Monitoring Roadway Vehicle Miles Traveled using Video Imagery from Transit Buses in Operational Use

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The Ohio State University
Columbus, OH

Smart Mobility Connection Seminar
Online

February 11, 2022

Outline

- Vehicle Miles Traveled
- Video-based Volume Estimates for VMT Determination: “Review”
- Methodological Improvements to Video-based Volume Estimation
- Empirical VMT Results
  - Meaningful empirical patterns
  - Comparison to alternative means of VMT estimation
- Summary and Ongoing Efforts

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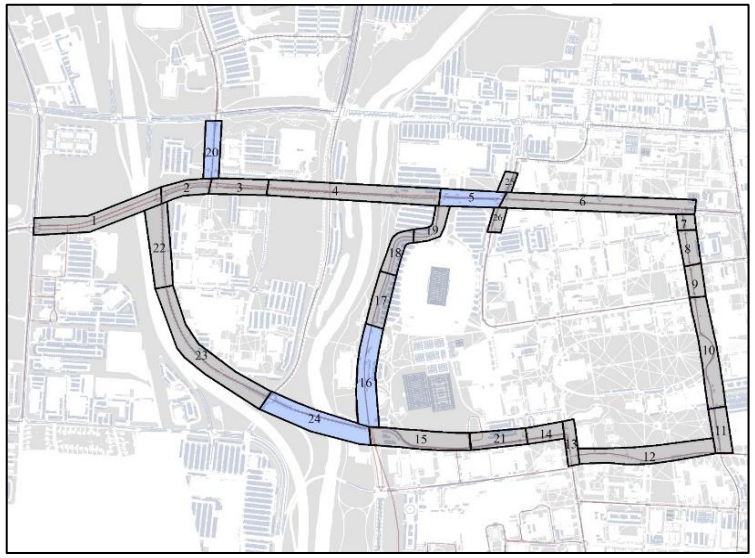
Vehicle Miles Traveled – VMT

- Most common metric of network-wide travel over a time period
- Used for a variety of monitoring and policy purposes

OSU 2019 Network



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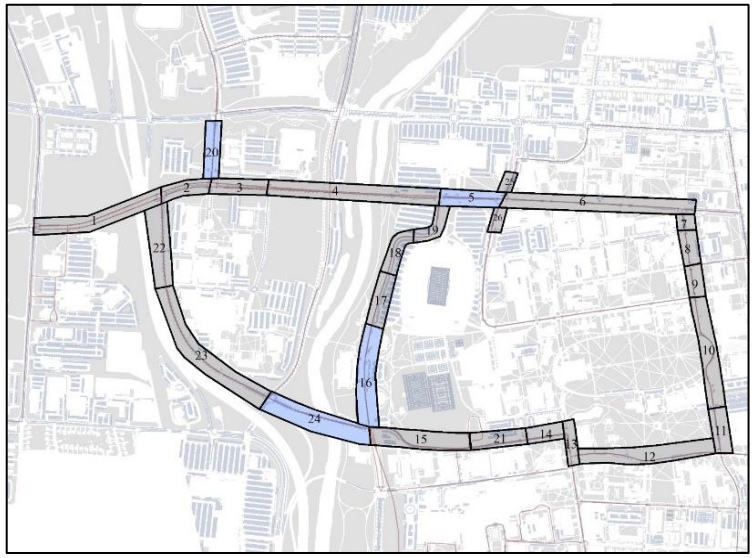

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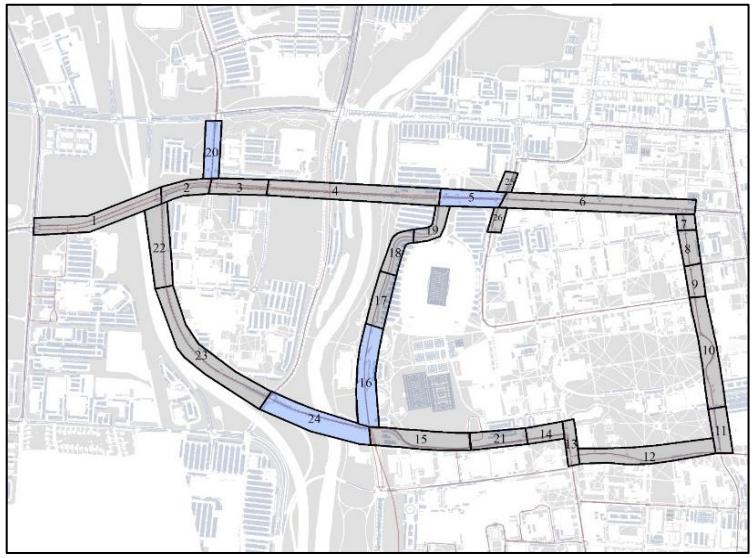

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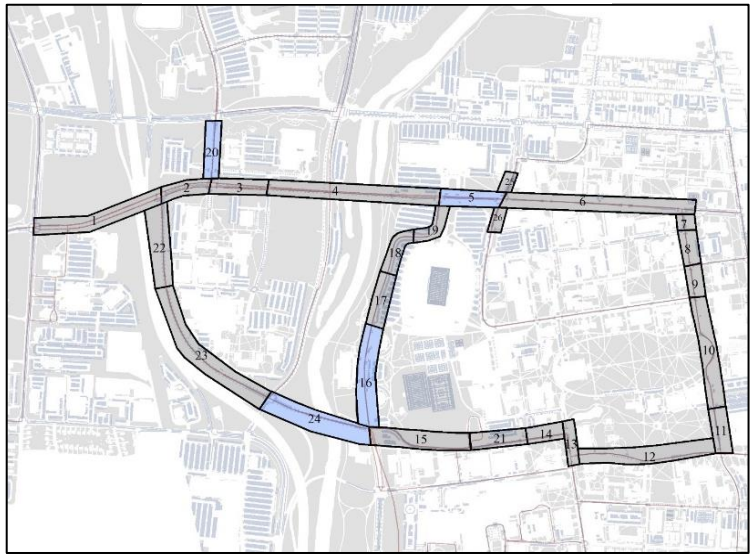

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  - Segment volumes: Traditionally from traffic counts

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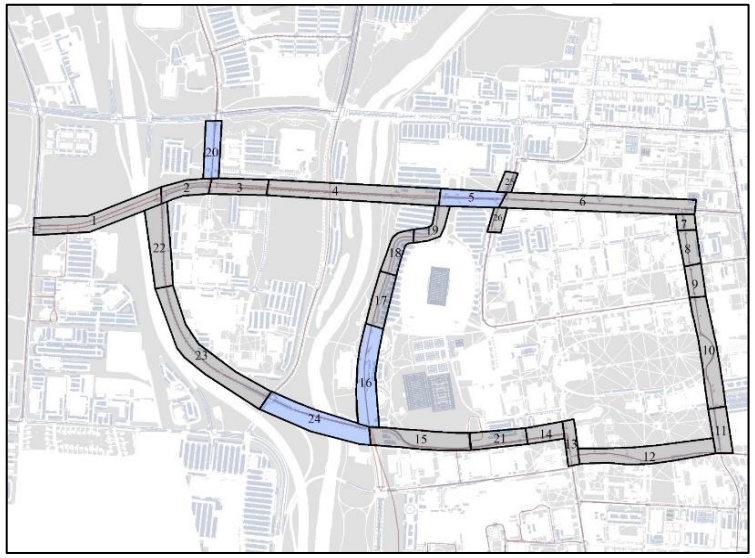

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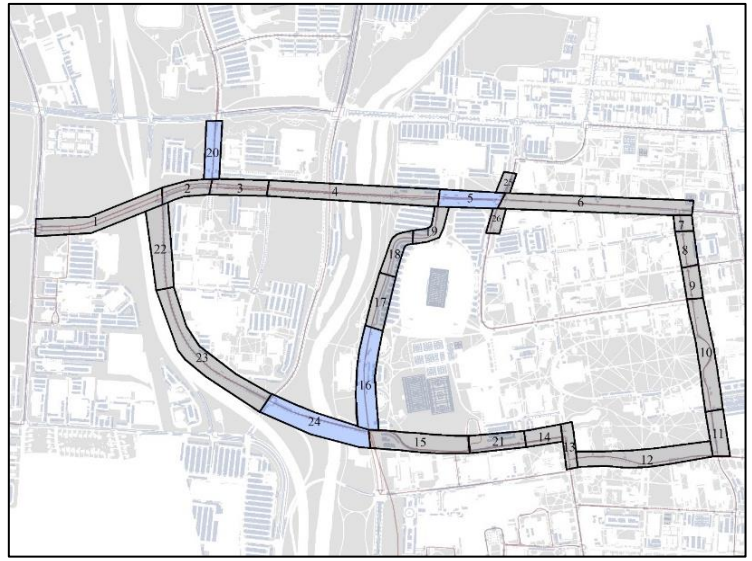
Segment Volumes from Traditional Traffic Counts

- Volume: Number of vehicles that pass a point on roadway segment over time
- Traditional approach: Go to a point on the roadway, “stay there,” and count

Manual Counting

Road Tubes

OSU Network

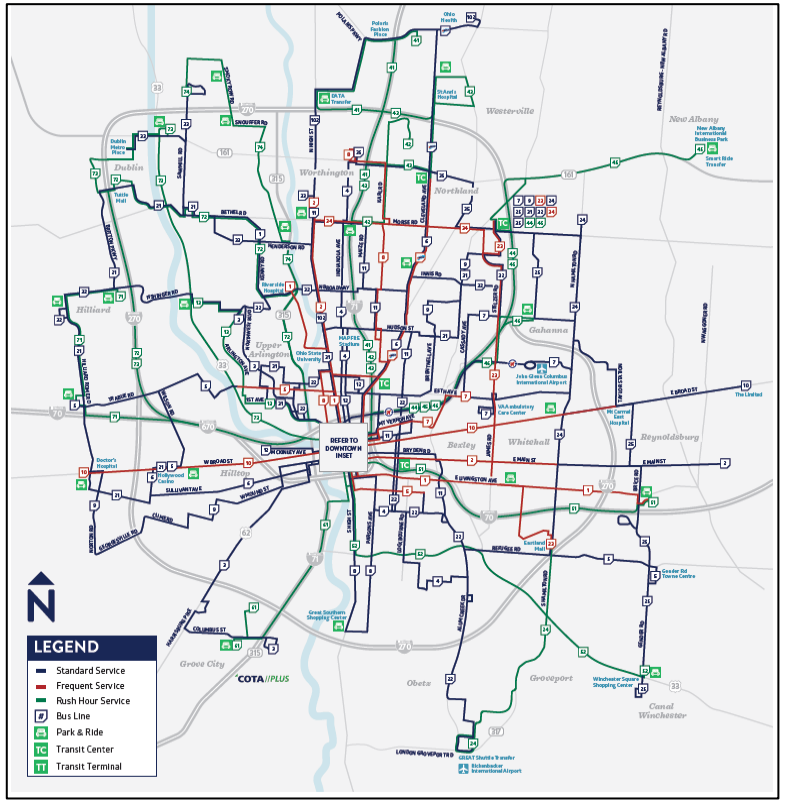


Traditional traffic studies obtain data to estimate traffic volumes over long time durations but only at *limited locations* and on an *infrequent basis*

Segment Volumes from Bus Video: Motivation

Transit buses cover major roadways *across the urban network* on a *regular, repeated, and ongoing basis*

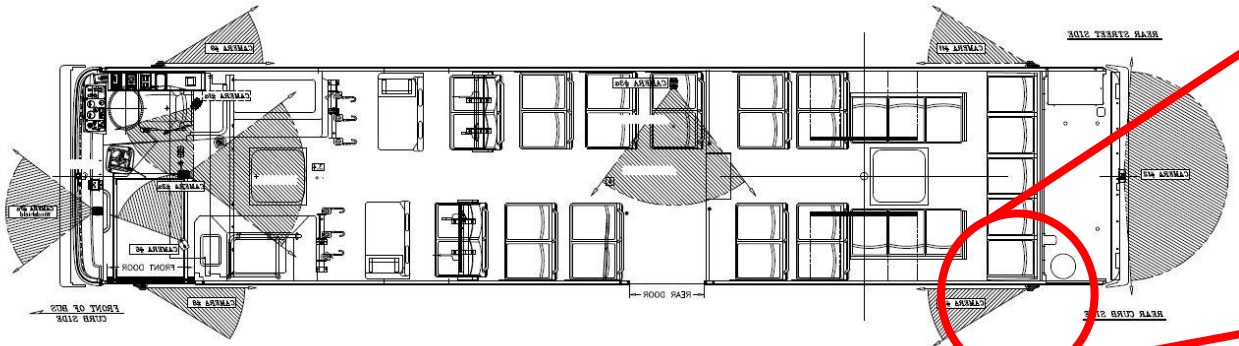
Central Ohio Transit Authority Route Map



Segment Volumes from Bus Video: Motivation

Transit buses are increasingly being equipped with video cameras for safety, security, and liability (i.e., *other*) purposes

CABS buses



Rear, road-side view camera

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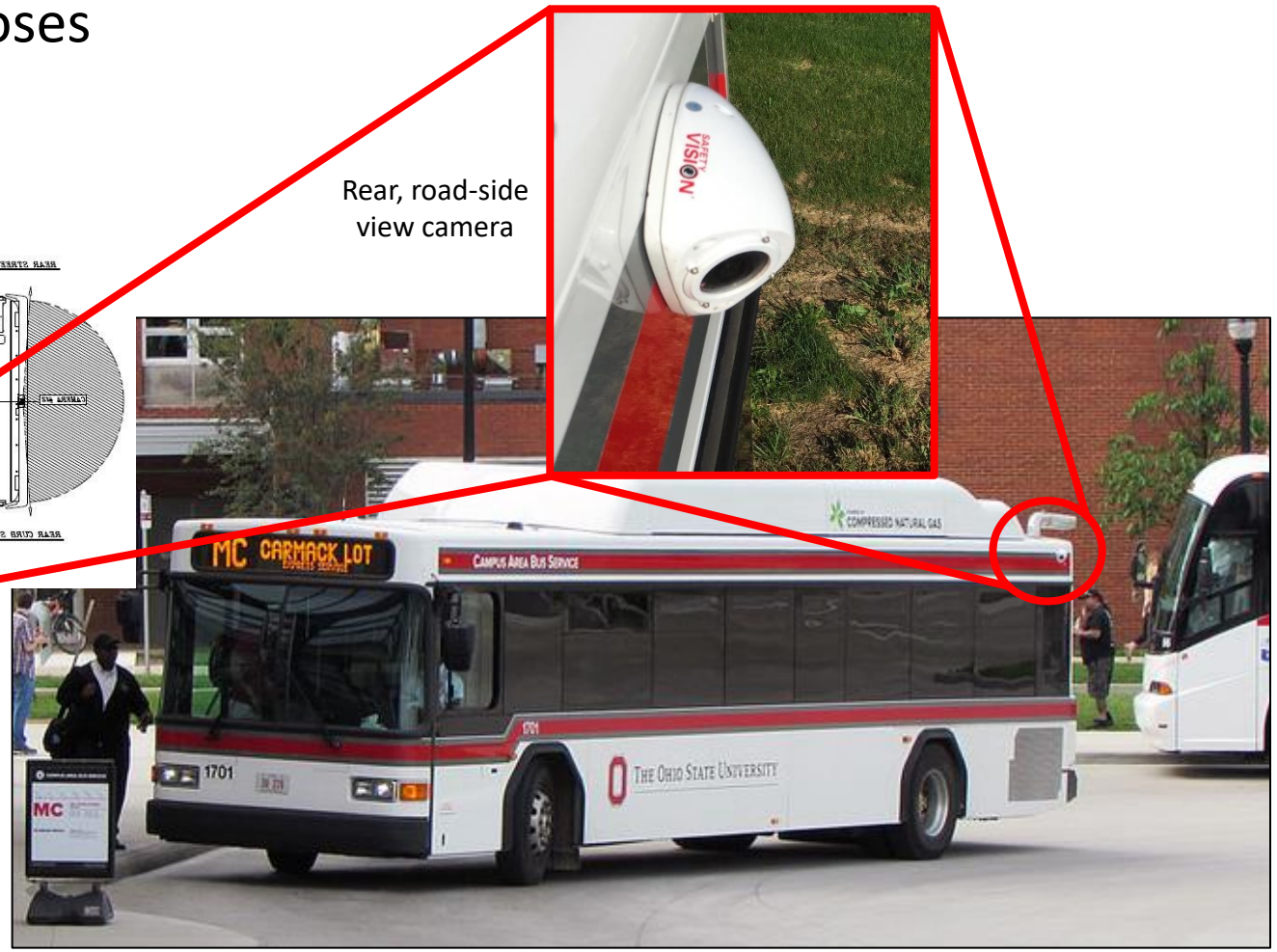

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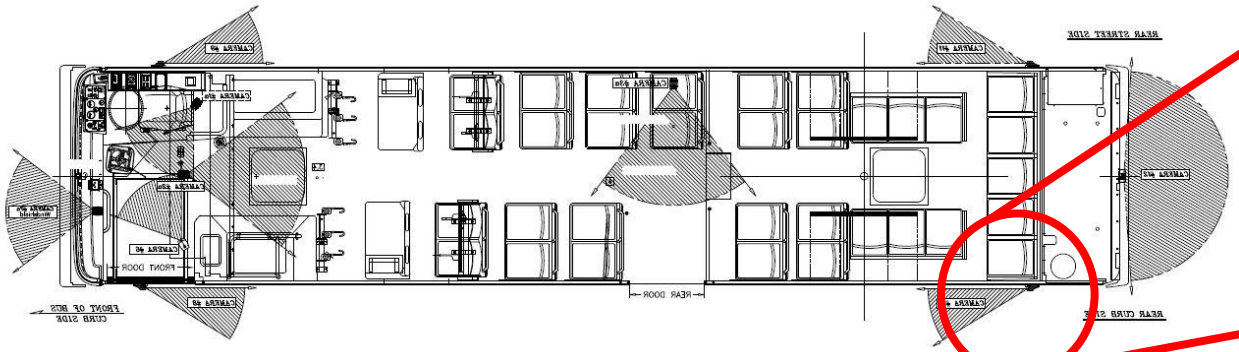

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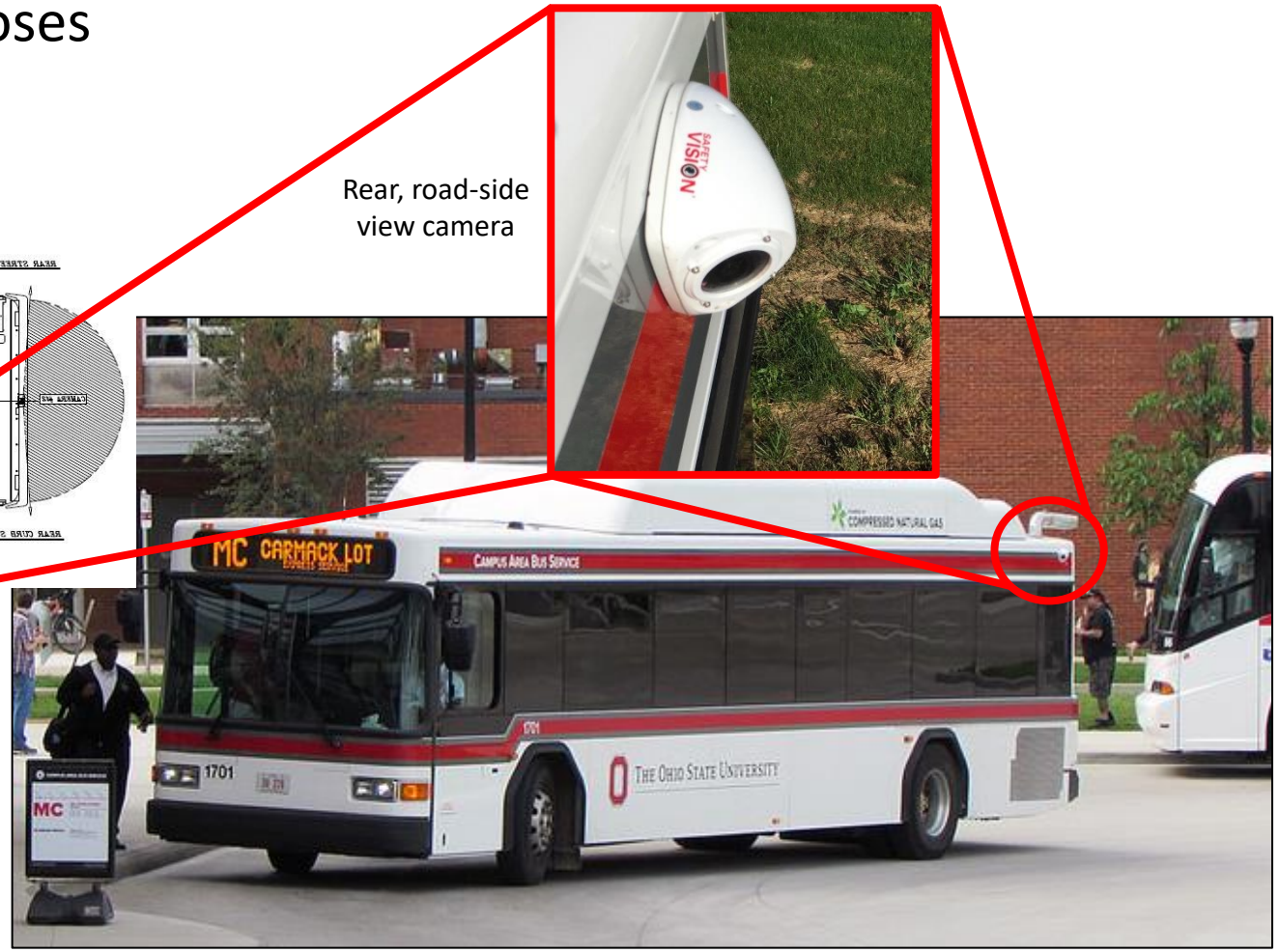

Exploit *available* video imagery and *repeated, ongoing coverage* of transit buses in regular service to estimate traffic volumes on major roadways across *spatially extensive* urban network

Segment Volumes from Bus Video: Methodology Review

- Step 0: Convert imagery to digital information

Developed MATLAB-based GUI to digitize vehicle observations, locations, and passage times

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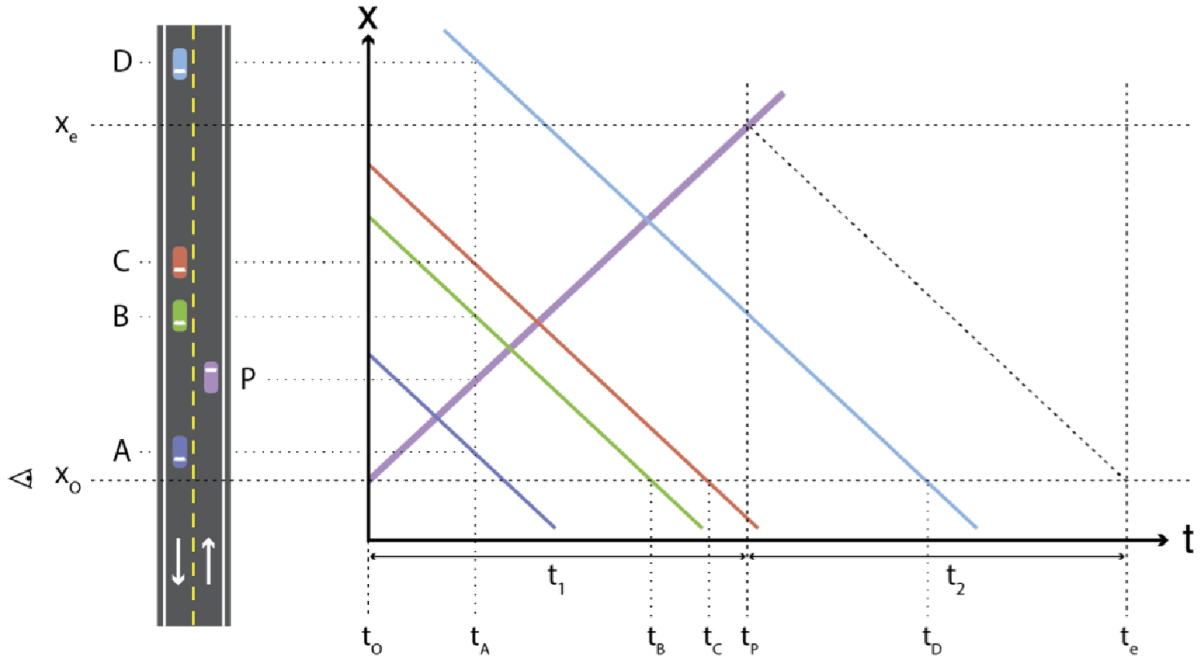
Modified the "moving observer" method to account for one-direction bus passes



Hourly Volume Estimate on Bus Pass i

$$V_i = 60 \times n^{veh}/(t_{1.i} + t_2)$$

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$$V^h = \mathrm{f}(V_1^h, V_2^h, \ldots, V_m^h)$$

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Automatic Image Identification
(we are not there yet)

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Before aggregating, filter out bus pass volumes

- *Equal to 0*

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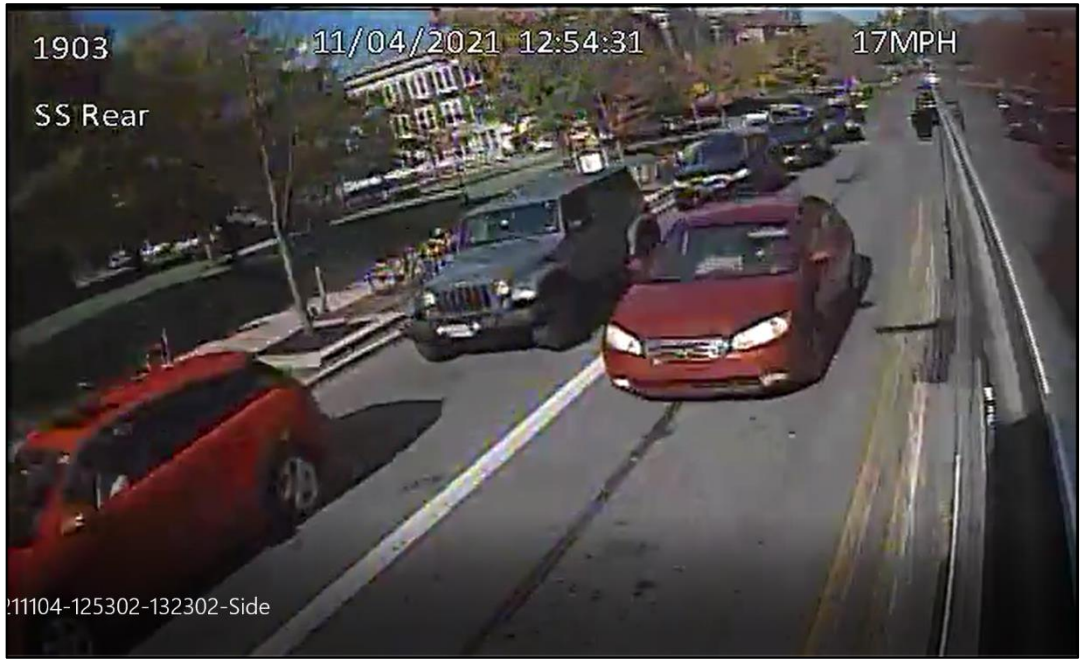

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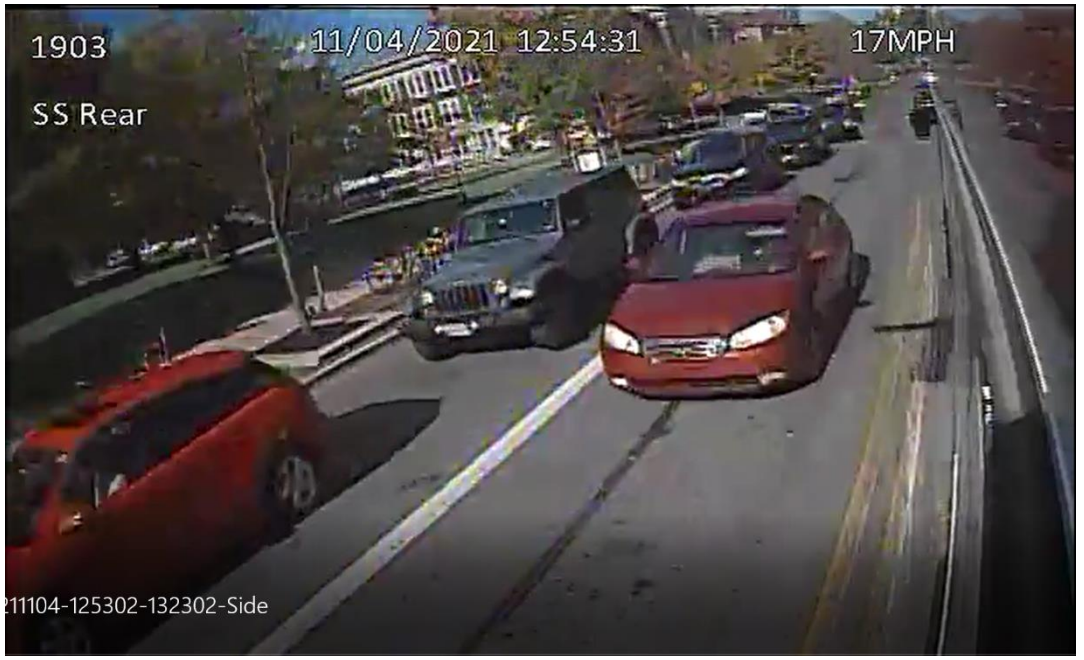
(Investigating other modifications of 0 or excessively large bus pass volumes)



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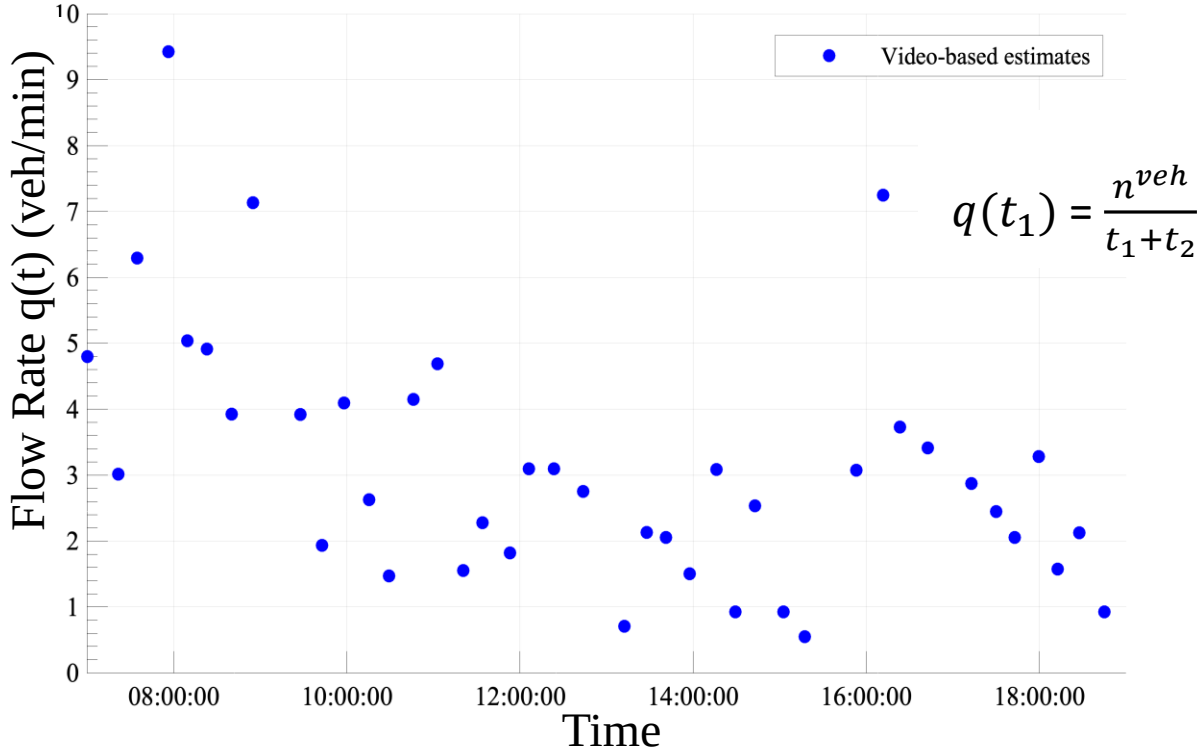

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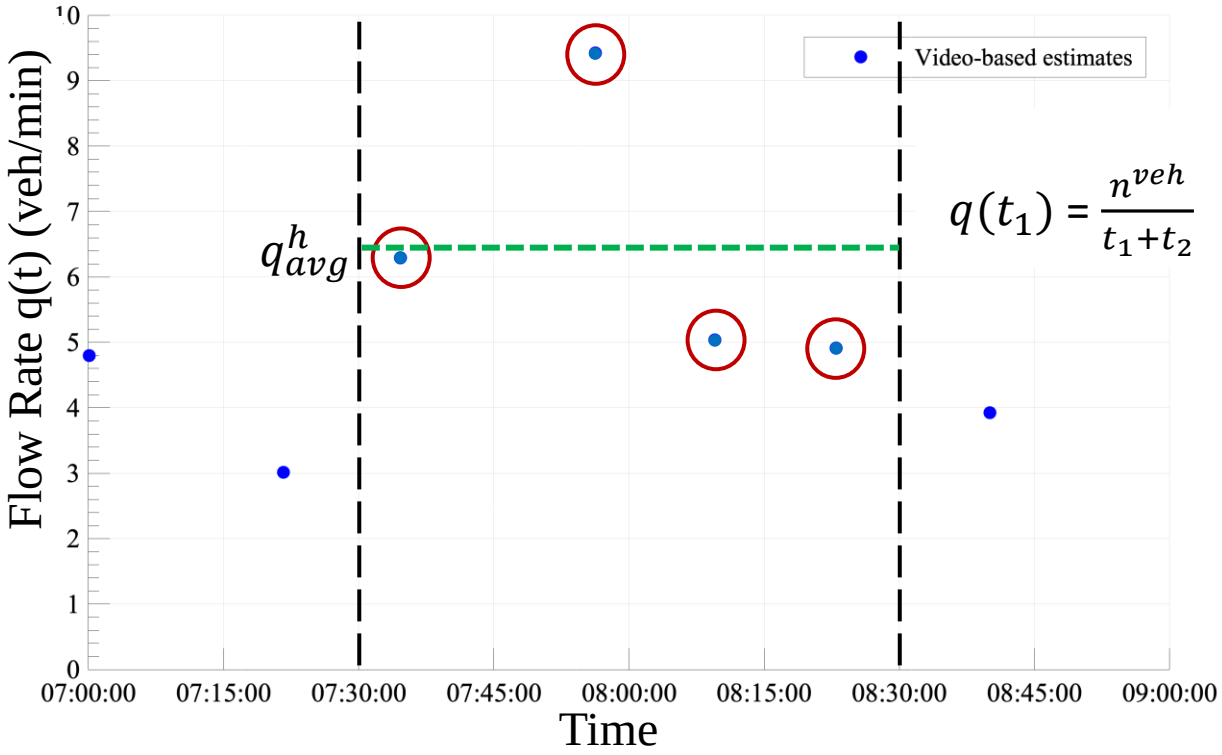

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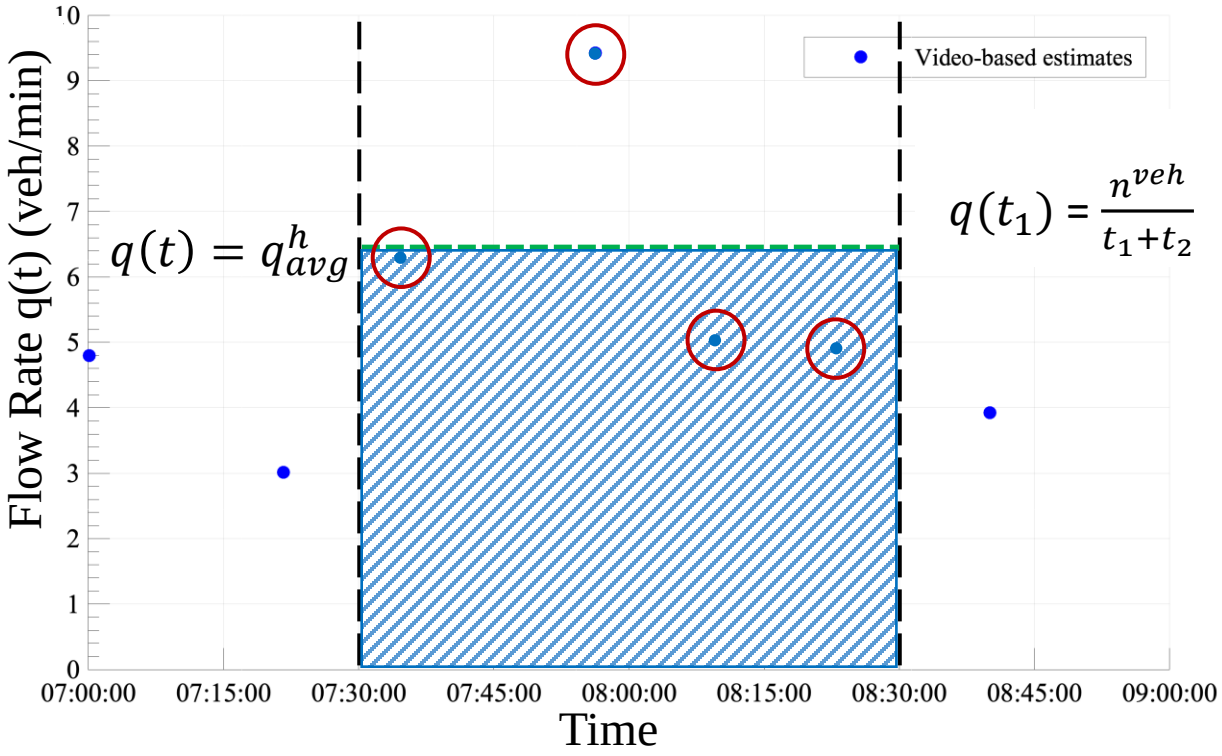

$$V^h = q_{avg}^h \cdot 60 \text{ min} = \int_{t \in h} q(t)dt$$

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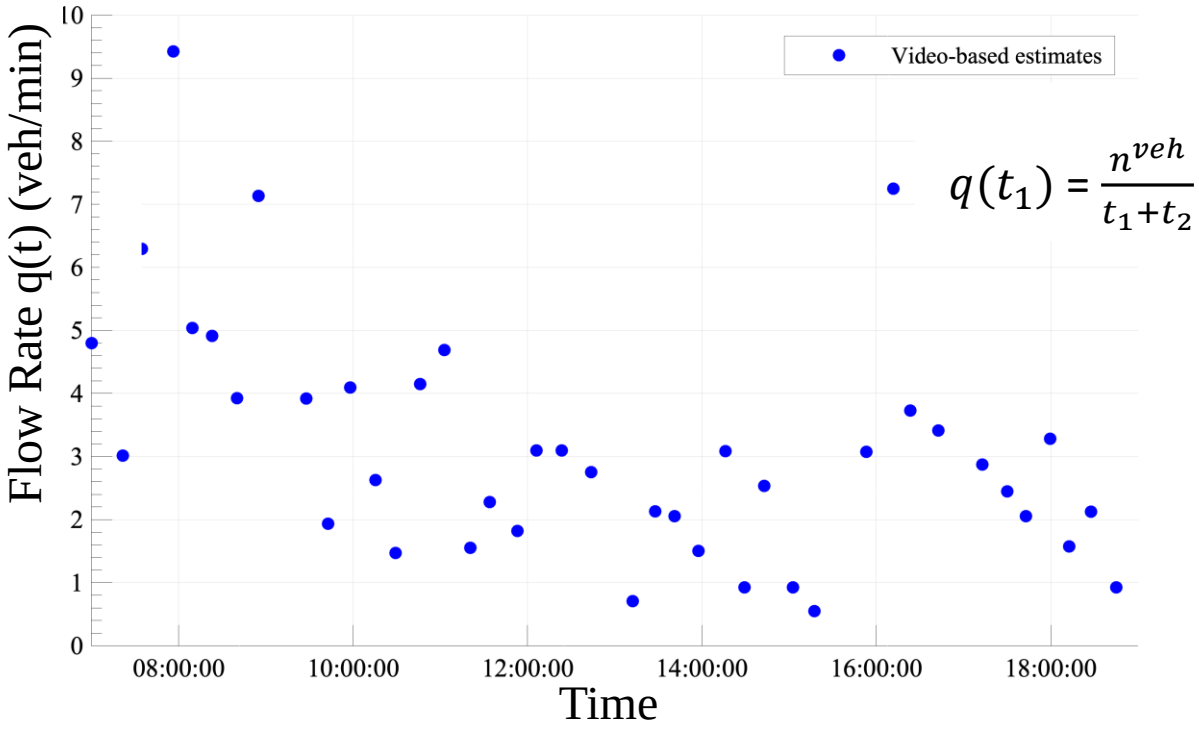
  Consider volume as the integral of flow rate q(t) over time during the time interval of interest



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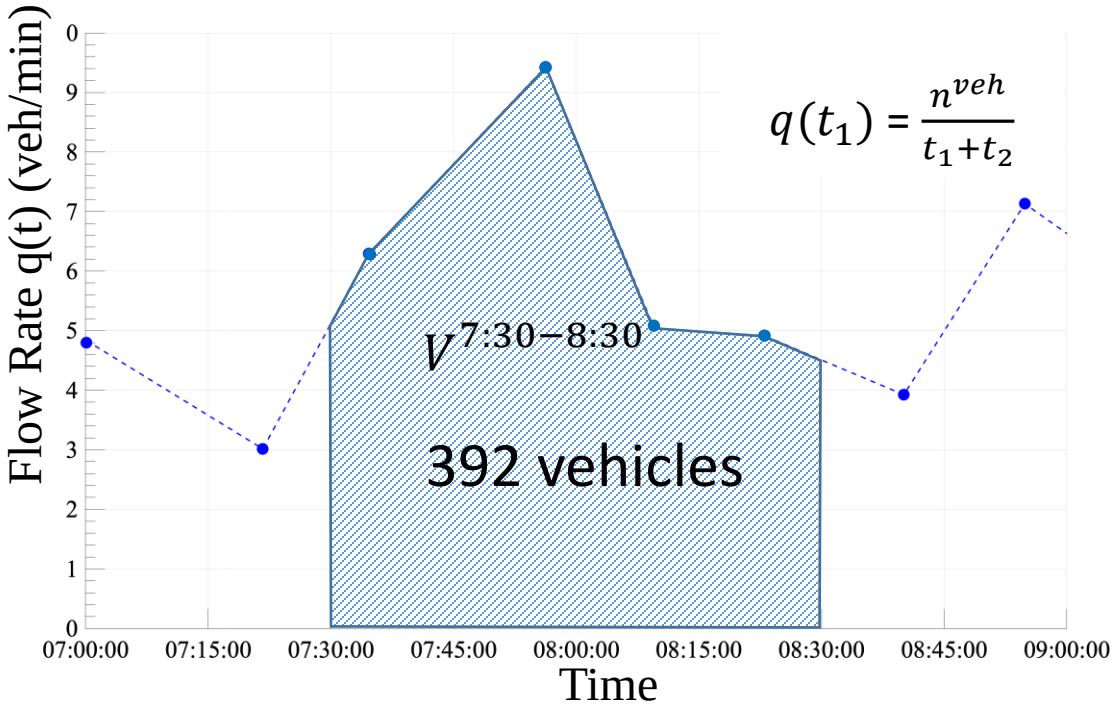

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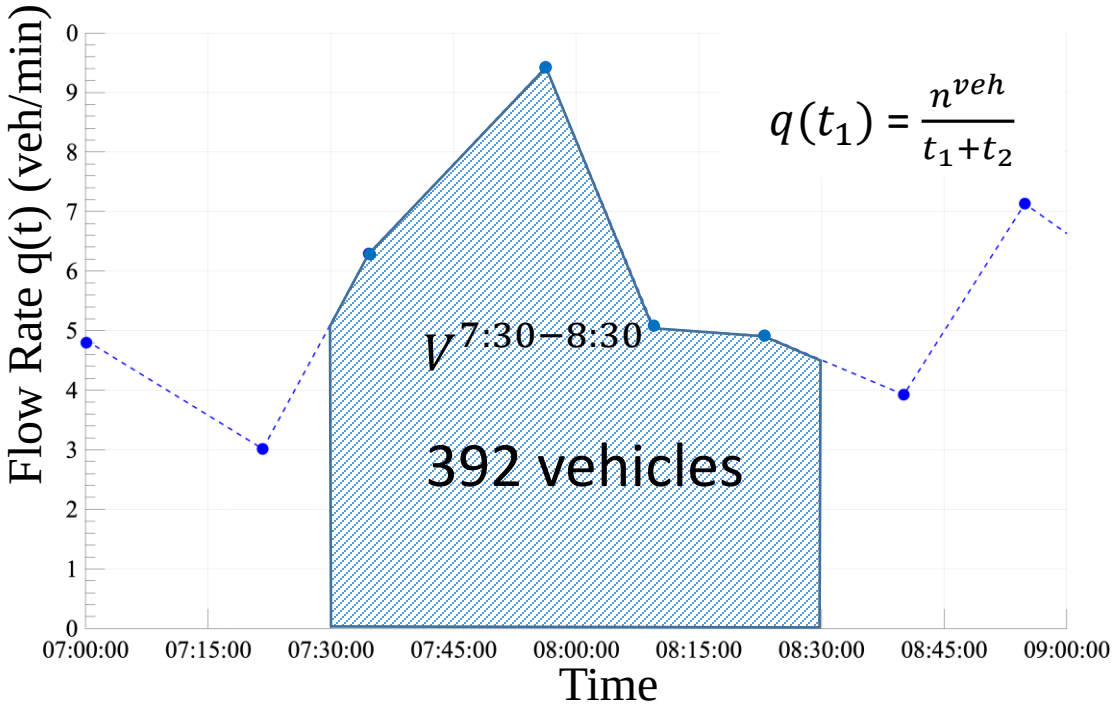
  – *Estimate q(t) function from individual bus pass estimates*
  – *Presently, linearly interpolate between observations*



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Segment Volumes from Bus Video: Empirical Comparisons

Compare estimates before and after “improvements” to road tube data considered to be ground truth by segment-hour-direction

Average, across Segment-Direction-Hours of Average Absolute Value of *Difference* between Video-based and Road Tube Hourly Volume

Year	No. Seg-Dir-Hr	Before Filtering Average	After Filtering Average
2018	100*	65.7	56.0
2019	80	116.2	100.0
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Note: Median differences are much lower than mean differences, but patterns are similar

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Compare estimates before and after "improvements" to road tube data considered to be ground truth by segment-hour-direction

Average, across Segment-Direction-Hours of Average Absolute Value of *Relative Difference* between Video-based and Road Tube Hourly Volume, i.e., (Video Vol – Tube Vol)/Tube Vol

		Before Filtering		**After Filtering**	
Year	**No. Seg-Dir-Hr**	Average	Integration	Average	Integration
2018	100*	23.4%	21.6%	22.2%	20.8%
2019	80	31.3%	29.3%	26.3%	23.7%
2020	100	19.9%	21.7%	19.3%	20.0%

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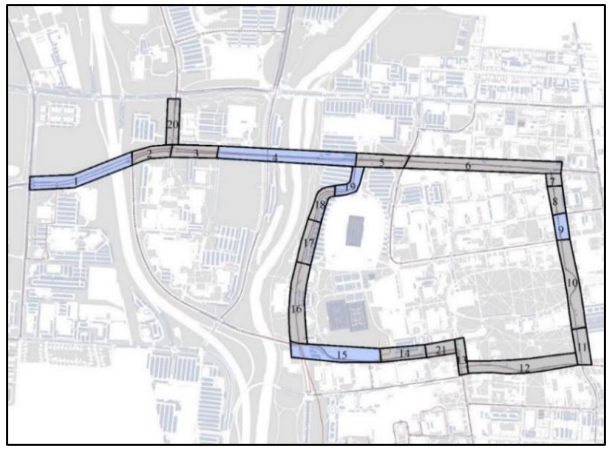

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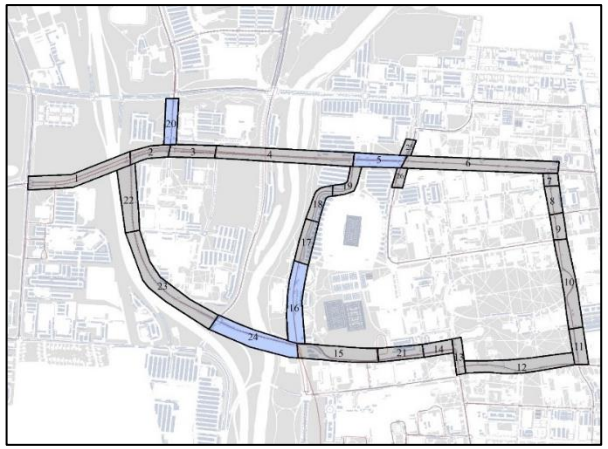

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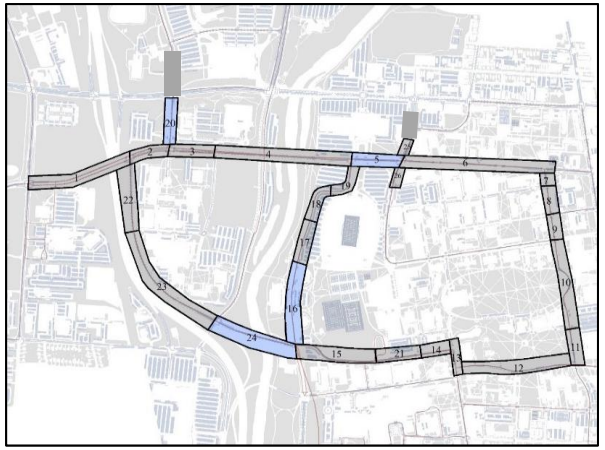

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**Three segments from 2020 network not included in 2021 network

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  - Volumes from Mid-Ohio Regional Planning Commission road tubes

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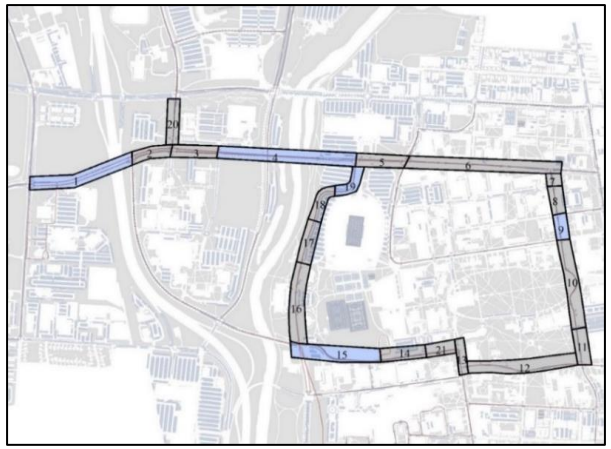

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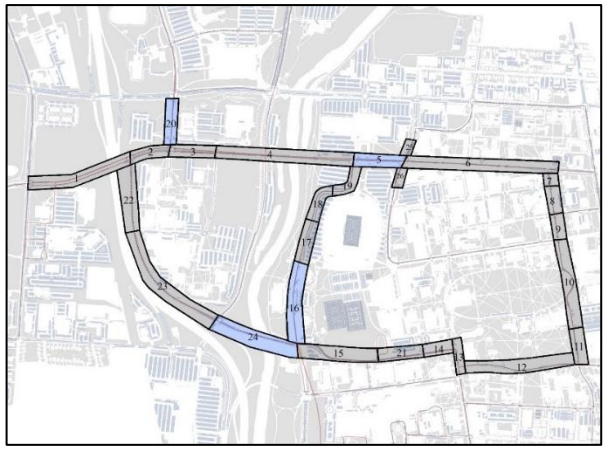

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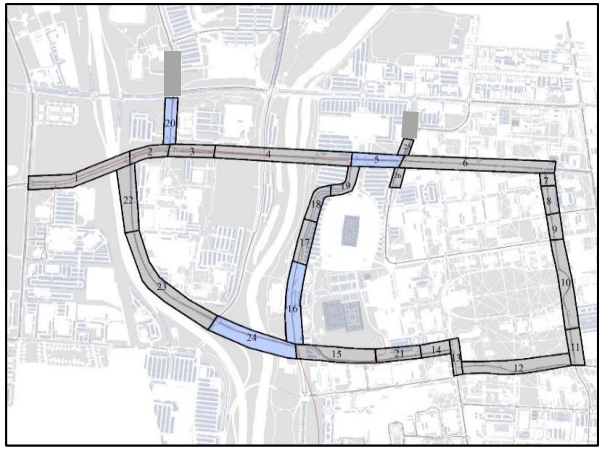

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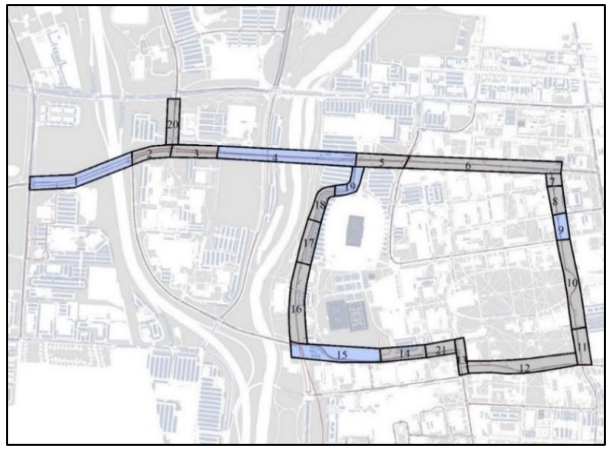

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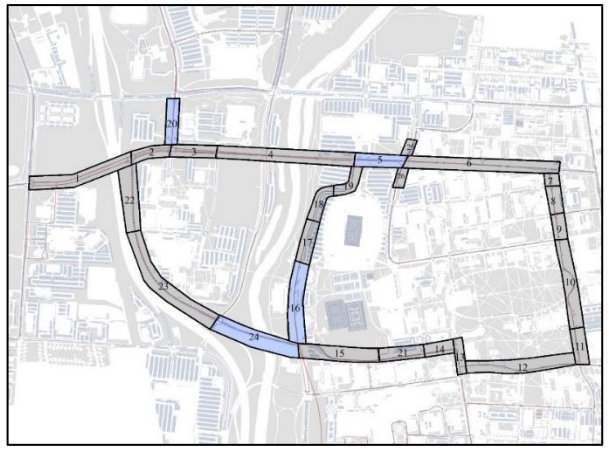

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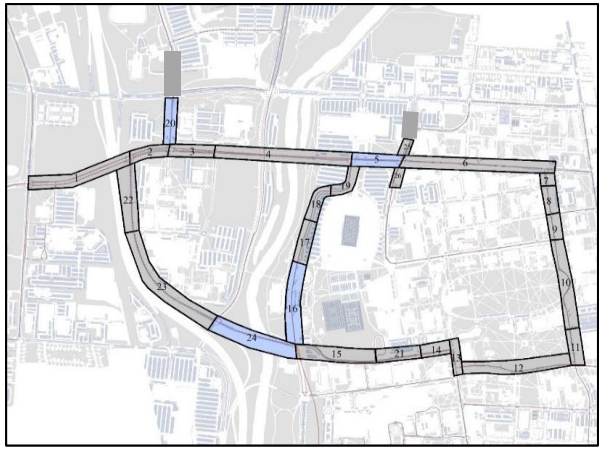

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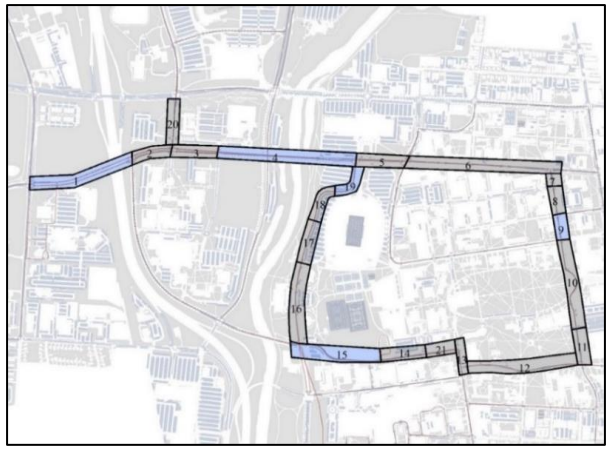
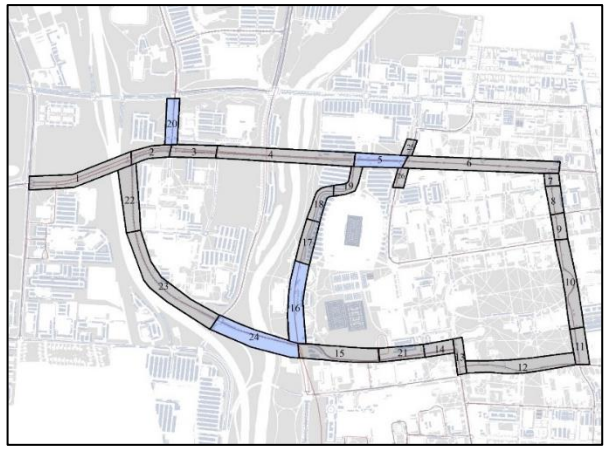
- Data collection, processing, analysis, and interpretation form basis of UG/Grad class term project
- Refined VMT estimates provided to OSU in outreach function

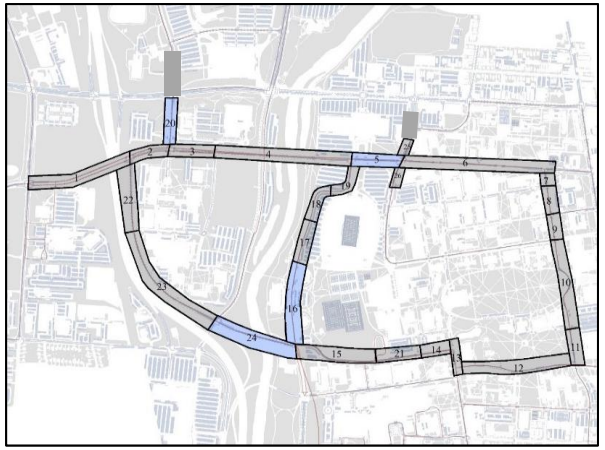
2018 Network
6.3 Dir-Mi (2.2 Dir-Mi*)



2019 Network
7.7 Dir-Mi (1.3 Dir-Mi*)



2020/2021** Network
8.0/7.7 Dir-Mi (2.2/0 Dir-Mi*)

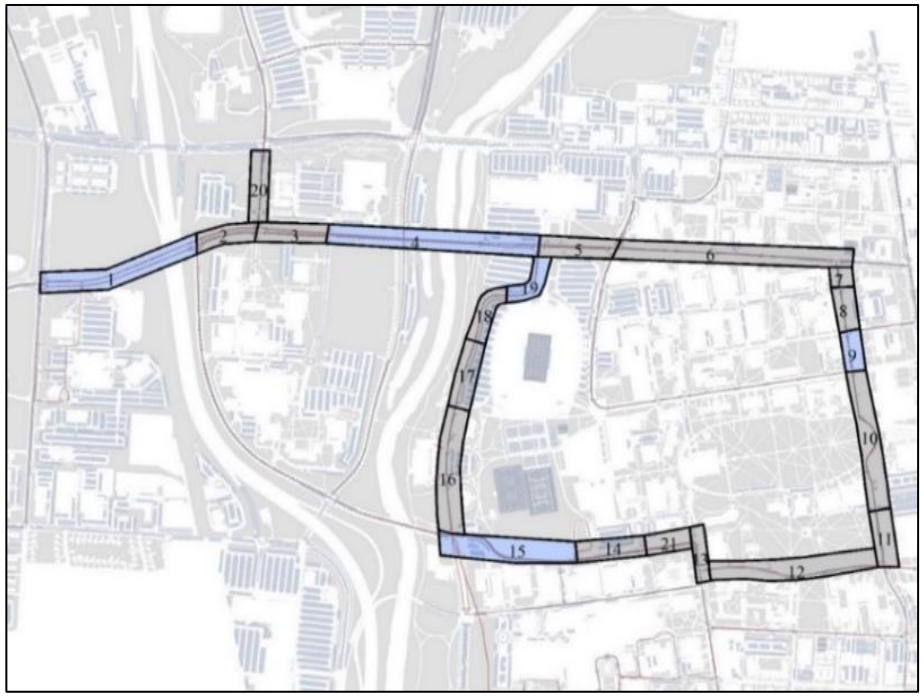


*Blue shaded segments: Road tube segments (no road tubes in 2021)

**Three segments from 2020 network not included in 2021 network

Annual VMT Monitoring on OSU Campus: Empirical Results

OSU 2018 Network
6.3 Direction-Miles



Vehicle Miles Traveled[1]			
2018	**2019**	**2020**	**2021**
18,673	19,068	10,455	15,424
G.F.[2]	1.021	0.559	0.825

[1] 8:00-18:00, after filtering, integration method

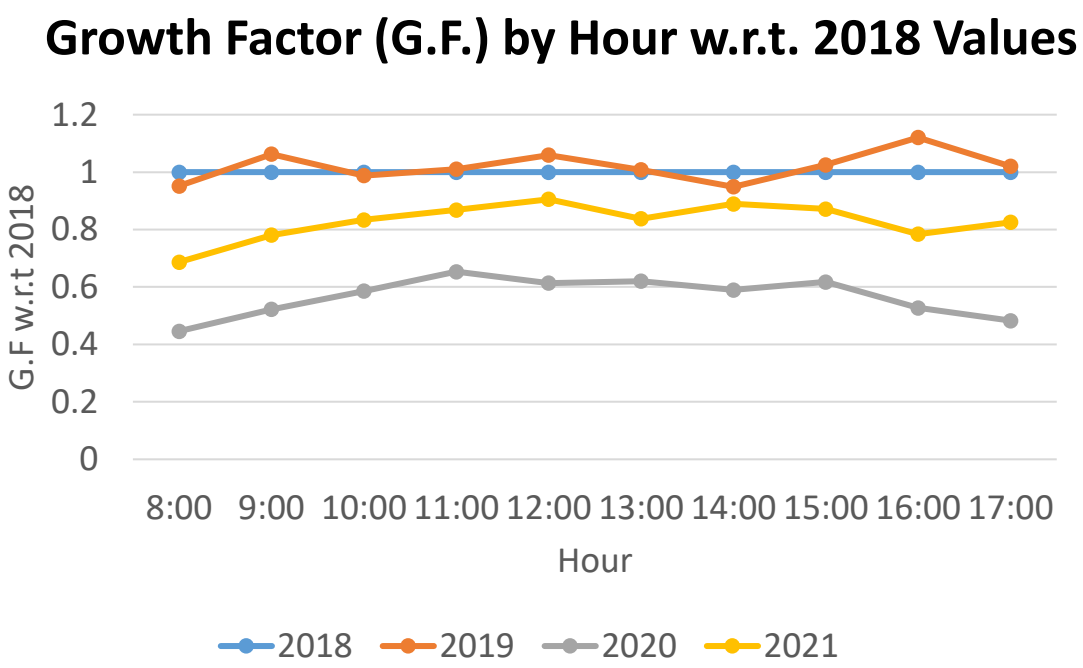
Annual VMT Monitoring on OSU Campus: Empirical Results

- 2018- 2019: Steady traffic
  - Reasonable: No change in campus policies or external events
  - Consistent with ODOT factor
- 2020: Noticeable traffic decrease
  - Pandemic, Online classes
  - Larger decrease on campus than in . general Ohio travel
- 2021: Noticeable increase w.r.t. 2020
  - Still markedly below 2018, 2019
  - ODOT factors not available yet

Vehicle Miles Traveled[1]			
2018	**2019**	**2020**	**2021**
18,673	19,068	10,455	15,424
G.F.[2]	1.021	0.559	0.825
ODOT G.F.[3]	1.015	0.916	NA[3]

[1] 8:00-18:00, after filtering, integration method
[2]Growth Factor (year *i* w.r.t. year 2018)
[3]ODOT/Technical Services/Traffic Monitoring/Annual Adjustment; Urban collectors/local
[3]Not yet available

Annual VMT Monitoring on OSU Campus: Empirical Results



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[3]Not yet available

Empirical VMT Comparisons with Results from Popular On-demand LBS Data-based Transportation Information Supplier

- 8:00 – 18:00 VMT on segments with road tubes calculated from
  - Road tube volumes
  - Bus-based video volumes
  - Data supplier volumes estimates
- Segments with road tubes varied by year

Year	No. Seg-Dir Considered	VMT* [miles]			Relative Difference**	
		Tube	Video	Supplier	Video	Supplier
2018	10	7,610	7,442	13,445	-2.2%	76.7%
2019	8	5,054	5,597	6,914	10.7%	36.8%
2020	10	4,929	5,299	11,039	7.5%	124%

*Different segments are considered in different years; VMT across years are not comparable

**Compared to tube-based VMT

Outline

- Vehicle Miles Traveled
- Video-based Volume Estimates for VMT Determination: “Review”
- Methodological Improvements to Video-based Volume Estimation
- Empirical VMT Results
  - Meaningful empirical patterns
  - Comparison to alternative means of VMT estimation
- Summary and Ongoing Efforts

Summary

- Methodological changes to video-based volume estimation were made and empirically seen to improve performance
- Estimates using transit buses video-based methodology are strikingly more accurate than those provided by a popular on-demand LBS data-based transportation information supplier
- Application of methodology to determine VMT changes over time showed meaningful and otherwise unavailable results

Ongoing Activities

- Continuing efforts towards methodological improvements
  - Using information in passes with zero or very large volumes
  - Smoothing flow rates in integration approach
  - . . .
- Applying video-based methodology to multi-day observations
  - Estimating volumes for an “average day”
  - Capturing daily variations
  - Ongoing monitoring: distinguishing daily variations from steady-state levels
- Quantifying uncertainty in volume estimates

Ongoing Activities (cont.)

- Educational activities
  - Continue using concept as class project in transportation data class
  - Continue involvement of graduate and undergraduate students

- Empirical results and outreach activities
  - Continuing to provide OSU campus VMT estimates to campus stakeholders (planners and operators)
  - Investigating impacts of COVID on campus
  - . . .

Acknowledgements

- Other OSU Students: Stephanie Ferzli (presently HDR), Diego Ribeiro de Oliveira Galdino, Marissa McMaster

- OSU Transportation and Traffic Management: Beth Snoke, Tom Holman, Sean Roberts

- Mid-Ohio Regional Planning Commission: Nick Gill, Hwashik Jang, Zhuojun Jiang (presently ODOT)

- ODOT: On-demand LBS data-based supplier of volume estimates