Time-of-Day Traffic Volumes Using Video Imagery Obtained from Transit Buses in Regular Operation

Mark McCord, Rabi Mishalani,
Benjamin Coifman
The Ohio State University
Columbus, OH

Mobility 21/Carnegie Mellon University
Smart Mobility Connections Seminar Series
Online

October 30, 2020

Overall Objective

Develop, demonstrate, and promote an approach for obtaining traffic flow estimates across extensive urban roadway networks from video data collected from transit buses

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

Motivation

Traditional traffic studies obtain data over long time durations but at limited locations and on an infrequent basis

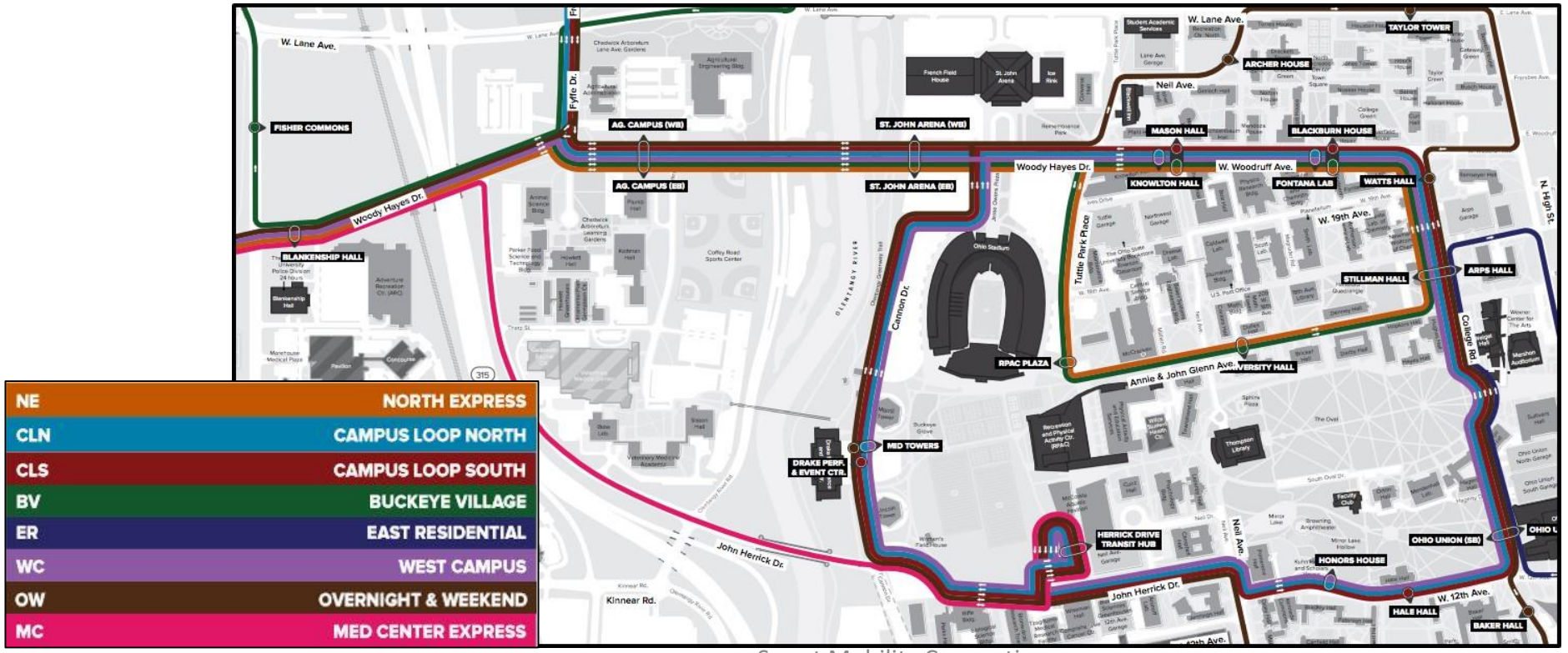
Manual Counting

Road Tubes

Motivation, cont.

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

Part of OSU Campus Area Bus Service (CABS) Route Map



- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

Concept

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service

Concept

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service

- Any single pass over a roadway segment would be an observation of very short duration
- However, repeated coverage allows aggregating multiple “independent” observations to provide estimates of repeated (e.g., time-of-day, day-of-week) patterns

Concept, cont.

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service

- Ongoing coverage would allow updates through time and detection of important changes in the repeated patterns

Concept, cont.

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to "observe" traffic on most major roadways in an urban area while providing regular service

- Spatial coverage would be unprecedented

Concept, cont.

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service

- Little, if any, additional cost to providing the sensing platform would be needed

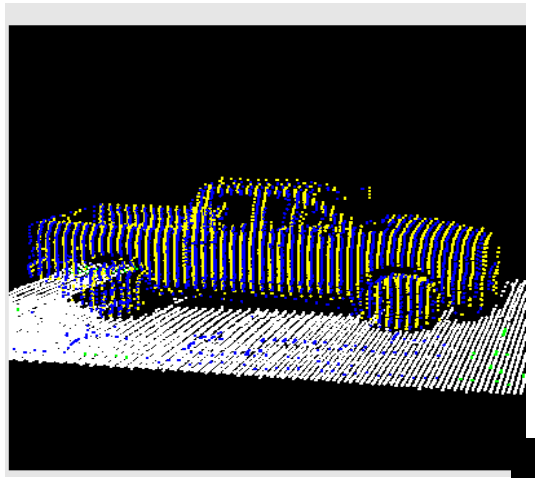
Concept, cont.

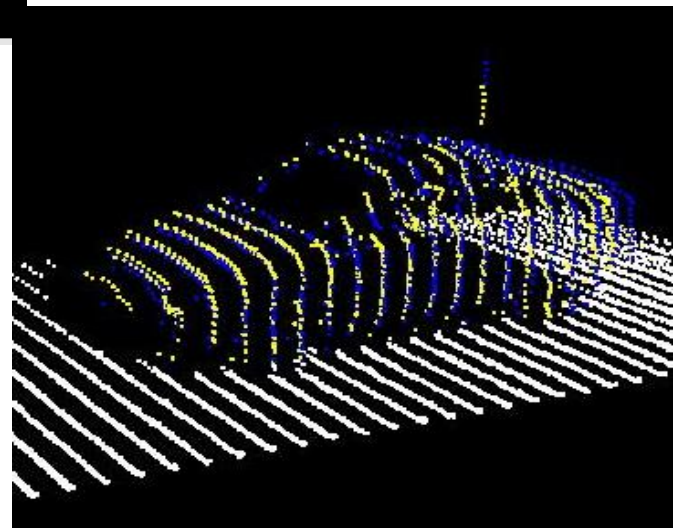
Take advantage of repeated, ongoing coverage of fixed schedule transit buses to "observe" traffic on most major roadways in an urban area while providing regular service

- Public service nature of transit buses should make institutional access to data for public use easier and less costly
- Providing the data would make transit a "good citizen" in the eyes of the public

First Take: LiDAR Sensing

Proof of concept from LiDAR equipped van





Concept

Take advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service

Take Two

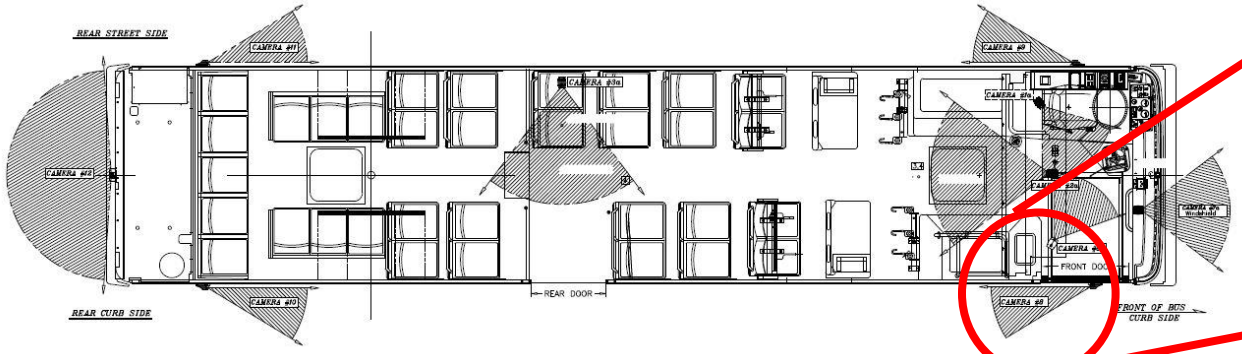
(happy coincidence?)

Take advantage of increasingly deployed bus-based video

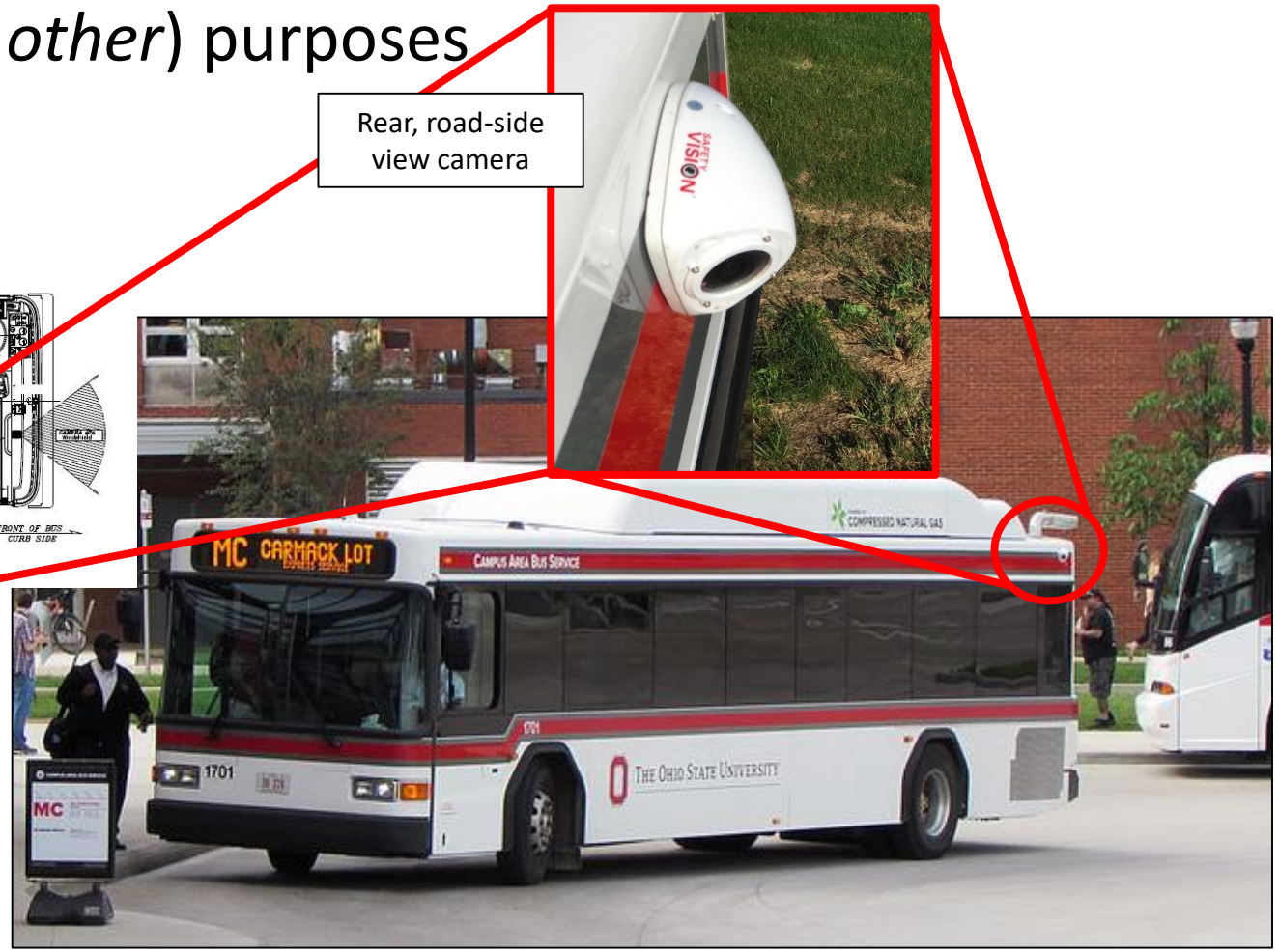
Revised Concept: Video from Transit Buses

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



Project team worked with CABS on selection and specifications for new cameras (2017)

Present Objective

Develop, demonstrate, and promote an approach for obtaining traffic time-of-day volume estimates *across urban roadway network*s from *existing video data* collected from transit buses in *regular operation*

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

Video-based Vehicle Counting GUI

Developed in MATLAB to digitize vehicle observations, locations, and passage times

Uncounted Vehicle

Counted Vehicle

Hourly Volumes from Mobile Observations

Traffic volumes traditionally from vehicles past a fixed location over time

“Textbook” moving observer method modified for volumes

from “one-way” observations

Hourly Volumes from Mobile Observations

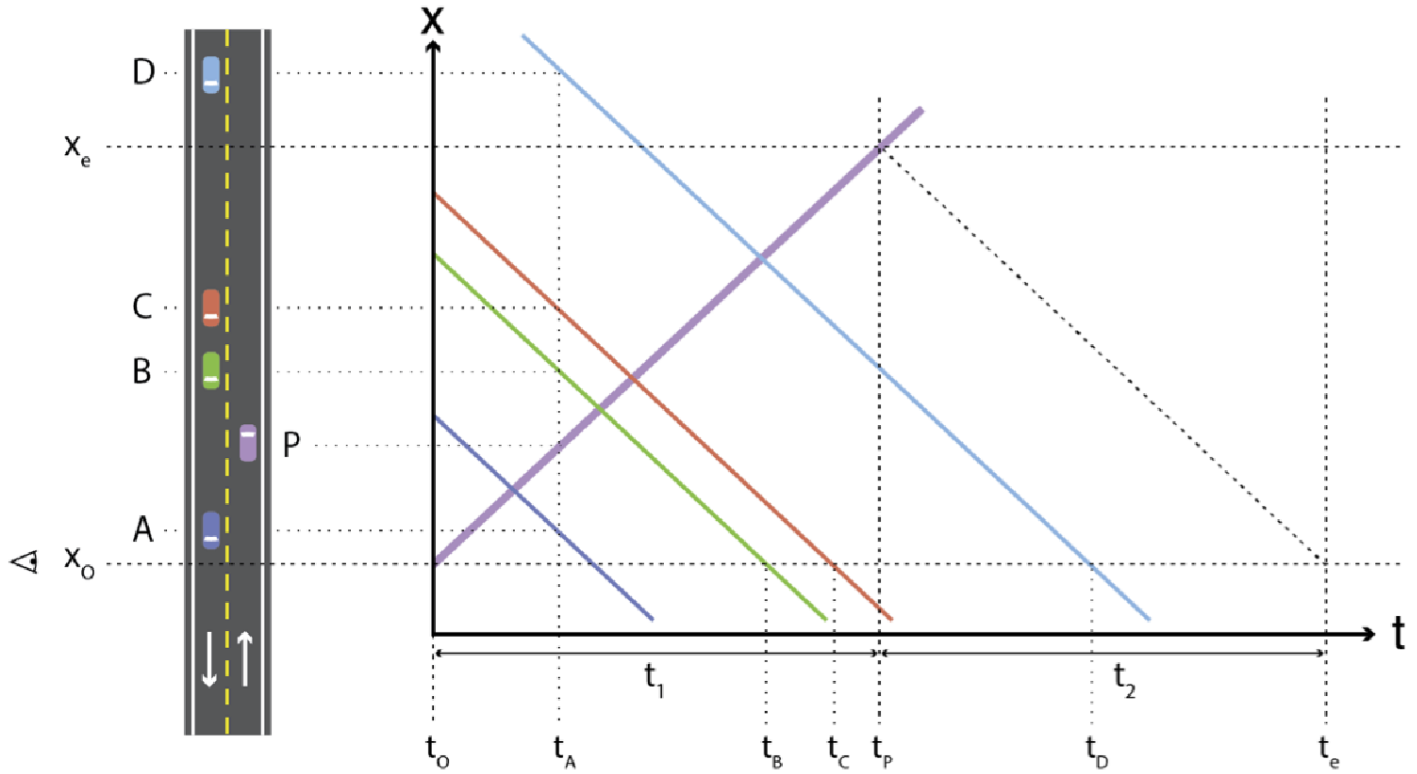
Traffic volumes traditionally from vehicles past a fixed location over time

"Textbook" moving observer method modified for volumes from "one-way" observations

- Flow rate q from an individual bus pass over a segment

$$q = n^{veh}/(t_1 + t_2)$$

- Aggregate q values from individual passes into hourly volumes



- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

Education

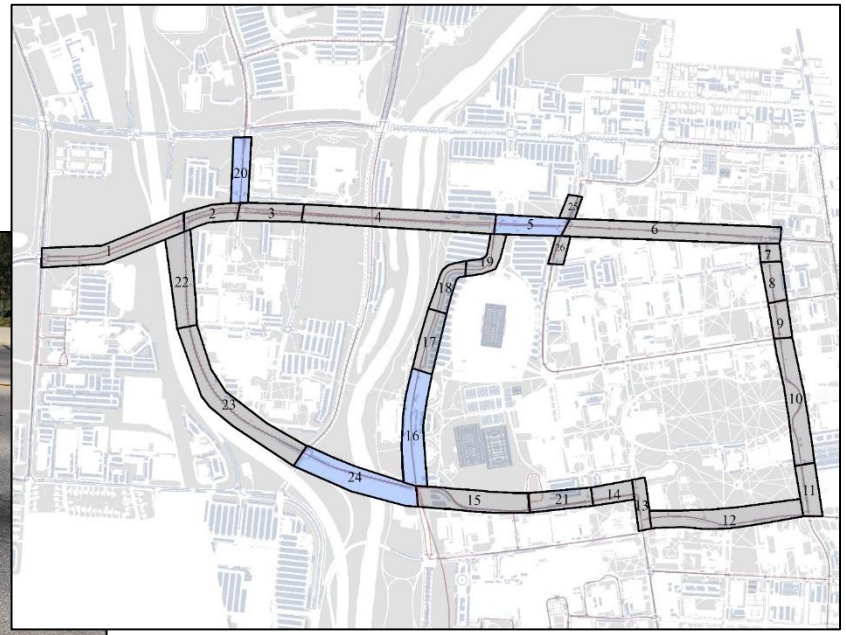
CIVILEN 5720 Transportation Data Studies Class Project

- Data collection on specified day between 7/8 a.m. and 7/6 p.m.
  - Students collect manual traffic counts for approximately 20% of the approximately 250 segment-hours

Education

CIVILEN 5720 Transportation Data Studies Class Project

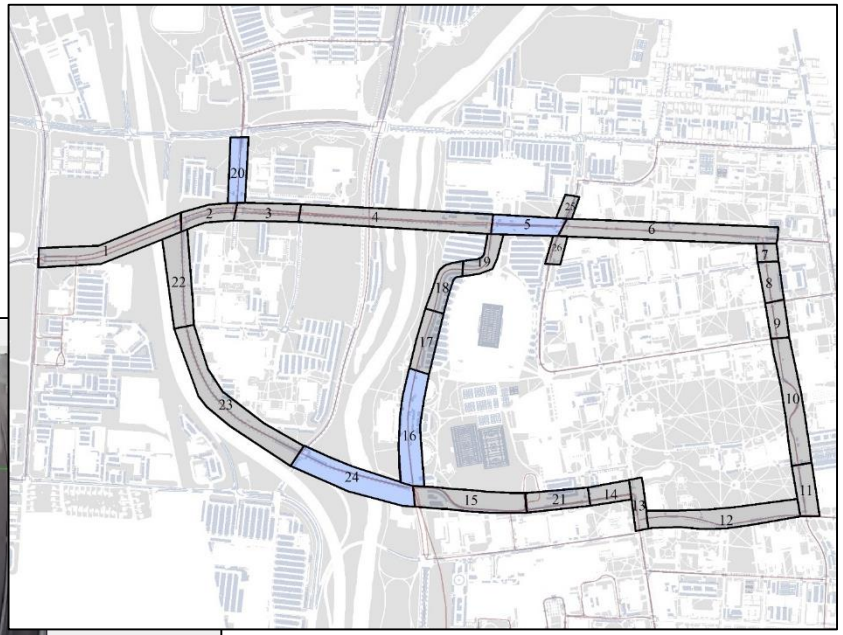
- Data collection on specified day between 7/8 a.m. and 7/6 p.m.
  - Students collect manual traffic counts . . .
  - Mid-Ohio Regional Planning Commission lays road tubes on 4 or 5 segments for entire period



Education

CIVILEN 5720 Transportation Data Studies Class Project

- Data collection on specified day between 7/8 a.m. and 7/6 p.m.
  - Students collect manual traffic counts …
  - Mid-Ohio Regional Planning Commission lays road tubes ….
  - OSU Transportation and Traffic Management provides ~60 hours of bus video covering the networks segments



Education

CIVILEN 5720 Transportation Data Studies Class Project

- Data collection on specified day between 7/8 a.m. and 7/6 p.m.
  - Students collect manual traffic counts for approximately 20% of the approximately 250 segment-hours
  - Mid-Ohio Regional Planning Commission lays road tubes ….
  - OSU Transportation and Traffic Management provides ~60 hours of bus video covering the networks segments
- Data processing and analysis
  - Students combine manual “coverage” counts with road tube “control” counts to estimate hourly directional volumes across all segments
  - Students process video to obtain (with help of research team) hourly direction volumes across all segments
  - Students compare traditional and video-based volumes and 12-hour vehicle miles traveled
- Reports

Education

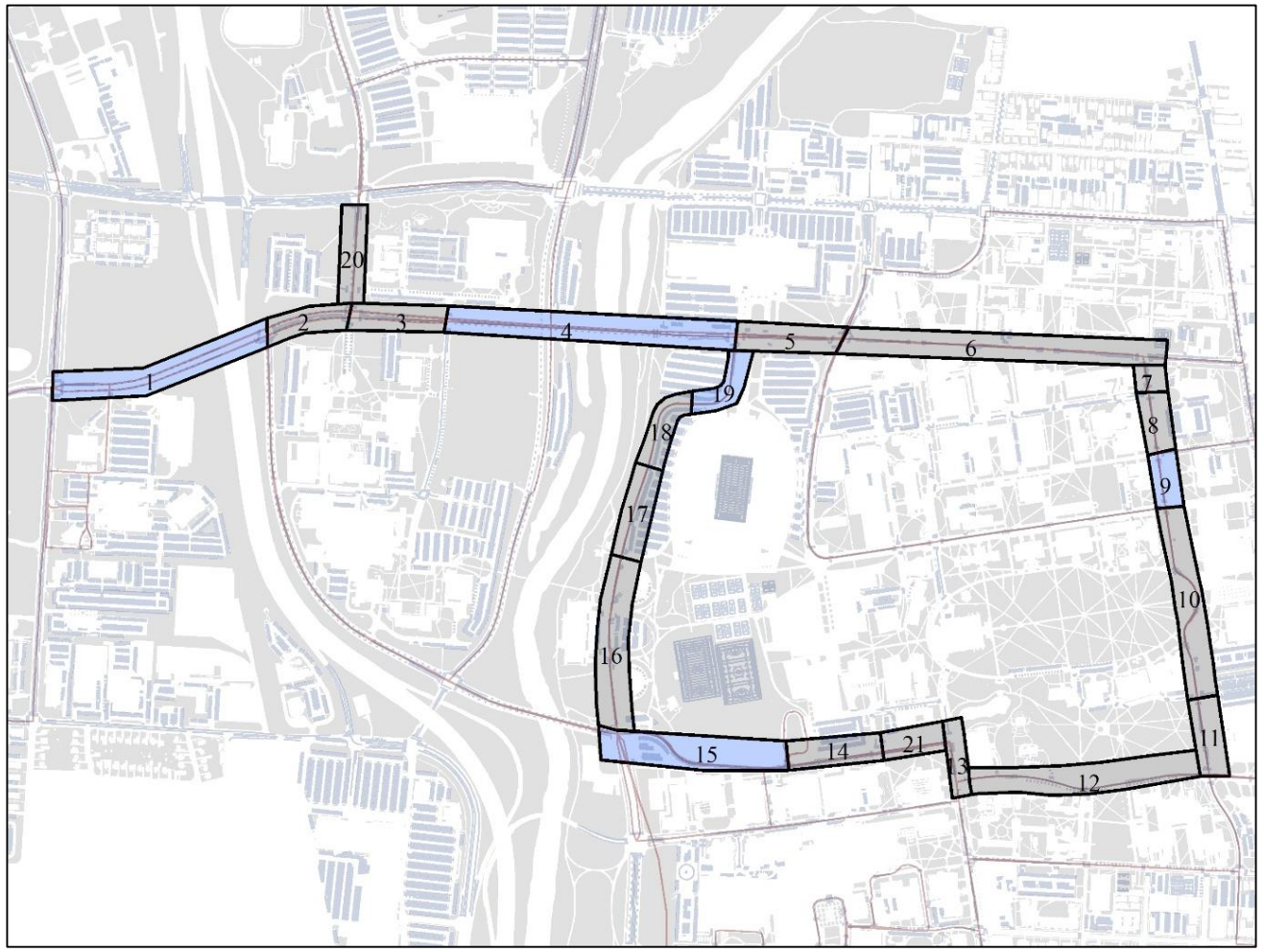
CIVILEN 5720 Transportation Data Studies Class Project

- Data collection on specified day between 7/8 a.m. and 7/6 p.m.
  - Students collect manual traffic counts for approximately 20% of the approximately 250 segment-hours
  - Mid-Ohio Regional Planning Commission lays road tubes ….
  - OSU Transportation and Traffic Management provides ~60 hours of bus video covering the networks segments
- Data processing and analysis
  - Students combine manual “coverage” counts with road tube “control” counts to estimate hourly directional volumes across all segments
  - Students process video to obtain (with help of research team) hourly direction volumes across all segments
  - Students compare traditional and video-based volumes and 12-hour vehicle miles traveled
- Reports

2018 VMT Study (30 students)

6.26 directional road miles

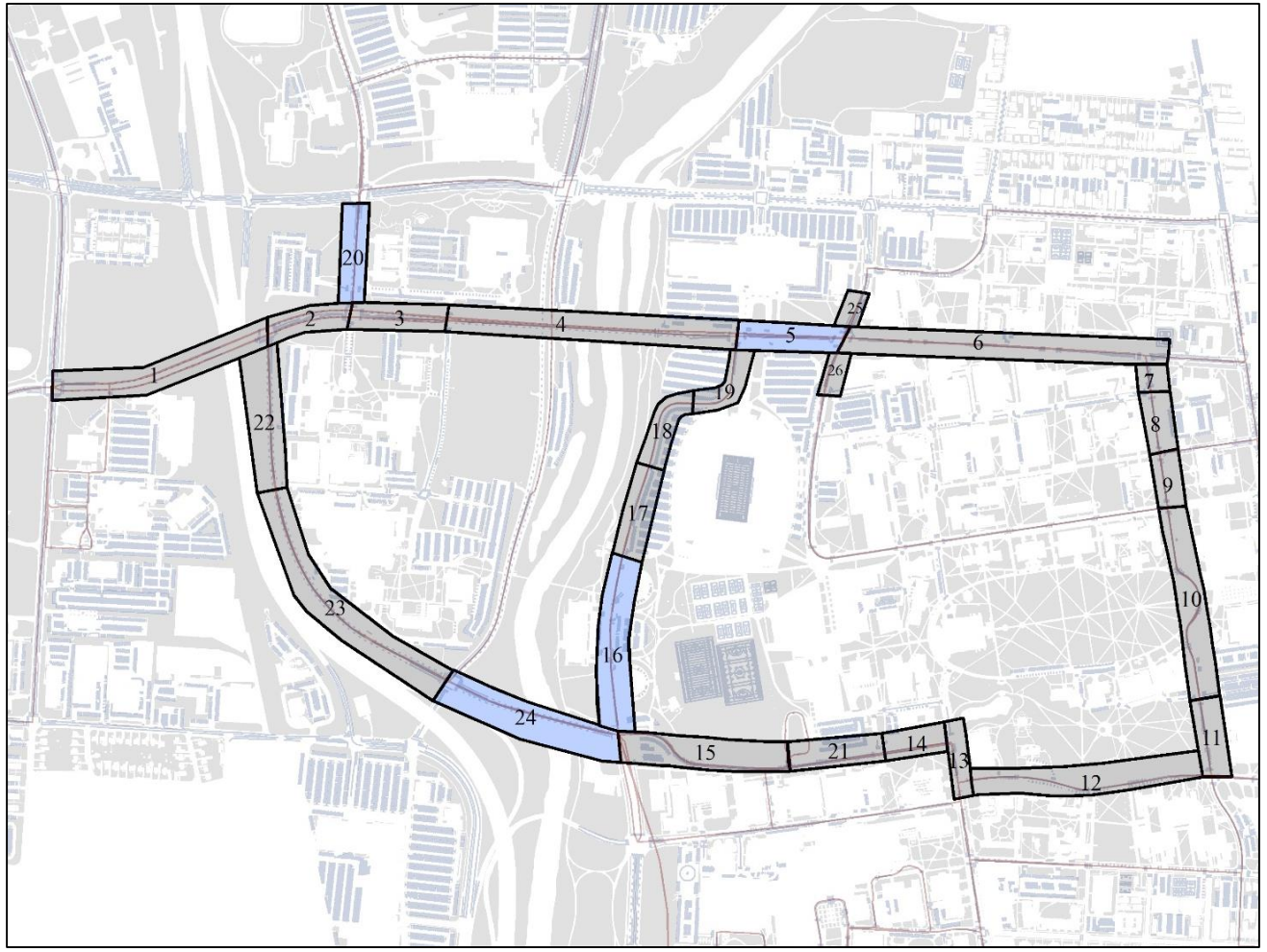
7 am to 7 pm, Thursday, 25 October 2018



2019 VMT Study (32 students)

7.86 directional road miles

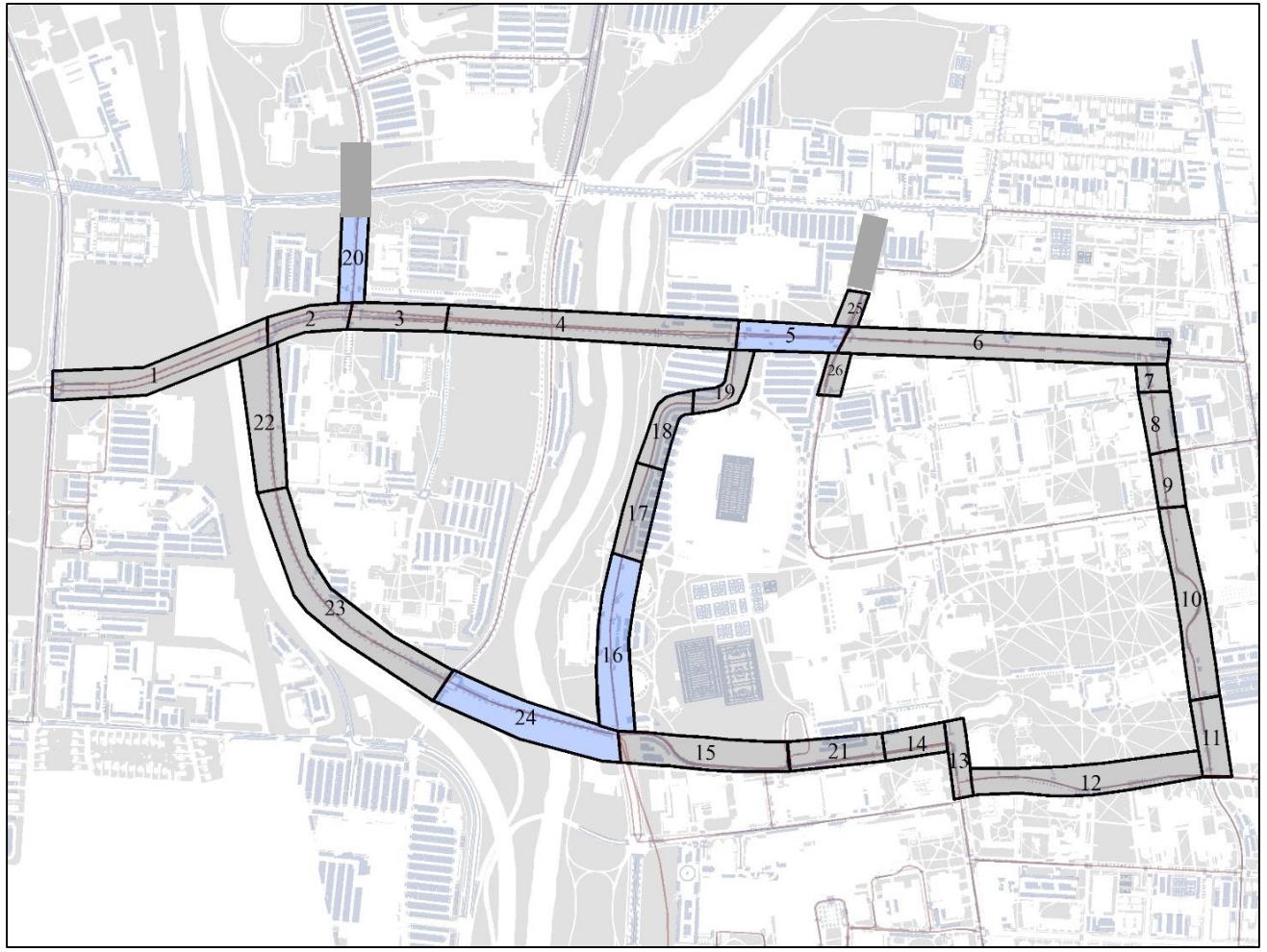
8 am to 6 pm, Thursday, 24 October 2019



2020 VMT Study (27 students)

> 7.86 directional road miles

7 am to 7 pm, *Thursday, 5 November 2020*



- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

2018 Video and Road Tube Hourly Volumes on Road Tube Segments

Segment and Direction	Sg. Length (miles)	Variables	Start Time of 1-hour period												12-hour Period
			7	8	9	10	11	12	13	14	15	16	17	18	
2.1	0.2563	Video Volumes	275	423	276	154	412	332	309	377	539	757	851	442	5147
		Tube Volumes	278	277	232	269	346	422	338	505	479	662	766	453	5027
		# passes	3	4	4	4	3	3	3	4	4	3	3	3	41
2.2	0.2563	video	706	630	398	330	310	358	192	262	182	640	320	185	4512
		tube	695	679	455	334	297	360	303	268	342	463	406	297	4899
		# passes	4	4	3	3	4	3	4	3	3	4	4	3	42
5.1	0.3262	video	164	236	257	266	345	371	384	432	550	478	669	551	4703
		tube	192	202	237	304	319	451	349	506	581	643	725	560	5069
		# passes	8	10	9	10	9	9	9	9	7	9	10	10	109
5.2	0.3262	video	671	849	656	504	373	410	353	292	467	558	420	322	5876
		tube	775	814	654	502	356	436	353	353	423	442	455	360	5923
		# passes	6	9	9	8	8	10	9	8	9	10	10	9	105
11.1	0.2316	video	135	90	164	116	104	274	191	165	196	200	199	162	1997
		tube	115	119	150	151	166	153	146	139	183	165	283	182	1952
		# passes	4	4	4	2	3	3	4	4	4	4	1	4	41
11.2	0.2316	video	149	164	174	178	141	226	168	227	285	225	424	174	2535
		tube	110	120	135	147	147	186	182	180	193	235	270	216	2121
		# passes	4	6	4	6	4	6	6	5	4	5	5	5	60
17.1	0.1939	video	429	233	266	305	188	378	402	366	673	807	965	593	5605
		tube	332	201	252	217	296	296	297	341	458	590	576	392	4248
		# passes	3	3	4	4	4	3	4	4	3	4	3	4	43
17.2	0.1939	video	725	667	247	349	320	343	352	311	209	320	301	374	4518
		tube	547	461	327	275	284	349	283	287	284	308	299	408	4112
		# passes	4	5	4	5	6	5	6	6	4	6	6	6	63
21.1	0.1121	video	363	183	196	203	109	133	157	90	143	137	215	207	2136
		tube	350	320	237	188	175	196	186	204	160	175	170	147	2508
		# passes	3	5	3	5	5	5	6	3	3	3	4	4	49
21.2	0.1121	video	90	210	153	179	226	400	154	376	267	183	435	188	2862
		tube	80	100	131	166	161	181	174	230	257	235	308	181	2204
		# passes	4	3	4	4	4	3	3	4	4	3	4	4	44

Compare Video-based Hourly Volumes to Road-tube based Hourly Volumes

Relative Difference (RD): Sign and magnitude

$$RD = \frac{Video\ Volume - Road\ Tube\ Volume}{Road\ Tube\ Volume}$$

Absolute Relative Difference (ABSRD): Magnitude

$$ABSRD = |RD|$$

"Difference": Road tubes are not ground truth

Comparisons of 12 Hourly and One 12-hour Video-based and Road Tube Volumes

Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Average hourly ABSRD is large but average hourly RD is close to zero

No obvious bias → larger aggregation would do better

Comparisons of 12 Hourly and One 12-hour Video-based and Road Tube Volumes

Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Average hourly ABSRD is large but average hourly RD is close to zero
No obvious bias → larger aggregation would do better

Comparisons of 12 Hourly and One 12-hour Video-based and Road Tube Volumes

Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Indeed, 12-hour volumes have much smaller average ABSRD than hourly volumes → 12% error is approaching "reasonable" levels

Comparisons of 12 Hourly and One 12-hour Video-based and Road Tube Volumes

Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Some segments have very low ABSRD

Comparisons of 12 Hourly and One 12-hour Video-based and Road Tube Volumes

Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Some segments have very low ABSRD
Determining explanatory characteristics is ongoing

Explanatory Factors: Regression Results

ABSRD(hourly volumes)

= 0.638 – 0.017(# Bus Passes) – 0.552(Segment Length)

- Low R^2 (0.142): Other factors are important
- Meaningful coefficient signs with significance (p-values 0.061 and 0.059)

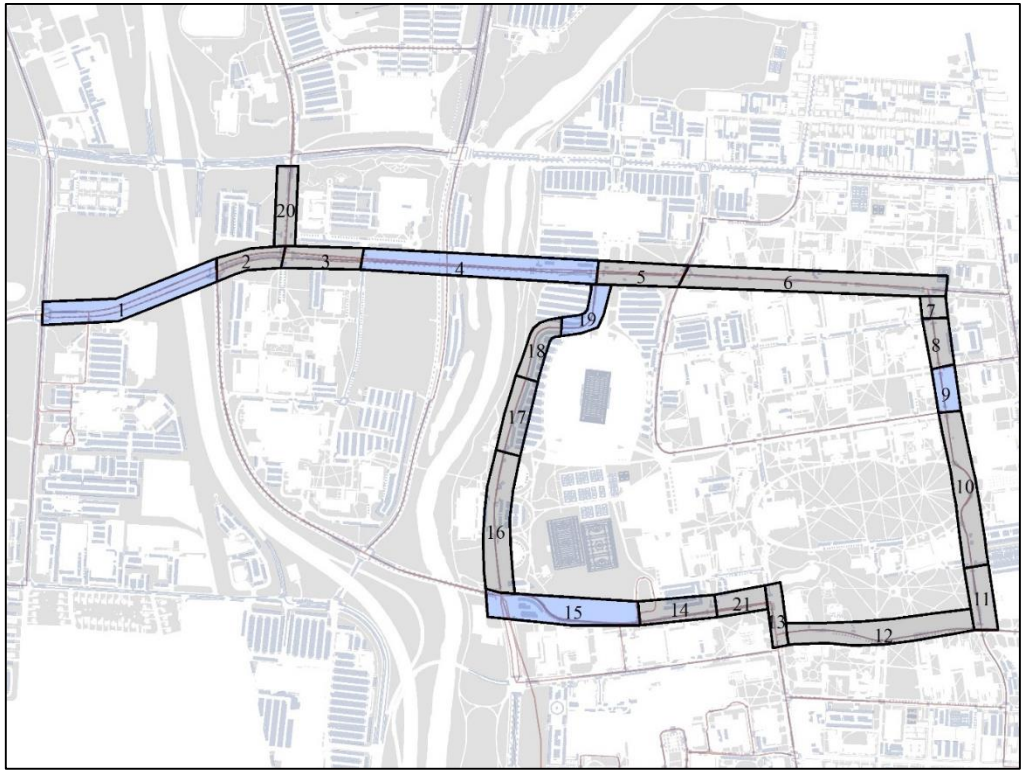
Results above are from one-day of bus passes

whereas transit buses repeat day after day

Vehicle Miles Traveled (VMT) Study: Video-based vs. Traditional Volumes

$$VMT \equiv \sum_{vehicles} Distance\ Traveled\ by\ Vehicle$$
$$= \sum_{segment} Length\ of\ Segment\ \times Volume\ of\ Segment$$

- Basic measure of vehicle travel over a network
- Video Volumes as above
- Traditional volumes
  - From manual coverage counts and tube-based control count
  - Assumptions needed: Different student groups made different assumptions



Vehicle Miles Traveled (VMT) Study: Video-based vs. Traditional Volumes

Network Considered	Video-based VMT	Traditional VMT	Relative Difference
Segments with road tubes	9,581	9,221	0.0390
Entire network	23,554	Mean: 22,589 Range: [20,568, 25,709]	0.0476 (from mean)

- Very low relative differences
- Relative difference on entire network much less than variability in range associated with assumptions in traditional approaches

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
  - Education component
  - Research validation study
  - Outreach component
- Ongoing and future efforts

The Ohio State University Columbus Campus Community

- One of largest single campuses worldwide
  - Approximately 1,665 acres (6.738 km^2)
  - Approximately ~100, 000 on-campus (pre-COVID) population on a regular basis

The Ohio State University Columbus Campus Community

- One of largest single campuses worldwide
  - Approximately 1,665 acres (6.738 km^2)
  - Approximately ~100, 000 on-campus (pre-COVID) population on a regular basis
- Multiple and diverse land uses and transportation network: large medical center, central campus, large and important park-and-ride facilities, major arterials and local streets

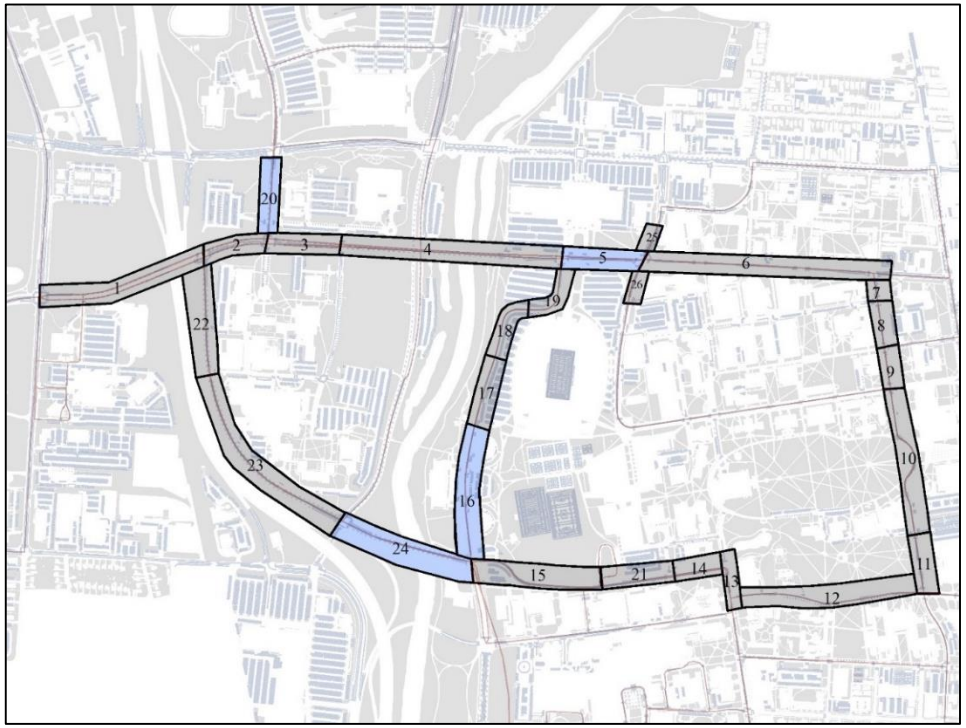
The Ohio State University Columbus Campus Community

- One of largest single campuses worldwide
- Multiple and diverse land uses and transportation network: large medical center, central campus, large and important park-and-ride facilities, major arterials and local streets

Functions like a small city

The Ohio State University Columbus Campus Community

- One of largest single campuses worldwide
  - Approximately 1,665 acres (6.738 km^2)
  - Approximately ~100, 000 on-campus (pre-COVID) population on a regular basis
- Multiple and diverse land uses and transportation network: large medical center, central campus, large and important park-and-ride facilities, major arterials and local streets



- Empirical VMT provided to University transportation and sustainability planners
  - University increasingly interested in sustainability measures and initiatives
  - Only empirical values available
  - Ongoing monitoring

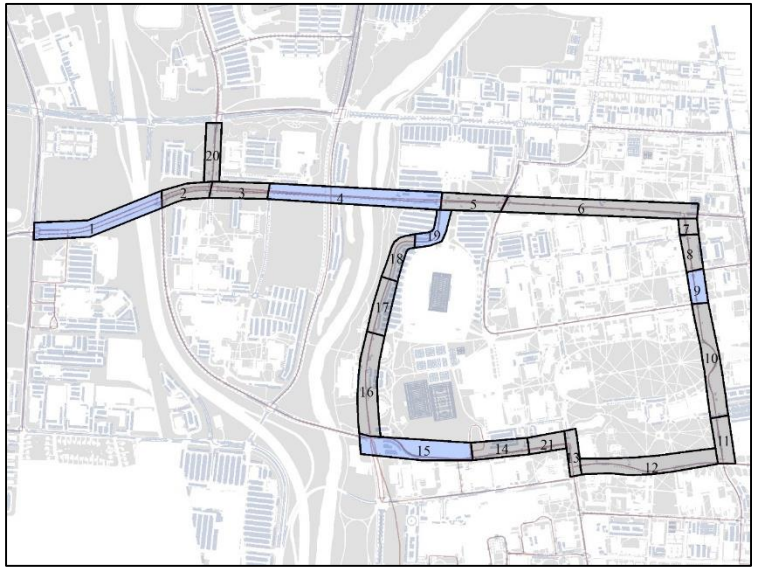
- Motivation for effort
- Concept
- Methodology
- Multi-faceted empirical study
- Ongoing and future efforts

Ongoing and Future Efforts

- Education and Outreach
- Research

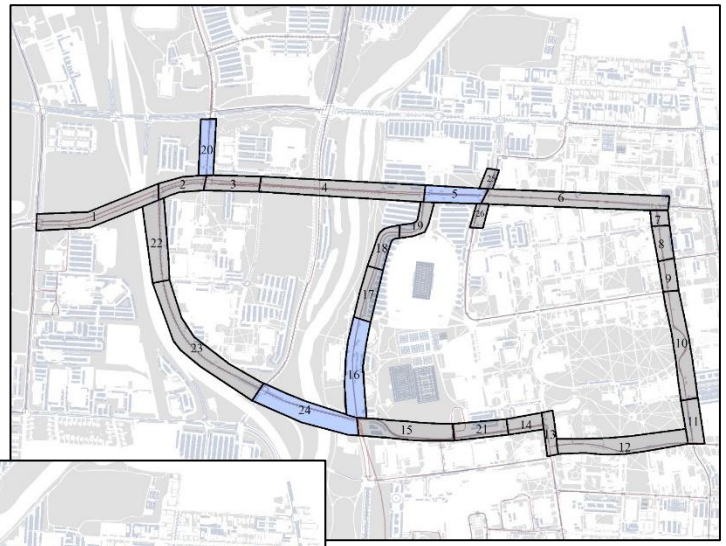
Ongoing and Future Efforts

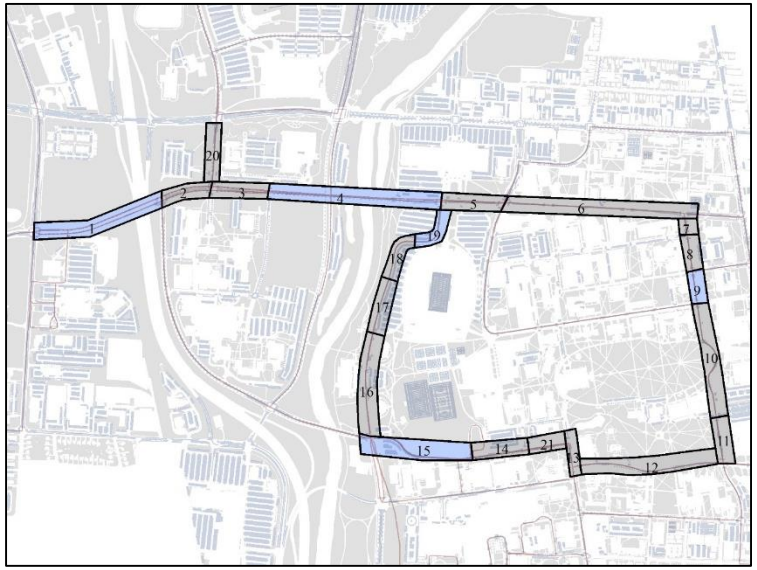
- Education and Outreach
  - Refining and repeating class projects
  - Continuing to provide VMT estimates to campus planners and decision-makers

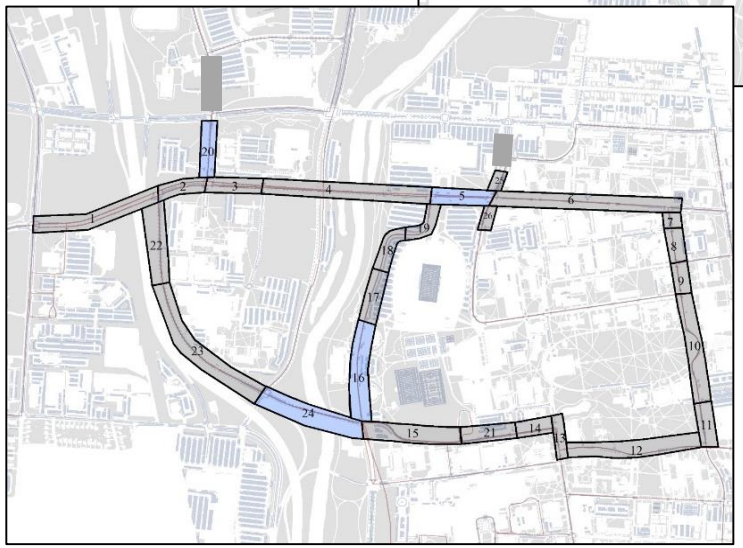


Ongoing and Future Efforts

- Education and Outreach
  - Refining and repeating class projects
  - Continuing to provide VMT estimates to campus planners and decision-makers





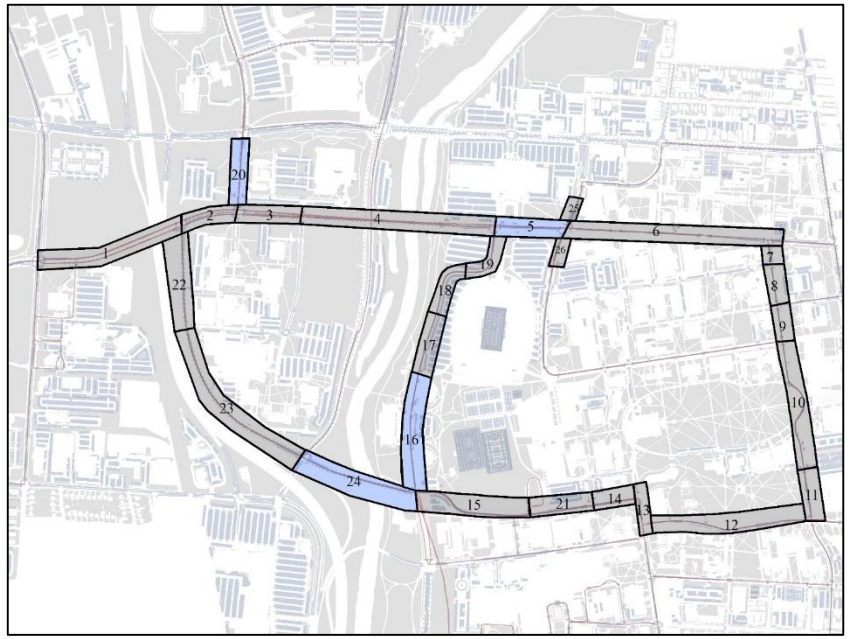


Ongoing and Future Efforts

- Education and Outreach
- Research
  - Confirm promising results
  - Determine explanatory variables associated with good or bad performance
  - Improve volume estimation
  - Develop efficient processing

Ongoing and Future Efforts

- Education and Outreach
- Research
  - Confirm promising results



Segment-Direction	Hourly volumes					12-hour volumes		
	N	RD		ABSRD		N	RD	ABSRD
		Mean	S.D.	Mean	S.D.			
2.1	12	0.0225	0.2511	0.1918	0.1531	1	0.0238	0.0238
2.2	12	-0.0755	0.2456	0.1809	0.1755	1	-0.0497	0.0497
5.1	12	-0.0468	0.1316	0.1192	0.0647	1	-0.0721	0.0721
5.2	12	0.0427	0.1800	0.1115	0.1443	1	0.0381	0.0381
11.1	12	0.0489	0.3266	0.2582	0.1913	1	0.0232	0.0232
11.2	12	0.1992	0.2384	0.2580	0.1660	1	0.1954	0.1954
17.1	12	0.3415	0.3348	0.4025	0.2502	1	0.3583	0.3583
17.2	12	0.0694	0.2332	0.1872	0.1464	1	0.0909	0.0909
21.1	12	-0.0929	0.3328	0.2972	0.1544	1	-0.0879	0.0879
21.2	12	0.3235	0.4545	0.3793	0.4047	1	0.2986	0.2986
Mean	120	0.0833		0.2386		12	0.0819	0.1238
S.D.		0.3127		0.2177			0.1545	0.1196

Network Considered	Video-based VMT	Traditional VMT	Relative Difference
Segments with road tubes	9,581	9,221	0.0390
Entire network	23,554	Mean: 22,589 Range: [20,568, 25,709]	0.0476 (from mean)

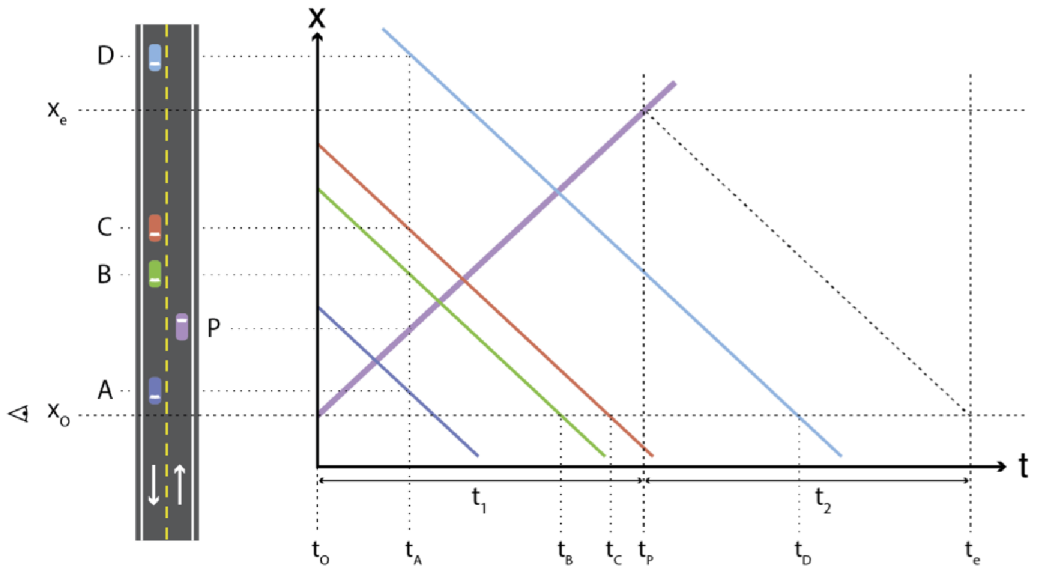
Ongoing and Future Efforts

- Education and Outreach
- Research
  - Determine explanatory variables associated with good or bad performance

ABSRD(hourly volumes) = 0.638 – 0.017 (# Bus Passes) – 0.552 (Segment Length)

Ongoing and Future Efforts

- Education and Outreach
- Research
  - Improve volume estimation



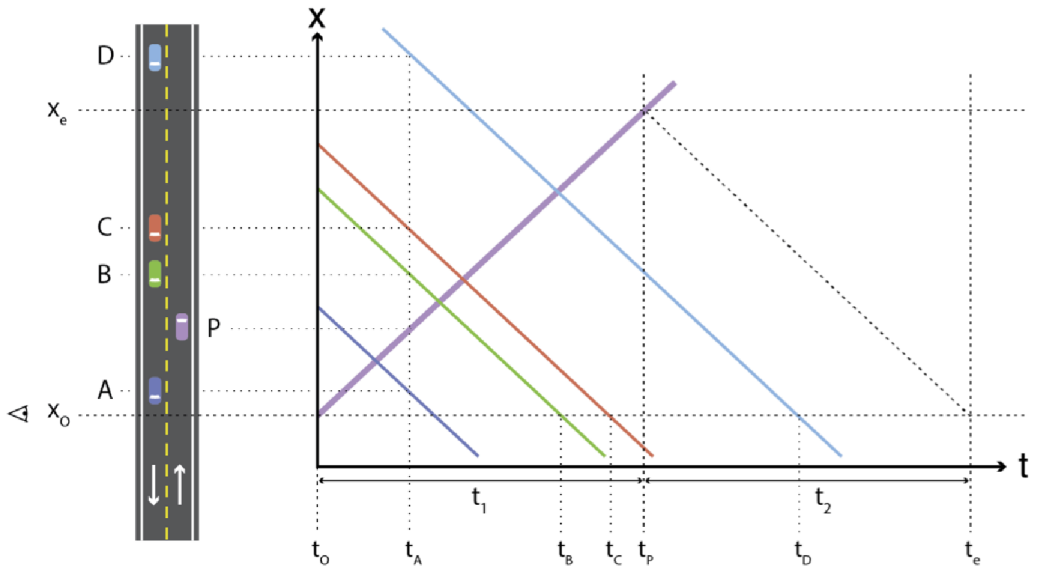
- Flow rate q from an individual bus pass over a segment

$$q = n^{veh}/(t_1 + t_2)$$

- Aggregate q values from individual passes into hourly volumes

Ongoing and Future Efforts

- Education and Outreach
- Research
  - Improve volume estimation



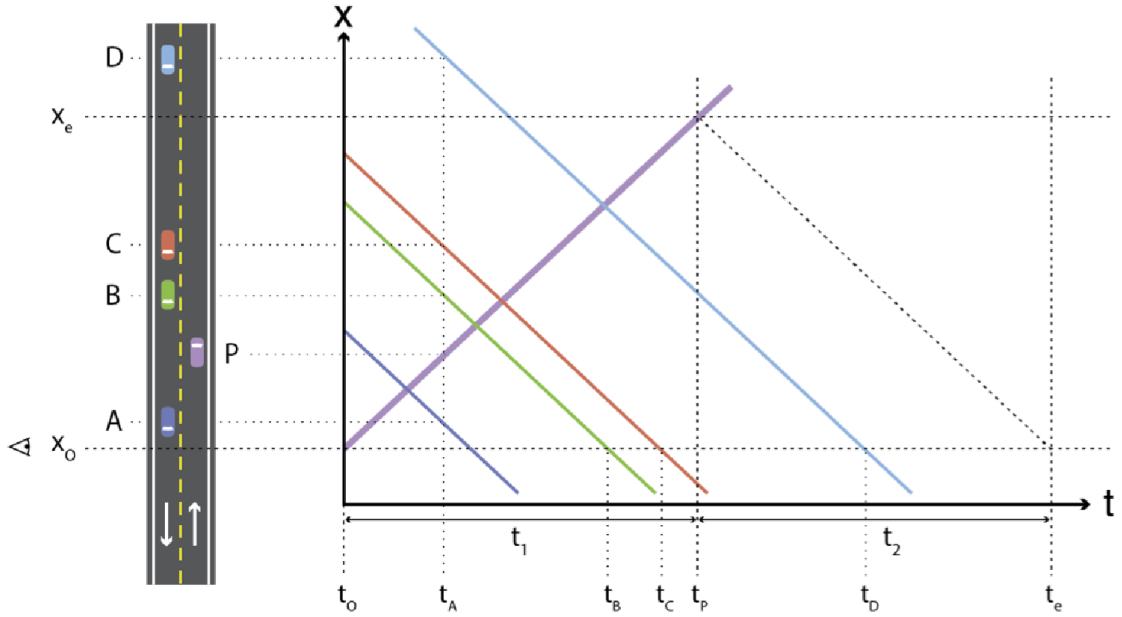
- Flow rate q from an individual bus pass over a segment

$$q = n^{veh}/(t_1 + t_2)$$

- Aggregate q values from individual passes into hourly volumes

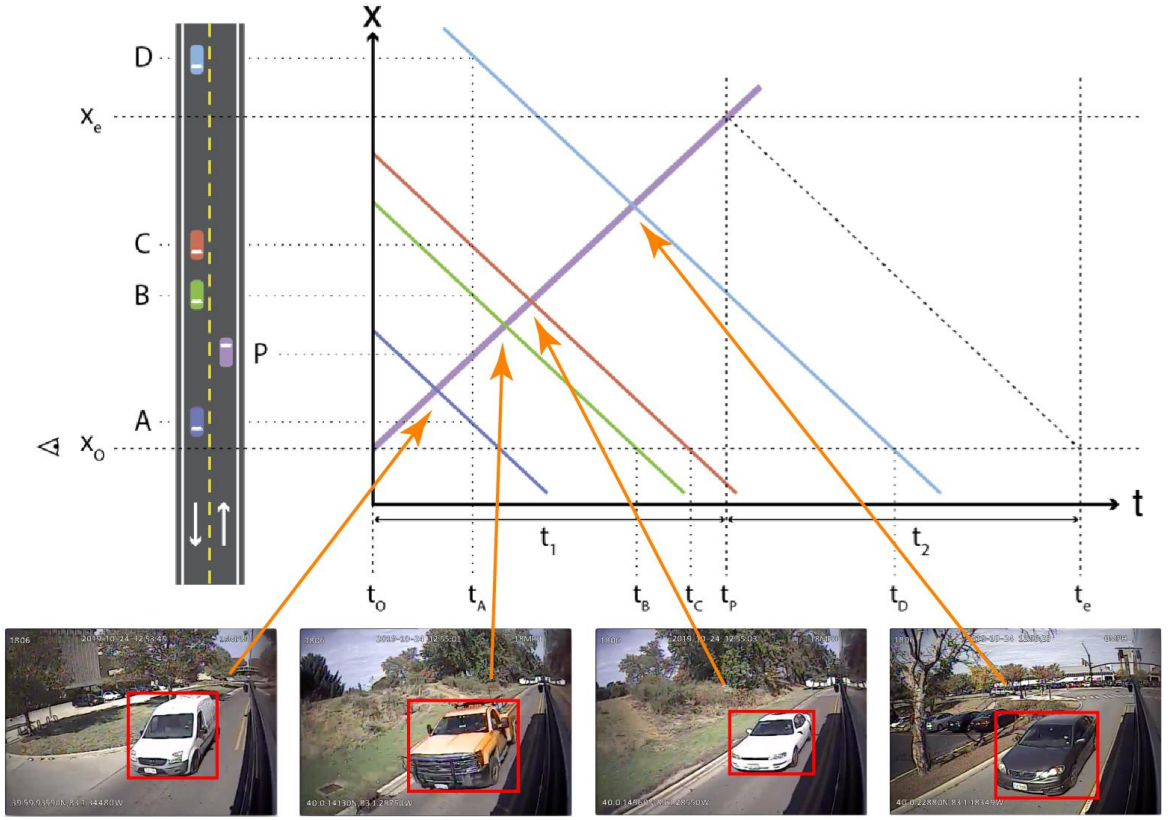
Ongoing and Future Efforts

- Education and Outreach
- Research
  - Develop efficient processing



Ongoing and Future Efforts

- Education and Outreach
- Research
  - Develop efficient processing



In Summary

- Developing, demonstrating, and promoting an approach for obtaining traffic flow estimates across extensive urban roadway networks from video data collected from transit buses
- Taking advantage of repeated, ongoing coverage of fixed schedule transit buses to “observe” traffic on most major roadways in an urban area while providing regular service
- Extensive monitoring of the OSU campus network using video imagery since 2018 producing encouraging results
- Several research and development components underway
- Leveraging the research study with education and outreach components

- Contacts
  - Mark McCord: mccord.2@osu.edu
  - Rabi Mishalani: mishalani@osu.edu
  - Benjamin Coifman: coifman.1@osu.edu

- Acknowledgements
  - OSU Graduate Students: Gio Hansel, Serkan Bicici, Mo Wu, Stephanie Ferzli, Diego Ribeiro de Oliveira Galdino, Shahrzad Charmchi Toosi
  - OSU Transportation and Traffic Management: Beth Snoke, Tom Holman, Sean Roberts
  - Mid-Ohio Regional Planning Commission: Nick Gill, Hwashik Jang, Zhuojun Jiang