CENTER FOR ADVANCED TRANSPORTATION TECHNOLOGY

Applications of Vehicle Probe Data for Performance Measurement

Baltimore Regional Transportation Board

October 25, 2016

Thomas H. Jacobs, Director

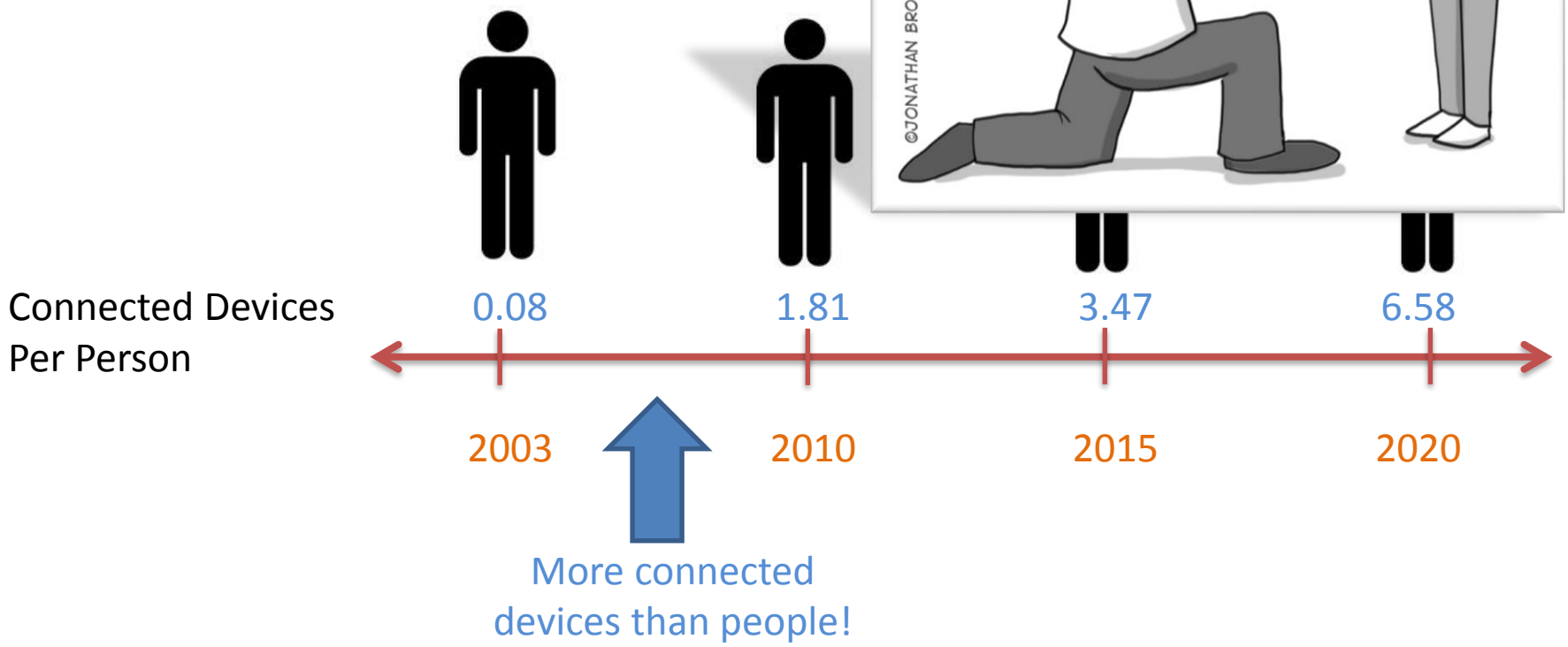
Center for Advanced Transportation Technology

Presentation

- Probe data background
- Applications in performance measurement
  - Freeways: Maryland Mobility Report
  - Arterials: Maryland Mobility Report
  - Weather Impact and Recovery
  - Work Zones
- Newly Acquired O-D Data & Applications

Background -The World is Changing

World Population	6.3 Billion	6.9 Billion
Connected Devices	500 Million	12.5 Billion

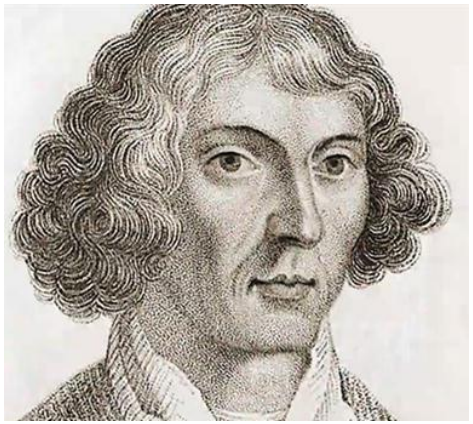


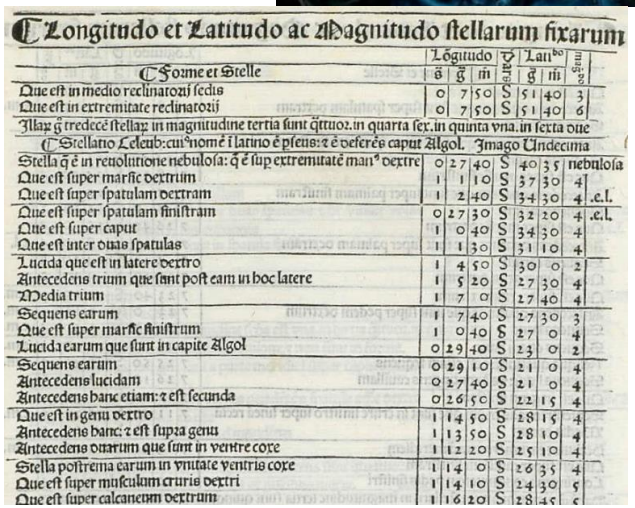
Data Source

- INRIX provides Internet services and mobile aps pertaining to road traffic and driver services (speeds, travel times, traffic counts)
- INRIX collects terabytes of data from over 250 million mobile phones, cars, trucks, vans and other fleet vehicles via GPS

- INRIX sold 4 months of trip O/D data to Maryland SHA
  - 20 million trips, which include 1.4 billion waypoints
  - **112 GB** of data

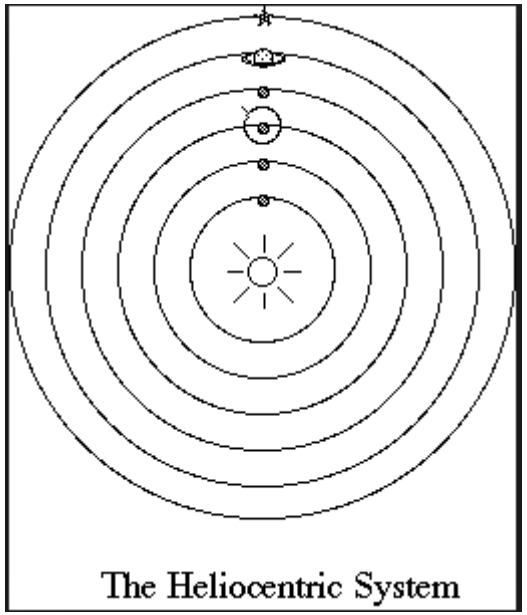
Background – Historical Significance of "Big Data"

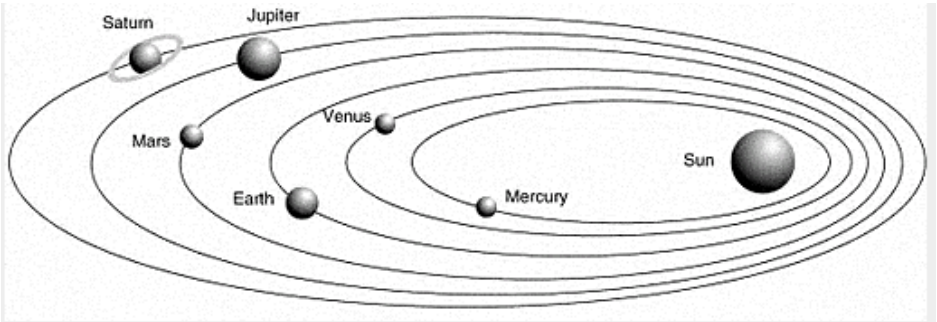




Longitudo et Latitudo ac Magnitudo stellarum fixarum

Forme et Stelle	Longitudo ♉ g	Longitudo ♉ m	Zodiacus	Latitudo g	Latitudo m	Magnitudo	
Que est in medio reclinatorij sedis	0	7	50	S	51	40	3	
Que est in extremitate reclinatorij	0	7	50	S	51	40	6	
Illaz ğ tredecē stellaz in magnitudine tertia sunt ğttuoz. in quarta sex. in quinta vna. in sexta due								
Stellatio Celeub: cui⁹ nomē i latino ē pseus: z ē deferēs caput Algol. Imago Undecima								
Stella ğ ē in reuolutione nebulosa: q ē sup extremitatē man⁹ dextre	0	27	40	S	40	35		nebulosa
Que est super marsic dextrum	1	1	10	S	37	30	4	
Que est super spatulam dextram	1	2	40	S	34	30	4	.c.l.
Que est super spatulam sinistram	0	27	30	S	32	20	4	.c.l.
Que est super caput	1	0	40	S	34	30	4	
Que est inter duas spatulas	1	1	30	S	31	10	4	
Lucida que est in latere dextro	1	4	50	S	30	0	2	
Antecedens trium que sunt post eam in hoc latere	1	5	20	S	27	30	4	
Media trium	1	7	0	S	27	40	4	
Sequens earum	1	7	40	S	27	30	3	
Que est super marsic sinistrum	1	0	40	S	27	0	4	
Lucida earum que sunt in capite Algol	0	29	40	S	23	0	2	
Sequens earum	0	29	10	S	21	0	4	
Antecedens lucidam	0	27	40	S	21	0	4	
Antecedens hanc etiam: z est secunda	0	26	50	S	22	15	4	
Que est in genu dextro	1	14	50	S	28	15	4	
Antecedens hanc: z est supra genu	1	13	50	S	28	10	4	
Antecedens duarum que sunt in ventre core	1	12	20	S	25	10	4	
Stella postrema earum in vnitate ventris core	1	14	0	S	26	35	4	
Que est super musculum cruris dextri	1	14	10	S	24	30	5	
Que est super calcaneum dextrum	1	16	20	S	28	45	5	

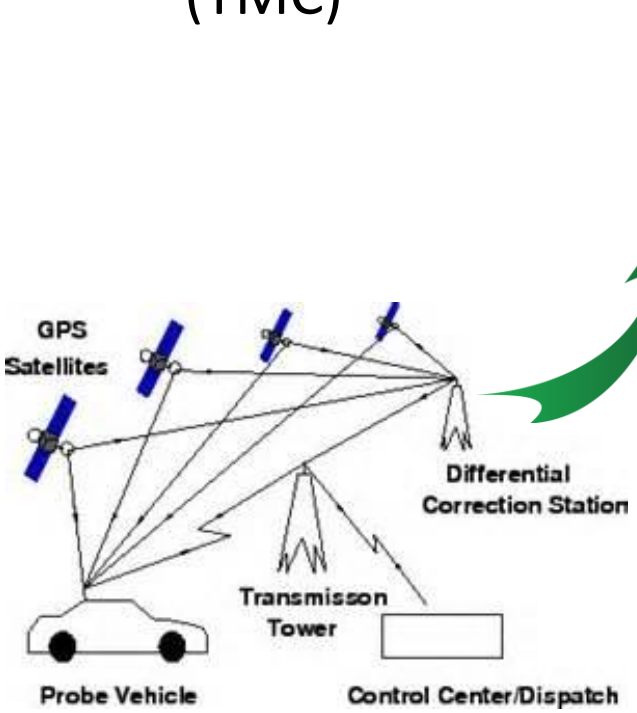




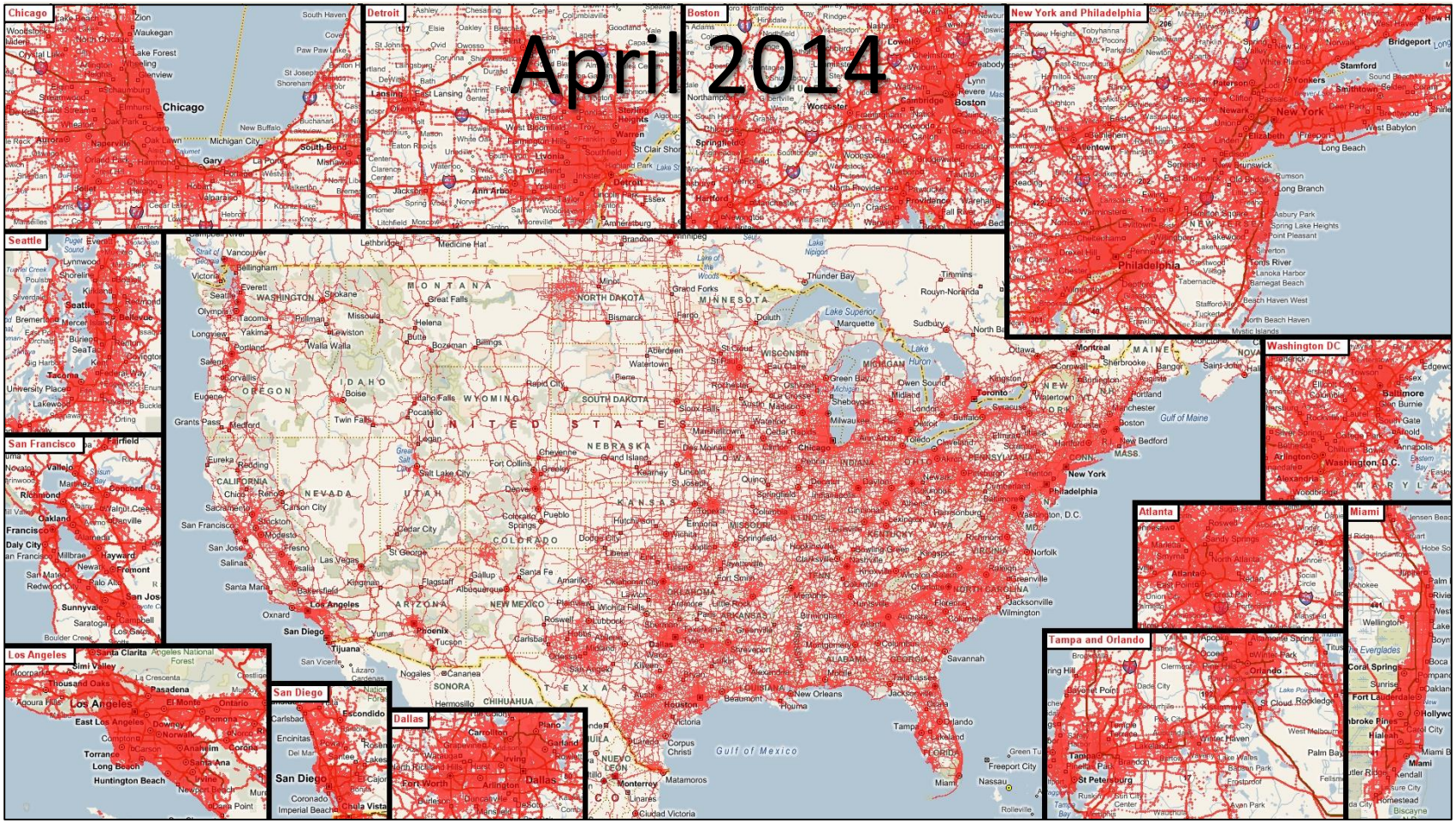
Source of all pictures: google

Background: Vehicle Probe Data

- Private data vendors collect and fuse data from several sources, including GPS probes
- Data is reported every minute on Traffic Message Channels (TMC)



Background: Incoming raw GPS data (Source: INRIX)



Background: Validation effort

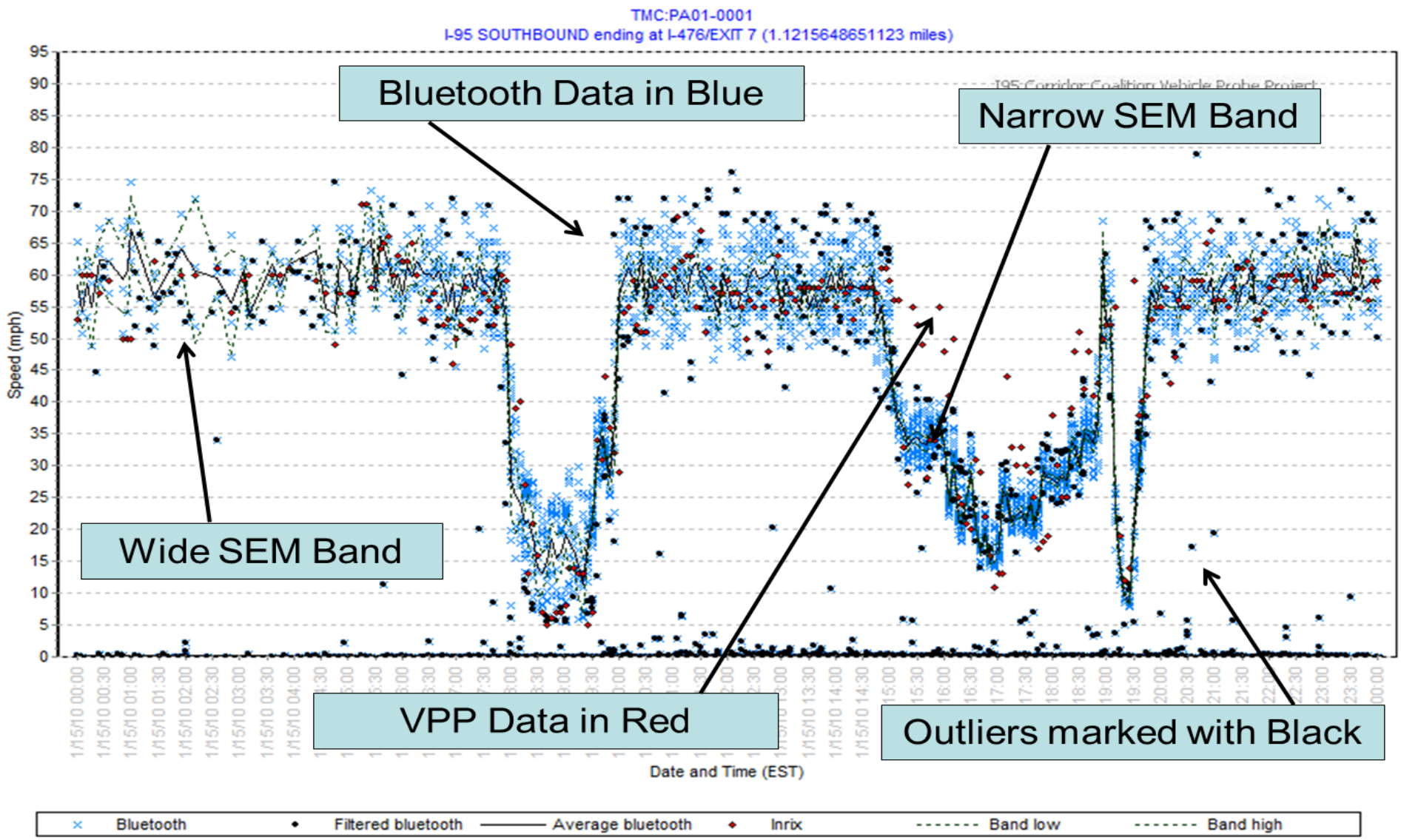
Through July 2015

- 11states
- 55 evaluation reports
- 57 deployments, 829 days sensors on the road
- 1282 centerline mile (994 mile freeway, 288 mile arterial)
- 95,706 hour worth of ground truth data resulting from 13 million Bluetooth observations

State	Validation rounds
CT	1
DE	6
FL	1
GA	1
MD	9
NC	6
NJ	13
PA	8
RI	1
SC	1
VA	10

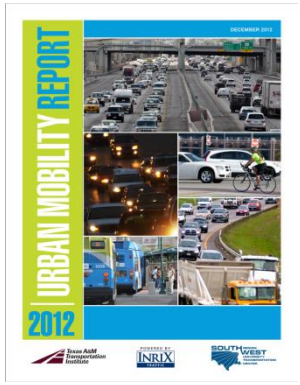
Reports are available on: http://www.i95coalition.org/projects/vehicle-probe-project/

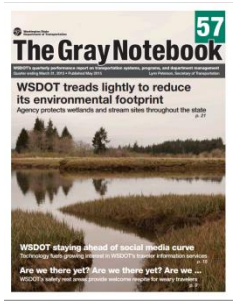
Background: Graphical output

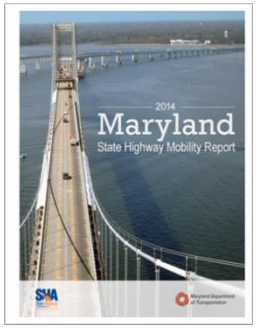


Mobility Reporting: National and State Level

- National
  - Urban Mobility Report (TTI)
  - Since 2010 based on probe speed data
- States
  - Washington (WSDOT)
    - The Gray Notebook
  - **Maryland (SHA)**
    - Mobility Report (Since 2012)
  - Indiana (IDOT)
  - …

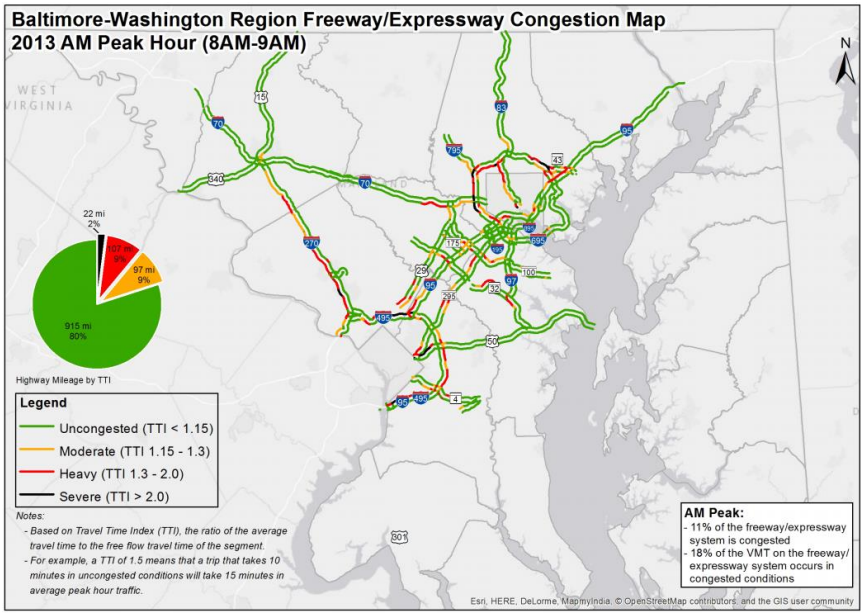






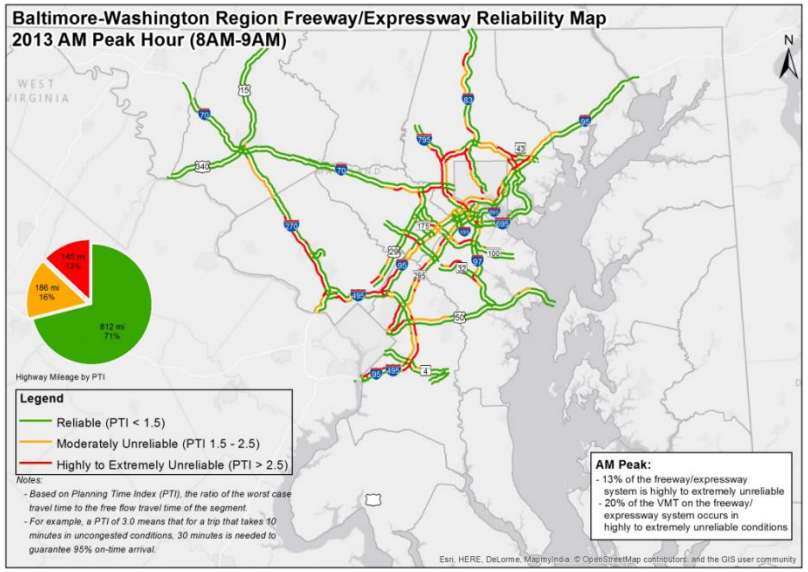
Mobility Reporting : Performance Measurement

- Congestion: Travel Time Index (TTI)
  - Refers to the ratio of expected (average) travel time to the (minimum) free flow travel time of the segment
- Uncongested (TTI<1.15)
- Light (1.15<TTI<1.3)
- Moderate (1.3<TTI<2.0)
- Severe (TTI>2.0)



Mobility Reporting: Performance Measurement

- Reliability: Planning Time Index (PTI)
  - Refers to the ratio of extreme (95th percentile) travel time to the (minimum) free flow travel time
- Reliable (PTI<1.5)
- Moderately Reliable (1.5<TTI<2.5)
- Unreliable (PTI>2.5)



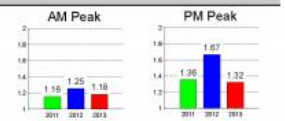
Mobility Reporting: Corridor Level Example

2014 Maryland State Highway Mobility Report

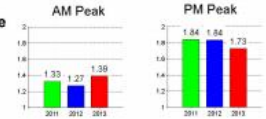
Capital Beltway

Trends[a]

Travel Time Index[b]
measure of average delay

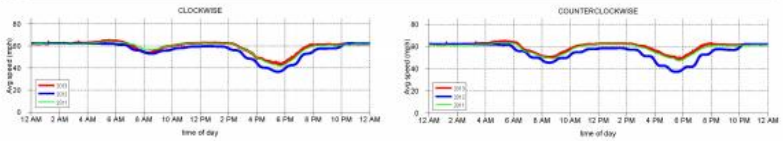


Planning Time Index[c]
measure of worst-case delay

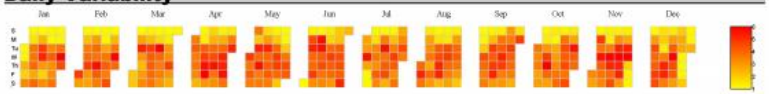


42 miles carrying 183,000 vehicles every day

Speed Profiles[d]



Daily Variability[e]



Top Bottlenecks[f]

2013 Rank	LOCATION	Direction	Number of Occurences Q1	Q2	Q3	Q4	Average Duration (minute)	Average Length (mile)	Impact Factor	2012 Rank	Change
1	I-495 CW @ I-270/Exit 35	Innerloop	172	266	214	208	186	13.8	**19.9**	140	-139
7	I-495 CCW @ Greenbelt Metro Dr/Exit 24	Outerloop	88	125	105	90	133	10.8	**5.2**	28	-21
17	I-495 CCW @ MD-185/Connecticut Ave/Exit 33	Outerloop	68	79	60	63	127	6.2	**1.9**	23	-6
24	I-495 CCW @ MD-97/Georgia Ave/Exit 31	Outerloop	78	118	99	114	102	3.5	**1.4**	26	-2
27	I-495 CW @ MD-214/Central Ave/Exit 15	Innerloop	65	84	157	111	72	6.0	**1.4**	53	-26
30	I-495 CCW @ US-50/Exit 19	Outerloop		101	114	113	89	4.6	**1.3**	31	-1
40	I-495 CW @ MD-4/Pennsylvania Ave/Exit 11	Innerloop	46	52	103	44	73	7.4	**1.1**	29	11
42	I-495 CW @ I-270 Spur	Innerloop	51	59	50	46	163	3.3	**1.0**	18	24
44	I-495 CW @ Woodrow Wilson Memorial Bridge	Innerloop	51	66	49	63	96	5.0	**1.0**	81	-37
57	I-495 CCW @ MD-295/MD-193/Exit 22	Outerloop	25	56	30	32	78	8.4	**0.9**	57	0

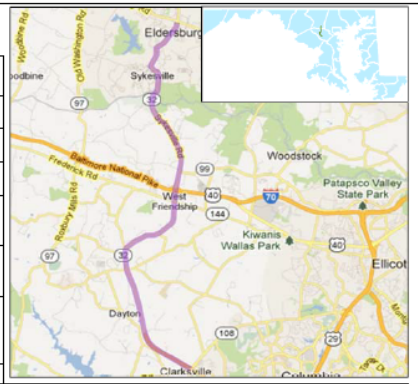
Notes

a - **Peak Hours** are considered as 6-9am and 5-6pm.
b - **Travel Time Index** (TTI) is the ratio of the *average* travel time during the peak hour to the time required under free flow.
c - **Planning Time Index** (PTI) is the ratio of the *worst-case* travel time (95th percentile) during peak hour to the free-flow time.
d - Typical work day speeds, calulcuated as the average speed of all weekdays for the entire year and shows it as varies by time-of-day.
e- Variability of worst-case travel experience along facility for each day of year, shown as plot of PTI by day of week and month, showing seasonal and weekly trends.
f - Top 10 bottlenecks on the facility, ranked by impact factor.
Impact factor is multiplication of total annual number of bottleneck occurences by their average duration and by their average length.
Bottlenecks are said to occur when speeds drop below 60% of free-flow speed for a period longer than 5 minutes.

Mobility Reporting:
Samples of Arterial Corridor Performance

MD 32

Limits:	MD 108 (Clarksville Pike) to MD 26 (Liberty Road)
Corridor Length:	16.3 miles
Speed Limit:	40 - 50 MPH
Travel Lanes:	(1 - 2) Northbound (1 - 2) Southbound
Signal Controlled Intersections:	11
Grade Separated Interchanges:	3
Major Cross Streets:	MD 108, Burntwoods Rd, MD 144, MD 26



Routes and Ridership	Routes	Avg. Daily Ridership
	N/A	N/A

2013 AADT	Trucks	Peak Hour Traffic
20,000 - 26,000 vpd	7% - 11%	8%

Intersection Operations

Signalized Intersections*:	AM Peak Hour	PM Peak Hour
LOS D or Better	3	3
LOS E	0	0
LOS F	0	0

Segment Operations

Level of Service	Northbound AM / PM (Miles of Roadway)	Southbound AM / PM (Miles of Roadway)
LOS D or Better	7.7 / 16.3	16.3 / 3.8
LOS E	3.2 / 0.0	0.0 / 6.3
LOS F	5.4 / 0.0	0.0 / 6.2

LOS 'E' Intersections

LOS 'F' Intersections

Color Key

PTI	TTI
1.0-1.5	1.0 - 1.15
1.5-2.5	1.15 - 1.3
>2.5	1.3 - 2.0
	> 2.0
No data	

Functional Class	Roadway Segment West to South	Length (miles)	TTI AM NB	TTI AM SB	TTI PM NB	TTI PM SB	PTI AM NB	PTI AM SB	PTI PM NB	PTI PM SB
Urban Other Principal Arterial	Liberty Rd. (MD-26) - Springfield Ave. (MD-851)	2.2								
	Springfield Ave. (MD-851) - Sandosky Rd./Raindliffe Rd.	0.7					W			
	Sandosky Rd./Raindliffe Rd. - Friendship Rd. (MD-851)	0.8					W			
Rural Minor Arterial	Friendship Rd. (MD-851) - River Rd.	1.7								
	River Rd. - Old Frederick Rd. (MD-99)	1.3								I
	Old Frederick Rd. (MD-99) - I-70/US-40	0.8								
Rural Other Principal Arterial	I-70/US-40 - Frederick Rd. (MD-144)	0.4								W
	Frederick Rd. (MD-144) - Burntwoods Rd./ Andrea Dr.	3.0								
	Burntwoods Rd./ Andrea Dr. - Clarksville Pike (MD-108)	5.4	W				W			

I = Improvement from 2013 W = Worsened from 2013 (blank) = No significant change from 2013

PTI: planning time index (95th percentile travel time / freeflow travel time)

TTI: travel time index (50th percentile travel time/ freeflow travel time)

US 1

Limits:	MD 410 to MD 198
Corridor Length:	10.7 miles
Speed Limit:	35 - 50 MPH
Travel Lanes:	(2 - 4) Northbound (2 - 4) Southbound
Signal Controlled Intersections:	40
Grade Separated Interchanges:	3
Major Cross Streets:	MD 410, MD 193, I-95, Rhode Island Ave, Ewing Rd, MD 212, Muirkirk Rd, Contee Rd, Cherry Lane

Routes and Ridership	Routes	Avg. Daily Ridership
	Green Line Greenbelt	6,757
	Green Line College Park	4,454
	METRO 86	4,668
	METRO 87	904
	METRO 88	904
	METRO 89M	803

2013 AADT	Trucks	Peak Hour Traffic
19,000 - 49,000 vpd	3% - 7%	6.5% - 8.5%

Intersection Operations

Signalized Intersections*:	AM Peak Hour	PM Peak Hour
LOS D or Better	21	20
LOS E	1	1
LOS F	2	2

Segment Operations

Level of Service	Northbound AM / PM (Miles of Roadway)	Southbound AM / PM (Miles of Roadway)
LOS D or Better	6.4 / 1.8	3.6 / 1.3
LOS E	3.7 / 3.6	7.1 / 5.8
LOS F	0.6 / 5.3	0.0 / 3.6

LOS 'E' Intersections

US 1 at Edgewood Rd / Ramp 6 from I-95 SB (AM)
US 1 (NB/L) at MD 198 (Talbott Ave) (PM)

LOS 'F' Intersections

US 1 at MD 410 (AM,PM)
US 1 at Cherry Hill Rd (AM)
US 1 at Edgewood Rd / Ramp 6 from I-95 SB (PM)

Color Key

PTI	TTI
1.0-1.5	1.0 - 1.15
1.5-2.5	1.15 - 1.3
>2.5	1.3 - 2.0
	> 2.0
No data	

Functional Class	Roadway Segment North to South	Length (miles)	TTI AM NB	TTI AM SB	TTI PM NB	TTI PM SB	PTI AM NB	PTI AM SB	PTI PM NB	PTI PM SB
Urban Other Principal Arterial	Gorman Ave (MD-198) - Cherry Ln.	0.6								
	Cherry Ln. - Cypress St.	0.7								
	Cypress St. - Contee Rd.	0.5								
	Contee Rd. - Muirkirk Rd.	1.3							W	
	Muirkirk Rd. - Ritz Way	0.4								
	Ritz Way - Powder Mill Rd. (MD-212)	1.8								
	Powder Mill Rd. (MD-212) - Rhode Island Ave.	0.6								
	Rhode Island Ave. - I-495/I-95	1.0								
	I-495/I-95 - Cherry Hill Rd.	0.3								
	Cherry Hill Rd. - Greenbelt Rd./ Metzerott Rd.	1.1								
	Greenbelt Rd./ Metzerott Rd. - Campus Dr./ Painted Branch Pkwy	0.7								
	Campus Dr./ Painted Branch Pkwy - Guilford Rd/Dr	0.8		I				I	I	I
	Guilford Rd/Dr - East West Hwy (MD-410)	0.9								

I = Improvement from 2013 W = Worsened from 2013 (blank) = No significant change from 2013

PTI: planning time index (95th percentile travel time / freeflow travel time)

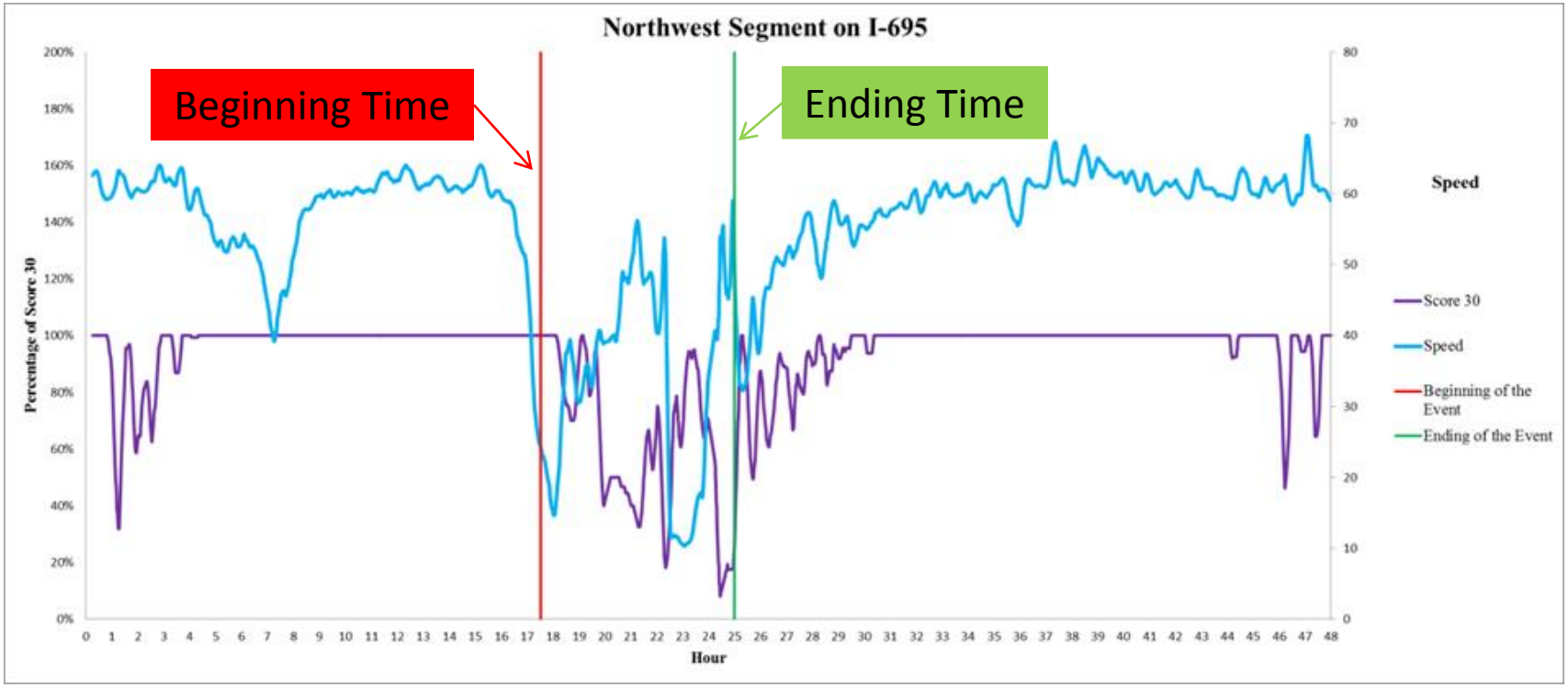
TTI: travel time index (50th percentile travel time/ freeflow travel time)

Mobility Reporting: Anticipated Arterial Probe Data Effectiveness

Likely to have accurate probe data	Possibly accurate probe data	Unlikely probe data is accurate
• AADT > 40000 • 2+ lanes • <= 1 signals per mile • Principal Arterials (HPMS) • Fully or Partially captures >75% slowdowns	• AADT 20K to 40K • 2+ lanes • <= 2 signals per mile • Minor Arterials (HPMS) • Should be tested	• Low Volume, AADT < 20K • >=2 signals per mile • Major Collectors (HPMS) • Not recommended

- **Probe data quality most correlated to signal density**
- Increased volume aids probe data, but does not overcome issues associated with signalized corridors
- Accuracy **ANTICIPATED** to improve with increased probe density and better processing

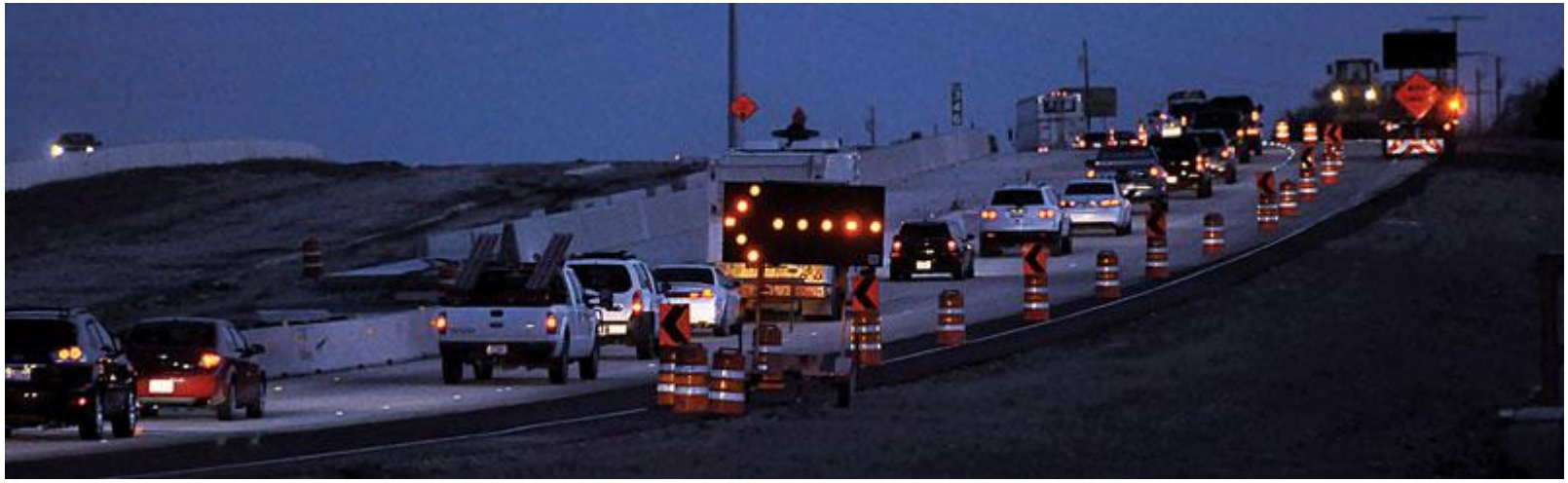
Mobility Performance: Ex. Winter Weather "Restoration Time" on I-695



Interval for Winter Road Restoration Time	Beginning Time	Ending Time	Duration
1	17:32	25:00	7:28

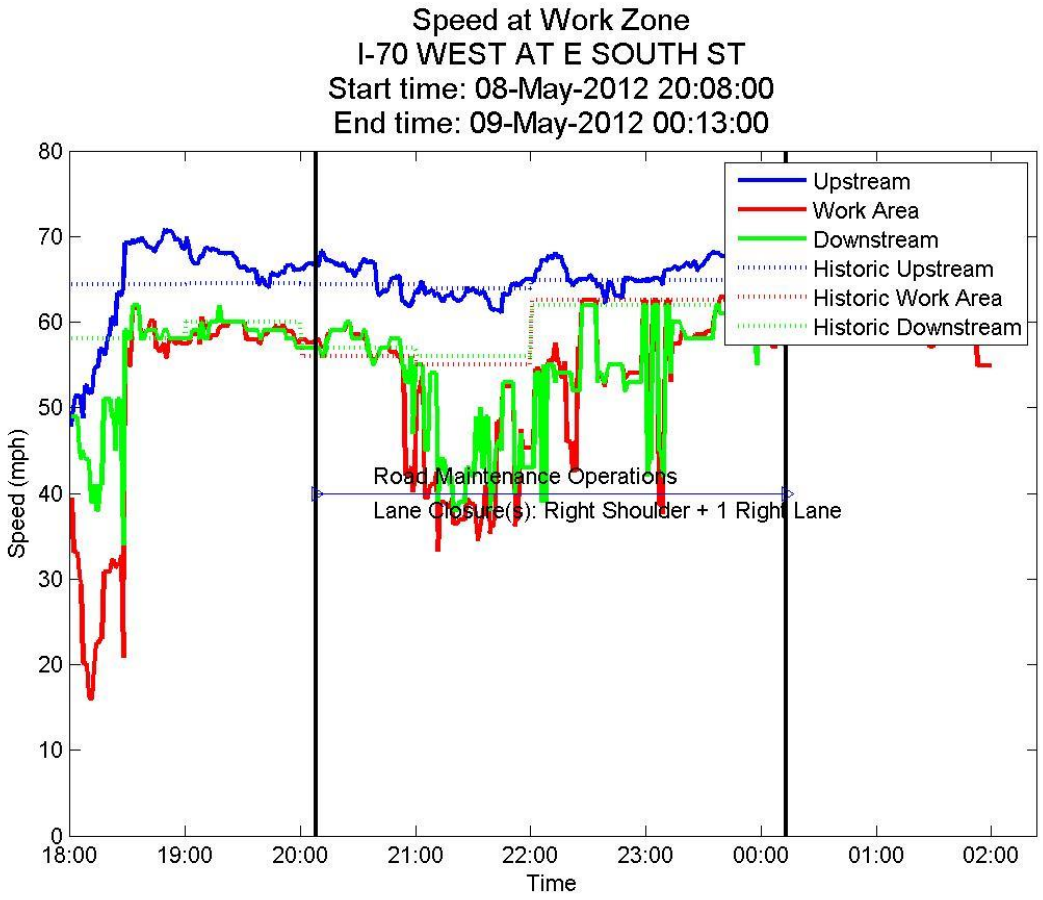
Mobility Performance: Work Zones

- Exposure
  - Volume
  - Site specific data
- Safety
  - Volume
  - Crash/incident data
- Mobility
  - Volume
  - Speed (probe data)



Sample Results

- Westbound I-70, East of Frederick
  - WZ3: Speeds



Mobility Performance: Work Zone PM Dashboard

Work Zone Dashboard

logged in as Kaveh Farokhi | logout

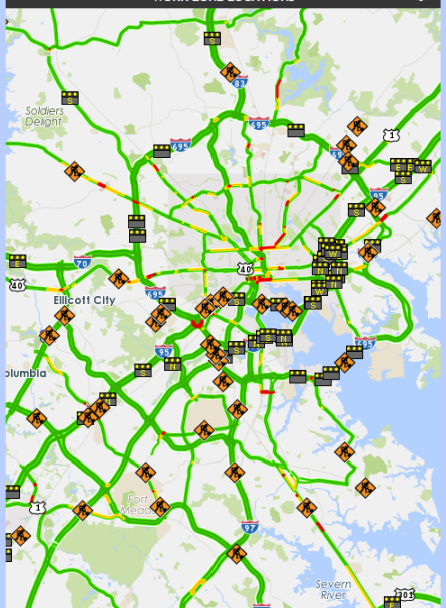
CURRENT WORK ZONES IN MARYLAND

REGION/EVENT	# OF NEARBY INCIDENTS	QUEUE LENGTH (MI)	USER DELAY COST ($)
Charles (2)	2	0	$82.9K
Dorchester (2)	0	0	$737
Frederick (13)	1	0	$12.4K
Harford (8)	34	0	$0.2M
Howard (6)	0	0	$2.0K
Montgomery (11)	0	0	$7.7K
Prince Georges (19)	2	0.1	$23.4K
US 50 EAST AT EXIT 8 M...	-	0	$8
MD 210 NORTH BETWEEN...	-	-	-
US 1 NORTH AT AMMEND...	-	0	$570
US 1 SOUTH BETWEEN C...	-	0	$897
MD 5 NORTH AT SURRAT...	-	0	$329
MD 221 WEST AT CAPITA...	-	0	$237
MD 5 SOUTH BETWEEN O...	-	0	$1.3K
I-95 INNER LOOP AT EXIT...	-	0	$6.6K
MD 337 SOUTH AT SUITL...	-	0	$235
MD 212 SOUTH AT BOND...	1	0	$911
MD 4 WEST AT WALTERS ...	-	0	$1.1K
MD 202 SOUTH BETWEEN...	-	0	$2.4K
MD 212 SOUTH AT BOND...	1	0	$1.3K
MD 201 SOUTH/NORTH B...	-	0	$198
US 1 NORTH BETWEEN C...	-	0	$1.1K
MD 193 WEST AT RHODE ...	-	0.1	$1.5K
US 1 SOUTH AT ALBION RD	-	0	$2.0K
MD 650 SOUTH AT LEBA...	-	0	$1.1K
MD 410 WEST BETWEEN ...	-	0	$1.6K
Queen Annes (9)	59	0	$62.8K
Saint Marys (5)	6	0	$0.1M
Somerset (2)	0	0	$277

TOP CRITICAL WORK ZONES

SEVERITY/EVENT	LANE STATUS	QUEUE LENGTH (MI)	USER DELAY COST ($)
Critical (1)		2.2	$1.5K
MD 90 EAST AT ST MARTINS NECK RD		2.2	$1.5K

WORK ZONE LOCATIONS



USER DELAY COST BY CORRIDOR AND DAY OF WEEK

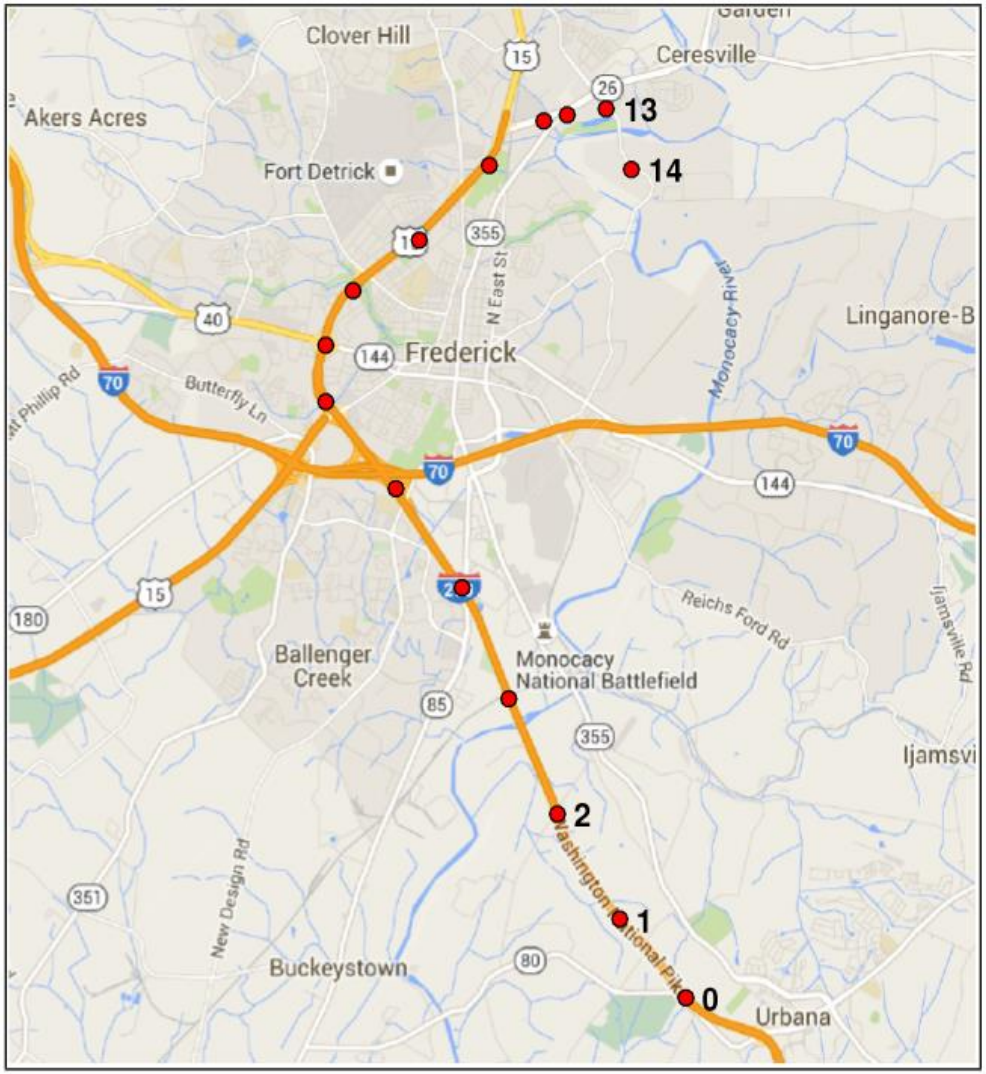
Total User Delay Cost

	I-95	I-695	I-495	US-50	I-70	Daily Totals
Tue 6/30	$237.7K	$234.5K	$900.9K	$131.9K	$58.4K	$1.6M
Wed 7/01	$365.9K	$339.7K	$785.6K	$190.6K	$128.3K	$1.8M
Thu 7/02	$491.7K	$416.8K	$1.2M	$318.2K	$95.3K	$2.5M
Fri 7/03	$83.4K	$8.6K	$79.5K	$126.9K	$121.4K	$419.8K
Sat 7/04	$17.4K	$13.4K	$45.1K	$80.4K	$20.8K	$177.0K
Sun 7/05	$314.0K	$7.5K	$65.6K	$183.0K	$122.9K	$692.9K
Mon 7/06	$168.6K	$443.9K	$485.4K	$129.4K	$48.8K	$1.3M
Tue 7/07	$280.1K	$355.4K	$784.2K	$100.4K	$65.5K	$1.6M
Corridor Totals	$2.0M	$1.8M	$4.3M	$1.3M	$661.3K	Grand Total: $10.0M

Weekend Lowest Highest No Data

Source: RITIS

Data Sample: Single Trip



Waypoint locations and order

Trip

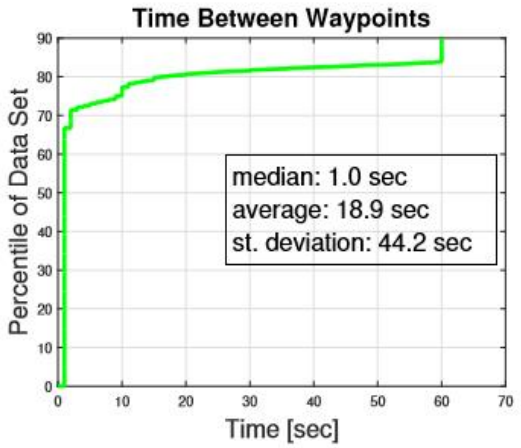
- Unique Id
- O/D locations and times
- Pedestrian or vehicle
- Vehicle: fleet, consumer, mobile
- Vehicle: weight class 1-3

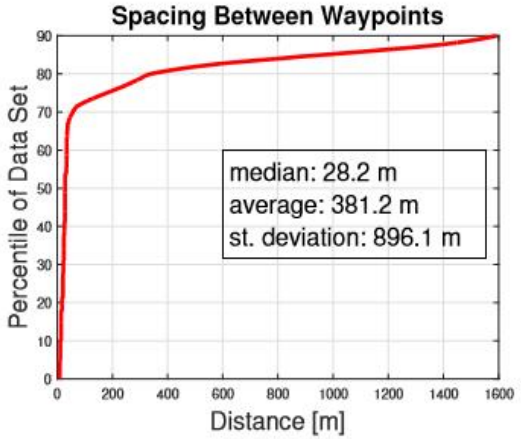
Waypoints

- Order: $0, 1, ..., n$
- Latitude and longitude
- Time stamp (sec)

1.4 Billion Waypoints

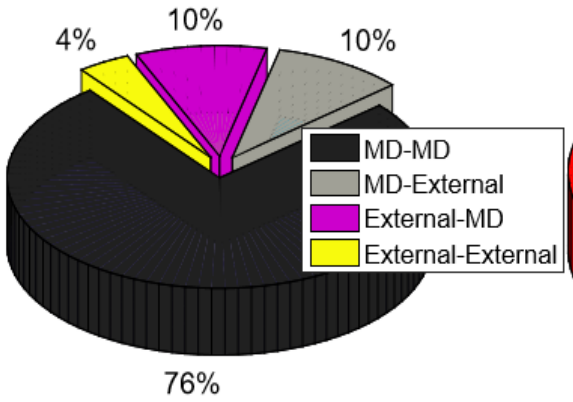
Waypoint locations (June 2015)

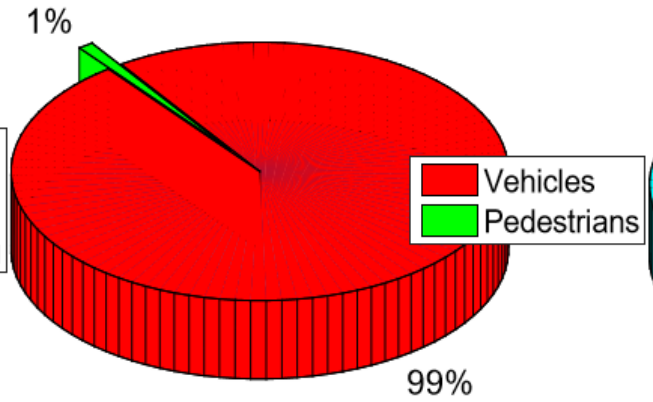


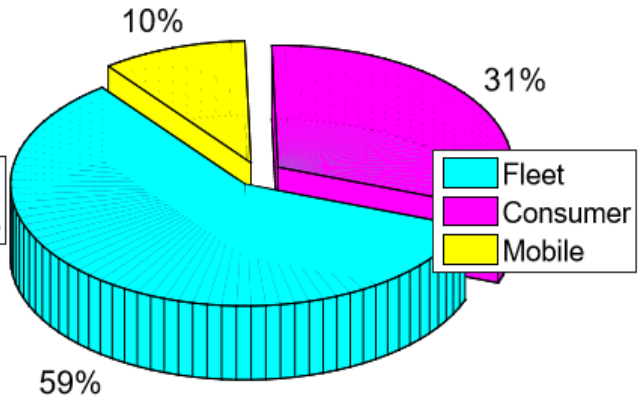


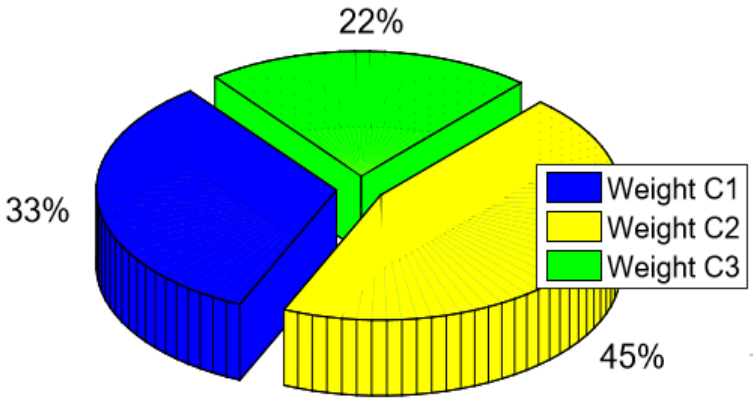
- Percentiles are based on a sample of 500 million waypoints from Feb and Oct

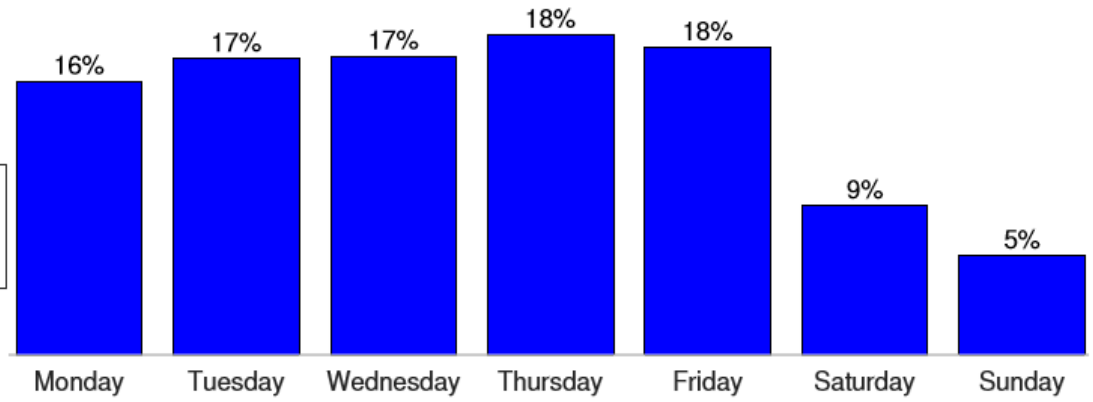
Trip Attributes





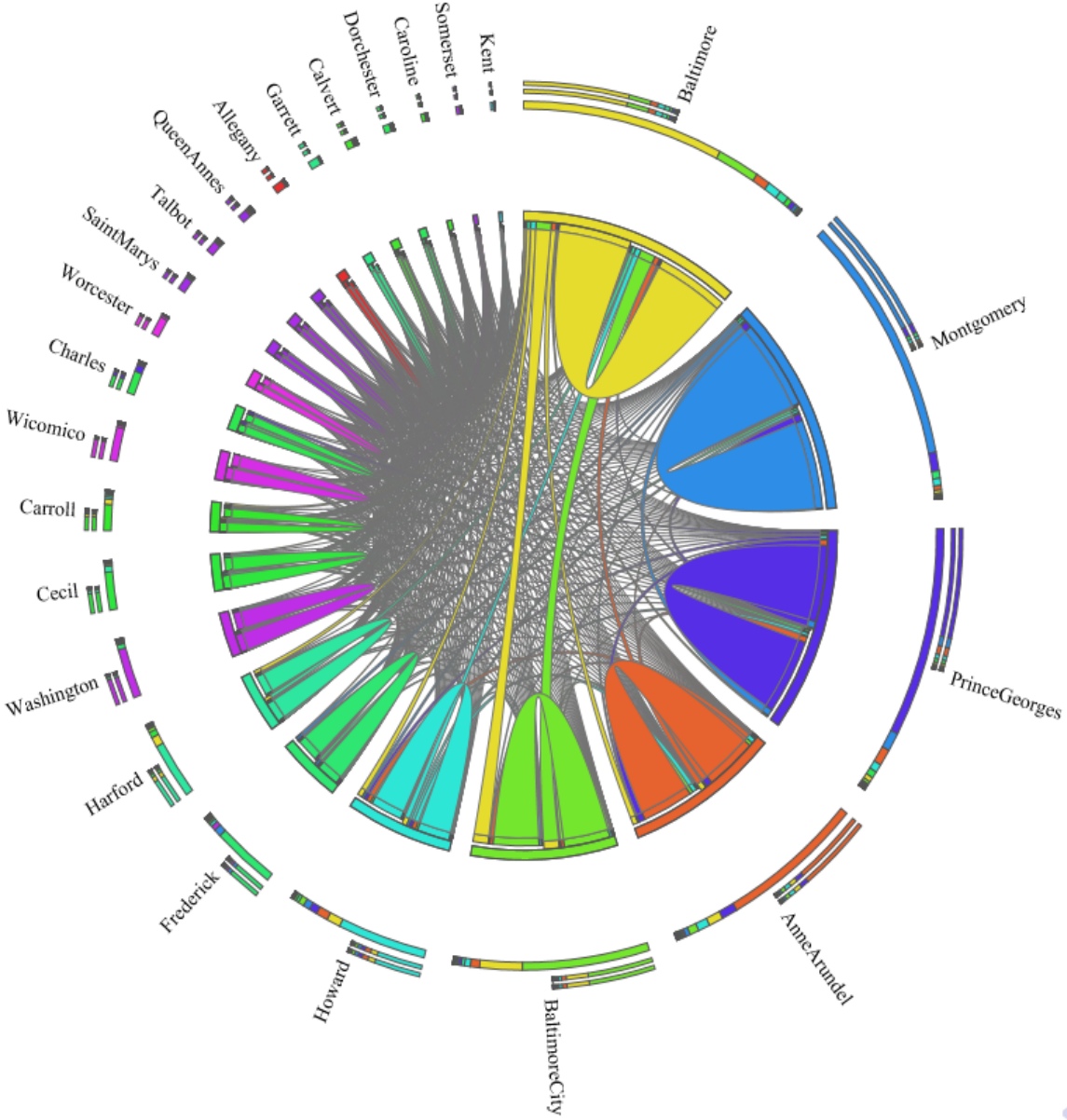






$C1 \leq 14{,}000$ lb, $C3 \geq 26{,}000$ lb

Trips within MD



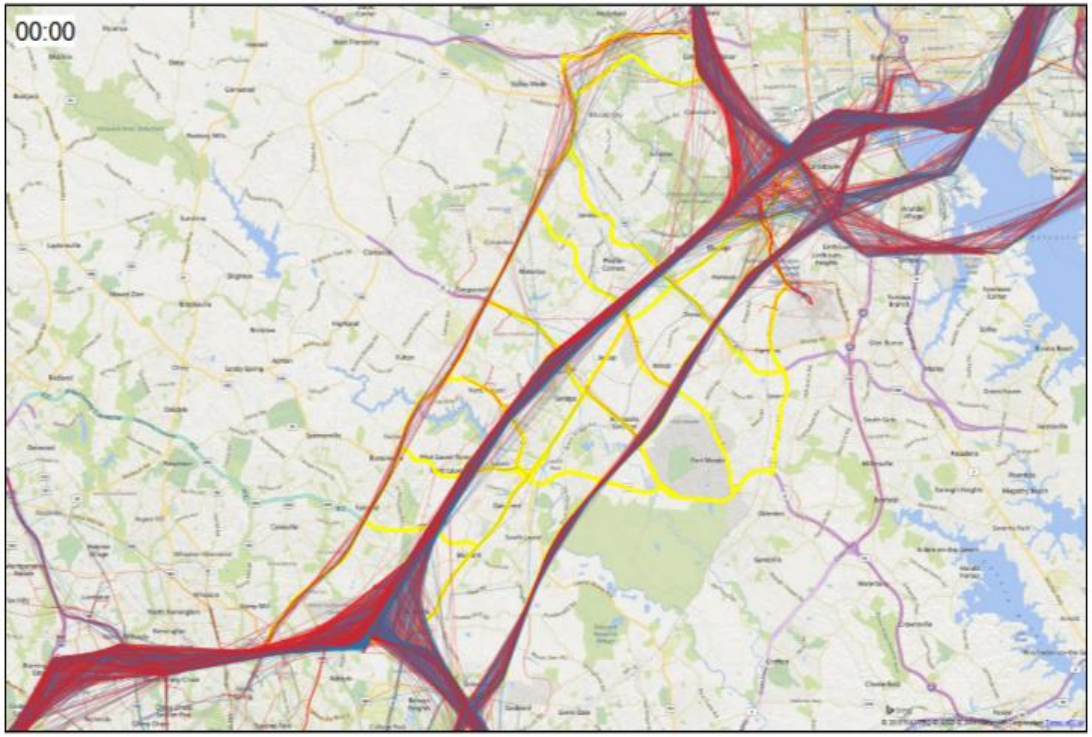
Chord Diagram

- Trips with O/D in MD
- Trips with a waypoint outside MD are filtered out

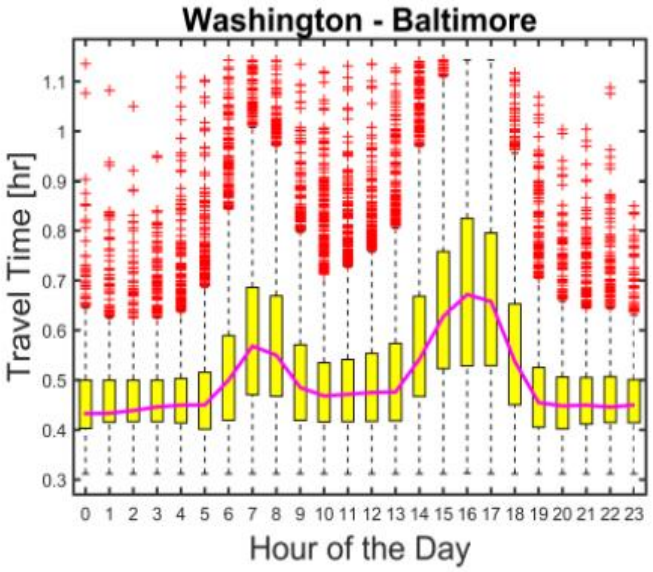
Observations

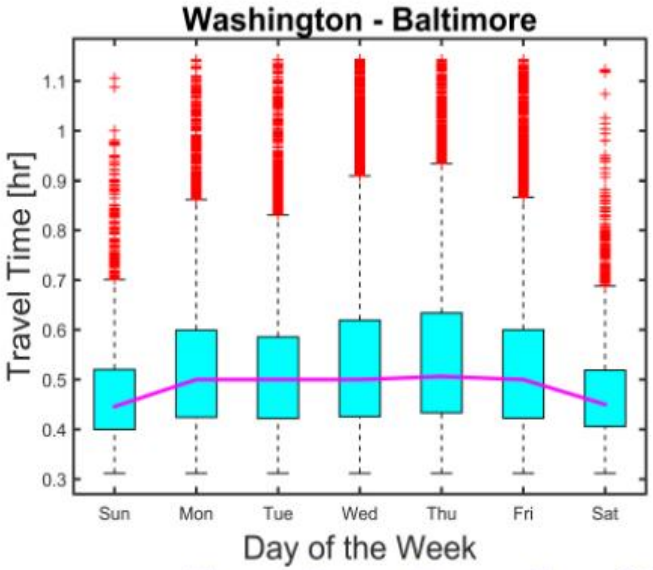
- Most trips are within the same county

Trips along I-95

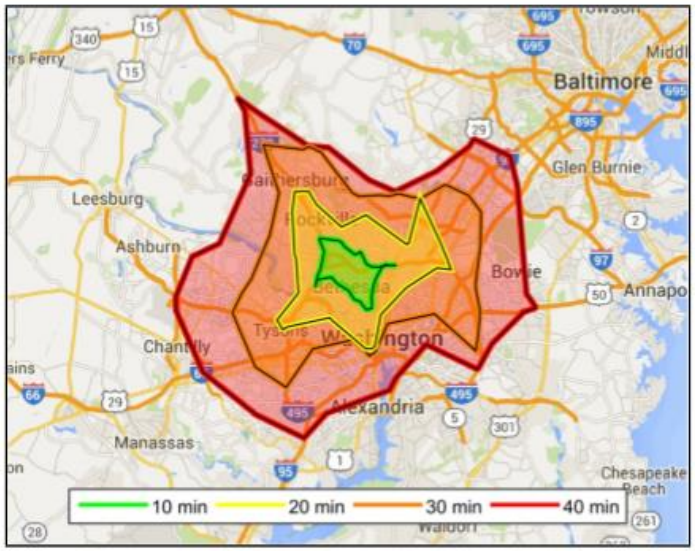


Blue/Red trajectories are North/South bound (70k trips during July)

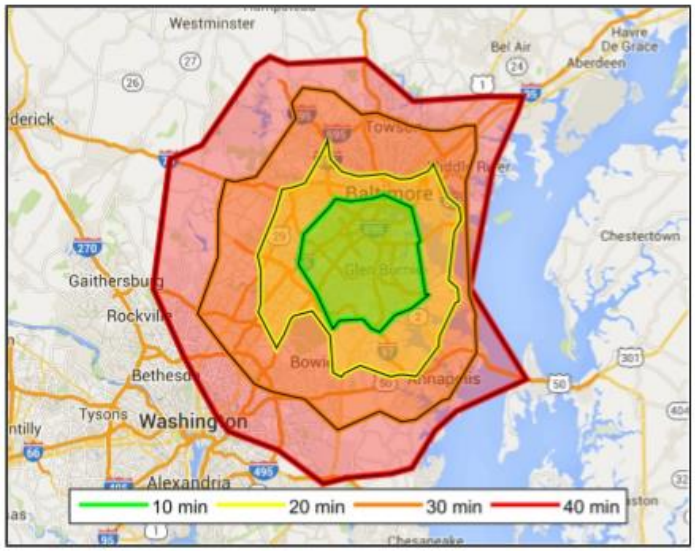




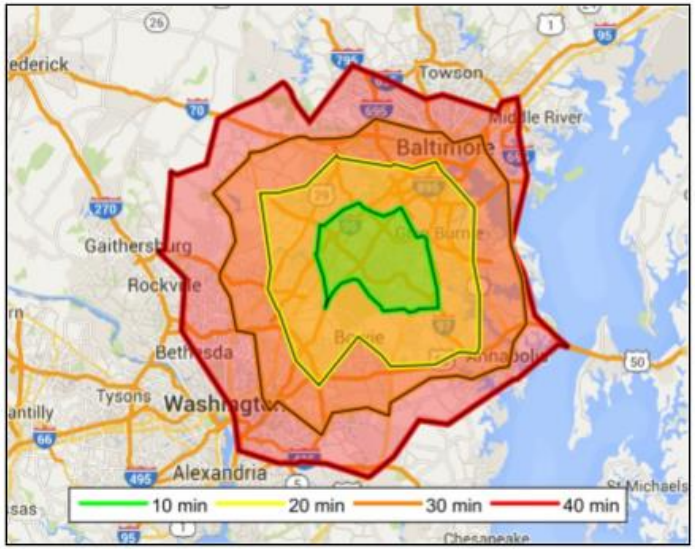
Trips from Activity Zones



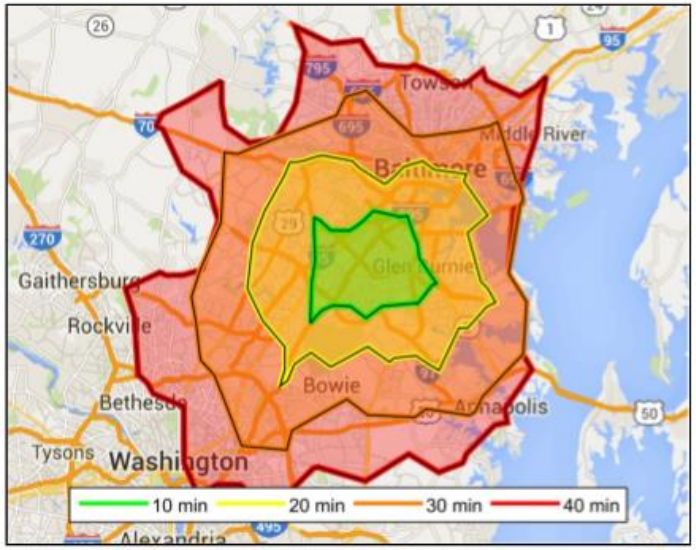
Walter Reed Medical Center



BWI



Fort Meade



Arundel Mills

Comparison

- Peak
  7:00 am - 9:00 a
  4:00 pm - 6:00 p
- Offpeak

Questions/Comments?

Thank you!

For more information…

www.catt.umd.edu

Tom Jacobs, Director
UMD Center for Advanced Transportation Technology & MD T2 Center
tjacobs@umd.edu
Office: 301-405-7328