

L_i = length of segment i
V_i = vehicle volume on segment i during specified period

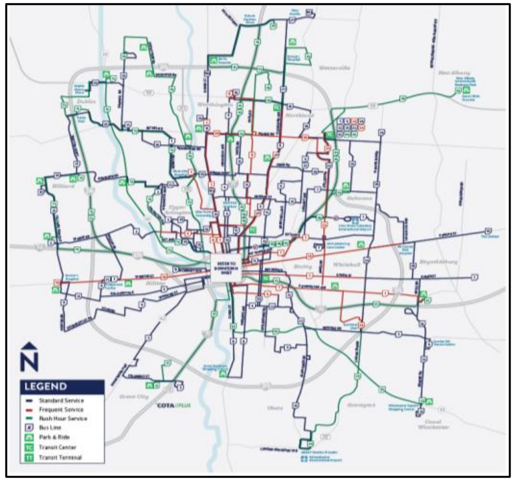
- Segment lengths are readily available in static roadway databases

- Volumes must be measured

Volume Measurement



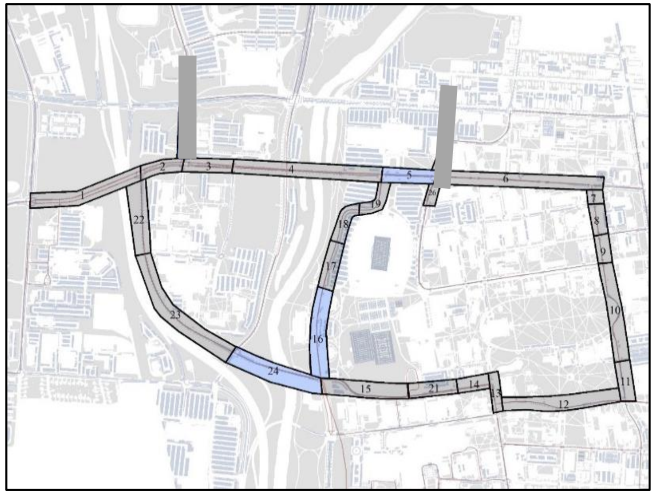
- Traditional methods involve automatic or human counters observing traffic at a fixed location on a roadway segment over a long time period
- Because of limited resources, few segments can be monitored and can only be monitored infrequently
- Video cameras are installed on transit buses for safety, security, and liability purposes



- Readily available video imagery provide a low-cost alternative covering major urban roadways on a repeated basis

Objective of Study

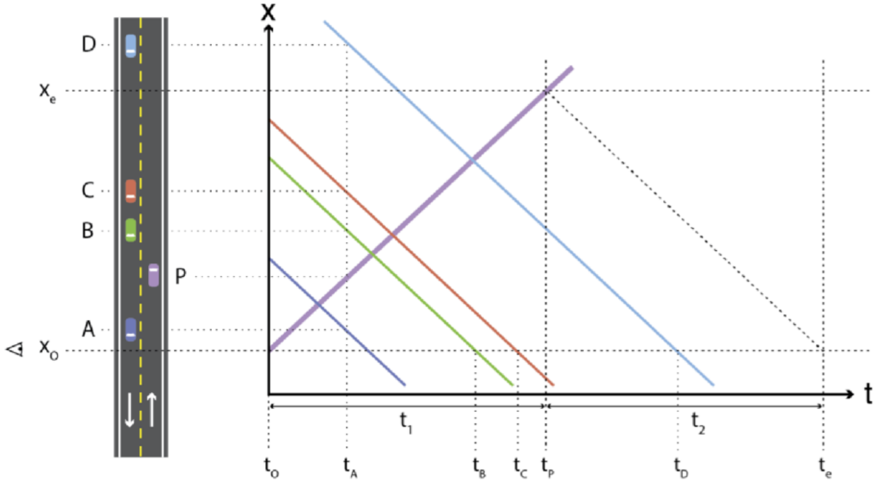
- Demonstrate the promise of an approach that takes advantage of presently available, public sector platforms – transit buses – and sensors – video cameras – to obtain urban traffic volumes for VMT monitoring

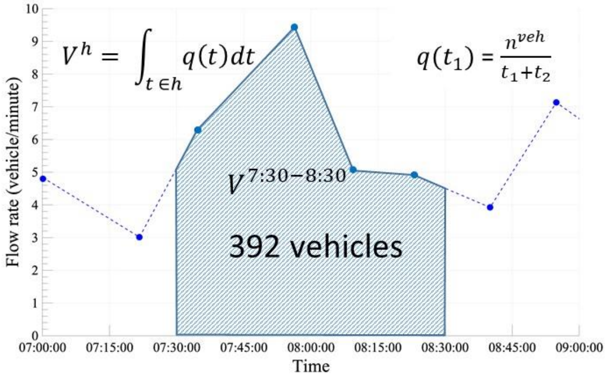


- Do so empirically in an operational setting
- Compare accuracy of results to those obtained when using a presently popular source of location based services (LBS) derived traffic volumes

Bus-based Volume Estimation

- A methodology was previously developed to estimate vehicle volumes from bus-based video imagery
- The two main components are:
  - Modified the "moving observer" method to determine volumes from one-direction bus passes
  - Refined and aggregated volumes estimated from individual bus passes into volume estimates for time-of-day periods

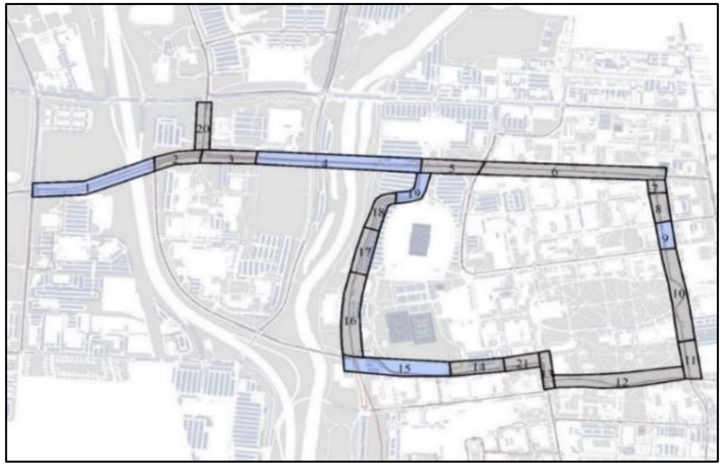




- A semi-manual graphical user interface is used to detect vehicles in the video imagery (an automatic machine-vision method is being developed)

Study Design

- Video imagery from cameras mounted on OSU's Campus Area Bus Service (CABS) provided by OSU's Transportation and Traffic Management, TTM) is used
- Hourly vehicle volumes between 8 am and 6 pm are estimated
- The estimates serve as input to 10-hour vehicle miles traveled (VMT) estimates and hourly time-of-day (TOD) patterns on the OSU campus roadway network on a Thursday in late October/early November in 2018, 2019, 2020, and 2021
- Concurrent hourly vehicle volumes obtained from road tubes data on subnetworks and from a popular Location Based Service (LBS) data aggregator and supplier are used to determine hourly volumes, 10-hour VMT, and TOD patterns
- Video-based and LBS-based VMT, TOD patterns, and changes in estimates over four years covering 40 segment-directions spanning 6.3 direction-miles are compared to:
  - Road tube-based results (serving as ground truth)
  - Published growth factors
  - Known year-to-year changes in TOD pattern



Empirical Results: Hourly Volumes

- Video and LBS based estimates of segment-hour-direction volumes are compared to ground truth tube volumes
- Segment-hour-direction volume absolute relative differences (ARDs) statistics:

	Video-based volumes	LBS-based volumes
No of seg-dir-hrs (sample size)	280	280
ARD mean	0.2070	1.1566
ARD standard deviation	0.1957	1.6110
ARD median	0.1565	0.5680
ARD 10th percentile	0.0278	0.1029
ARD 90th percentile	0.7392	6.8811

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- Video based estimates are much closer to the ground truth than the LBS estimates

Empirical Results: 10-hour VMT

- Video and LBS based estimates of 10-hour VMT are compared to ground truth tube VMT
- 10-hour VMT on road-tube subnetworks (different subnetworks were equipped with road tubes in different years):

Year	Video VMT	LBS VMT	Tube VMT	Video vs. Tube ARD	LBS vs. Tube ARD
2018	7,592	13,445	7,610	0.0023	0.7668
2019	5,570	6,914	5,054	0.1021	0.3680
2020	5,210	11,039	4,929	0.0572	1.2396

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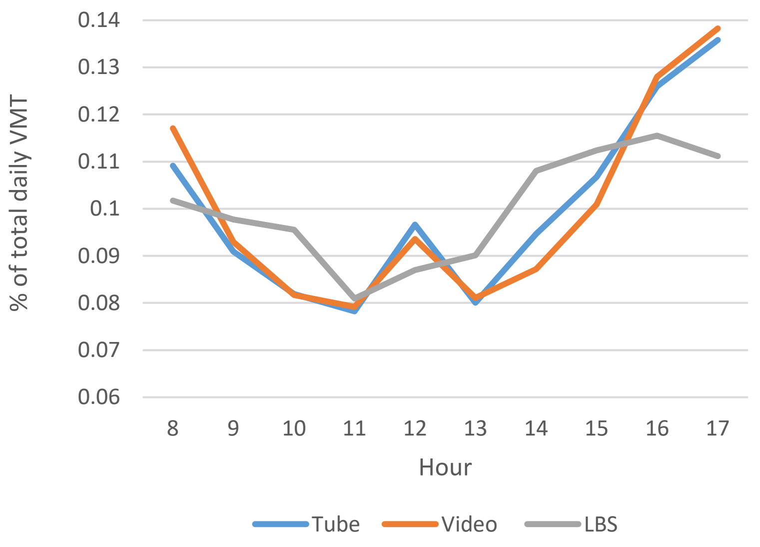
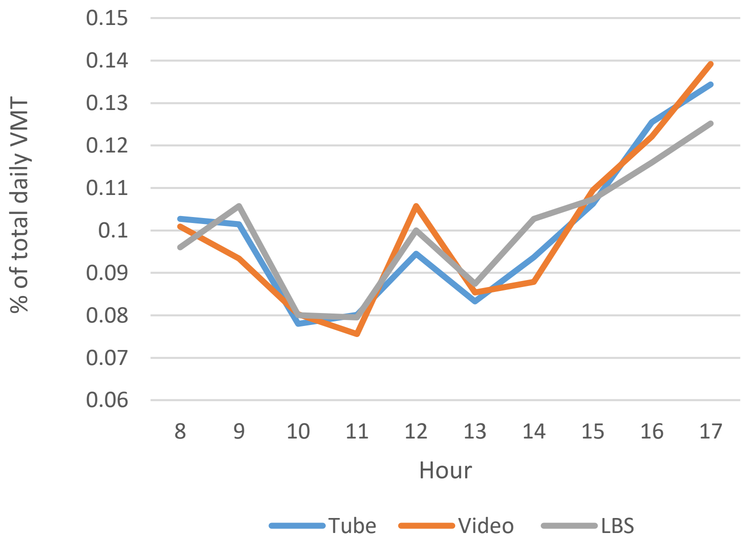
Empirical Results: Time-of-day VMT Patterns

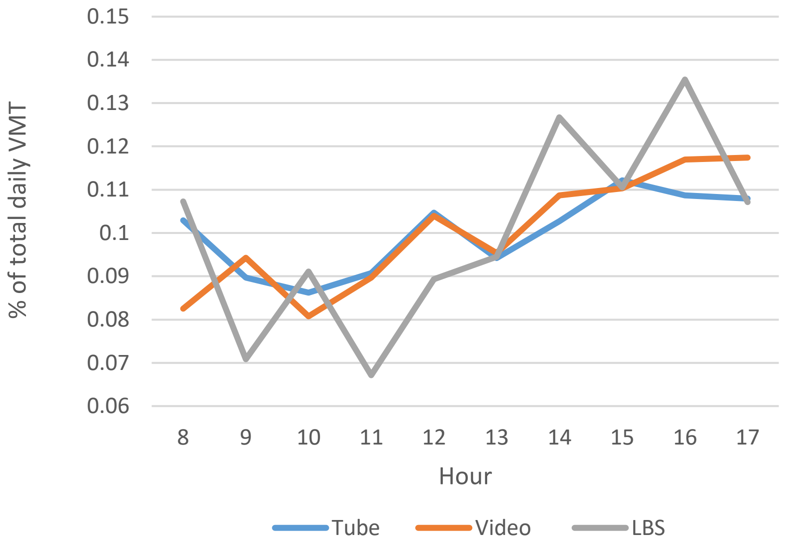
- Video and LBS based estimates of TOD VMT patterns are compared to ground truth tube TOD patterns and known patterns
- Proportion of 10-hour VMT carried in hour by data source:



2018



2019



2020

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Empirical Results: Time-of-day VMT Patterns (cont.)

- Average absolute value of differences (AADs) of video and LBS VMT from ground truth tube TOD patterns:

Year	Video vs. Tube	LBS vs. Tube
2018	0.0054	0.0104
2019	0.0027	0.0052
2020	0.0059	0.0121

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- The AAD values obtained when using video are approximately half the AAD values obtained when using LBS data

Empirical Results: Year-to-year Changes in VMT

- Video and LBS based estimates year-to-year changes in 10-hour VMT are compared to published Ohio DOT growth factors
- 10-hour network VMT by year and Growth Factors (GFs) using 2018 as reference (using 2018 network less one segment where LBS estimates are not available):

Year	Video VMT	LBS VMT	Video GF	LBS GF	ODOT GF
2018	18,268	34,269	–	–	–
2019	18,303	38,230	1.00	1.12	1.02
2020	9,431	32,883	0.52	0.96	0.92
2021	14,378	37,322	0.79	1.09	0.98

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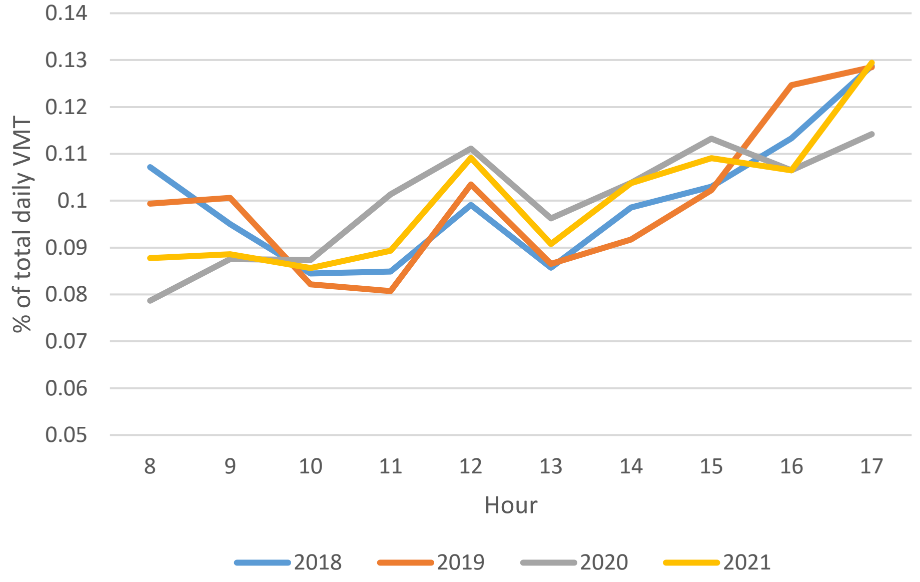
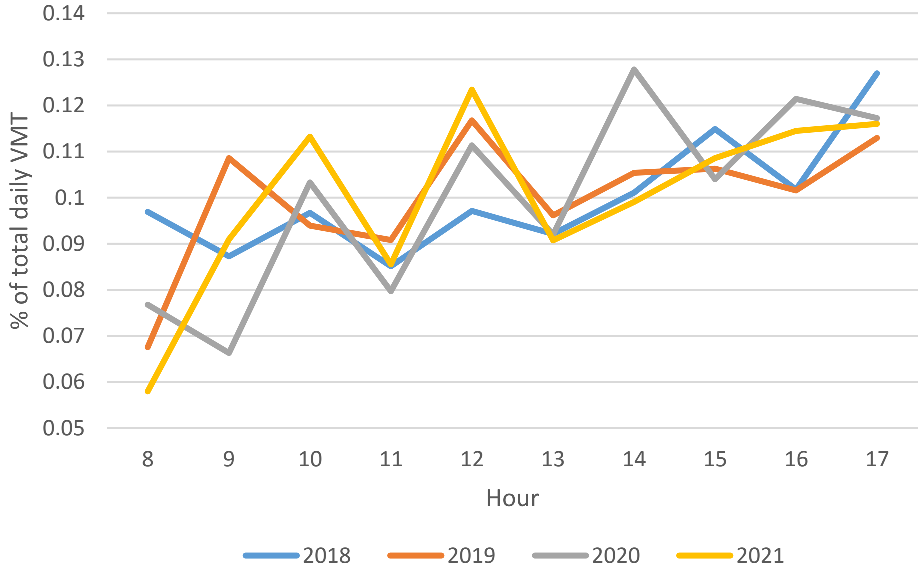
- Video based year-to-year changes correspond to ODOT GFs and known changes in the local network much more precisely than LBS year-to-year changes

Empirical Results: Year-to-year Changes in TOD patterns

- Video and LBS based year-to-year changes in TOD patterns are compared to known changes in the local network
- Proportion of 10-hour VMT carried in hour by year:



Video



LBS

- TOD patterns are expected to be similar in 2018 and 2019, which is seen in video patterns but not in the LBS ones

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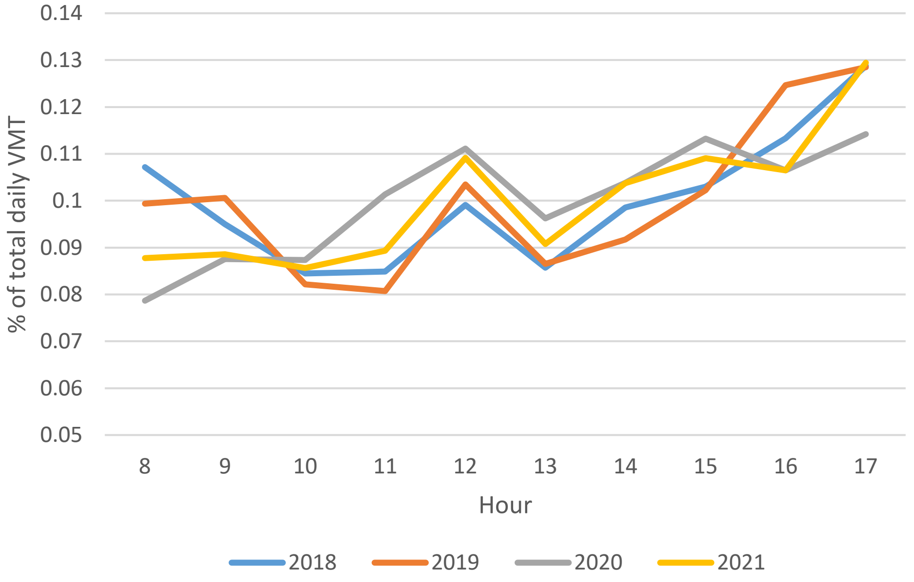
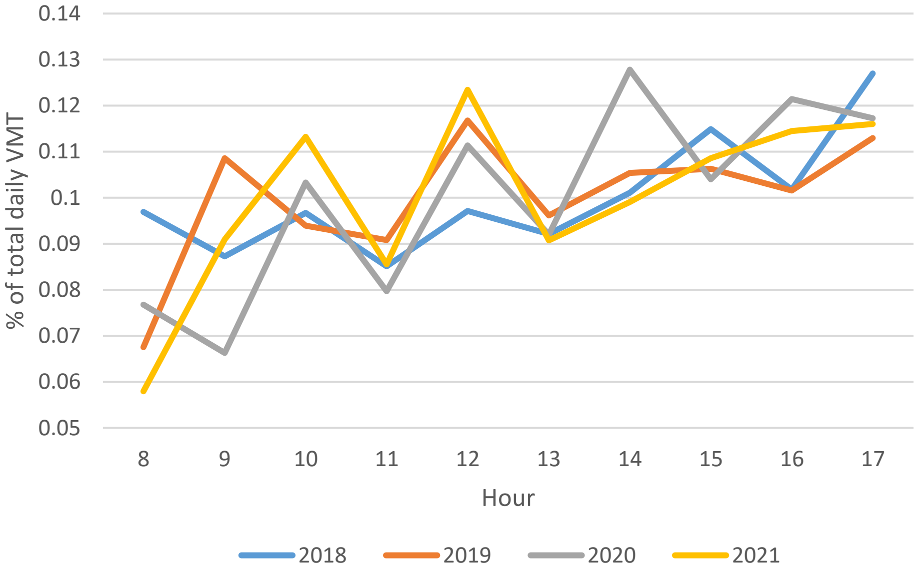


Video



LBS

- TOD patterns are expected to be similar in 2018 and 2019, which is seen in video patterns but not in the LBS ones
- COVID-19 2020 and 2021 TOD patterns appear reasonable in the video patterns but no explainable patterns are seen in the LBS patterns

Empirical Results: Year-to-year Changes in TOD patterns (cont.)

- Average absolute value of differences (AADs) in TOD patterns for consecutive years:

Year, Year + 1	Video AAD	LBS AAD
2018-2019	0.0044	0.0110
2019-2020	0.0132	0.0130
2020-2021	0.0051	0.0114

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- Again, the 2018-2019 AAD of 0.0044 seen in the video TOD pattern is much smaller than the AAD of 0.0110 seen in the LBS pattern, indicating that the LBS data are leading to much larger differences in patterns between two years where the patterns are expected to be similar

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- Again, the 2018-2019 AAD of 0.0044 seen in the video TOD pattern is much smaller than the AAD of 0.0110 seen in the LBS pattern, indicating that the LBS data are leading to much larger differences in patterns between two years where the patterns are expected to be similar
- The much smaller 2018-2019 AAD of 0.0044 in comparison to the 2019-2020 AAD of 0.0132 seen in the video TOD patterns is also expected and not seen in the corresponding LBS values of 0.0110 for 2018-2019 and 0.0130 for 2019-2020

Summary

- The video VMT values differ from the ground truth tube values by between 0.2% and 10%, whereas the LBS VMT values differ by between 36% and 123%
- Differences between video TOD patterns and tube patterns are approximately half the differences between LBS and tube patterns
- Year-to-year changes seen in the video VMT values are reasonable, whereas those seen in the LBS VMT values are not

Overall Conclusion

If efficient implementation is available, bus-based video imagery appears to be a very cost-effective data source for VMT estimation and monitoring

Future Research

- Further improve volume estimates obtained from video imagery from a single bus traversals of roadway segments

- Further improve aggregation of information obtained from multiple bus traversals

- Continue to develop and test machine vision methods to automatically and validly identify vehicles in the video imagery obtained from a moving bus platform (automation will further improve the cost-effectiveness of using transit bus video imagery for ongoing VMT monitoring)

- Further empirically validate the approach on a larger and more diverse roadway network

Acknowledgements

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- LBS volumes provided via subscription by Ohio Department of Transportation
- The views, opinions, findings, and conclusions reflected in this study are the responsibility of the authors only and do not represent the official policy or position of US DOT, OSU, or any other person or entity