VMT Monitoring of an Urban Network Using Bus-based Video Imagery: Empirical Evaluation and Comparison with LBS Data Derived Estimates

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Transportation Research Board 102nd Annual Meeting, Washington, DC, January 8-12, 2023

THE OHIO STATE UNIVERSITY

MOTIVATION

- Vehicle distance/miles travelled (VDT/VMT) is the **fundamental measure** used **to monitor** aggregate **vehicular travel** on a geographically extensive roadway **network** during a specified time period (e.g., average day) **over time** (e.g., years).
- VMT can be determined by the following:

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

where L_i is the length of segment i in miles and V_i is the vehicle volume on segment i during the specified time period.
- Segment lengths L_i are readily available in static roadway databases.
- VMT is monitored over time because the vehicle **volumes V_i** vary by time **and must be determined** during the specified time period **repeatedly** during the monitored period.
- Traditional traffic data collection is based on automatic or human counters observing traffic at a **fixed location** on a roadway segment over a **long time period**. As a result of limited resources, few segments can be monitored and can only be monitored infrequently.
- **Transit buses** are presently equipped with video cameras for safety, security, and liability purposes and cover most major urban roadways on a **repeated basis**.
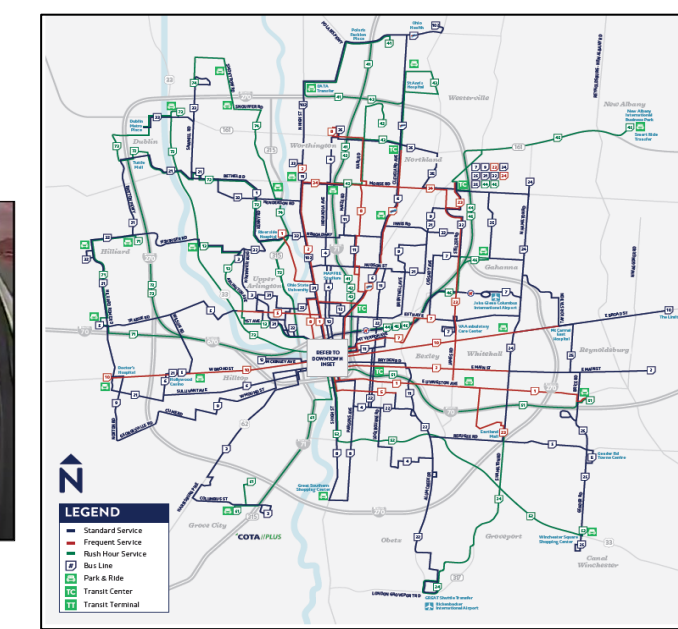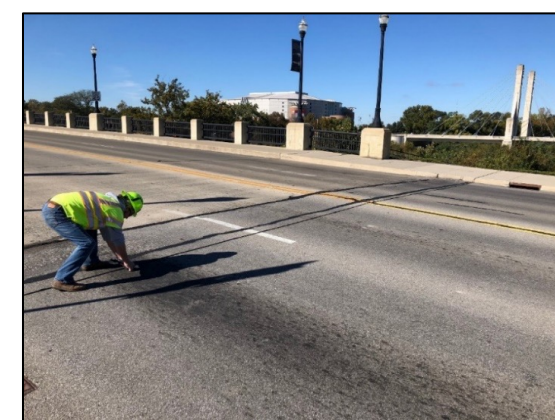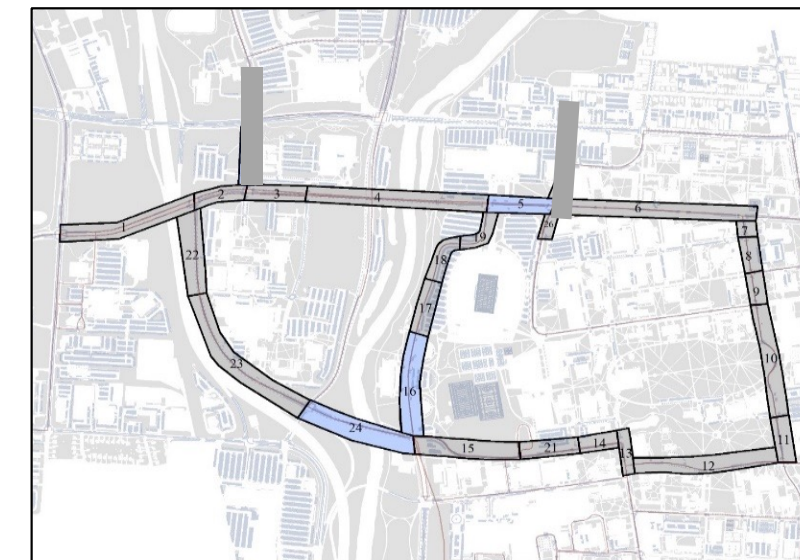
- This study seeks to **demonstrate** the promise of **an approach** that takes advantage of presently available, public sector platforms (transit buses) and sensors (video cameras) to obtain urban traffic volumes for **VMT monitoring** through an **empirical study** in an **operational setting** and to demonstrate the much better accuracy compared to that obtained when using a presently popular source of traffic volumes.

BUS-BASED VOLUME ESTIMATION

- A methodology is developed to estimate vehicle volumes from bus-based video imagery. The two main components are the following:
  - Modification of the **"moving observer"** method to determine volumes from one-direction **bus passes**.
  - Refining and aggregating volumes estimated from individual bus passes into **volume estimates for time-of-day periods**.

$$V^h = \int_{t \in h} q(t)dt \qquad q(t_1) = \frac{n^{veh}}{t_1 + t_2}$$

$V^{7:30-8:30}$
392 vehicles
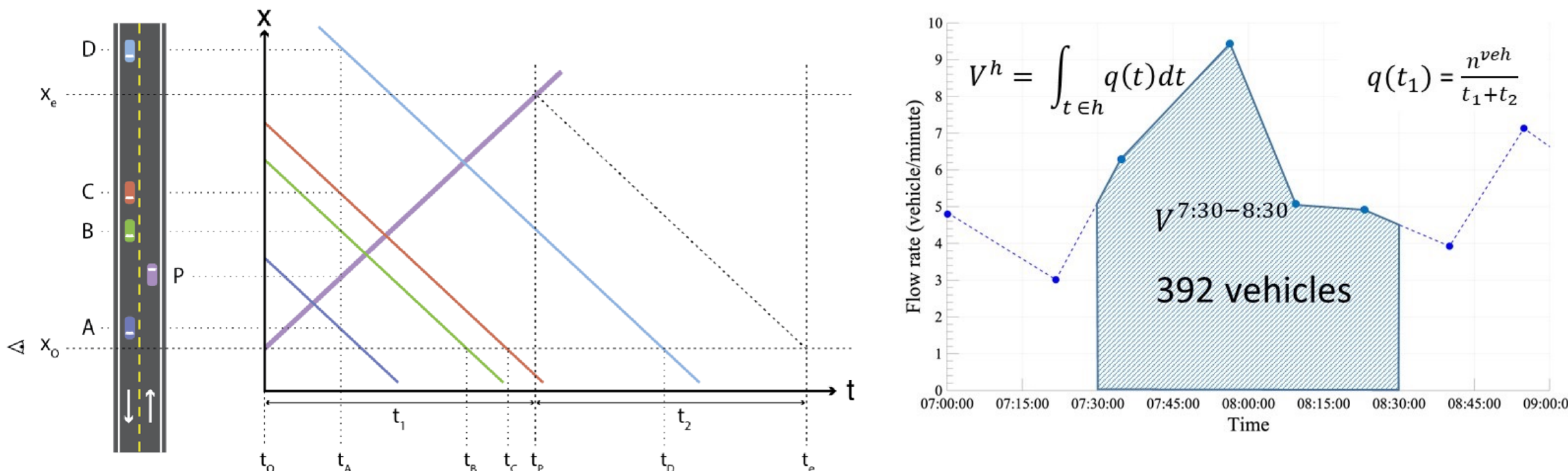
- Presently, a semi-manual **graphical user interface** is used to detect vehicles in the mobile video imagery.
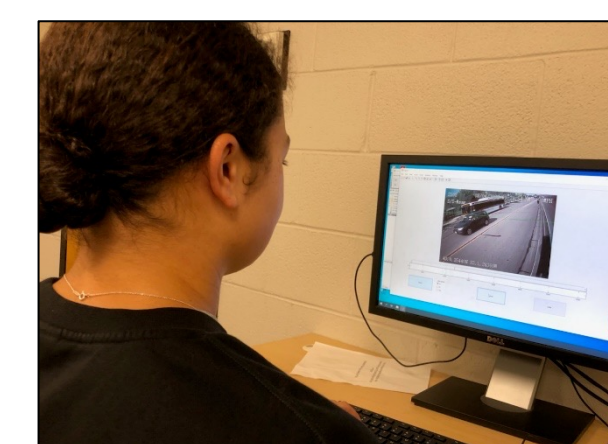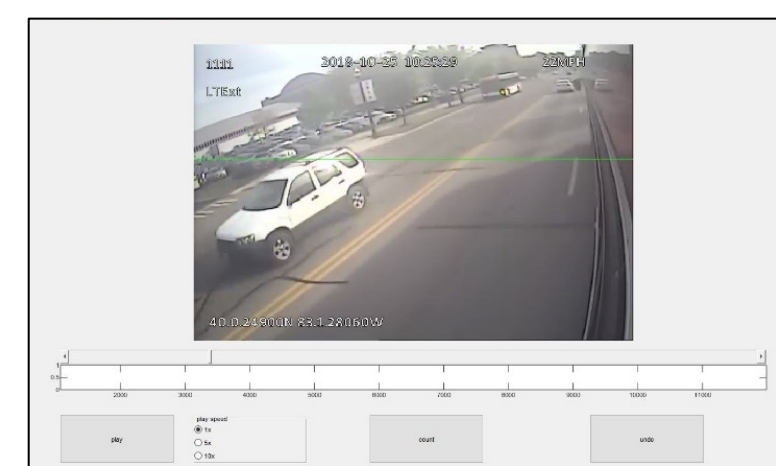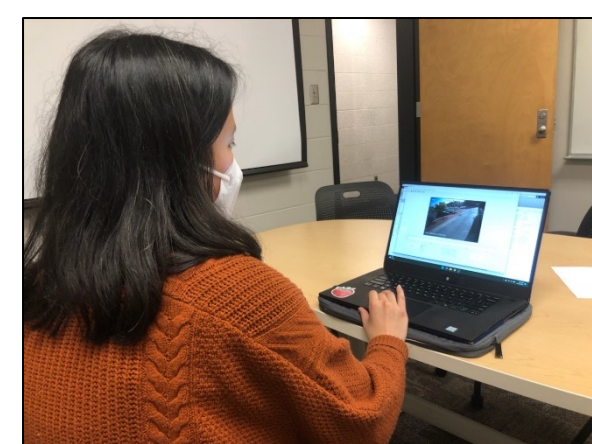
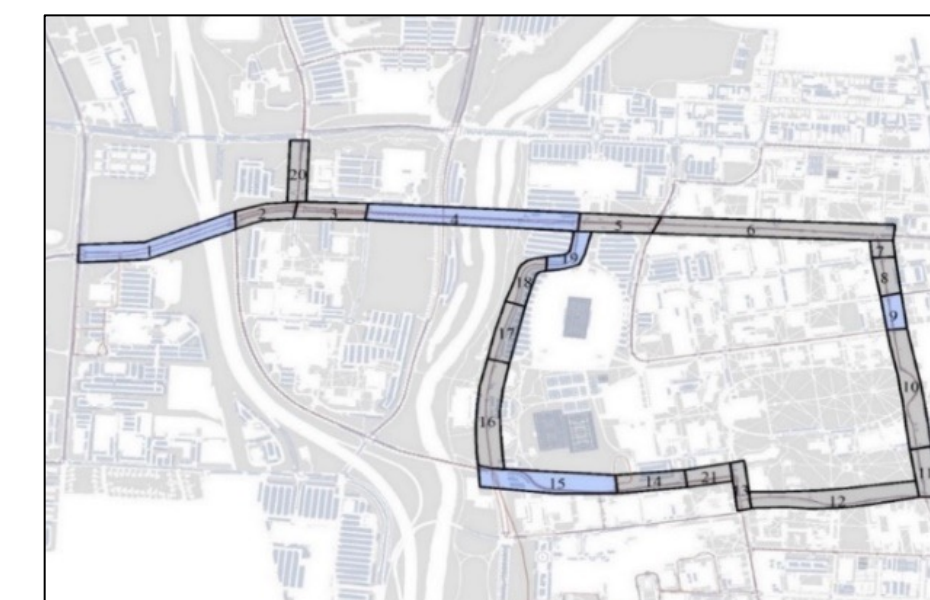- Research is ongoing to automatically detect vehicles from the imagery.

EMPIRICAL STUDY DESIGN

- Bus-based **video-imagery** provided by The Ohio State University Transportation and Traffic Management is used to estimate hourly vehicle volumes between 8 a.m. and 6 p.m. that serve as input to **10-hour vehicle miles traveled (VMT)** estimates and **time-of-day (TOD) patterns** on the OSU campus roadway network on a Thursday in late October/early November for four consecutive years.
- Concurrent hourly volumes obtained from **road tubes** data on subnetworks and from a popular **Location-based Service (LBS) data** aggregator and supplier are used to determine 10-hour VMT and TOD patterns.
- Video-based and LBS-based estimates and changes in estimates over years are compared to road tube-based results (serving as **ground truth**), to **published growth factors**, and to **known TOD traffic patterns**.

Road Tubes
Compliments of Mid-Ohio Regional Planning Commission

| FC	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
R 1	2.404%	3.50%	2.10%	2.30%	1.00%	0.50%	-18.10%	16.60%
R 2	1.885%	3.50%	4.30%	5.10%	0.00%	1.00%	-14.90%	14.30%
R 3	1.165%	3.60%	3.20%	3.40%	0.50%	1.10%	-12.20%	11.80%
R 4	0.862%	2.60%	1.10%	2.10%	0.00%	2.20%	-11.10%	9.20%
R5	1.687%	1.50%	2.60%	1.00%	0.50%	0.50%	-8.00%	5.70%
R 6 & 7	-0.785%	4.40%	2.50%	0.00%	0.30%	1.60%	-3.70%	1.10%
U 1	0.482%	2.90%	2.00%	1.80%	1.00%	0.30%	-18.10%	13.60%
U 2	1.615%	2.70%	2.40%	2.90%	1.40%	2.40%	-15.20%	11.80%
U 3	0.663%	1.90%	2.10%	0.00%	0.00%	1.00%	-12.40%	9.90%
U4	-2.540%	1.10%	4.20%	2.70%	0.90%	0.70%	-7.40%	4.80%
U 5 & 6 & 7	1.460%	3.30%	5.00%	2.80%	1.20%	1.50%	-9.80%	7.20%

Ohio DOT Annual Adjustment Factors for ADT: 2014 – 2021
https://www.transportation.ohio.gov/programs/technical-services/tech-services-respository/annual-adjustment-factors-thru-year

OSU Comparison Network
40 Segment-Directions
6.3 direction-miles

EMPIRICAL RESULTS

- Estimates of segment-hour-direction volume estimates, 10-hour VMT, and time-of-day patterns determined from bus-based volumes are **much closer to road tube-based results** (ground truth) than are estimates determined from LBS data.

Segment-hour-direction volumes (ARD: Absolute value of relative difference from road tube based values)

	Video-based volumes	LBS-based volumes
No of seg-dir-hrs (sample size)	280	280
ARD mean	0.2070	1.1566
ARD std	0.1957	1.6110
ARD median	0.1565	0.5680
ARD 10th percentile	0.0278	0.1029
ARD 90th percentile	0.7392	6.8811
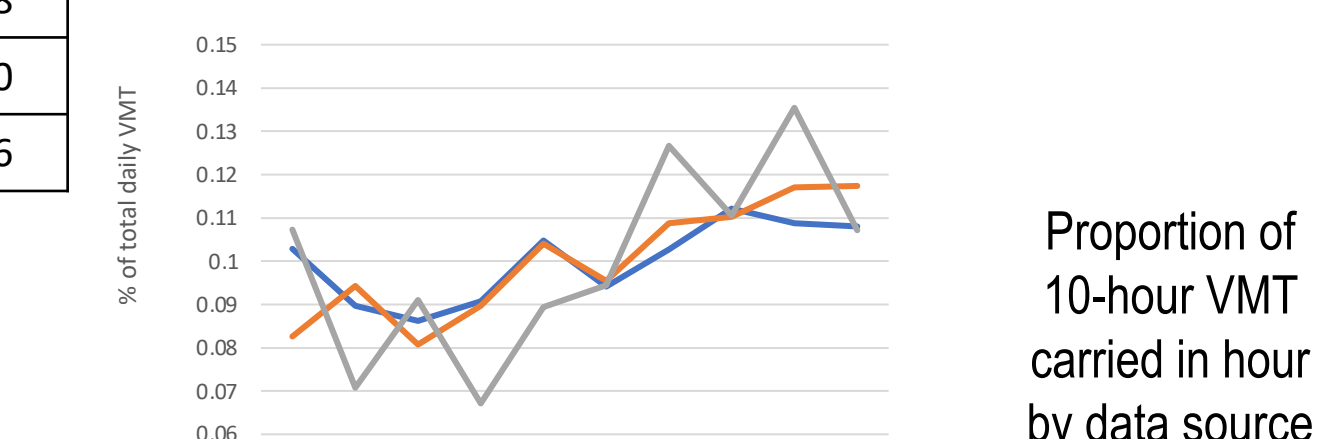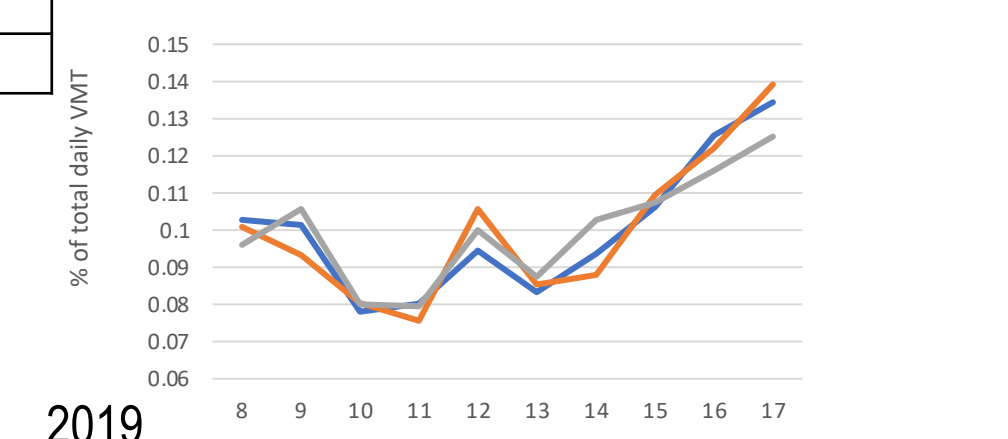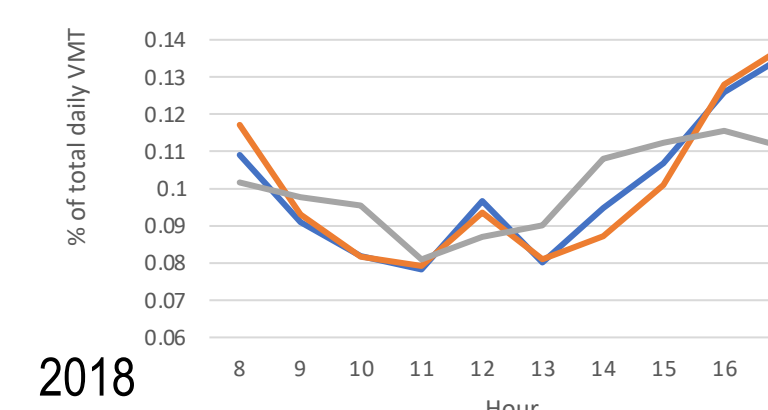
10-hour Network Vehicle Miles Traveled (VMT) on road-tube subnetworks*

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

*Different subnetworks were equipped with road tubes in different years, therefore, VMT comparisons across years are not meaningful.

Proportion of 10-hour VMT carried in hour by data source

2018
2019
2020

Average absolute value of differences from road-tube TOD patterns of TOD patterns on road-tube subnetworks determined when using video- and LBS-based VMT

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

EMPIRICAL RESULTS (CONT.)

- **Year-to-year changes** in 10-hour VMT and time-of-day patterns determined from bus-based volumes **correspond to published Ohio DOT growth factors** and known local TOD traffic patterns **much better** and with much better precision than do **changes determined from LBS data**.

10-hour network* Vehicles Miles Traveled (VMT) by year and Growth Factors (GF) using 2018 as reference

| 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

*VMT obtained for 2018 network excluding one segment (both directions) where LBS data-based traffic information is not available in 2021.
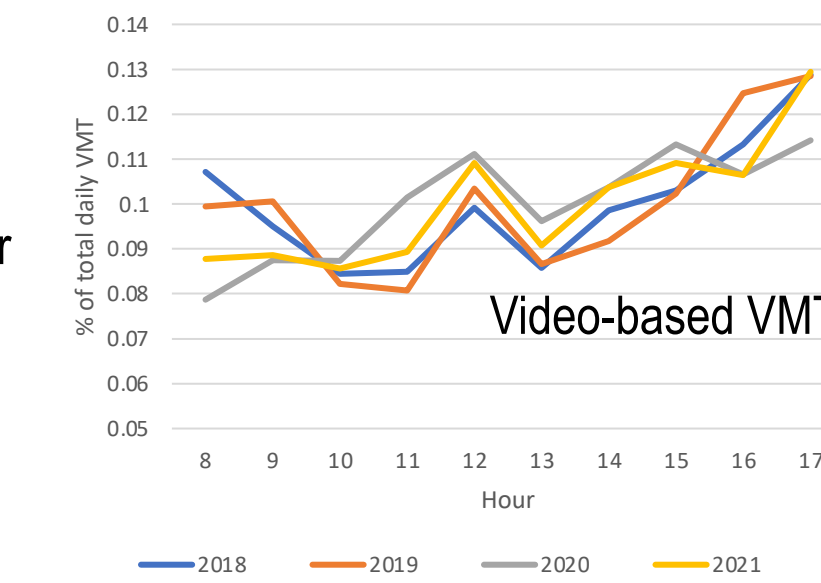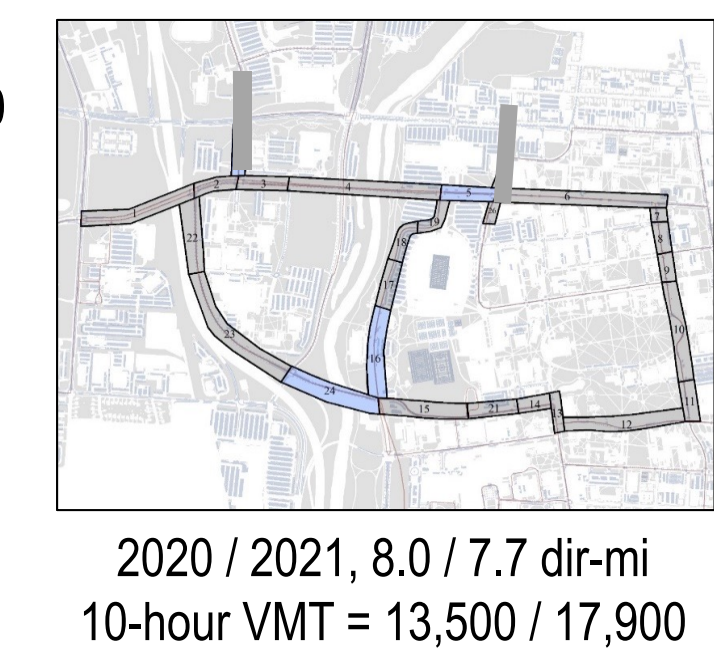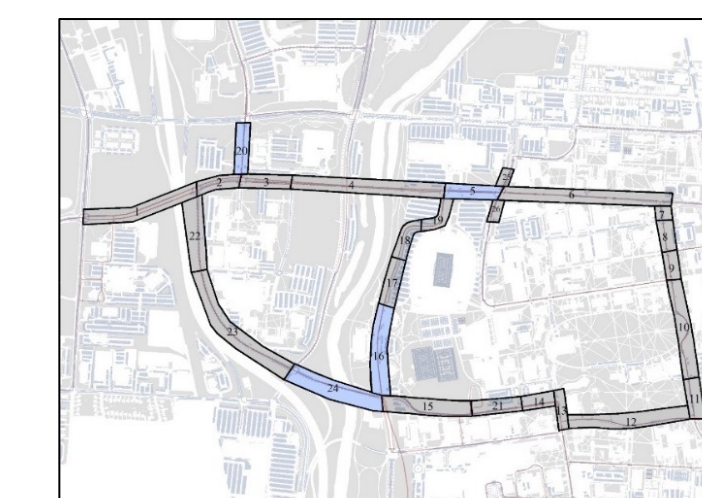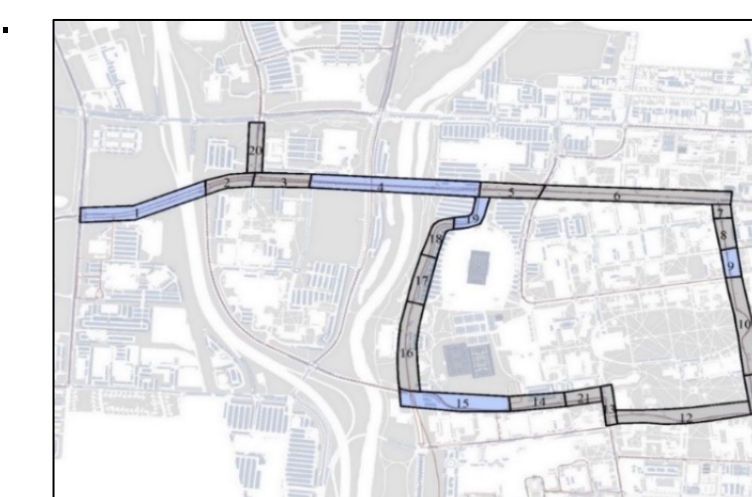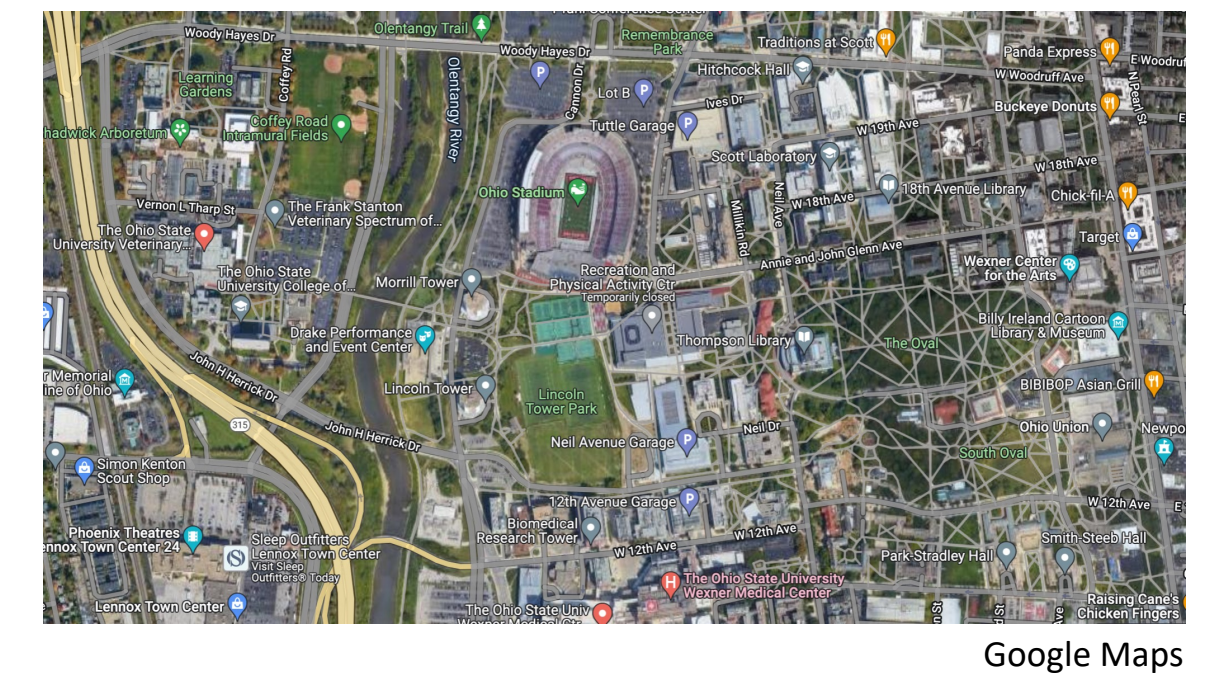
Average Absolute Value of Differences (AAD) in time-of-day patterns for consecutive years

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

Proportion of 10-hour VMT carried in hour by year

Video-based VMT
LBS-based VMT
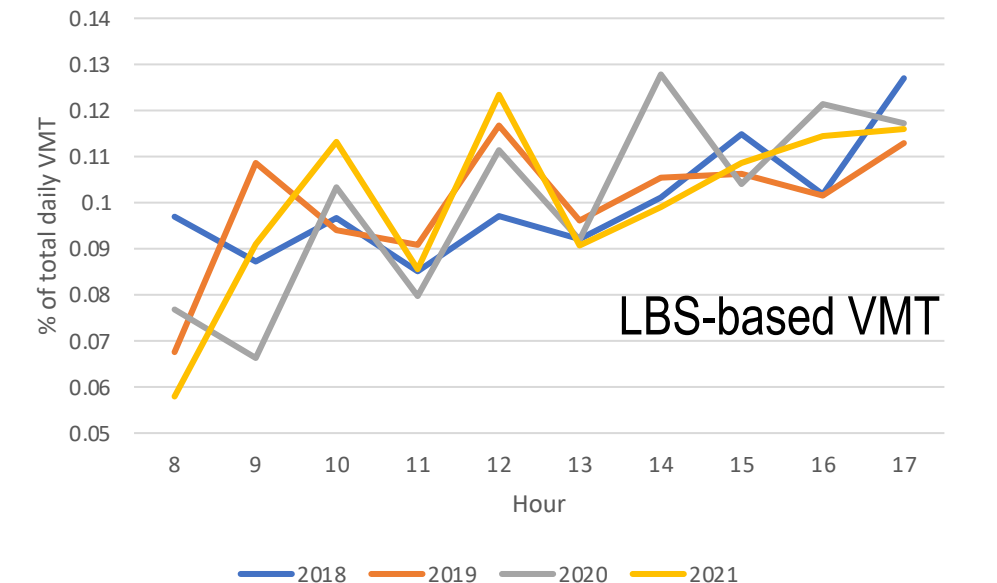
ONGOING APPLICATION

- Annual estimates of campus roadway network vehicle miles traveled (VMT) determined from bus-based video volumes are **provided annually to OSU administrators, planners, and operators** at and through Transportation and Traffic Management (TTM).
- Size of network monitored has increased since initial effort.
- **Time-of-day patterns** are now provided.
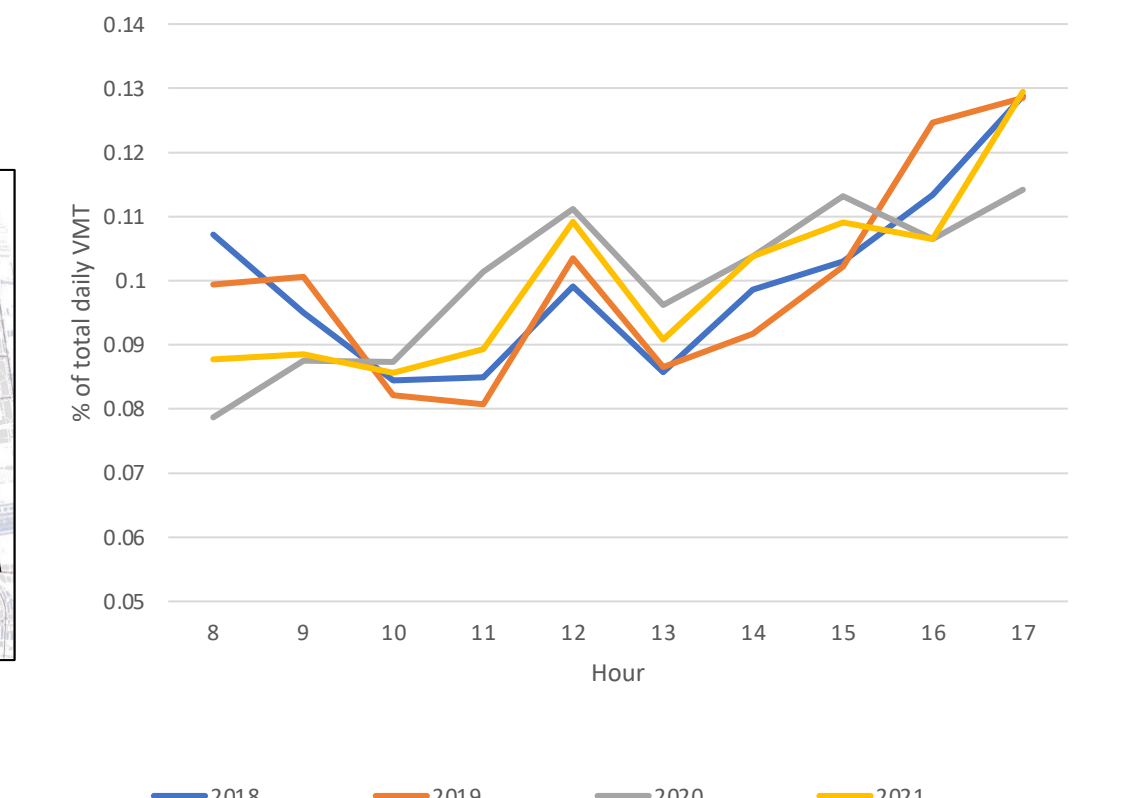- These are the **only available estimates of campus VMT**.

Google Maps

2018, 6.3 dir-mi
10-hour VMT = 18.500

2019, 7.7 dir-mi
10-hour VMT = 23,300

2020 / 2021, 8.0 / 7.7 dir-mi
10-hour VMT = 13,500 / 17,900

10-hour VMT by year and Growth Factors (G.F.) using 2018 as base on common 6.3-direction-mile network*

Year	2018	2019	2020	2021
VMT	18,673	19,068	10,455	15,424
G.F. w.r.t. 2018	–	1.02	0.56	0.83

*Includes the one segment (both directions) where LBS data-based traffic information is not available in 2021 (see footnote above).

Proportion of 10-hour VMT carried in hour by year