Processing Of Delaware TMC Raw Bluetooth Data

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Overview

The Delaware Department of Transportation (DELDOT) Traffic Management Center (TMC) has been active over the last 6 years in developing a Blue Tooth monitoring system that at present includes close to 250 sensors located on major travel ways. Work focused on the identification and processing of years 2016 thru 2020 data, provided courtesy of the TMC, as part of and supported by DelDOT's yearly research program. This document describes the processing, products developed, and examples of the use of products.

Summary: The bluetooth data provides a wealth of information about travel times in many highly traveled areas of Delaware. There is a large amount of information for analysis by time of day, day of week, month, and year, to support operations. Data can be incorporated well into GIS and transportation network modeling and routing software for a greater visualization of travel and integration with land use and travel demand data. Detection activity and derived trip data are promising resources to examine travel demand. The data may provide valuable activity measures and origin/destination data to better understand where people want to go.

Primary Goal of Processing: Create a complete extraction that represents all information contained in the source data, organized into separate products that facilitate next steps toward effective use of this large data resource.

Research Goals: Explore the information provided by the current detection points in the road network, in particular toward identifying transportation activity centers by time of day, and illustrating the origins and destinations of travelers, and resultant volume loadings on the roads. Develop GIS based models that integrate trip generation and land use with measures of traffic. Examination of origin and destination information that can be derived from sensors.

Expected Next Steps:

- For next processing, study and reformulate screening for stationary vehicles (3 minutes max), and examine trip length parameter (1.7 x average) used in recognizing trip chains.
- Study detection characteristics of individual detectors toward using detections to estimate activity and traffic flow. Compare detection with intersection and road volume counts.
- Incorporate new data into time enabled internet mapping applications to better visualize the data through time.
- Time series analysis. The data could provide very interesting insights on how travel changed through Covid.
- Consideration of detector configurations that can tell us the most about travel.

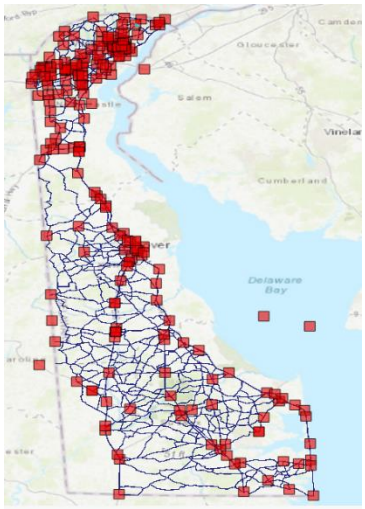
Discussion And Example Uses of Products

To motivate the topic, examples of the use of products will be discussed first. The processing of the raw data is discussed in the second half of this report.

Uses of Detector to Detector Pair Tables (ODPairs)

Detector Locations

Route Analysis / Station to Station Statistics and Distributions

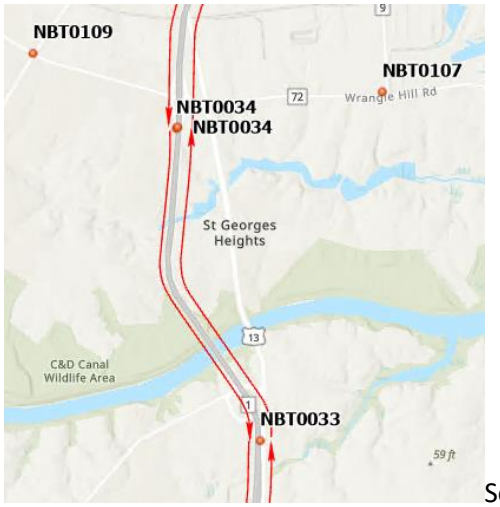


Detections of particular vehicles identified by their bluetooth MACID(media access control) address can be examined and associated with uninterrupted trips taken through time. In some cases, a vehicle is seen only at one detector. In other cases, there can be several. Considering a trip from Detector A to Detector B to Detector C to Detector D, the data would provide 6 travel time measures between the various detectors which would include A to B, A to C, A to D, B to C, B to D, and C to D. Travel time between detectors is the primary data product and one most used, and data was compiled for all years 2016 thru 2020. This table is compiled for all detector to detector pairs in the data by month and is referred to here as the ODPairs Table. An analyst can pick Detectors/Stations from this table that bound the particular routes under study and see a number of measures usually in the hundreds or thousands in a month for a particular pair. Detectors (named like 0001951FFEF0) are the physical device identifiers in the data, where stations (like NBT0030) are the area identifiers for a blue tooth location. Occasionally, there is more than one detector id associated with a particular location/station. For a particular year, month, day, or time of day all records for particular station to station trips can be selected and studied.

ODPairs Table Example (TID = trip id)

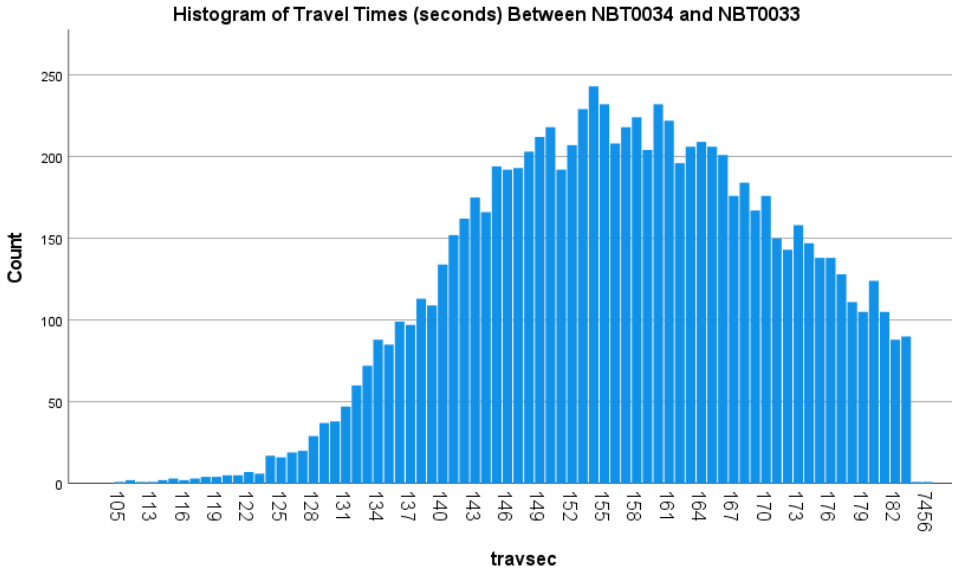
mac	originDetector	destDetector	originTime	destTime	travTime	TID
00:00:26:0C:59:E7	0001951F6832	00D0694A9C76	2017-09-01 13:11:31	2017-09-01 13:15:04	0 days 00:03:33	8september17
00:00:26:0C:59:E7	0001951F6832	0001951FFF19	2017-09-01 13:11:31	2017-09-01 13:17:39	0 days 00:06:08	8september17
00:00:26:0C:59:E7	00D0694A9C76	0001951FFF19	2017-09-01 13:15:04	2017-09-01 13:17:39	0 days 00:02:35	8september17
00:00:26:0C:59:E7	0001951FFF19	00D0694A9C76	2017-09-01 19:45:03	2017-09-01 19:48:22	0 days 00:03:19	9september17
00:00:26:0C:59:E7	0001951FFF19	0001951F6832	2017-09-01 19:45:03	2017-09-01 19:53:00	0 days 00:07:57	9september17
00:00:26:0C:59:E7	00D0694A9C76	0001951F6832	2017-09-01 19:48:22	2017-09-01 19:53:00	0 days 00:04:38	9september17
00:00:26:0C:59:E7	0001951F6832	0001951FFF19	2017-09-05 11:16:03	2017-09-05 11:25:31	0 days 00:09:28	10september17
00:00:26:0C:59:E7	0001951F682F	0001951F681B	2017-09-05 21:50:14	2017-09-05 21:52:25	0 days 00:02:11	12september17
00:00:26:0C:59:E7	0001951F682F	0001951FFF04	2017-09-05 21:50:14	2017-09-05 21:54:08	0 days 00:03:54	12september17
00:00:26:0C:59:E7	0001951F681B	0001951FFF04	2017-09-05 21:52:25	2017-09-05 21:54:08	0 days 00:01:43	12september17

For example, let us randomly examine travel between stations NBT0034 and NBT0033 in year 2017 for the month of April on any day at any time. This portion is an unrestricted, infrequently congested, limited access highway, Route 1. This includes 8,752 measures of the 4.7 million pairs in the April 2017 ODPairs Table.

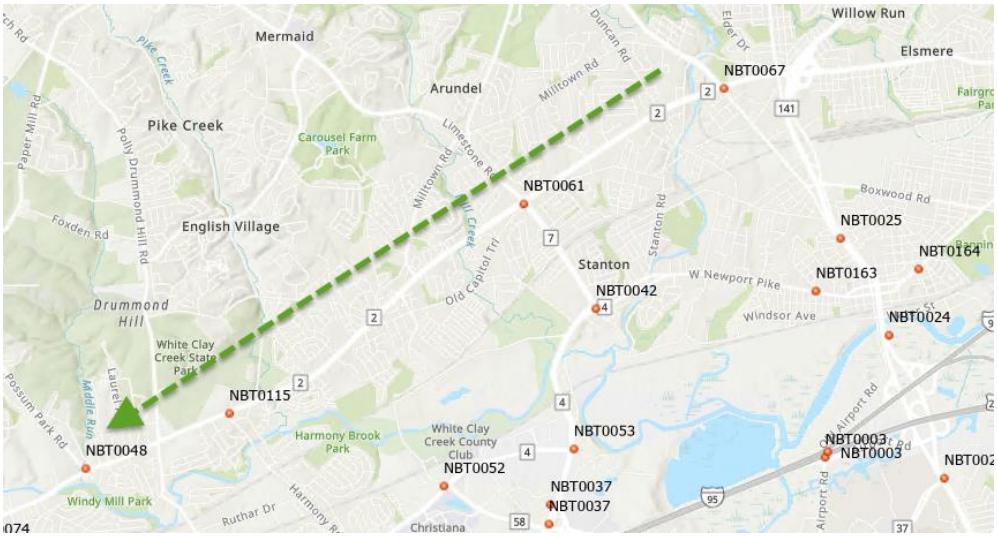


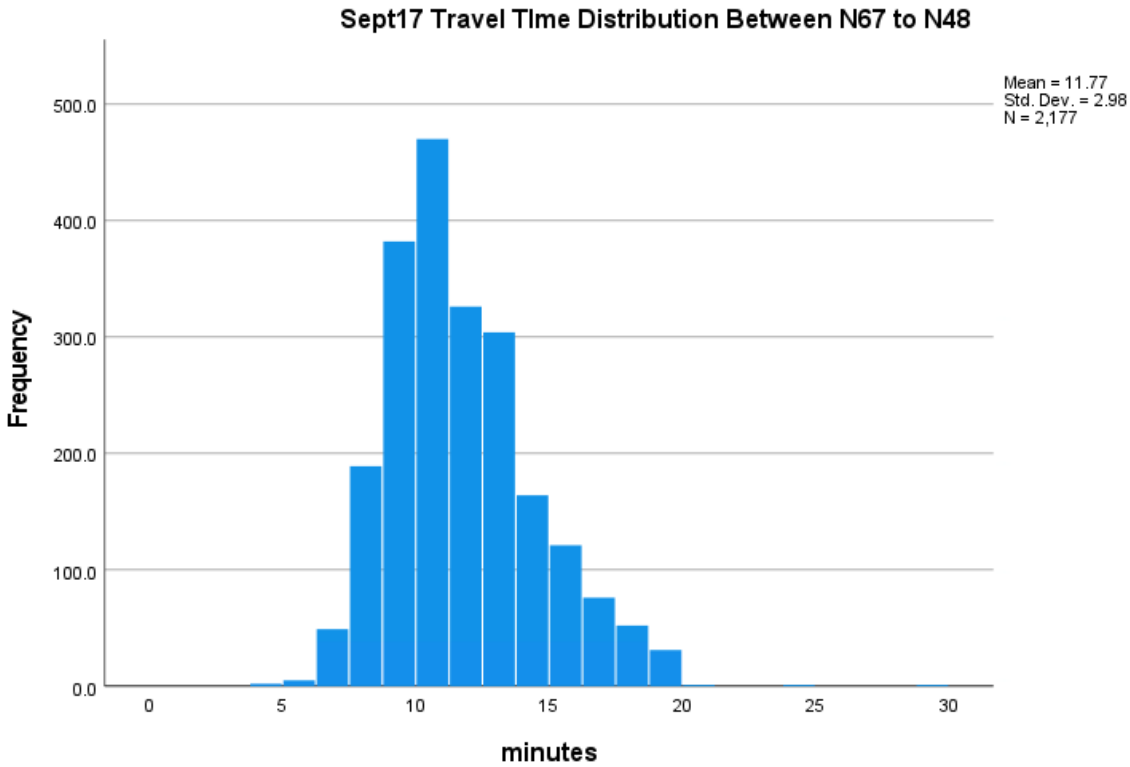
So

A histogram can be generated to examine the distribution of travel time measures in seconds. The average in this case is 158 seconds (2.6 minutes) which for this 3.3 mile stretch is about 75mph with most records being between 140 and 180 seconds (65mph to 85) .



Considering another route, we will examine blue tooth stations NBT0067 to NBT0048, the segment on Route 2, Kirkwood Highway between Route 48 and Possum Park Road in New Castle County, DE.
For this origin/destination there are 2,177 measures in the data for September 2017 and the mean travel time is close to 12 minutes. A distribution of travel time by minute is below followed by a table of mean travel times by hour of the day.





Mean

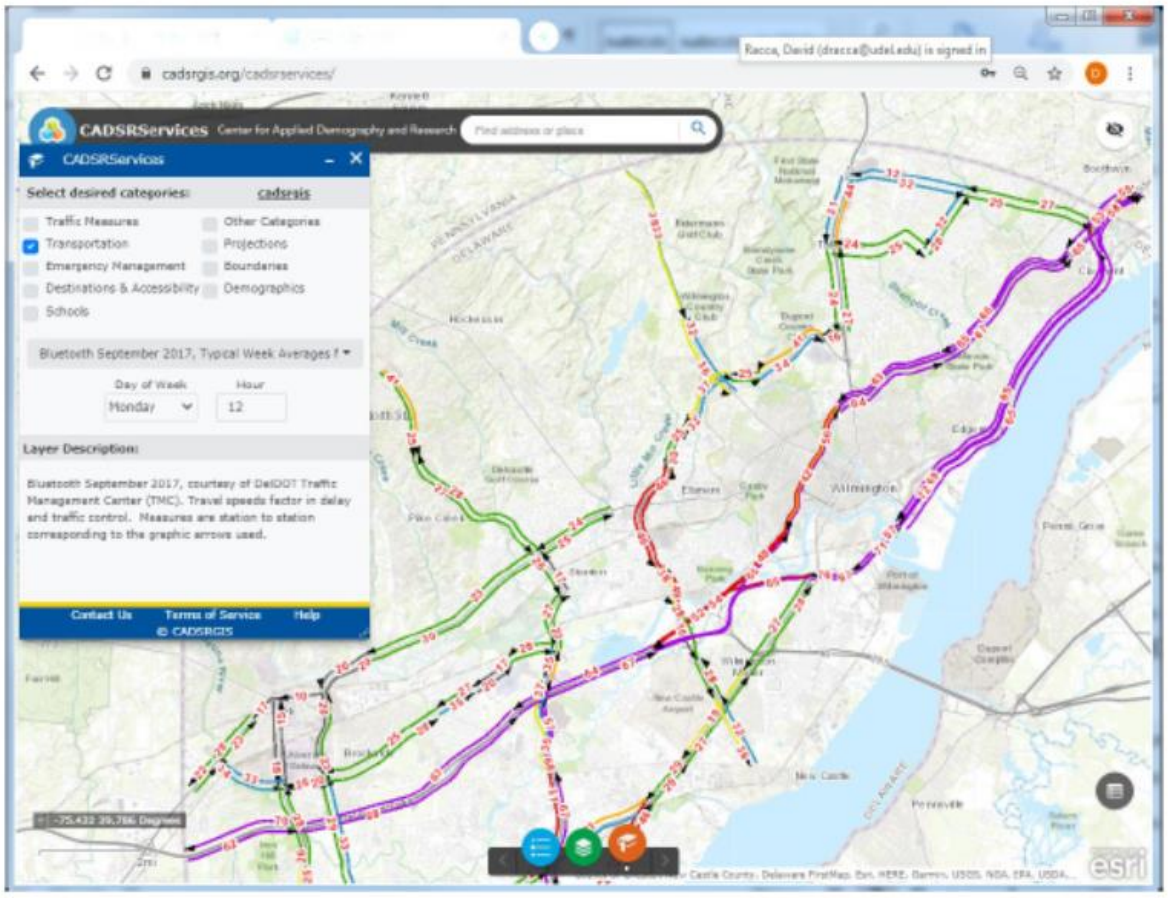
Travel TIme By Hour NB67 to NB48

Hour	MeanTravMin	SecFromMean	observations
0	0:10:02	-104.00	15
1	0:09:51	-115.00	8
2	0:13:03	77.00	20
3	0:09:49	-117.00	31
4	0:09:02	-164.00	31
5	0:10:46	-60.00	88
6	0:12:42	56.00	170
7	0:13:02	76.00	116
8	0:11:00	-46.00	97
9	0:11:08	-38.00	115
10	0:11:34	-12.00	144
11	0:11:39	-7.00	129
12	0:11:34	-12.00	120
13	0:12:14	28.00	143
14	0:12:42	56.00	135
15	0:12:53	67.00	167
16	0:13:42	116.00	148
17	0:11:51	5.00	136
18	0:11:07	-39.00	88
19	0:10:41	-65.00	84
20	0:10:01	-105.00	76
21	0:09:26	-140.00	58
22	0:10:19	-87.00	28
23	0:09:32	-134.00	30
.	0:11:46	.00	2177

Time Enabled GIS Mapping

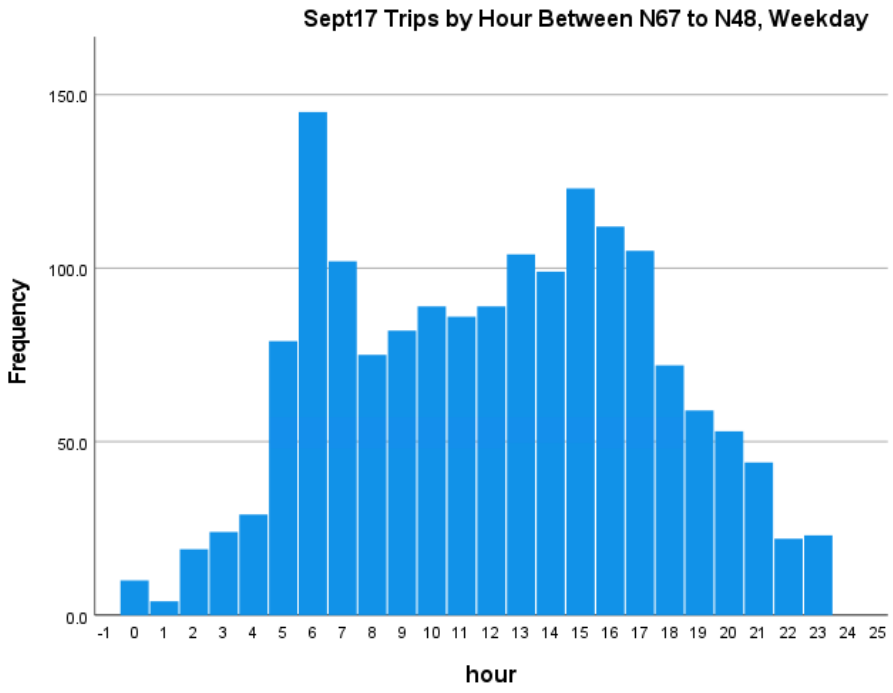
The previous discussion tabulated travel time between particular origin and destination blue tooth stations. When blue tooth tables are brought into GIS, measures for various routes can be mapped together at a given time. An example is the screen shot below of CADSR's traffic data internet mapping applications where in this example travel speeds at noon on monday are shown. Each day of the week and time of day can be specified to map statistics for the routes shown. The internet maps are "time enabled" as the map is regenerated as various time of day or day of week is selected. In the background the data is being filtered by time by the map server. Various visualizations can be constructed and related to other transportation and land use data.

Typical speeds in New Castle County, Noon on Monday, Blue Tooth Data

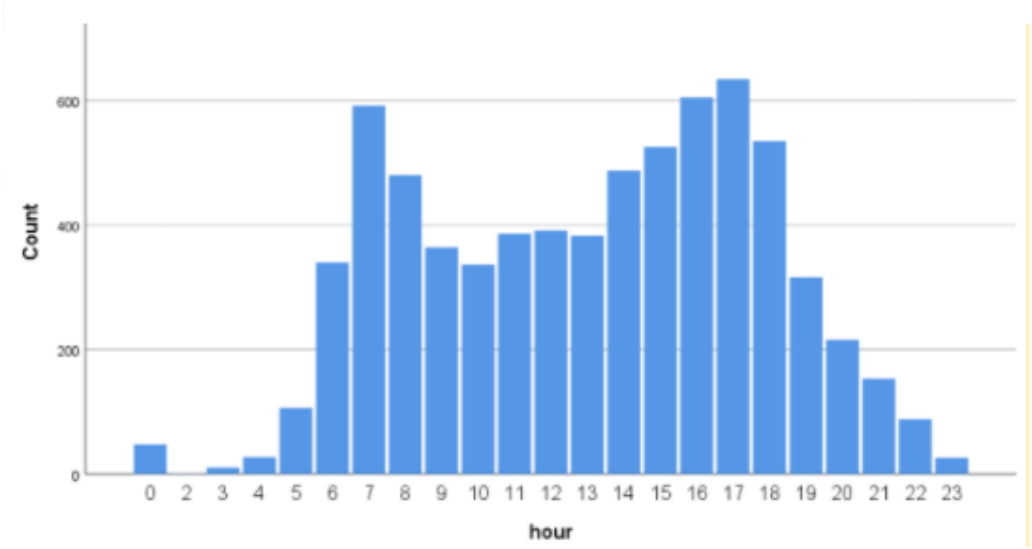


Amount of Travel by Time of Day

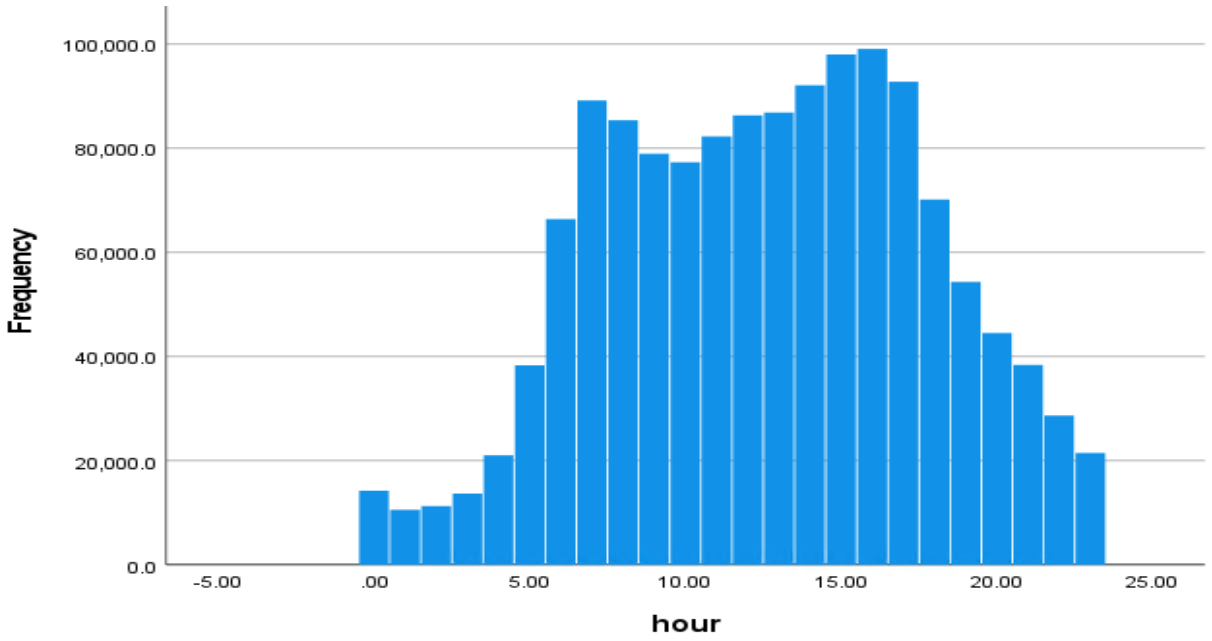
We can also look at the distribution of the trips on this segment throughout the day as in the chart below. So beyond knowing the travel speeds from station to station we know relative volumes of detection by time of day as seen below. This is a familiar distribution of weekday travel, and similar to the distribution from Delaware's residential transportation survey, and similar to the distribution of all the September 2017 bluetooth data, as shown below.



Delaware Travel Monitoring System, Distribution of Residential Trips by hour of the day

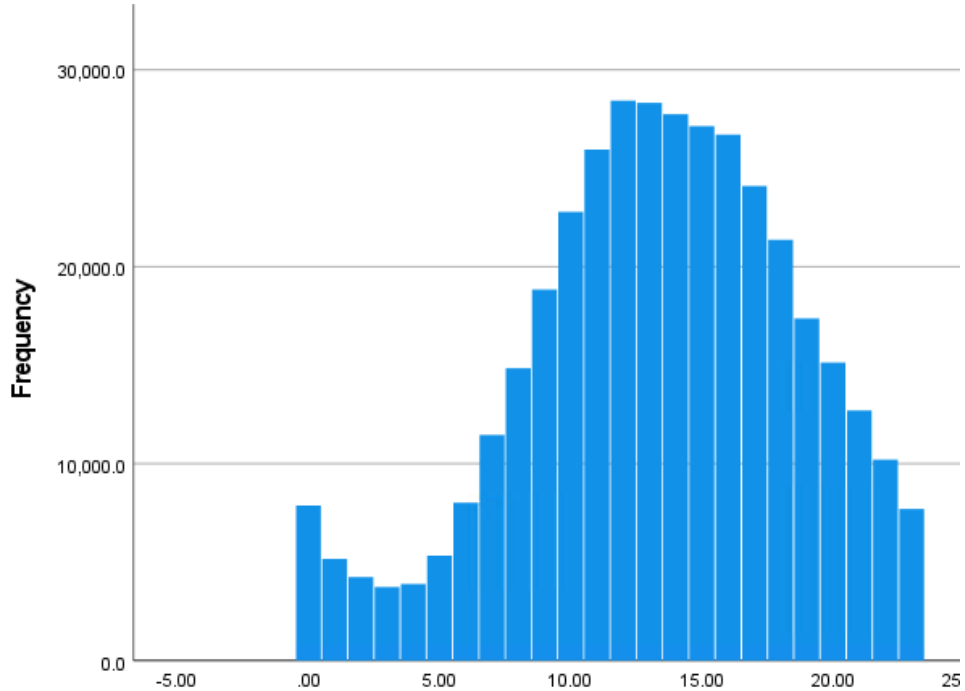


Sept17 Trips per hour, Weekday, All Trips



Weekend travel is different as shown below.

Sept17 Trips per hour, Weekend, All Trips



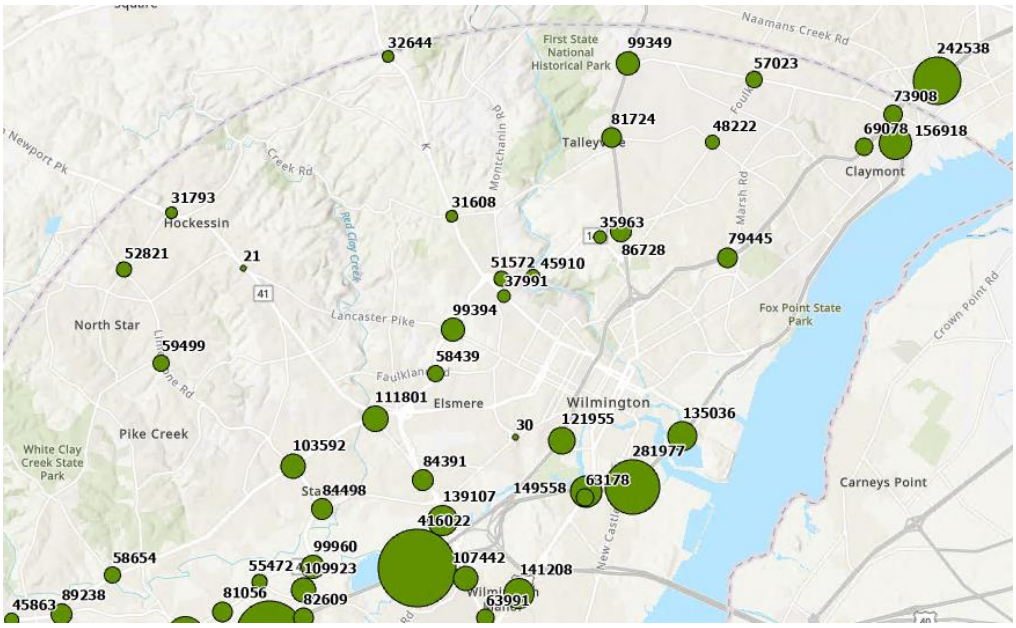
Examination of the Number of Detections

The preceding example showing distributions of trips by hour of the day is an example of using bluetooth data to estimate activity or travel demand. The number of vehicles detected at a particular detector depends on traffic volume, sensitivity of the detector, geometry of the local roads and land use, and other factors, but viewing the data could provide a measure of activity around the sensor which may be useful for planning, and it also provides insight into the operation of the sensor. The total number of detections is related to the capture rate of the sensor, but where sensors show consistent numbers relative to percentage changes in traffic conditions, the number detections by time of day could provide figures very related to activity and traffic flow, which greatly adds to the usefulness of the data. As research continues, we can better understand how data from one sensor compares with other sensors, perhaps by estimating a detection rate for each. The trips by hour above are familiar distributions and distributions using a few other months are consistent. Another indication that detections have some consistency and are what we would expect is when looking at percentage of trips by each day of the week.

Bluetooth Percentage of Trips by Day of Week (September 2017)

Sunday	10.1
Monday	13.1
Tuesday	13.8
Wednesday	13.9
Thursday	14.7
Friday	19.6
Saturday	14.8

Sept 2017 detections per detector weekday



Using Detections to Judge Traffic Volumes

Indications are that the blue tooth data detections at intersections provide stable measures of travel activity. Figures below show the percentage difference in detections at particular intersections from 2019 to 2020 for six months. This is of particular interest given the very substantial changes that occurred due to Covid-19. In particular, the effects of the stay-at-home travel restrictions implemented in April and May of 2020 are very apparent, as are the gradual return toward 2019 levels. Detections dropped by 30% to 60% for various sensors, and increasingly in late evening and early morning hours. These patterns were similar across several blue tooth detectors studied. This would seem consistent with perceptions of traffic and it would be interesting to compare these figures with intersection device counts (loops).

		Route 7 and Kirkwood Highway							
		Percentage Difference in Detections 2019 to 2020 Bluetooth							
		Hour	mar	apr	may	jul	sep	nov	Avg 6 mnths
0	0001951F6899-0	0	-4	-38	-25	15	-6	15	-7
1	0001951F6899-1	1	-19	-28	-46	-15	-16	3	-21
2	0001951F6899-2	2	-9	-11	-23	-3	-9	-11	-11
3	0001951F6899-3	3	-22	-35	-36	-16	-31	-11	-25
4	0001951F6899-4	4	-29	-35	-39	3	-8	-1	-19
5	0001951F6899-5	5	-10	-26	-31	-2	-10	-14	-16
6	0001951F6899-6	6	-12	-35	-32	-3	-15	-9	-18
7	0001951F6899-7	7	-17	-41	-38	-15	-13	-15	-24
8	0001951F6899-8	8	-17	-39	-38	-25	-20	-18	-27
9	0001951F6899-9	9	-20	-38	-36	-8	-10	-11	-21
10	0001951F6899-10	10	-18	-38	-34	-6	-15	-10	-21
11	0001951F6899-11	11	-17	-31	-29	-5	-5	-10	-17
12	0001951F6899-12	12	-15	-33	-31	-10	-10	-10	-18
13	0001951F6899-13	13	-18	-33	-27	-2	-8	-5	-16
14	0001951F6899-14	14	-20	-34	-30	-7	-11	-11	-19
15	0001951F6899-15	15	-23	-35	-30	-8	-4	-9	-18
16	0001951F6899-16	16	-16	-33	-29	-8	-3	-8	-17
17	0001951F6899-17	17	-18	-36	-32	-16	-4	-10	-20
18	0001951F6899-18	18	-22	-43	-36	-10	-8	-10	-22
19	0001951F6899-19	19	-22	-46	-39	-8	-4	-11	-22
20	0001951F6899-20	20	-26	-50	-45	-12	-14	-16	-28
21	0001951F6899-21	21	-29	-56	-47	-17	-16	-16	-31
22	0001951F6899-22	22	-27	-56	-47	-9	-9	-16	-28
23	0001951F6899-23	23	-18	-55	-47	-9	-10	-20	-27

Route 1 near Clayton

Percentage Difference in Detections 2019 to 2020 Bluetooth

		Hour	mar	apr	may	jul	sep	nov	Avg 6 mnths
0	00D0694B759D-0	0	24	-12	-31	-10	-19	-12	-12
1	00D0694B759D-1	1	23	-3	-22	-7	-12	-5	-6
2	00D0694B759D-2	2	30	0	-12	-10	-7	-6	-2
3	00D0694B759D-3	3	24	-1	-22	-5	-15	-5	-6
4	00D0694B759D-4	4	26	-4	-29	-5	-15	-5	-8
5	00D0694B759D-5	5	6	-10	-37	-10	-21	-8	-15
6	00D0694B759D-6	6	1	-16	-38	-13	-29	-21	-21
7	00D0694B759D-7	7	-13	-22	-42	-15	-32	-23	-26
8	00D0694B759D-8	8	-7	-31	-45	-17	-35	-26	-28
9	00D0694B759D-9	9	-11	-33	-49	-18	-35	-31	-31
10	00D0694B759D-10	10	-13	-36	-49	-18	-29	-31	-30
11	00D0694B759D-11	11	-15	-38	-49	-20	-26	-31	-31
12	00D0694B759D-12	12	-7	-37	-46	-20	-26	-28	-29
13	00D0694B759D-13	13	-8	-34	-44	-16	-25	-28	-27
14	00D0694B759D-14	14	-11	-36	-46	-18	-28	-32	-29
15	00D0694B759D-15	15	-18	-35	-50	-20	-28	-31	-31
16	00D0694B759D-16	16	-21	-40	-52	-21	-28	-33	-33
17	00D0694B759D-17	17	-20	-39	-52	-16	-32	-34	-33
18	00D0694B759D-18	18	-17	-42	-53	-19	-32	-40	-35
19	00D0694B759D-19	19	-23	-43	-55	-20	-35	-41	-36
20	00D0694B759D-20	20	-16	-42	-56	-25	-34	-40	-37
21	00D0694B759D-21	21	-3	-35	-56	-23	-29	-37	-33
22	00D0694B759D-22	22	14	-25	-55	-21	-24	-27	-27
23	00D0694B759D-23	23	6	-13	-42	-16	-14	-26	-20

Foulk and Silverside

Percentage Difference in Detections 2019 to 2020 Bluetooth

		Hour	mar	apr	may	jul	sep	nov	Avg 6 mnths
0	0001951FFEF9-0	0	25	-26	-19	-31	24	-14	-10
1	0001951FFEF9-1	1	34	-48	-21	-39	2	3	-14
2	0001951FFEF9-2	2	20	-54	-47	-22	-24	-15	-25
3	0001951FFEF9-3	3	3	-39	-49	-14	6	45	-11
4	0001951FFEF9-4	4	6	-19	-37	-27	-14	160	-2
5	0001951FFEF9-5	5	-2	-50	-35	-21	-32	-17	-27
6	0001951FFEF9-6	6	-10	-52	-53	-20	-36	-31	-34
7	0001951FFEF9-7	7	-26	-62	-60	-30	-33	-31	-42
8	0001951FFEF9-8	8	-16	-56	-47	-31	-23	-23	-33
9	0001951FFEF9-9	9	-6	-39	-28	-19	-16	-21	-22
10	0001951FFEF9-10	10	-10	-36	-25	-15	-5	-12	-17
11	0001951FFEF9-11	11	-16	-41	-27	-18	-8	-11	-20
12	0001951FFEF9-12	12	-7	-40	-32	-19	0	-8	-18
13	0001951FFEF9-13	13	-11	-33	-30	-12	-8	-9	-18
14	0001951FFEF9-14	14	-9	-36	-35	-7	-10	-13	-19
15	0001951FFEF9-15	15	-12	-40	-35	-11	-1	-14	-19
16	0001951FFEF9-16	16	-12	-39	-34	-12	-11	-12	-20
17	0001951FFEF9-17	17	-23	-48	-40	-11	-20	-19	-27
18	0001951FFEF9-18	18	-14	-44	-41	-15	-18	-26	-27
19	0001951FFEF9-19	19	-21	-51	-39	-2	-10	-24	-25
20	0001951FFEF9-20	20	-26	-56	-45	-14	-21	-29	-32
21	0001951FFEF9-21	21	-18	-58	-50	-14	-23	-25	-32
22	0001951FFEF9-22	22	-27	-63	-49	-16	-16	-31	-33
23	0001951FFEF9-23	23	0	-45	-23	-27	13	-17	-19

		Route 1 and Route 9 (Kings Hwy, near lewes)							
		Percentage Difference in Detections 2019 to 2020 Bluetooth							
		Hour	mar	apr	may	jul	sep	nov	Avg 6 mnths
0	0001951F6830-0	0	-12	-36	-49	-26	16	-12	-21
1	0001951F6830-1	1	-9	-56	-51	-32	-11	-18	-31
2	0001951F6830-2	2	-19	-39	-57	-34	-6	14	-26
3	0001951F6830-3	3	29	-5	-30	-28	-11	-34	-16
4	0001951F6830-4	4	32	-2	-39	-19	-14	-2	-11
5	0001951F6830-5	5	6	-34	-38	-13	-5	9	-14
6	0001951F6830-6	6	1	-29	-34	-6	1	8	-11
7	0001951F6830-7	7	9	-35	-39	-10	-8	-2	-15
8	0001951F6830-8	8	-2	-39	-32	-10	4	-2	-14
9	0001951F6830-9	9	-3	-39	-38	-9	0	-3	-16
10	0001951F6830-10	10	2	-38	-37	-7	10	1	-13
11	0001951F6830-11	11	-7	-41	-35	-6	9	0	-14
12	0001951F6830-12	12	-4	-37	-29	-1	7	-4	-12
13	0001951F6830-13	13	-7	-38	-32	-6	7	-1	-13
14	0001951F6830-14	14	-11	-41	-35	-2	10	-3	-14
15	0001951F6830-15	15	-6	-40	-33	-3	13	5	-11
16	0001951F6830-16	16	-4	-41	-29	4	15	8	-9
17	0001951F6830-17	17	0	-33	-27	-2	10	1	-9
18	0001951F6830-18	18	-4	-43	-37	-1	2	0	-15
19	0001951F6830-19	19	-5	-47	-38	-2	11	1	-14
20	0001951F6830-20	20	-21	-55	-47	-11	-2	-2	-24
21	0001951F6830-21	21	-18	-64	-58	-9	1	-1	-26
22	0001951F6830-22	22	-12	-66	-66	-20	7	-23	-31
23	0001951F6830-23	23	-26	-63	-52	-31	-6	-28	-34

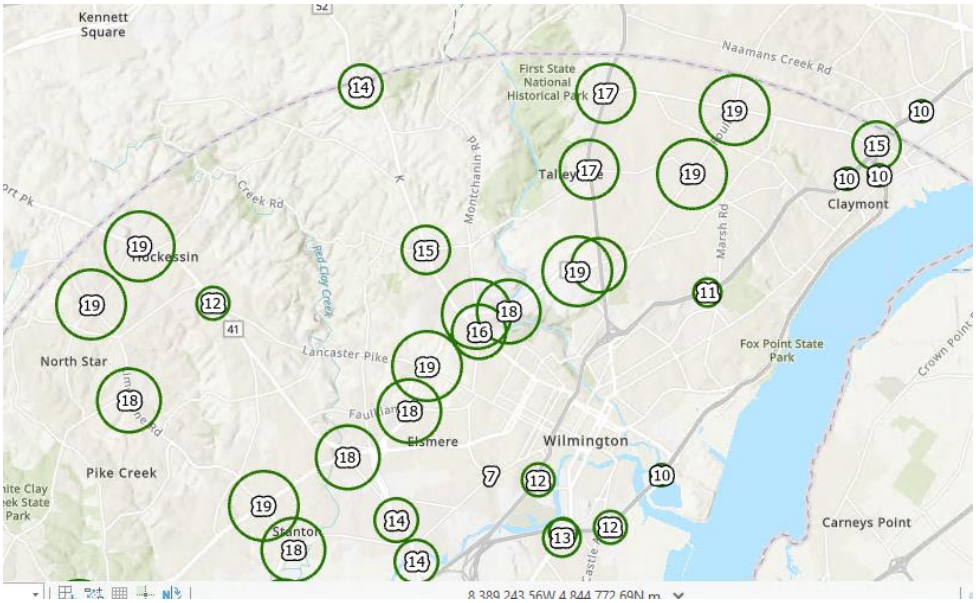
Examination of the Dwell

Records for repetitive measures of the same vehicle at an intersection within seconds of each other are collapsed to entry and exit time records. The total time a vehicle spends within the range of the detector (exit time minus entry time) is referred to as the “dwell”. The dwell could result from cars waiting at an intersection for the light to change and this wait time is of interest. Or it could be a signal from a parked vehicle or otherwise nonmoving or slow-moving vehicle and since the data is processed to reveal vehicles in travel, that is screened out of the raw data. The range a sensor could detect a vehicle would of course affect the size of the dwell. The dwell could be a useful measure of congestion and traffic flow if certain factors that affect it can be addressed. The dwell could be included when estimating the time one takes to go from one detector to another as there are a few ways to calculate it:

- Time interval is when first detected at first detector and first detected at second detector. This is what is used in the OD Pairs table.
- Time interval is when first detected at first detector and leaving second detector.
- The time leaving the first detector (entry time plus dwell) to the second detector (entry time)
- The time leaving the first detector (entry time plus dwell) to leaving the second detector (entry time plus dwell

Below is a sample map of average dwell at sensors at the 8am hour on weekday .

Average Dwell at Intersections



Trips and Origins and Destinations

A focus of transportation planning is on understanding where people and organizations are and where they want to go. Raw data records in the bluetooth data are processed and grouped as belonging to trips. A trip is where a vehicle (mac) moves from detector to detector with timing that would indicate a continuous trip.

Example: Cleaned Bluetooth data, sorted in time and by mac, interpreted as trips (TID)

mac	detector	datetimel	TID	hour	dow
00:00:26:0C:59:E7	0001951F6832	2017-09-01 08:11:31	8september17	8.00	6.00
00:00:26:0C:59:E7	00D0694A9C76	2017-09-01 08:15:04	8september17	8.00	6.00
00:00:26:0C:59:E7	0001951FFF19	2017-09-01 08:17:39	8september17	8.00	6.00
00:00:26:0C:59:E7	0001951FFF19	2017-09-01 14:45:03	9september17	14.00	6.00
00:00:26:0C:59:E7	00D0694A9C76	2017-09-01 14:48:22	9september17	14.00	6.00
00:00:26:0C:59:E7	0001951F6832	2017-09-01 14:53:00	9september17	14.00	6.00
00:00:26:0C:59:E7	0001951F6832	2017-09-05 06:16:03	10september17	6.00	3.00
00:00:26:0C:59:E7	0001951FFF19	2017-09-05 06:25:31	10september17	6.00	3.00
00:00:26:0C:59:E7	0001951F682F	2017-09-05 16:50:14	12september17	16.00	3.00
00:00:26:0C:59:E7	0001951F681B	2017-09-05 16:52:25	12september17	16.00	3.00
00:00:26:0C:59:E7	0001951FFF04	2017-09-05 16:54:08	12september17	16.00	3.00
00:00:26:0C:59:E7	0001951F680A	2017-09-05 17:38:41	15september17	17.00	3.00
00:00:26:0C:59:E7	0001951FFEEE	2017-09-05 17:46:26	15september17	17.00	3.00
00:00:26:0C:59:E7	0001951F6839	2017-09-05 17:48:54	15september17	17.00	3.00

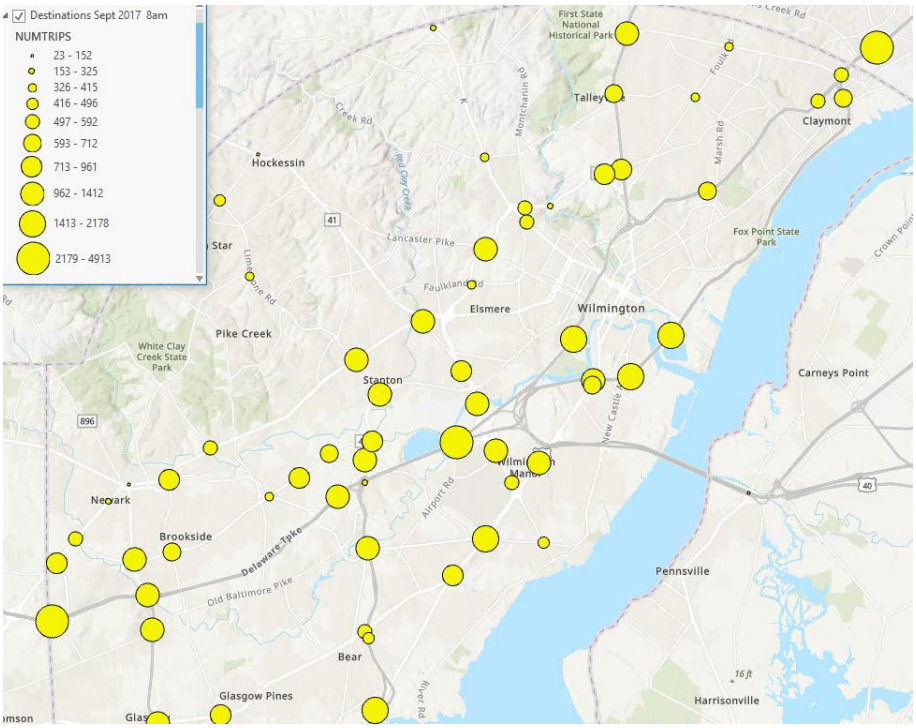
The trips have a beginning and end, and the origin and destination detectors of trips show where travelers are coming from and going to, of course at the resolution of the number and distribution of the sensors.

Bluetooth Detector Origin-Destination Table for Trips

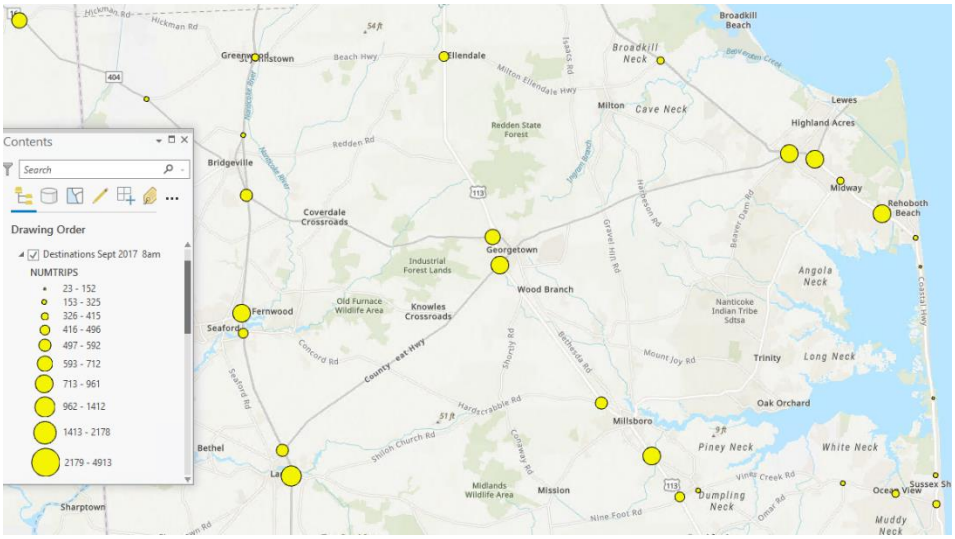
mac	originTimel	originDetector	destinationTimel	destinationDetector	travTime	TID
00:00:26:0C:59:E7	2017-09-01 08:11:31	0001951F6832	2017-09-01 08:17:39	0001951FFF19	0 days 00:06:08	8september17
00:00:26:0C:59:E7	2017-09-01 14:45:03	0001951FFF19	2017-09-01 14:53:00	0001951F6832	0 days 00:07:57	9september17
00:00:26:0C:59:E7	2017-09-05 06:16:03	0001951F6832	2017-09-05 06:25:31	0001951FFF19	0 days 00:09:28	10september17
00:00:26:0C:59:E7	2017-09-05 16:50:14	0001951F682F	2017-09-05 16:54:08	0001951FFF04	0 days 00:03:54	12september17
00:00:26:0C:59:E7	2017-09-05 17:38:41	0001951F680A	2017-09-05 17:48:54	0001951F6839	0 days 00:10:13	15september17

Below are maps of destination detectors with size relative to the number of trips with that destination at the *am hour on a weekday. Detectors at the most northern and southern portions of Route I-95 will always show as large destinations because it is the detection from any travel leaving the State.

Detector Destinations (September 2017)



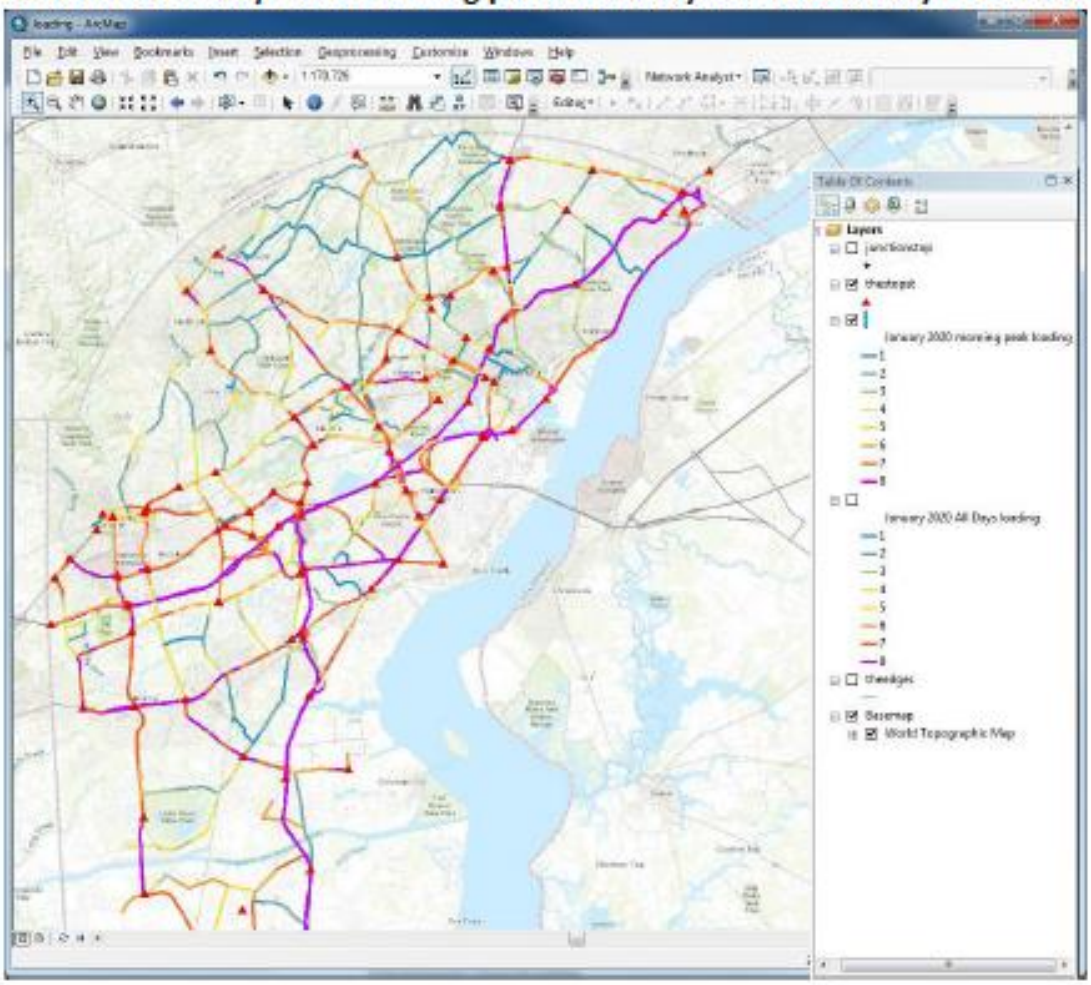
Detector Destinations (September 2017)



Loading Origins and Destinations Onto the Road Network

Taking the origin and destination detectors of bluetooth trips we could estimate the travel effect on roads by determining minimum paths for all pairs and accumulating (loading) the crossings of each directional road segment. Loading volumes onto the network from origin-destination tables allows us to see the impact of that travel in the network. An example from only one month is shown below. Examining the correlation with actual measures of volumes would be interesting research. As more detectors are added, the loadings would be expected to approximate traffic volumes by time of day even better. Loadings could also provide estimates of turning movement percentages at intersections and coupled with actual intersection counts could produce a detailed picture of travel by time of day, day of week, month and season.

Loadings of blue tooth origin and destination information on to the road network. Quantiles January 2020 morning peak weekdays. Data courtesy of DelDOT TMC



Other Exploration Possibilities

There are a few other applications and views of the data not discussed here that certainly will be investigated. Examining detections, speeds, and loadings with traffic count data would tell us a lot about how the detections reflect traffic. As more data is processed, various trend analysis over months and years can be done. Perhaps the biggest question is; Where are good spots to put new sensors?

Data Processing

The Bluetooth data processing focuses on:

- Filtering out repeated detections for a given vehicle
- Removing confounding detections and other anomalies
- Filtering out parked vehicles
- Assigning arrival and departure times
- Identifying trips
- Identifying vehicle detections

Source Data

The raw data includes three file types with extensions *.gps, *.data, and *.info. The file type ending with .info does not contain any useable information.

The .gps file includes the detector name in the file name and the coordinates of the detector as well as the date and time. The file looks like this:

Time 040029
Lat 3844.8993N
Long 07510.4065W
HDOP 0
Alt 0
Fix 0
COG 0
Spd 0
Date 230620
Sat 0
DecLat 0N
DecLong 0W

The coordinate format is the following: DDMM.MMMM. For instance, in the sample above, a latitude of 3844.8993N translates to 38 degrees, 44.8993 minutes. Converting to decimal degrees would be 38 + 44.8993 / 60 which equals 38.748322°. The complete list of gps files comprises all of the detectors in the data. To discover additional stations would require compiling all GPS data and associated coordinates with the detector name in the file name. For example, a file named 00D0694B6FD9-20200623-040029-gps in the above example would be identified as detector 00D0694B6FD9 with the remaining portion of the name representing the date {year month day minutes} when the sample was downloaded. Programs can be run on the set of .GPS files to extract a list of unique detectors and their gps location.

The .data files are named by detector-datetime-minutes. It primarily consists of the blue tooth mac-id and date and time fields, as shown below. A record number, the MAC-ID, the Date and Time. In the raw data, Time is in Greenwich Mean Time . To generate the files to Delaware's time zone, 5 hours were subtracted from the raw time/date.

Source .data Example

Record	MAC		Date	Time
39730	FD:F4:C6:6A:FF:F1	6.0000	20201020	035942
39730	36:0E:E0:B7:07:A4	6.0000	20201020	035945
39731	FD:F4:C6:6A:FF:F1	6.0000	20201020	035947
39731	36:0E:E0:B7:07:A4	6.0000	20201020	035949
39756	D7:FF:E1:F5:2D:C1	6.0000	20201020	040220
39757	D7:FF:E1:F5:2D:C1	6.0000	20201020	040228
39758	D7:FF:E1:F5:2D:C1	6.0000	20201020	040233
39759	D7:FF:E1:F5:2D:C1	6.0000	20201020	040239
39760	D7:FF:E1:F5:2D:C1	6.0000	20201020	040244
39772	EB:BF:01:38:5F:C6	6.0000	20201020	040403
39772	CF:BE:7F:24:7D:4F	6.0000	20201020	040405
39773	EB:BF:01:38:5F:C6	6.0000	20201020	040406
39774	EB:BF:01:38:5F:C6	6.0000	20201020	040408
39792	9C:CC:16:CE:46:81	6.0000	20201020	040605
39793	9C:CC:16:CE:46:81	6.0000	20201020	040606
39794	9C:CC:16:CE:46:81	6.0000	20201020	040607
39796	CF:E2:AD:06:08:27	6.0000	20201020	040622
39797	CF:E2:AD:06:08:27	6.0000	20201020	040628
39798	8F:FA:51:60:76:BD	6.0000	20201020	040633
39798	CF:E2:AD:06:08:27	6.0000	20201020	040638
39799	CF:E2:AD:06:08:27	6.0000	20201020	040639
39800	CF:E2:AD:06:08:27	6.0000	20201020	040643

Preprocessing / "Cleaning"

Repeated Detections While Vehicle is in Proximity to Sensor

Within a certain proximity, sensors will detect a vehicle and may log additional readings before the car leaves the location particularly in the case of waiting for a traffic light. The record which is the first detection time is kept and subsequent detections are removed. The last time a particular vehicle is detected is noted on the record which allows for an estimate of the length of time that a vehicle was in the detectable vicinity of the blue tooth detector. That interval of time between when the vehicle is first detected and last time detected is referred to here as the "dwell" time around the detector.

Stationary Vehicles Not Involved in Trips

Vehicles that could be detected at a sensor could in some cases be parked vehicles or otherwise idle and not part of a trip. Any vehicles that dwells within a specific detector for longer than **180 seconds** is removed. This **180 second** number is a hard coded estimate that we use to designate cars that we suspect are idle, and could be changed after further study.

Simultaneous or Near Simultaneous Detections at More Than One Detector

It was found that in a case where blue tooth detectors are close together, a vehicle can be detected by two detectors at once. This confounds the measurement. While there may be a way of guessing which detector the vehicle is at thru travel times to next destinations, this was not pursued at this time, and where the detector shows up at the same time (10 second window) at two detectors, the records are deleted. Further study will determine how frequently this happens and to what level it impacts the amount of user information

Unexplained Frequent Detections Of a Particular Vehicle/MacID

In each month about a dozen mac addresses show up an unusually high number of times. Often several of the MacID across months are the same. This will be further studied but at this stage if a particular MacID is found more than 1000 times in a month (30 or so a day) it was removed.

Identification of Trips

When one measures the travel time between two detectors one assumes its for a particular vehicle and part of a particular trip. The raw data is sorted by date/time and MAC address. That sequence of records is examined to group detections into trips. To verify that the progress from one detector to another is part of a continuous path which can be used to get a travel time estimate, its necessary to compare values to a typical travel time . If two detectors are 10 minutes away and the difference between readings of one detector and the other is a value like 2 hours, then one can assume something else happened like a stop to do shopping before being detected at the second detector. So what is needed is a typical travel time between detectors.

Average travel times between detectors were initially calculated using CADSR's routing network corresponding to expected speed limits. In subsequent processing, we were able to obtain a more accurate average that is derived from distributions of travel times in the blue tooth data itself.

Using the average time we were able to group subsequent vehicle records into trips stipulating that travel between two detectors was within some tolerance of that average. Travel between two detectors was considered to be part of a trip if the time was within 1.7 times the average travel time which was decided upon by examining various distributions and doing several test runs. Choosing 1.7 means that travel time between two detectors is not used as a travel time measure if it takes 70% longer than the average. Additional consideration is needed, as some very bad congestion events would not be reflected in the data. And the 1.7 parameter is expected to have a non-linear effect depending on the travel time. A difference of 50% on a five minute trip could occur much more frequently then a 50% on a half-hour trip. Also average travel time between detectors can be significantly affected by time of day.

Origin Destination, Identification of Beginning and End of Trips

Having identified trips in the bluetooth records, we can then tabulate an origin and destination detector for the trip. This data may be helpful in using the bluetooth data to estimate where people are coming from and going to, and to specify travel direction by time of day. Origin and destinations and time of trips were calculated.

	mac	originTime	originDetector	destinationTime	destinationDetecto	TID
0	b'00:01:2F	4/6/2020 3:18	b'000195149B6B'	4/6/2020 3:25	b'00D0694A9C58'	13
1	b'00:02:18	4/14/2020 16:33	b'00D069501B49'	4/14/2020 16:47	b'00D069501B45'	30
2	b'00:02:18	4/14/2020 17:27	b'0001951F67FE'	4/14/2020 17:28	b'0001951E6A87'	31
3	b'00:02:A1	4/25/2020 14:09	b'0001951F682F'	4/25/2020 14:13	b'0001951F6807'	67
4	b'00:02:FE	4/5/2020 17:11	b'00D0694B6FD7'	4/5/2020 17:13	b'00D0694A9DDA'	76
5	b'00:03:41	4/10/2020 20:53	b'0001951F682F'	4/10/2020 21:08	b'0001951E6A83'	83
6	b'00:03:41	4/10/2020 21:24	b'00D0694A9C64'	4/10/2020 21:33	b'0001951F682B'	84
7	b'00:03:A4	4/24/2020 14:14	b'0001951E6A87'	4/24/2020 14:16	b'0001951F67FE'	111
8	b'00:04:29	4/7/2020 23:00	b'0001951FFEED'	4/7/2020 23:01	b'00D0694B6FD1'	123
9	b'00:05:8A	4/25/2020 18:17	b'0001951E6A8C'	4/25/2020 18:28	b'00D0694A9CB0'	128
10	b'00:05:8A	4/25/2020 18:43	b'0001951E6A83'	4/25/2020 19:01	b'00D0694A9C64'	129
11	b'00:05:8A	4/25/2020 21:13	b'0001951F682F'	4/25/2020 21:23	b'0001951E6A8C'	132
12	b'00:06:77	4/26/2020 0:46	b'00D069501B49'	4/26/2020 0:55	b'00D0694B6FF9'	140
13	b'00:06:E3	4/15/2020 10:47	b'0001951F6829'	4/15/2020 10:54	b'00D0694A9C7A'	156
14	b'00:06:E3	4/27/2020 17:19	b'0001951F6899'	4/27/2020 17:21	b'0001951F6807'	162
15	b'00:06:E3	4/27/2020 17:59	b'0001951F6807'	4/27/2020 18:02	b'0001951F6899'	163
16	b'00:06:E3	4/30/2020 12:17	b'00D0694B6FD1'	4/30/2020 12:17	b'0001951FFEED'	166

Solitary Records

A situation arises where a vehicle is found at a detector and then is not detected at any other detector. We designate these as “solitary” records. These records are tabulated for possible use later as a measure of the number of cars located at a detector by time of day, or possibly an indication of activity in the vicinity of the detector.

Detector to detector pairs

In the context of a trip of a particular vehicle, a number of measures of travel time between each detector is provided in the data. For instance where a trip consists of travel from detector A to detector B to detector C to detector D, we have a measure not only of the beginning and end, A to D, but also A to B, A to C, A to D, B to C, B to D, C to D. With all of the data we could then examine distributions of measures of travel time between any two detectors. Processing includes the creation of this table for all combinations of detector to detector travel.

Products

Products tartgeted from data throughout the days and years of collection are;

- Cleaned processed raw data to address repeated measures and considerations of the sensing technology.
- Detector sequences identified as part of a trip
- Generation of travel time statistics between any two detector locations in the data by time of day/dow/month/year (ODPair Table)
- Origin and destinations for all trips. When examining the first and last detections of detections identified as a trip, this provides information relative to the detector distribution about where people are coming from and going to. When loading trips onto the road network this may provide measures of expected volumes and traffic patterns on specific roads.
- The number of detections at each detector. The number of vehicles detected at a particular detector depends on traffic volume, sensitivity of the detector, geometry of the local roads and land use, and other factors. Studying the number of detections may provide valuable information about activity around detectors and the performance characteristics of individual detectors.

Post Processing

Various compilations, aggregations, summations, and GIS representations and visualization is possible with the product files. The tables are detector based. The detector point file provides the lookup table (dbf) to associate station with detector. Certainly there is a long list of summations like "Average speed by weekday hour by month" that could be created and reused. web mapping of time dependent/enabled data can be very helpful in scanning through road usage.

Product Description

Source Data: Raw data as provided by DelDOT TMC, 2016 to 2020

CLEANRECORD : all multiple detection records stripped from raw data, tabulates arrival and dwell time at a detector, removes cases of simultanious detection at more than one detector. A step before trips are identified.

TRIPS : Detections grouped into Trips, assigns trip identifiers to CleanRecord. in the process removes all solitary detections.

ODTRIPS : Trip Origin Detector, Origin Arrival time, Destination Detector, and Destination Arrival time

SOLITARY: Records where a vehicle is detected at only one location and is not part of a trip to another detector.

ODPAIRS -: tabulates detector to detector travel times for all trip pairs in the data

OVERLAY: output of detections at more than one detector at the same or similar time.

GIS Detector Point File: GIS mapping file for Bluetooth Detectors. Includes detector to Station look up file. Also available as an XY table.

GIS Paths Between Detectors: road segments that are part of each detector to detector route.

GIS Graphic Line File: Graphic file used to display directional movement and create thematics for detector to detector travel