Integration of Traffic and Travel Demand Data in Delaware

DELDOT RESEARCH SUMMARY **DRAFT Aug 31, 2022**

Project: **Planning Data Analytical Support Services** **NOT FOR DISTRIBUTION**

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Abstract - Brief Overview of Research Activities for Integration of Transportation Data

Transportation performance measures from many sources are integrated using a set of road network and graphic elements locationally referenced to identifiers from standard linear referencing systems. Data from DelDOT Bluetooth sensors, NPMRDS, TMC devices, traffic counts, ATRs, intersection counts, and other data were compiled and integrated. In a similar way, the approach incorporates travel demand modeling estimates and relates them to measures. Such performance measures are always referenced to specific collection dates and times so it is critical for integration that the time dimension of measures and estimates be managed and consolidated. Efforts made to array measures through time of day and season are discussed. A goal is to bring measures together with estimates, to provide an automated dynamic statewide presentation of what we know or think we know about the travel network during various times of interest. A higher level of integration is achieved when the relationships among travel flow network elements are examined. Relationships can be what is constrained by road geometry and permissible flow, or typical flow patterns. Sources of information that would indicate directional flows by time of day, such as the percentage volume flowing into and out of intersections provide a means to extend measures to estimates of neighboring unmeasured areas. It is expected that incorporating the data in a system as outlined could guide and realize increased benefit from our information collection investments. (tags: travel demand forecasting, traffic data, integration, estimate of traffic flow direction, GIS-T)

Acknowledgements

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General Approach to Integration of Traffic and Planning Data

Integration is achieved by referencing all types of transportation measures and estimates to a common interrelated set of road travel network and landuse GIS features and tables. Blending data resources also depends greatly on approaches to dealing with the time dimension. Trip generation, trip purpose, distribution of trips through the day, and origin and destination estimates are areas of travel demand analysis that are incorporated. Seeing the large amount of various data together has many applications and greatly improves data quality and supports efficient collection. A step further is to understand the spatial and network relationships of measures to build more comprehensive estimates and pictures of transportation system usage and performance This report and organization of the research can be viewed below. Examples of the use of transportation elements are distributed throughout the Data Elements section.

OUTLINE

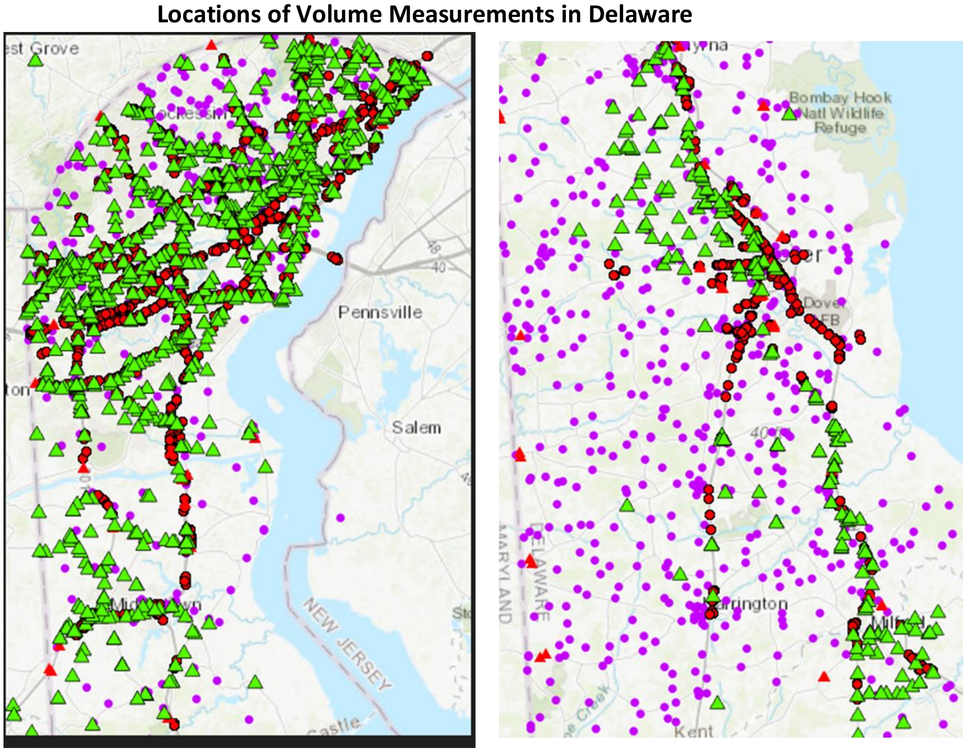
- **Research Goals**
- **Data Elements for Integration of Travel Demand and Traffic Data**
  - Data Location foundation, segmentation and identification
  - Directional Road Segment Measures
  - Turning movements/Turn Tables
  - Junctions/Intersections
  - Access Points
  - Graphical Layers
  - Parcel Based Land Use
  - Zones
  - Routing Networks
- **Time Dimension - Time Enabled Data**
  - Intervals, aggregations, typical time
- **Travel Demand**
  - Trip generation
  - Trip Purpose
  - Trips by time of day
  - Origins, Destinations, Activity Centers
- **Estimation**
  - Travel flow and relationships between paths, traffic algebra
  - Ins and Out, Directional flow percentages
  - Activity Centers and Gravity Modeling
  - Directional tendencies through time
- **Distribution and Presentation**
  - Cloud Based Data, Mapping sites, Hubs, and Storybooks

Goals and Benefits of Research

There are several components to this research project, and it is helpful to start this progress report at a top level view to suggest how some of efforts relate.   Research generally focused on the following goals:

- Establish an integrated method for location of traffic data and travel demand data that facilitates locational referencing and measurement, and relation to a wide variety of data sources
- Develop an efficient information systems approach that can support capture, management, processing, and presentation of traffic and travel demand.
- As new data from new sources is developed, provide a framework to incorporate it.
- Realize additional value in existing data while enhancing and promoting data collection.
- Have travel demand measures and estimates allocated to specific travel network locations and turning movements, and relate conditions and performance to travel demand.
- Development of a dynamic assessment of travel throughout Delaware's network that updates with available data from several sources.
- Be able to predict travel and transportation network performance where data is sparse. Identify where data gaps exist and where measures are most needed.
- Determine ideal traffic and trip generation measurement points and approaches that can efficiently produce a detailed and reliable picture of travel in Delawar

Locations of Volume Measurements in Delaware



Data Elements for Integration of Travel Demand and Traffic Data

This section describes the information structures used for referencing and working with traffic data.

Travel Network Locational Reference and Segmentation

Locational reference of transportation data is based on the Delaware Linear Referencing System (Delaware LRS). Locations are expressed as a particular route and milepoint for point events and as a beginning and end milepoint for sections of roads or paths. Road segments are assigned a linear reference system identifier, LRSID. It is formed as a text field constructed from a concatenation of the DelDOT RDWAY ID and the beginning and end mile point, for example:

LRSID = 000015 08360 08710 is DelDOT rdway id = 15 for from-mp = 8.36 and to-mp = 8.71.

The first six places are the RDWAYID and the mile points are each 5 places (NN.NNN). This approach also captures direction of flow. One side of the road would be as above and for the opposite travel direction in this example.

LRSID = 000015 08710 08360 (rdwayid=15 from mile point 8.71 to 8.36

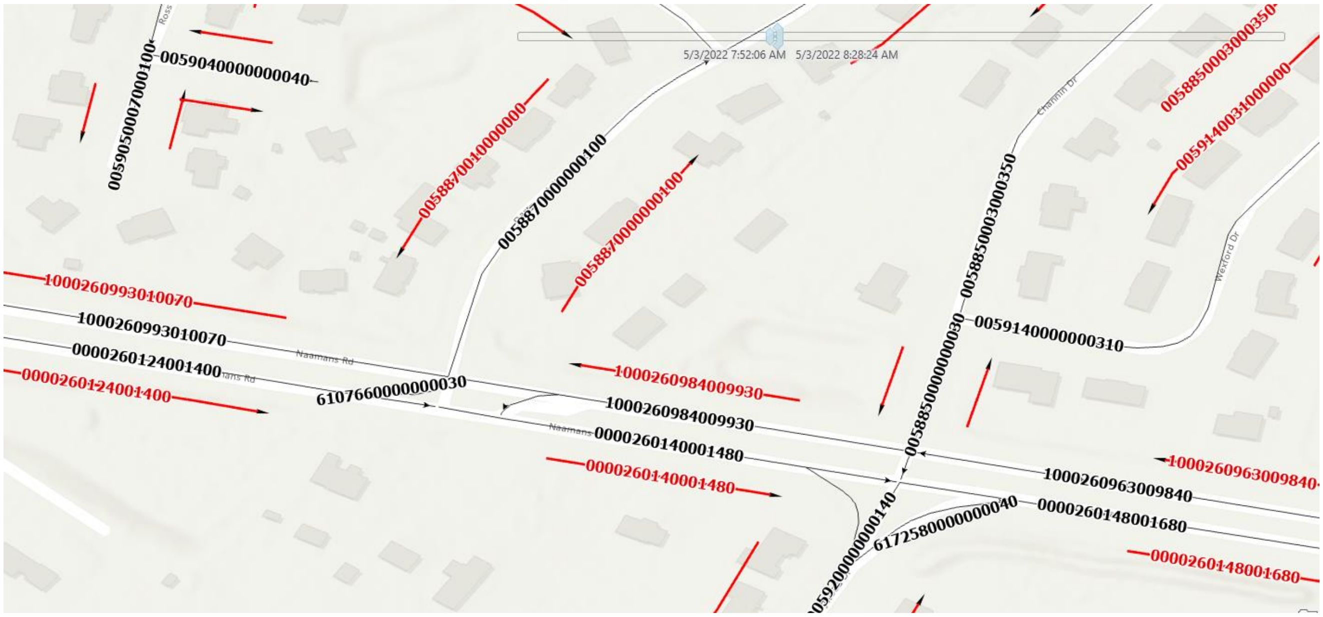
Beginning and end milepoints are reversed. The advantage to this method in addition to direction is that any data table can be mapped without using a particular GIS representation. Data could be referenced on the DelDOT Centerline as published , or any GIS that included the Delaware LRS and had linear referencing capabilities. Another advantage is that the identification scheme does not require a particular segmentation scheme. Larger portions of road can be referenced by using different milepoints. The embodiment of that is a streets or paths network and that establishes locational identification.

The segmentation used by CADSR is typically where there are major and minor intersections of roads. A driveway may create a segment/split in cases where there is a large amount of traffic, such as with a shopping center or large employer or school or apartment complex. The identification scheme addresses data for any segment length though and in many cases, data is provided at a route level or as the path between two segments and describe much larger portions of roads.

Directional Road Segment Measures

Many transportation measures are about a portion of road in a particular direction. When working with a particular data set the measurement device, a loop or station or traffic count or sensor is referenced to a particular road segment and direction. For instance TMC volumes from intersection devices typically measure the portion of road leaving the intersection. Attributes of a road, like the number of lanes or average speed or capacity or routing impedance, are this type of measure and are attributes of the streets and paths and the routing networks built on the paths. A graphic layer of directional arrows has been developed to display the directional road segment data and a view of these are in red showing the directional LRSID's.

Main road file with identifiers and (graphic features for directional movements shown in red)

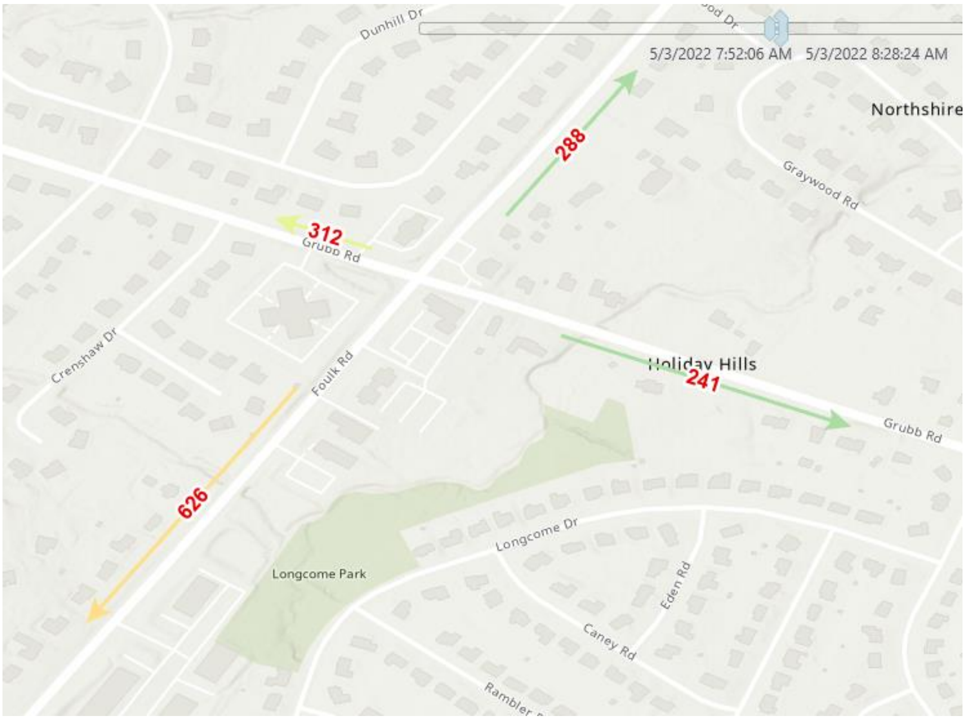


Examples of transportation data that are referenced by directional segments include:

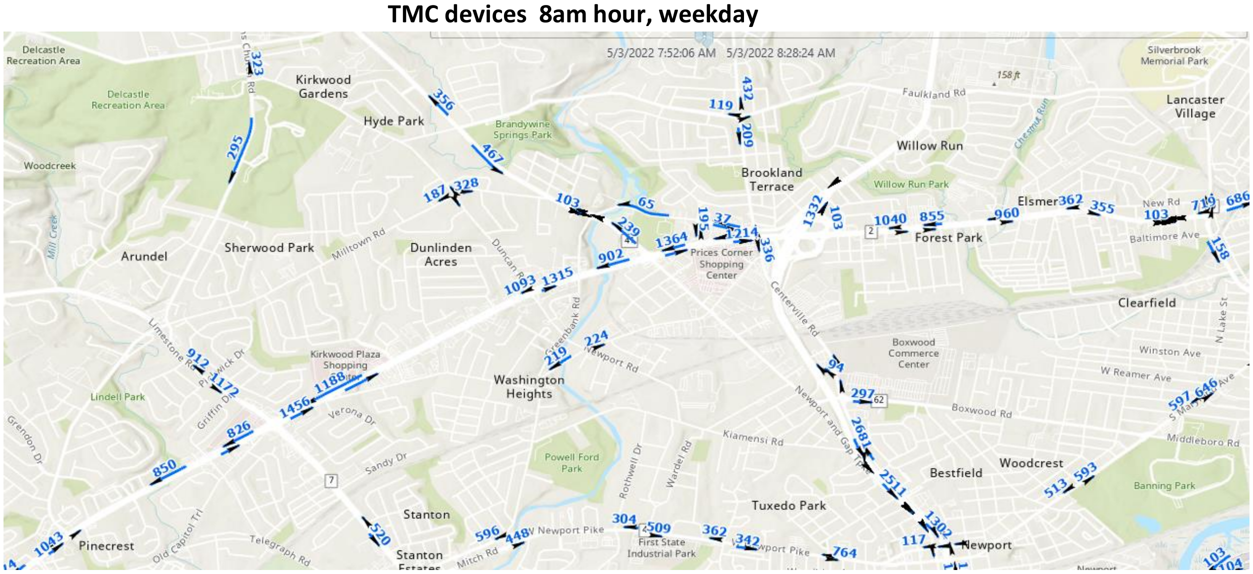
- Volume
- Speed
- Capacity
- Percentage Flow
- Impedance
- Various road attributes
- Trips Entering or Leaving an Area (Productions/Attractions)

Example mapping is below.

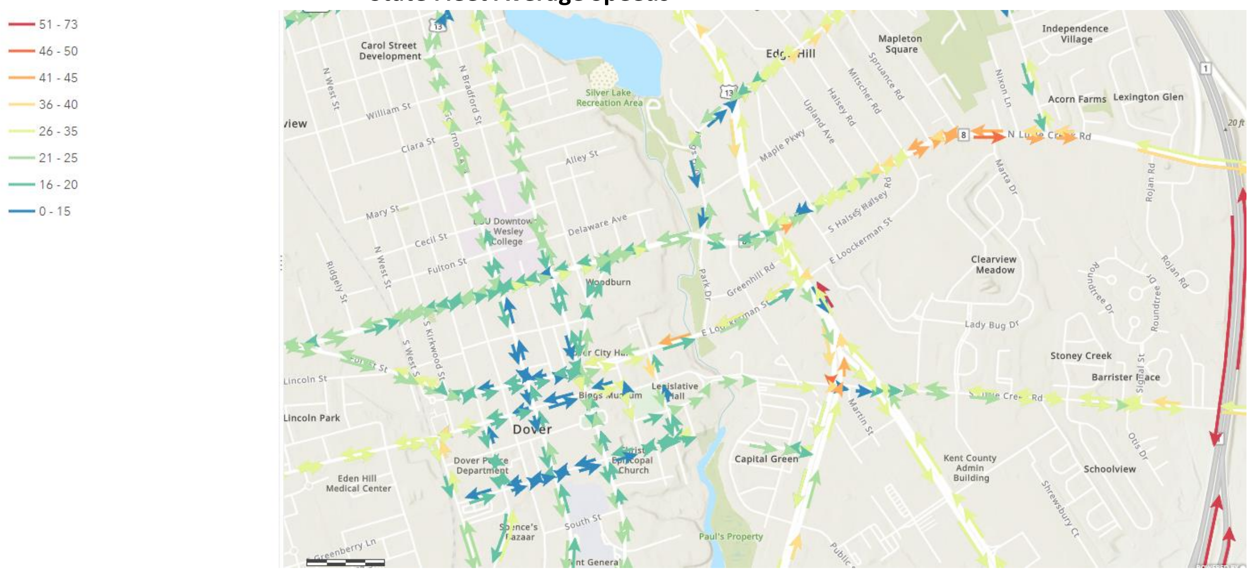
Volumes leaving an intersection from Traffic Counts



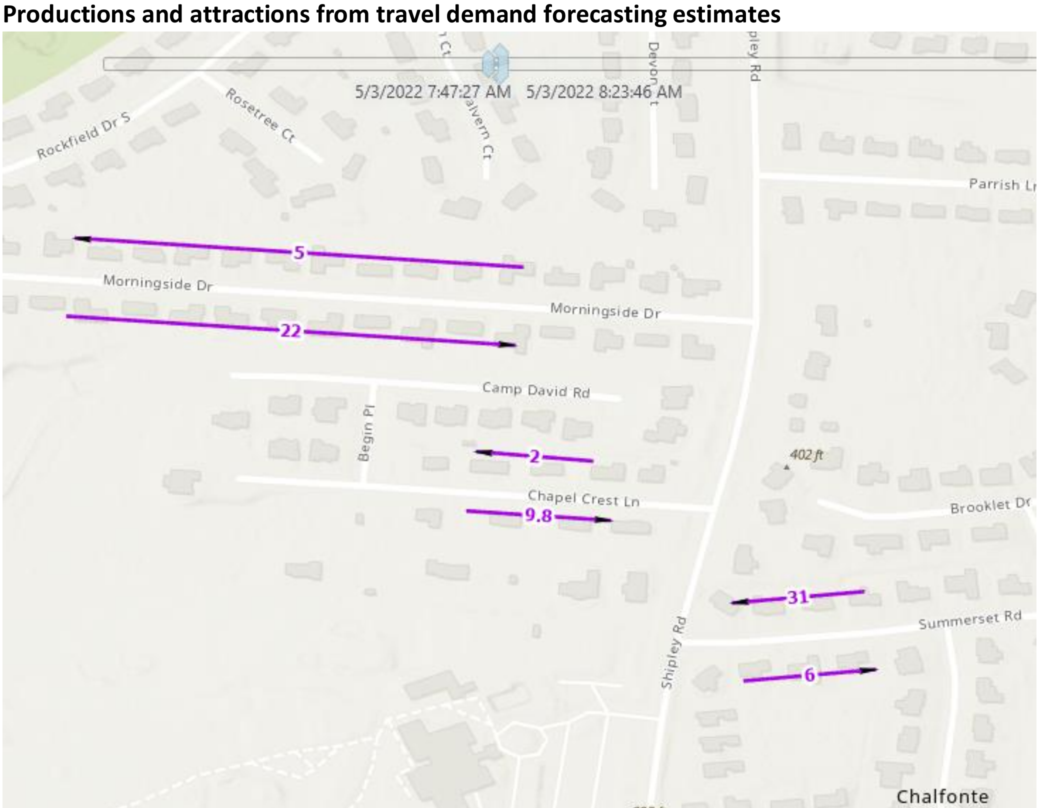
TMC devices 8am hour, weekday



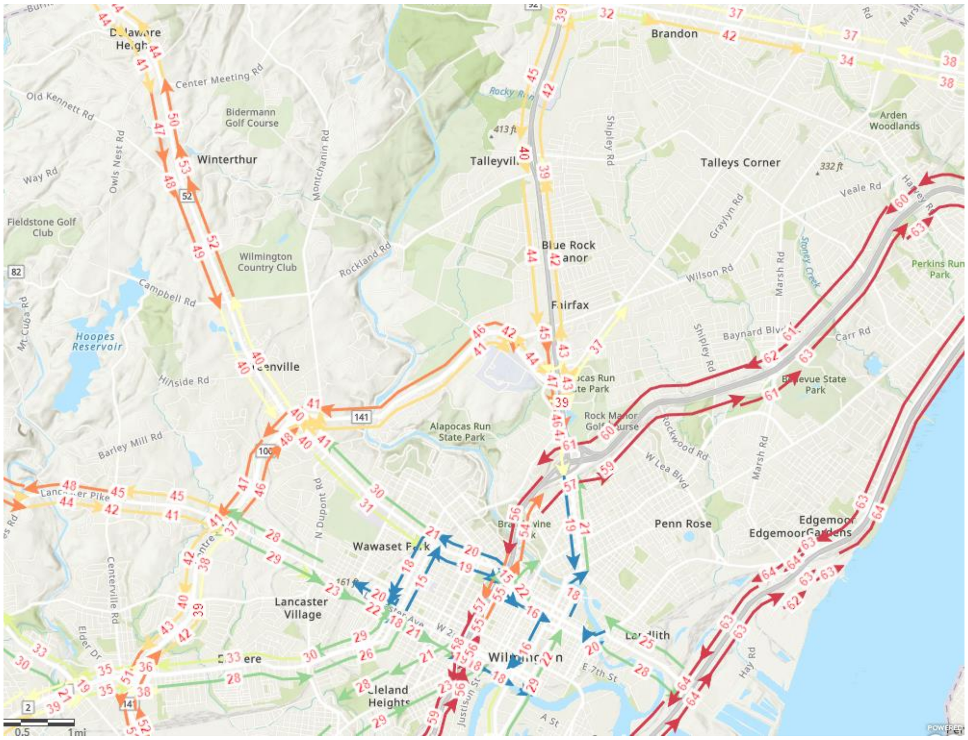
State Fleet Average Speeds



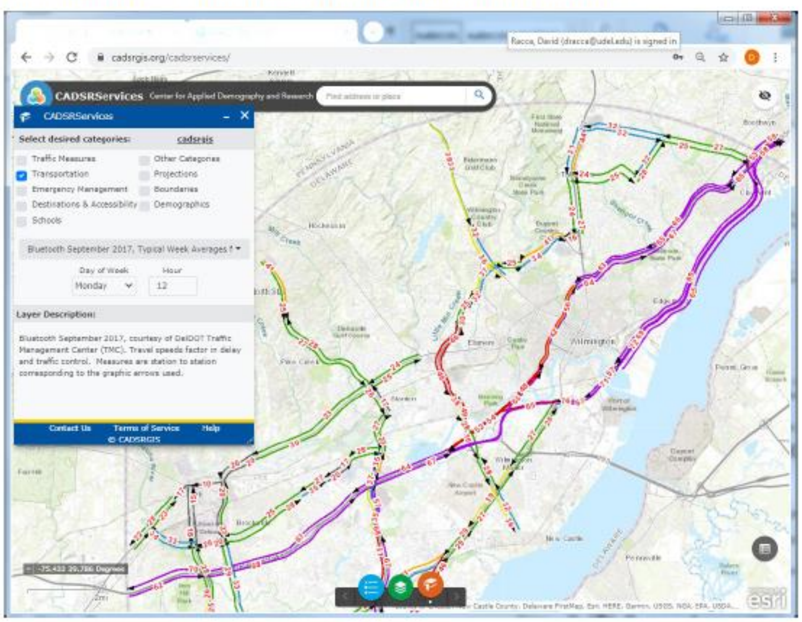
Productions and attractions from travel demand forecasting estimates



Typical speeds NPMRDS

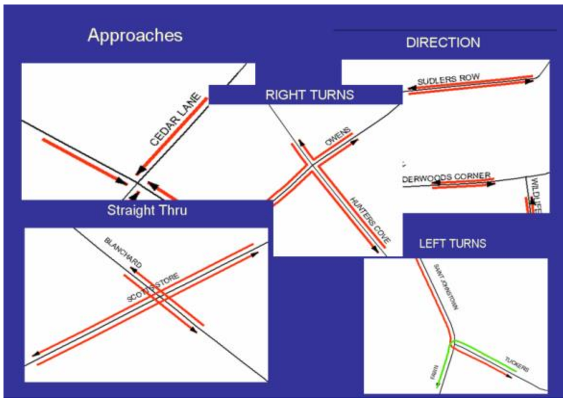


Typical speeds in New Castle County, Noon on Monday, Blue Tooth Data

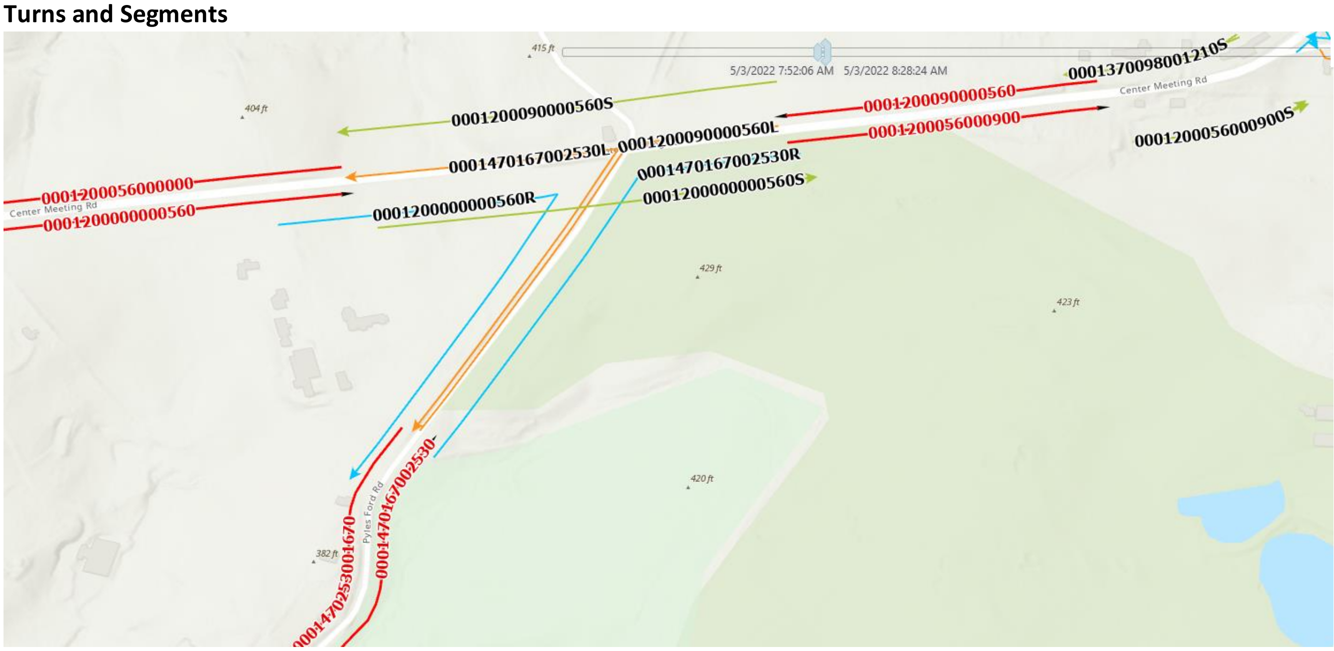


Turning Movements

Another common measure for traffic is for a turning movement A turn is travel from one path segment to another,which could be considered a right, left, thru, or U turn. In the management system being discussed the identifier used for turns is the direction road segment identifier described above with a suffix of R, L, T or U. As with directional road segment layers, a graphic layer was developed to symbolize the various turns.



Turns and Segments



A turn table tabulates the identifier for the turn and the identifiers for the start and end segment of the turn. A turntable for the entire road network in Delaware has been created and provides a means to list all connections to any path segment and can completely identify all movements allowed by the network. It can also be used for tracing through the network as it specifies every connection in a tabular form.

Example of a Turn Table

turnid	angle	azimuth	dir	lrsid *	slrs	elrs	sname	ename
57568057569	-77.5425	39.4833	R	0000150236002520R	0000150236002520	0040460026000230	MAIN	AMSTEL
57568057703	-2.18649	39.4833	S	0000150236002520S	0000150236002520	0000150252002580	MAIN	MAIN
57703057731	-25.0229	28.0431	S	0000150252002580S	0000150252002580	0000150258002700	MAIN	DELAWARE
57718057759	90.5201	89.3025	L	0000150258002700L	0000150258002700	6247970000000040	DELAWARE	U of D Road
57718057656	-89.2846	89.3025	R	0000150258002700R	0000150258002700	0042300069000600	DELAWARE	ORCHARD
57718057659	0.370874	89.3025	S	0000150258002700S	0000150258002700	0000150270002790	DELAWARE	DELAWARE
57659057937	89.7599	88.9316	L	0000150270002790L	0000150270002790	0003410879008870	DELAWARE	COLLEGE
57659057660	-92.1333	88.9316	R	0000150270002790R	0000150270002790	0003410879008680	DELAWARE	COLLEGE
57659057673	7.04772	88.9316	S	0000150270002790S	0000150270002790	0000150279003010	DELAWARE	DELAWARE
57673057830	89.8825	84.9969	L	0000150279003010L	0000150279003010	6247290000000050	DELAWARE	U of D Road
57686057907	87.0535	84.342	L	0000150279003010L	0000150279003010	6247300000000080	DELAWARE	U of D Road
57715057981	80.5153	84.3421	L	0000150279003010L	0000150279003010	0040400009000000	DELAWARE	ACADEMY
57715057716	-100.027	84.3421	R	0000150279003010R	0000150279003010	0040400009000260	DELAWARE	ACADEMY

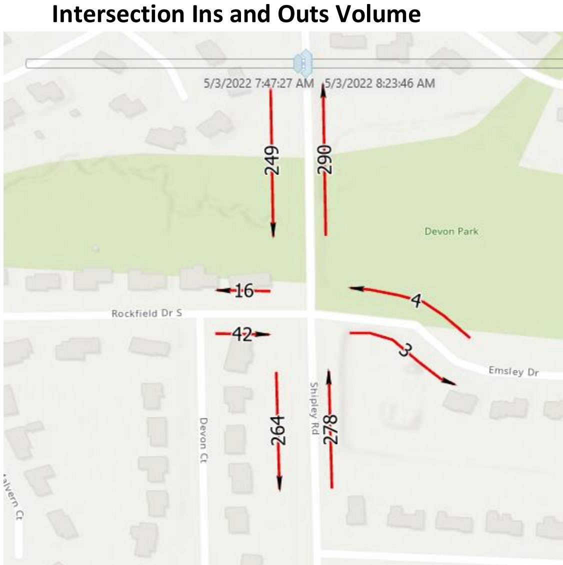
The prime example of turning movements is what is surveyed in a typical intersection count. The figure below tabulates turning movements for peak 15 minute intervals. From that data one can view volume for any turn, total traffic entering the intersection, total and percentage travel out to any direction (N,S,E,W), totl and percentage travel from any direction . Each 15 minute measure in time is a record that is tied to a particular turning movement or directional segment. There are close to 500 different measures provided when totals and direction percentages are included and in GIS systems these are each associated with a directional segment or turn as a record.

Intersection Count
Shipley Rd and S. Rockfield Drive

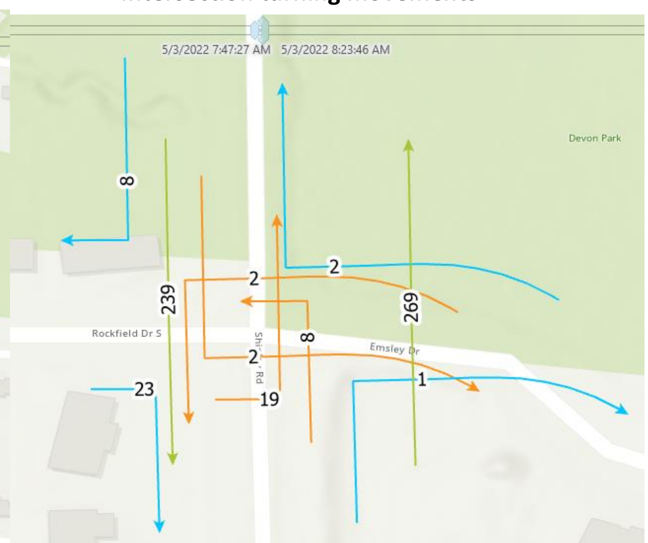
junction	int	thedate	thetime	ampm	SBr	SBt	SBl	SBu	WBr	WBt	WBl	WBu	NBr	NBt	NBl	NBu	EBr	EBt	EBl	EBu
35044	15	4/12/2016	7:00	AM	1	57	0	0	0	0	1	0	0	92	1	0	6	0	5	0
35044	15	4/12/2016	7:15	AM	1	92	0	0	1	0	1	0	1	88	0	0	0	0	5	0
35044	15	4/12/2016	7:30	AM	2	78	0	0	1	0	2	0	2	78	1	0	4	0	1	0
35044	15	4/12/2016	7:45	AM	0	79	0	0	0	0	2	0	0	80	0	0	10	0	7	0
35044	15	4/12/2016	8:00	AM	3	49	0	0	0	0	0	0	0	82	2	0	6	0	2	0
35044	15	4/12/2016	8:15	AM	2	49	0	0	1	0	0	0	0	46	3	0	8	0	8	0
35044	15	4/12/2016	8:30	AM	1	63	2	0	0	0	0	0	0	67	0	0	5	0	5	0
35044	15	4/12/2016	8:45	AM	2	78	0	0	1	0	2	0	1	74	3	0	4	0	4	0
35044	15	4/12/2016	4:00	PM	6	112	0	0	1	0	0	0	0	101	4	0	2	0	1	0
35044	15	4/12/2016	4:15	PM	7	106	0	0	1	0	0	0	1	105	3	0	2	0	2	0
35044	15	4/12/2016	4:30	PM	6	103	0	0	0	0	1	0	0	98	3	0	2	0	4	0
35044	15	4/12/2016	4:45	PM	3	96	0	0	2	0	1	0	3	103	4	0	2	0	2	0
35044	15	4/12/2016	5:00	PM	4	99	0	0	0	0	0	0	1	120	7	0	2	0	0	0
35044	15	4/12/2016	5:15	PM	8	111	0	0	0	0	0	0	0	124	8	0	5	0	1	0
35044	15	4/12/2016	5:30	PM	8	104	0	0	0	0	0	0	0	128	6	0	4	0	6	0
35044	15	4/12/2016	5:45	PM	3	112	0	0	0	0	0	0	2	134	4	0	3	0	5	0

The counts below are hourly summations from the traffic count table for the 8AM hour.

Intersection Ins and Outs Volume



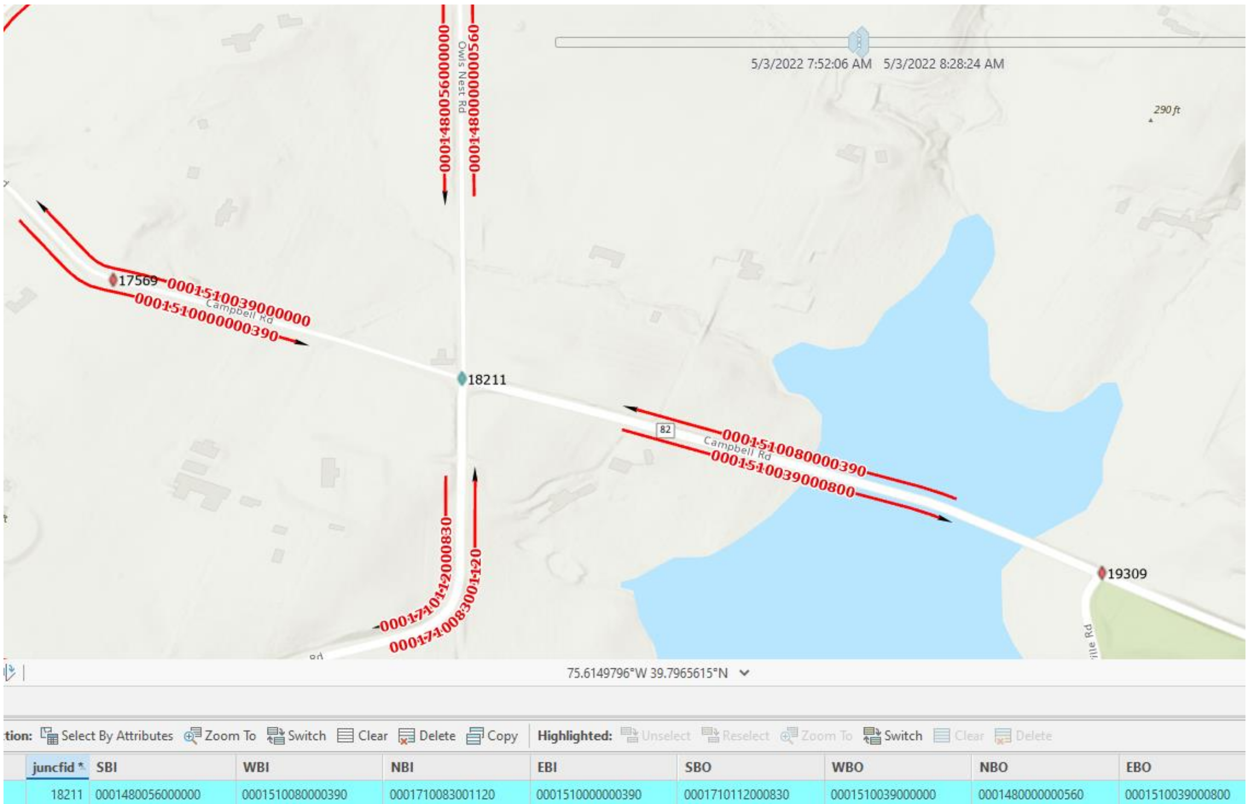
Intersection turning movements



Junctions/Intersections

Some traffic data is about intersections. Particularly useful for network modeling and integration is the reference to what roads are entering the intersection and exiting the intersection. The junction table tabulates the identifiers (LRSID's) for all roads entering and leaving the intersection, and assigns them to a travel direction. By examining data we have for those road segments we can judge where traffic is coming from and directed to. Having a generalized intersection point feature is especially useful in cases where the geometry of the network is more complex (as with crossing dual highways).

Junction 18211 with roads going in and coming out.

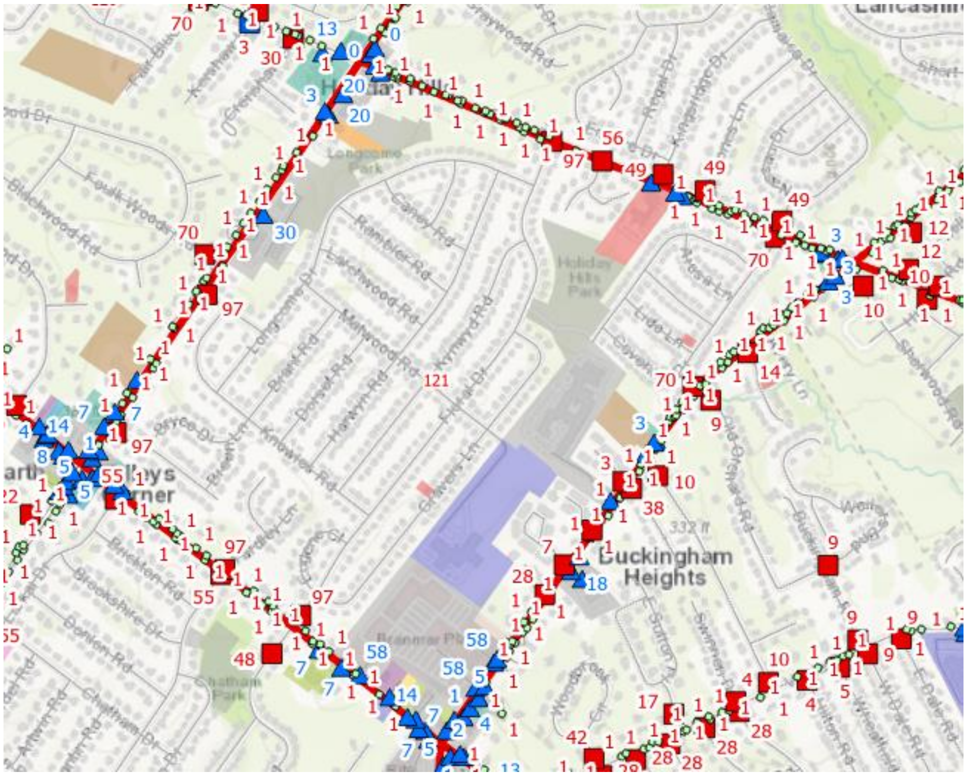


juncfid	SBI	WBI	NBI	EBI	SBO	WBO	NBO	EBO
18211	0001480056000000	0001510080000390	0001710083001120	0001510000000390	0001710112000830	0001510039000000	0001480000000560	0001510039000800

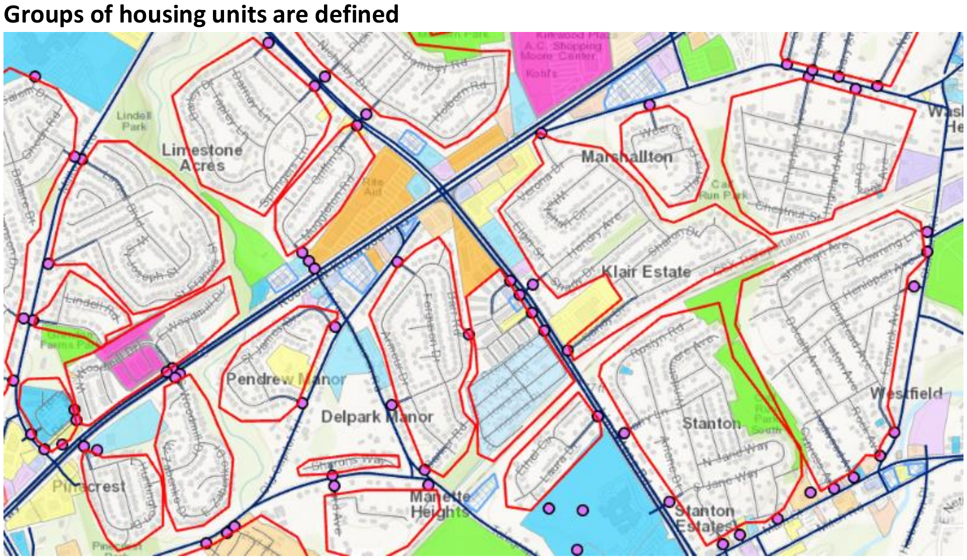
Access Points

Land Use and travel demand is associated with access points to the network and for travel demand are typically about trips entering or leaving an area. Trips entering or leaving a particular area can be associated with the directional road segments, and turning movements can reference the turns made to go into or out of the area. In network modeling, access points could be the location of demand.

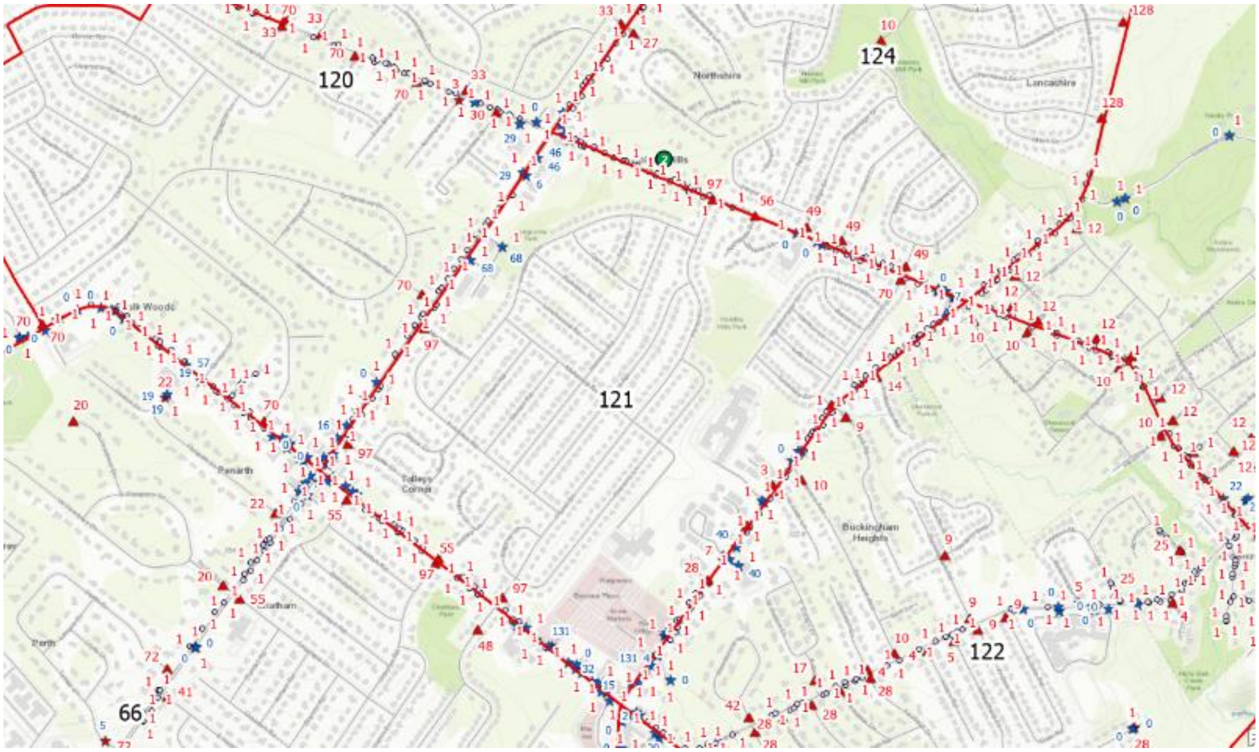
Access points on the network with housing unit and attractions summations



Groups of housing units are defined



Access point with traffic zones



An advantage of an access file is that it can simplify models and display by focusing on the major network, and of course the number of access points and type certainly affects traffic flow. One of the biggest advantages to an access layer for integration with travel data is that access points can be used to allocate zone level data. For instance consider the zone 121 in the above figure. Each access point can reference tabulations of housing data, parcel data, population estimates, total trip and other travel demand data. If one wanted to allocate a zone based number of attractions or productions to particular places in the travel network, the assignment of each access to a zone number could facilitate the disaggregation. Nothing new, connectors from the zone to points on the road network were often used to allocate zone information to the road network.

Routing Network

A routing network allows for the calculation of optimum routes, examination of origin destination pairs, and calculation of accessibility. Where origin to destinations trip information is available, volume estimates can be loaded onto expected paths to view a result at the small road segment level. Network analysis yields information referenced by directional road segments and turning movements. CADSR's network was built initially from Delaware and neighboring state DOT centerlines, includes various paths and driveways. A focus is on identification by the lrs, and where possible a close correspondence to DelDOT mapping. Having a linear referencing system on the roads layer offers resources when working with different segmentations and geographies.

Zone Data

There is a great deal of data at the traffic zone level. Zone delineations typically correspond to Census geography, in particular Census Block Groups as it is the smallest demographic unit that includes questions about relevant information on travel, income, housing type, and employment. DelDOT's TDFM includes numerous data such as employment sector figures, trips by purpose, race, gender, age, and usage to name a few. The Census Transportation Planning Package based on census block group boundaries is a large transportation data resource that reference zones defined by census geography. For some areas of the country, detailed origin and destination information is available.

Where People Work - from Census Transportation Planning Package

About Date Time and Time Enabled Views

Measurements are taken at all different dates and times and often for aggregations of various time intervals such as every 5 or 15 minutes of the day, or hour of the day, or for the whole day (AADT). In some cases data is missing for some hours as with traffic counts that only have data for peak periods. To relate data for traffic data and travel demand, time frames need to be consolidated by some strategy

Time Interval

Traffic data can be at points of time and various intervals of time. Common intervals are 5, 15, 30 and 60 minutes and sometimes figures are daily totals. The approach is to aggregate data to a common interval. Generally in this research trip productions and attractions and traffic data were arrayed and compared by hour.

Universal Times

Measurements are taken at all different timesof the day, days of the week, months, seasons, and years. GIS display systems allow for a specification of slices of time. Viewing a single data source that has continuous measures through time is straightforward. But viewing and comparing volumes by hour of the day for instance with traffic counts that very rarely would be in the same date-time frame requires adjustments. In addition to capturing actual measurement data-time, a “universal time” is associated with the measure. For instance when comparing weekday traffic, the first week of May 2022 was selected in some cases as the dates used, one reason being that May 1 is Sunday and day of the week coding is typically set as 1 for Sunday to 7 for Saturday. This allows a scan of the day hours from various counts and sources. Whether or not particular data is comparable for different months or years is an issue but in terms of viewing and display a universal time is helpful for viewing systems.

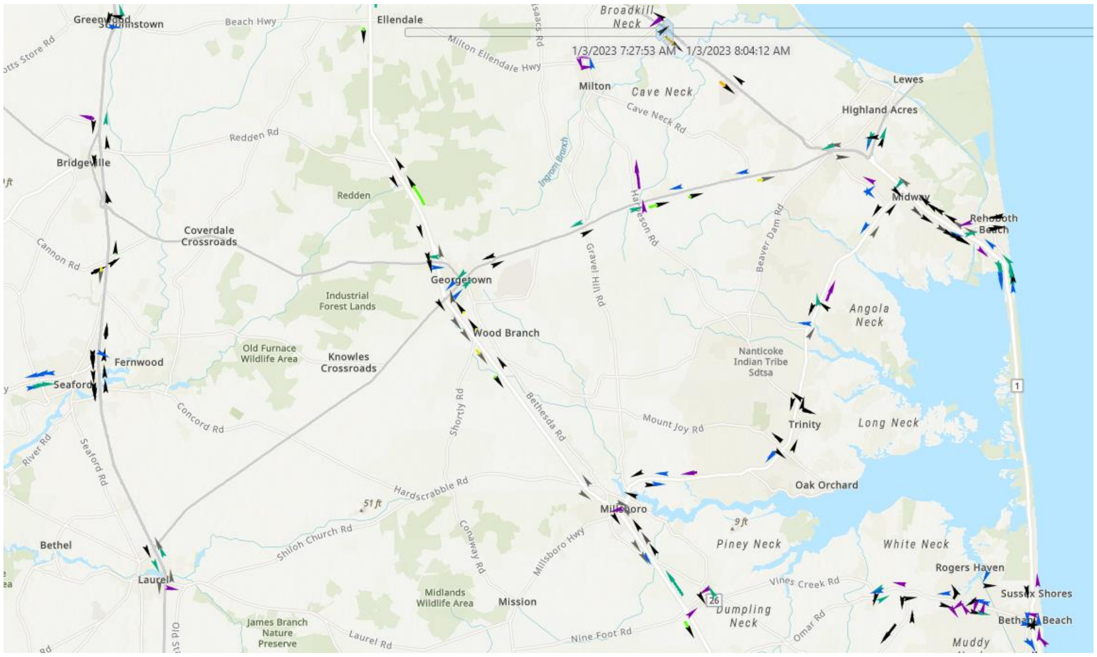
Typical Aggregations and Views

Often planning is interesting in the typical or expected travel behavior, not specific measures for a specific date, as with real time data. So data sets are aggregated into typical views to take account of expected differences and interest, for example:

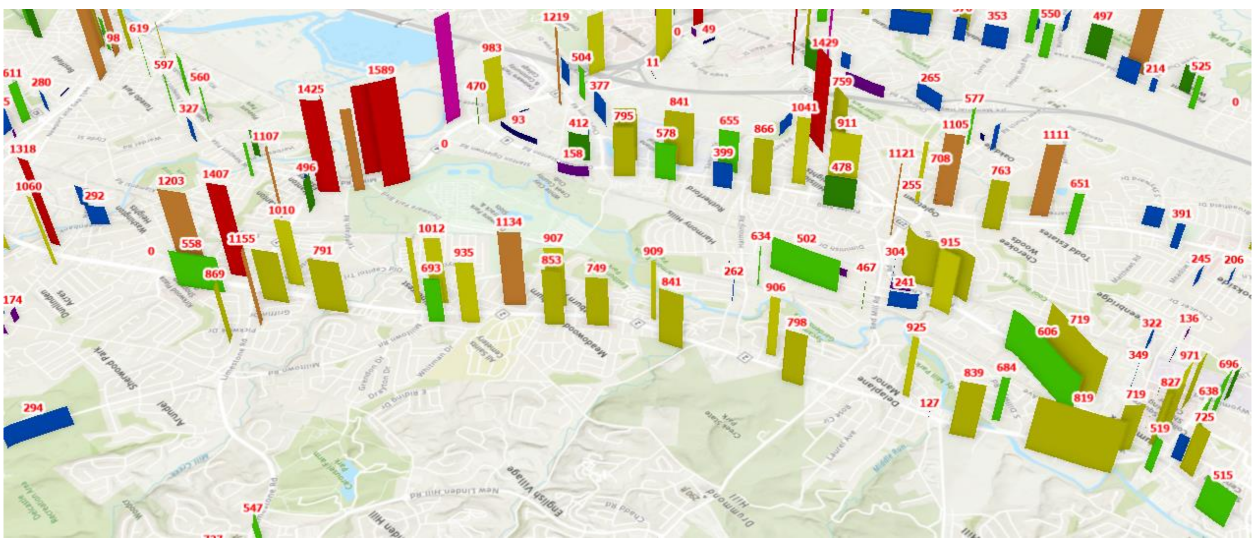
- Average Hourly Volume for weekdays Monday thru Thursday in the Fall
- Average Volume for Saturdays in Summer
- Average Volume for Fridays in the Fall
- Maximum Hourly Volumes by Month

Example mapping of time enabled TMC Loop Data, Tuesday 7am hour

Sussex County



New Castle County



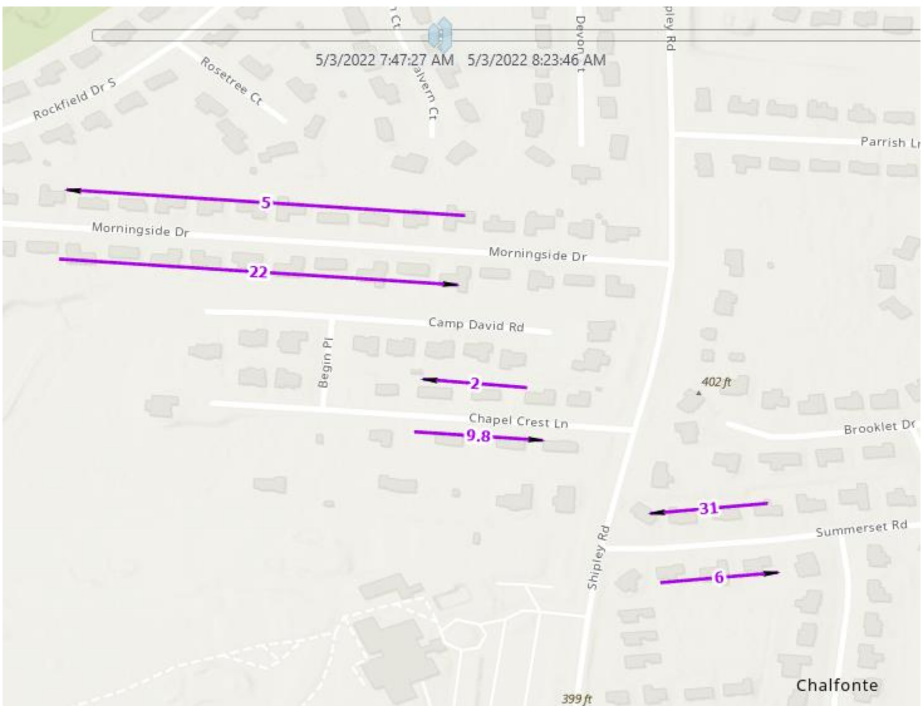
Integrating Travel Demand Data

Trip generation, Productions and Attractions

Models are continually being developed to estimate the number and types and location of trips taken. Trips enter the network at some access point whether it is a street or driveway or intersection and the trip is going In or Out of the property, or house, or traffic zone. A simple production/attraction table could be as below. A number of trips for the household, tax parcel, or traffic zone is assigned to the path segment with the directional identifier (LRSID) .

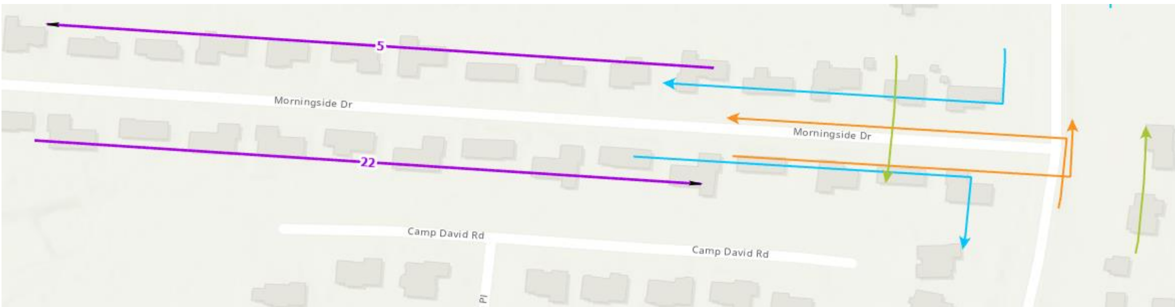
Production and Attraction Table

LRSID	HOUR	DOW	FLOW	TRIPS	datetime
0061370000000330	8	3	OUT	22	4/12/2016 8:00:00 AM
0060090000000100	8	3	IN	6	4/12/2016 8:00:00 AM



The map above is similar to road loop measures, it shows the directional flow going into or out of the intersection. Of course a more detailed view of the flow would include information on the turning movements associated, like the total volume entering the destination or leaving the origin by turning right or left. Turning movements associated with a production or attraction of a traffic generator would need to be allocated to a particular direction which might be done by looking at the directional tendencies of nearby roads and intersections.

Traffic Volumes In and Out of a residential subdivision with Turning Movements



Trip Purpose

Understanding the reason people travel is vital to efforts to explain and predict travel and understand the needs of communities.   Trips are often classified by purpose.

Distribution of Destination Categories		
	Percent	Frequency
Home	39	2870
Work	17.1	1260
Store	9.3	685
Recreational (for exercise/pleasure)	6.3	466
School	3.7	275
Drop off/Pick up a person	3.6	264
Social (visit neighbor, friend or family)	3.1	230
Restaurant	3.1	227
Doctor_s (medical)	2.7	196
Food Store	1.8	130
Recreational Facility	1.3	96
fitness and therapy	1.2	85
Bank or Post Office	1.0	77
Community-courts,utilities,government	0.9	67
Church/House of Worship	0.7	51
Other	0.7	50
vehicle-buy,repair,rent	0.7	52
Public Transportation Stop (Train/Bus)	0.6	45
Gas	0.5	40
Pharmacy-walgreens,cvs,riteaid	0.4	28
Home Improvement	0.4	32
Personal Serices beauty	0.3	23
Library	0.2	16
Transportation Connection	0.2	14
Agricuture,land care, hunting	0.1	8
Beach	0.1	8
Convenience -snacks,coffee,gas	0.1	4
Pet Med/Care	0.1	5
Child Care Facility	0.1	11

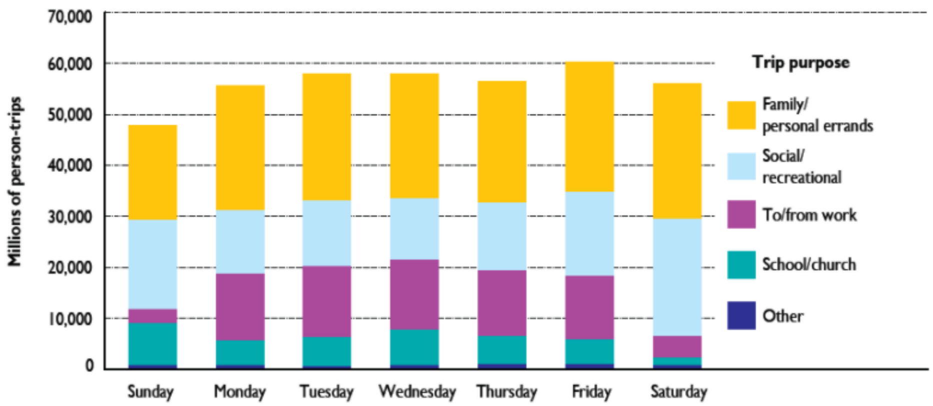
Percentage of all trips by purpose, home trip distributed	
Work	29.2
Store	16.2
Recreational (for exercise/pleasure)	6.6
School	6.2
Drop off/Pick up a person	5.6
Social (visit neighbor, friend or family)	5.6
Restaurant	3.1
Bank or Post Office	2.8
Doctor_s (medical)	2.7
Recreational Facility	2.4
fitness and therapy	2.1
Food Store	1.8
Community-courts,utilities,government	1.4
Church/House of Worship	1.4
Other	1.4
vehicle-buy,repair,rent	1.1
Public Transportation Stop (Train/Bus)	1.1
Gas	0.8
Home Improvement	0.7
Pharmacy-walgreens,cvs,riteaid	0.5
Personal Serices beauty	0.5
Transportation Connection	0.4
Library	0.3
Beach	0.3
Child Care Facility	0.2
Agricuture,land care, hunting	0.2
Convenience -snacks,coffee,gas	0.1
Pet Med/Care	0.1

Example of Trip Purpose, Bureau of Transportation Statistics

Annual Person-Trips by Purpose and Day of Week: 2009

Millions of person-trips

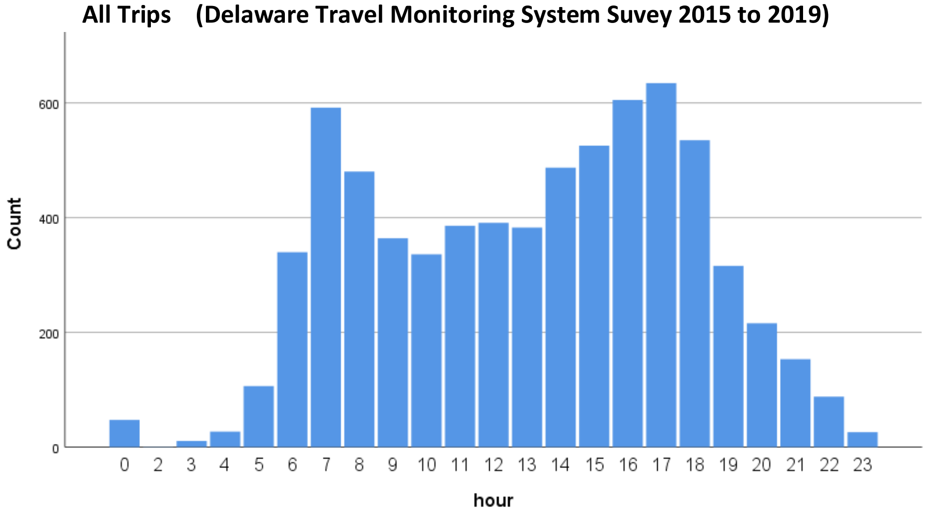
Figure



Trips by Time of Day

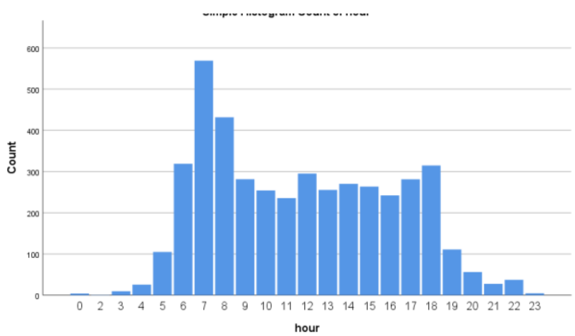
Traffic measures are linked to time, to integrate and relate trip generation estimates to traffic measures requires the time dimension.   If we wish to display travel flow together with measured flows we need a comparable time measure or estimate. Trips by time of day can be analyzed using the Delaware Travel Monitoring System Survey, Below are the trip distributions by time of day for types of trips.

All Trips   (Delaware Travel Monitoring System Suvey 2015 to 2019)

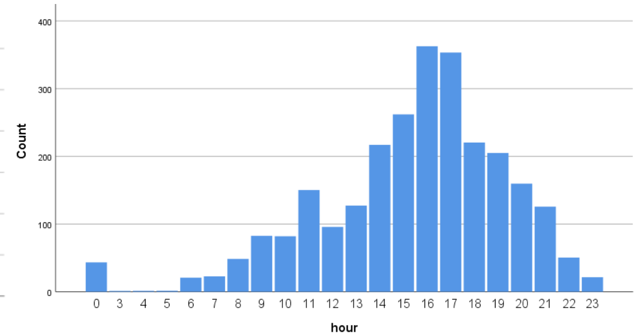


(Tables below from Delaware Travel Monitoring System Suvey 2015 to 2019)

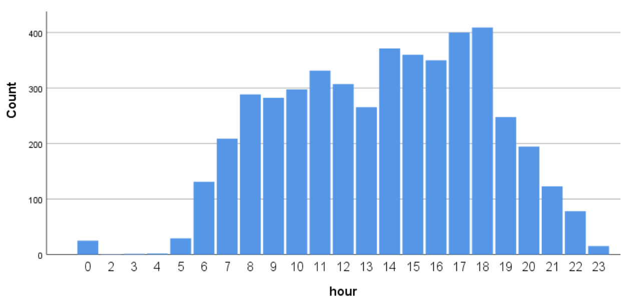
All Trips Except Return Home



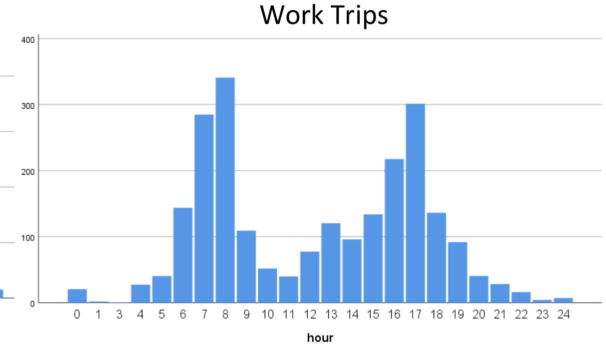
Return Home Trips



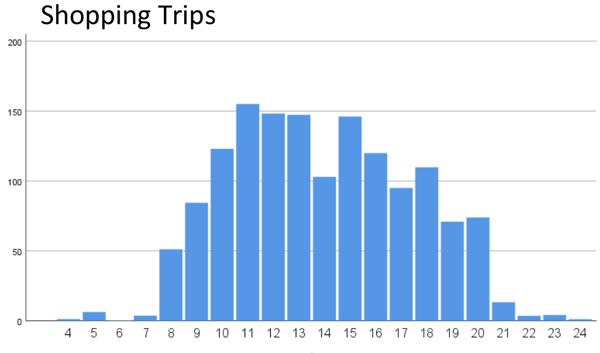
All Trips Except Work



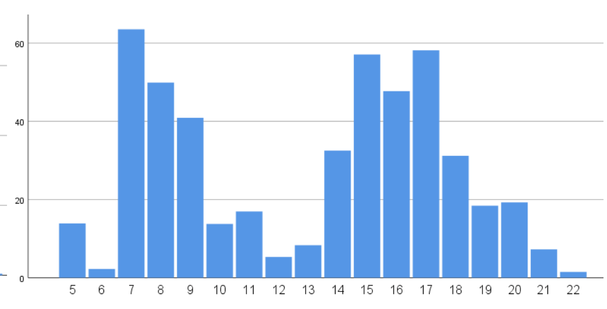
Work Trips



Shopping Trips



Dropoff – Pickup Trips



Hour Fr Home To Home

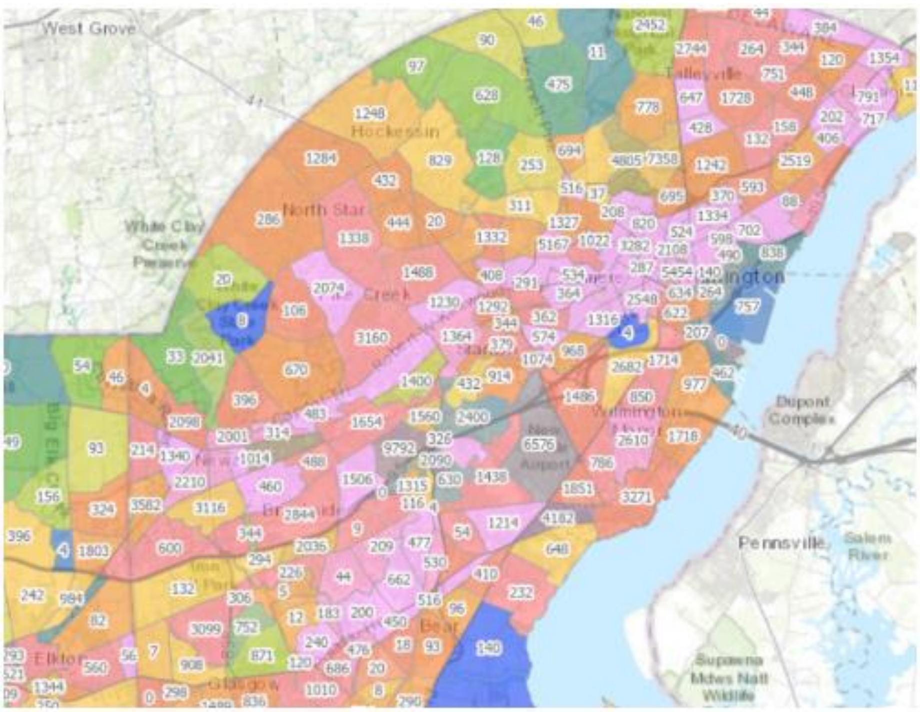
An approach to incorporate travel demand modeling production volume estimate with traffic data would be to array the trips by the hourly distribution of the day trips in the DTMS.

0		0.1	0.9
1		0.0	0.3
2		0.0	0.2
3		0.4	0.1
4		0.6	0.1
5		2.9	0.1
6		8.2	0.4
7		14.9	1.4
8		11.1	2.3
9		8.4	2.4
10		6.6	3.2
11		5.0	5.5
12		5.1	4.7
13		4.9	5.5
14		4.8	7.7
15		4.8	10.9
16		4.8	12.1
17		5.6	12.7
18		6.0	8.4
19		2.8	7.0
20		1.5	6.3
21		0.6	4.3
22		0.7	2.5
23		0.1	0.8

Trip Origins and Destinations

Travel demand data can be developed at the person level, household, tax parcel, traffic zone, Census Block Group level, or a range of other demographic units. For relation to traffic flow at the road segment level a higher resolution is needed. Historically and recently, origin and destination data is produced for traffic zones corresponding to Census Block Groups for the State as the demographic data is available from the Census and other sources. Zone figures need to be allocated to access points in the transportation network for volume loadings and to see where trips are expected to be.

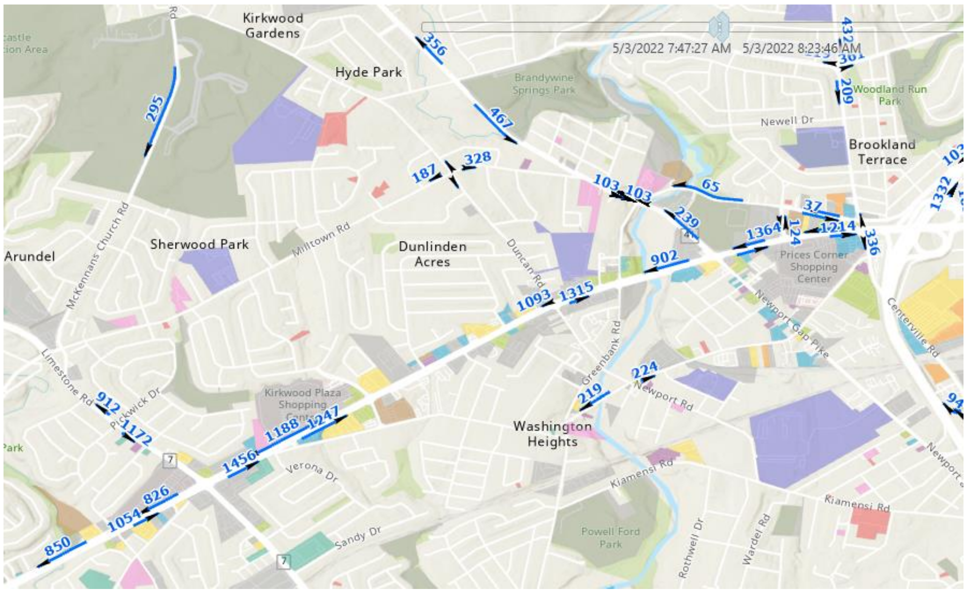
DelDOT TDFM – Total Trips by Traffic Zone Thematic



Total Trips , DelDOT TDFM 2018

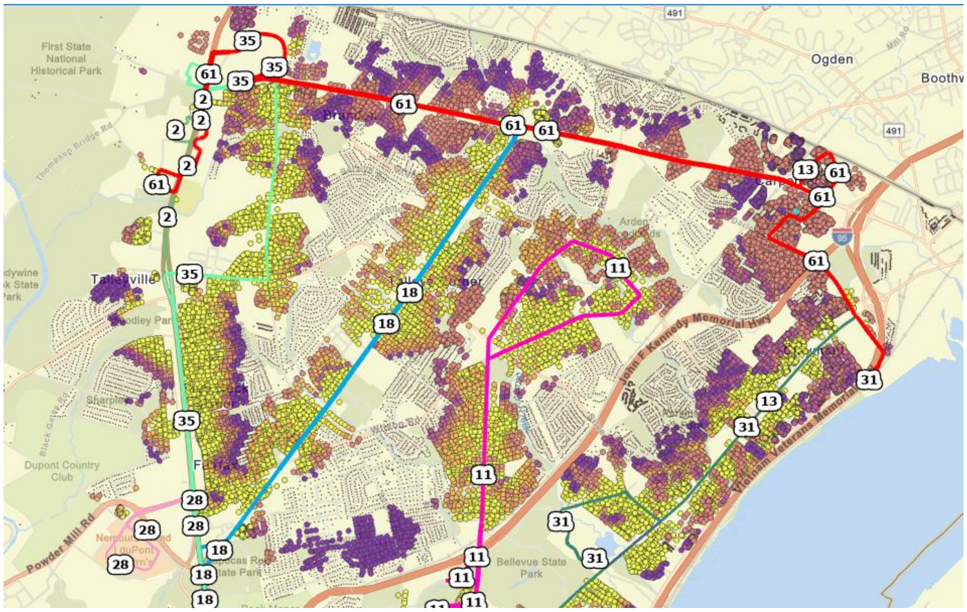
In recent years DelDOT has produced trip generation and travel studys at the tax parcel level which though more demanding computationally allows for more detailed community views. Origins and destinations can both be at this level. CADSR has created a Tax Parcel Destination file from a detailed Place file. The tax parcel level may have other benefits as it involves ownership and more tied to access rights. With a parcel based destination file, shopping centers contain numerous destinations.

Parcel Based Destinations



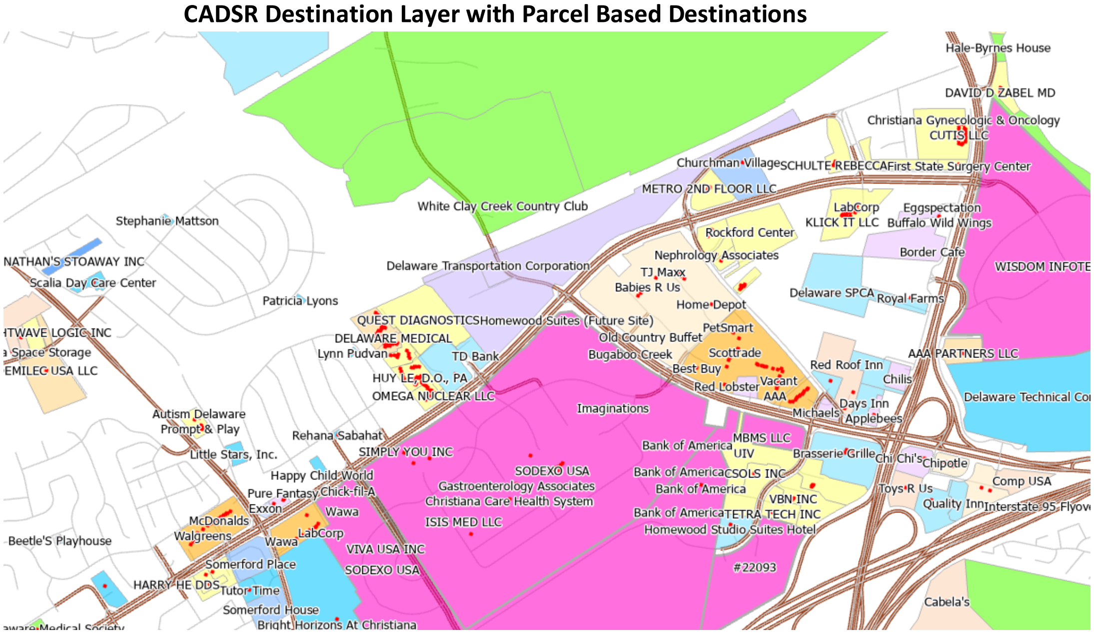
In some cases, analysis can be done at the housing unit level for greatest detail.

Housing Unit Based Transi Access to Employment Centers



For the highest resolution of destination data CADSR developed a place file that includes the location of close to 30,000 non-residential destinations classified by land use and NAICS code.

CADSR Destination Layer with Parcel Based Destinations



Estimation

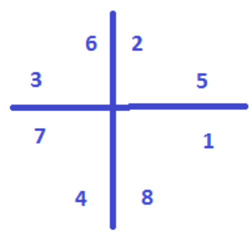
This section reviews issues for travel demand estimation, and travel flow estimation where no measure exists. The focus is on how travel demand data and traffic flow data can be used together.

Having developed a framework for consistently locating the various types and sources of travel data, we can view what we know and move toward interpreting the data to understand what it is telling us and further integrate based on the relationships that exist between measures in the network. From travel demand studies we could produce trip estimates by time of day for residential areas, to combine with measures.

Intersection Counts, TMC Device Volumes, and Travel Demand Trips

Perhaps we would like to fill in the blank areas where we don't have data, or we would like to compare neighboring path measures. For volume of traffic the network produces constraints and relationships for intersections as summarized by figure below that shows relationships for turning movements. The equations/constraints for volume counts that exist in the network can be easily derived from the turn tables.

Turning Movement Algebra



From	To	Direction
5	2	Eastbound Right (5r)
5	3	Eastbound Straight (5s)
5	4	Eastbound Left (5l)
8	1	NB right 8r
8	2	NB straight 8s
8	3	NB left 8l
7	4	EB right 7r
7	1	EB straight 7s
7	2	EB left 7l
6	3	SB right 6r
6	4	SB straight 6s
6	1	SB left 6l

5,6,7,8 are going in

1,2,3,4 are going out

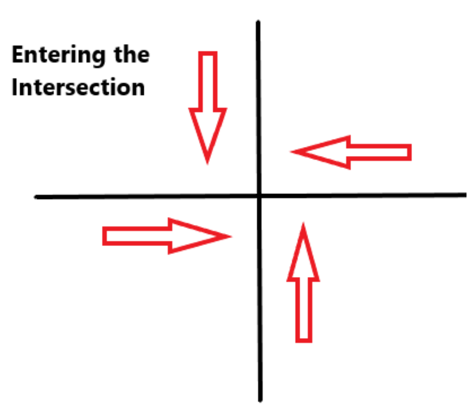
U turns would be 6-2, 5-1, 7-3, 8-4

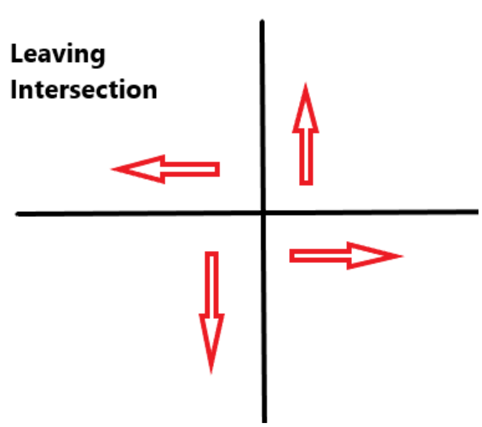
Volume out
$1 = 7s + 8r + 6l + 5u$
$2 = 8s + 5r + 7l + 6u$
$3 = 5s + 6r + 8l + 7u$
$4 = 6s + 7r + 5l + 8u$

Volume in
$7 = 7s + 7r + 7l + 7u$
$8 = 8s + 8r + 8l + 8u$
$5 = 5s + 5r + 5l + 5u$
$6 = 6s + 6r + 6l + 6u$

Understanding turning movements is certainly needed when timing street lights and specifying the connectivity of a network. Taking a step back from the traffic within the intersection, an alternative to focusing on turning movement percentages would be to examine percentages of inbound and outbound in the network. This has advantages:

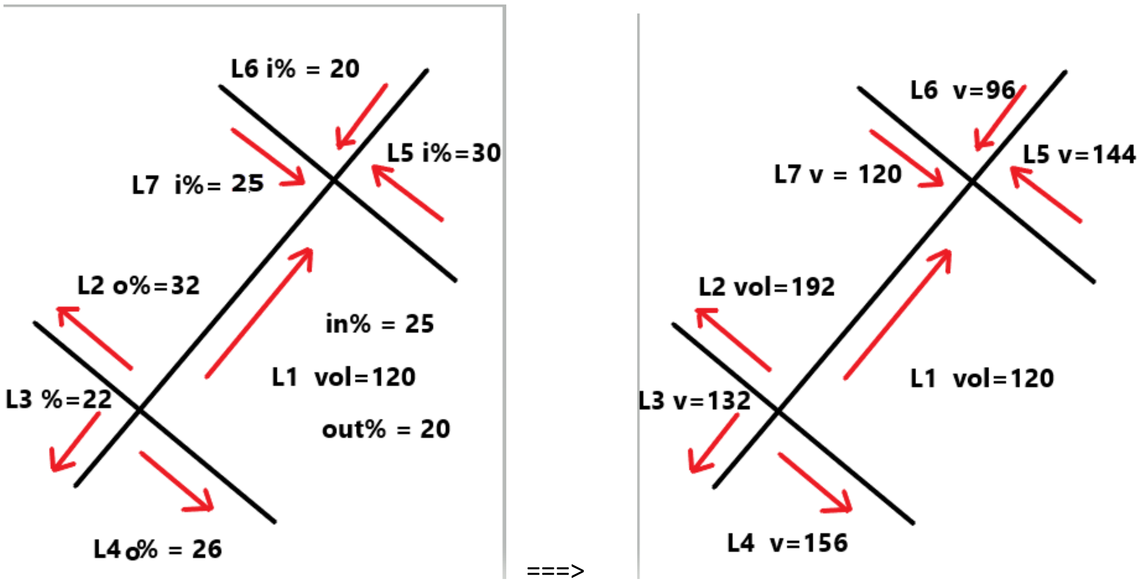
- directional movements in and out of the intersection are easier to measure than turning movements.
- Usually, the focus is on volume on the road segment, not where the traffic on the road came from
- While the same type of information is needed when estimating turning movements, flows in and out appear to be easier to estimate





Intersection In and Out Percentages

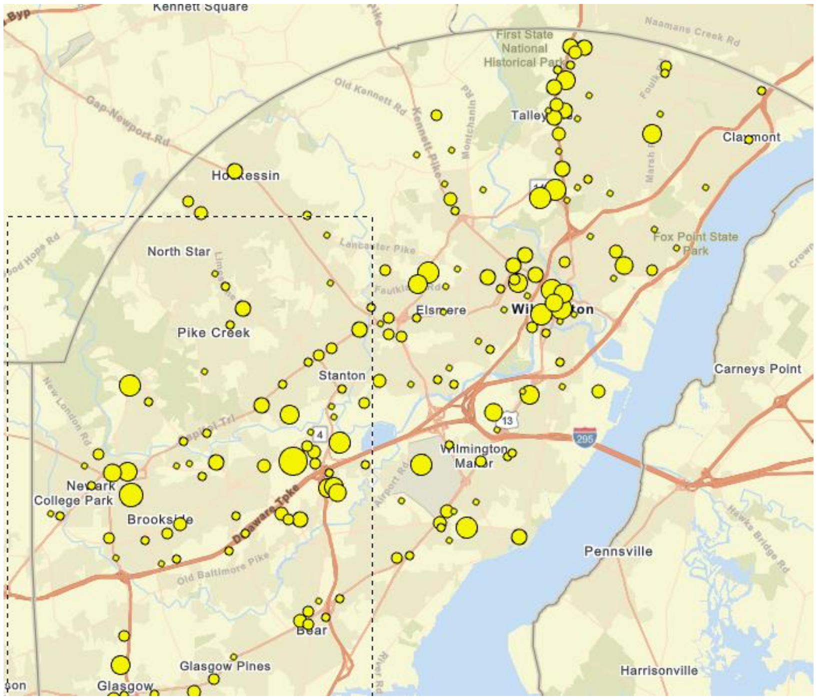
In the absence of an intersection count, Directional Percentage In or Out could be used to estimate parts unknown. For instance, in a simple example, suppose we know the percentage of volume exiting and entering the intersections as below. Knowing L1 had a particular volume (120) and that L1 is 20% of the traffic leaving the bottom intersection and 25% of the traffic entering the top intersection, we could estimate the volumes as in figure below.



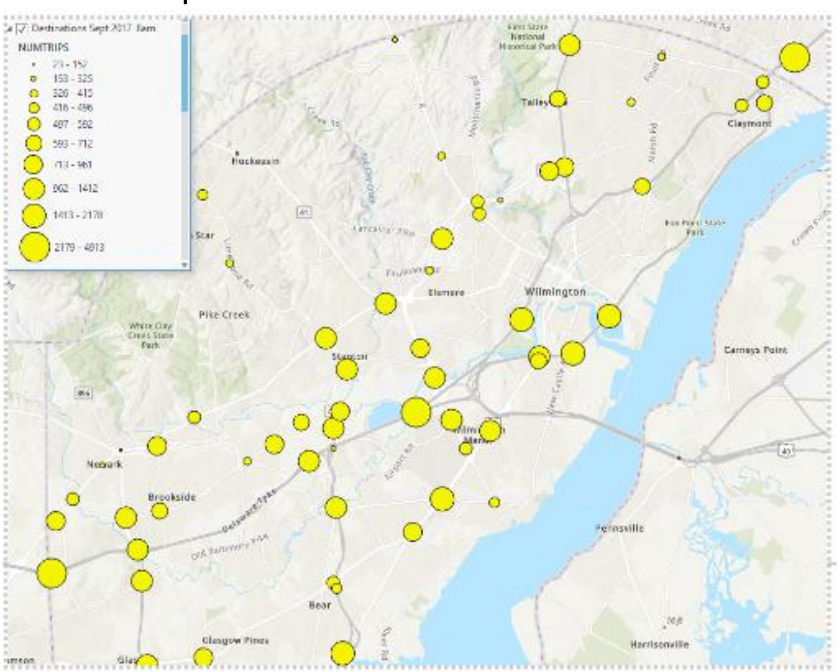
We might be comfortable predicting how many trips are generated from origins, but understanding where those trips go and the flow and direction of traffic is determined from a balance of trip productions and attractions. Gravity modeling directs the selection for where produced trips go, a balance of attractiveness and distance to travel.

It's directional. We expect traffic to go toward where jobs are for work trips, and towards stores for shopping trips. Measures of activity, particularly by time, are other types of information that we want to incorporate.

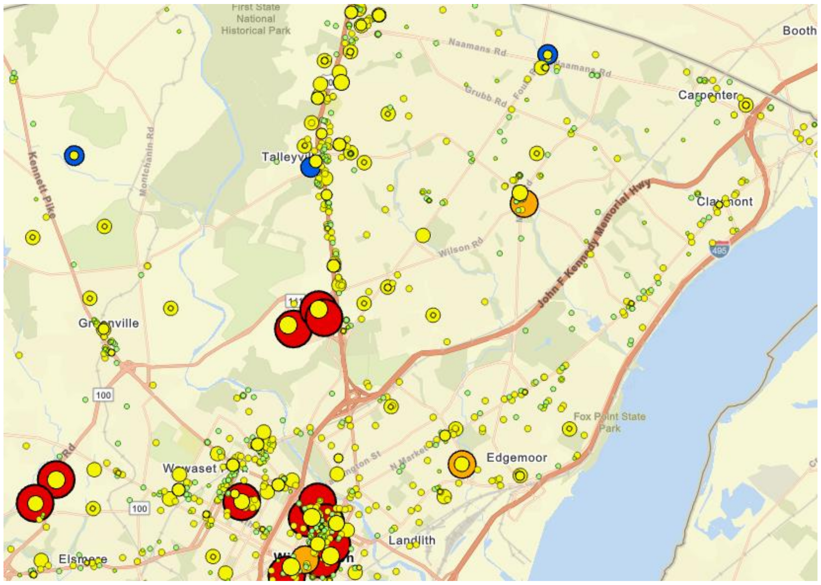
Job clusters in New Castle County

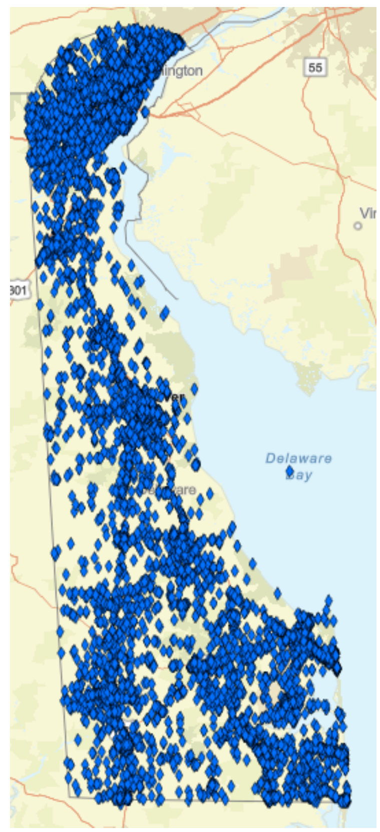


Trip destinations in Bluetooth Data.



Employment Centers





CADSR maintains a place file that includes the location of close to 30,000 non-residential destinations. The ability to estimate directional flows out of intersections was tested for a few intersections. Given that a traveler was in the center of an intersection, the goal was to estimate the likelihood of going a particular direction. Each destination could be weighted with an attraction value, for instance the number of jobs, and the weight would be inverse square distance factor (= NumberEmployed * 1/mile^2). In one example using the intersection at Route 7 and Paper Mill Road, destinations were not weighted. the influence of each destination (1/mile^2) was summed and percentages in out directions were tabulated. The resulting percentages were Westbound 17%, Southbound 44% and Northbound 39%. By comparison, percentages in each direction were obtained from a traffic count and are shown in figure below for morning and evening peak and midday. The day average from the traffic count was WB 19, SB 43, and NB 38, very similar to WB 17%, SB 44 and NB 39 based on proximity to destinations. And only the distribution of the destinations affected it since they weren't weighted by an attraction estimate. A day directional average or a midday average would be expected to be a closer value than a morning or evening peak in this comparison because of the effect of employment travel. Similar results occurred with investigations of two other intersections, where percentages calculated were within a few percentage points of what the traffic count indicated. This could be coincidental and certainly this method of determining intersection volume flow out percentages would have to be studied more but it seems promising and somewhat expected that gravity models have something going for them.

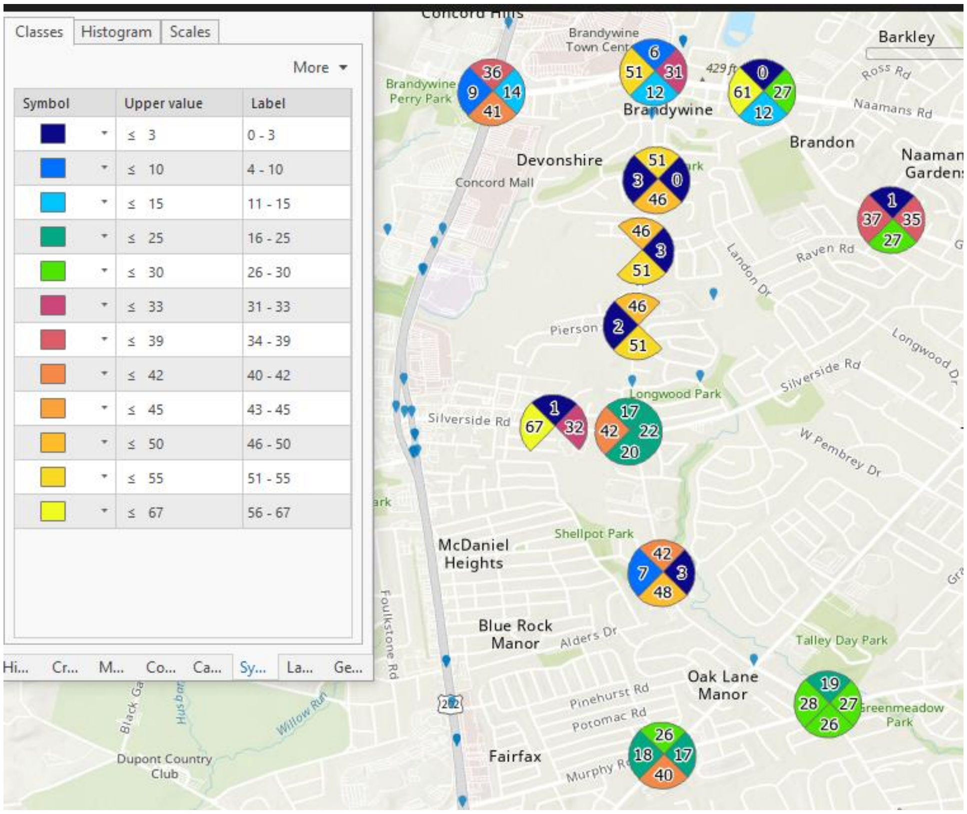
Percentage Trips Out for Route 7 and Paper Mill Road (southbound, westbound, northbound)

Tabulated Traffic Count

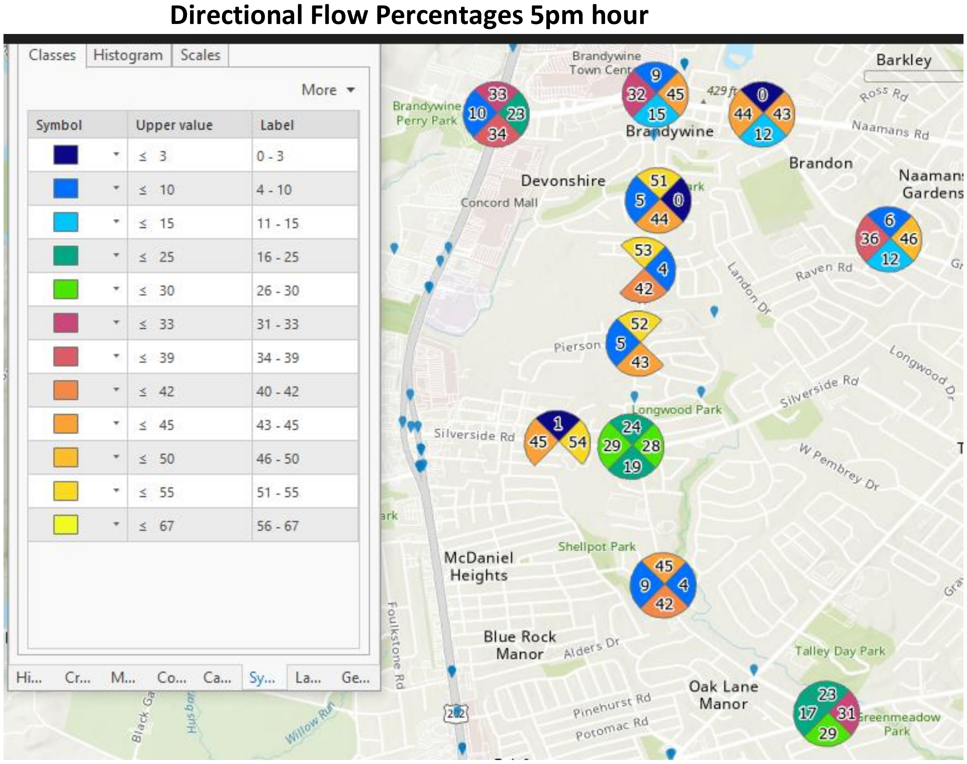
	PROB SB	PROBNB	PROBWB	avg sb pk	avgnbpk	avgwbpk
7:00-7:15	56	29	16	48.375	33.75	17.625
7:15-7:30	51	35	14			
7:30-7:45	43	37	20			
7:45-8:00	44	31	25			
8:00-8:15	50	34	16			
8:15-8:30	51	34	15			
8:30-8:45	48	33	18			
8:45-9:00	44	37	17			
11:00am	41	42	17	43.75	39.875	16.375
11:15am	47	37	17			
11:30am	45	41	15			
11:45am	45	42	13			
12:00pm	40	40	18			
12:15pm	43	40	18			
12:30pm	44	40	16			
12:45pm	45	37	17			
4:00-4:15	38	41	21	35.625	40.625	23.75
4:15-4:30	37	44	19			
4:30-4:45	34	40	26			
4:45-5:00	35	41	24			
5:00-5:15	32	41	27			
5:15-5:30	39	38	23			
5:30-5:45	34	41	25			
5:45-6:00	36	39	25			
day average	43	38	19			

Traffic counts can show measures of the expected direction of traffic. Figures below show the percentage direction of traffic in each direction of the intersection for 8am and 5pm for a number of weekday traffic counts. Directional tendencies can also be provided by other data sources, for instance as available from TMC devices. It gives the impression that you could use various measurements to produce directional vector fields by time of day, by day of week, by month, etc.. Understanding that directional flow by time of day would greatly help in the extension of measures and fully understanding the flow of the system. It is about land use and the travel network and describes where people want to go.

Directional Flow Percentages 8am Hour



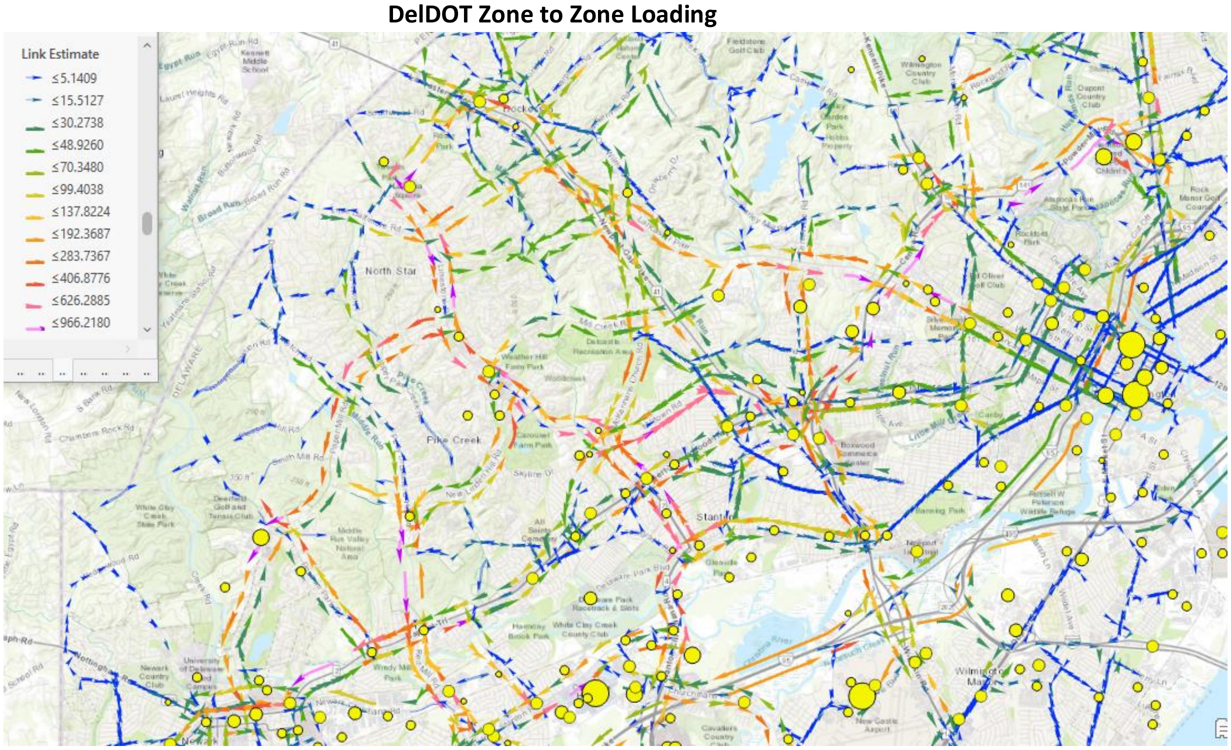
Directional Flow Percentages 5pm hour



Origin Destination Loading

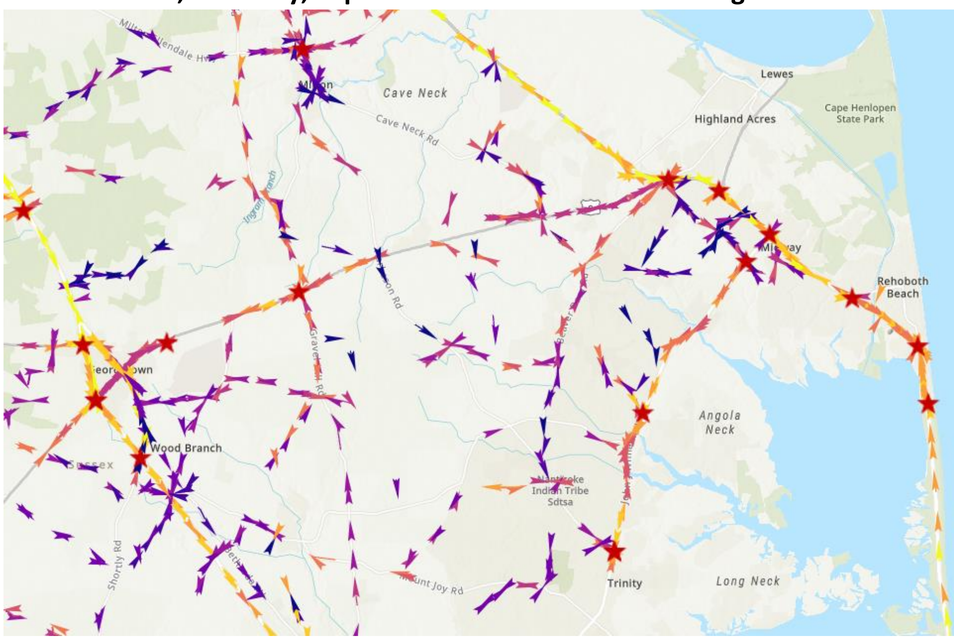
Another interesting method of determining flows through the network is the loading of volumes from origin to destination tables onto paths. For instance, a zone to zone origin-destination table can be produced as part of travel demand modeling. It tabulates all zone pairs with estimated number of daily trips for each origin-destination pair. As a result of the modeling of the paths between origins and destinations the frequency each directional road segment is traveled can be determined. This is how volumes on path segments are estimated. Below is a partial view of the loading of a 2018 zone to zone TDFM tables. From this, intersection flow percentages could be estimated for all major intersections. The OD table is a daily summary table of total trips to destinations, not the return trip home, that is arrayed by 5 trip purposes, Home Based Work, Home Based Shopping, Home Based Other, Non Home Based Work. It is expected that this loading and the trip classification could be a basis for intersection directional (N,S,E,W) volume out percentages by time of day

DelDOT Zone to Zone Loading



In a similar way, trip origin and destination pairs can be extracted from the Blue Tooth data and one example is shown below. If detections are comparable between detectors this could be very useful since the collection is continuous and a percentage flow could be calculated by time of day, day of week, season, etc. . Further study could yield interesting results about optimal measures interspersed throughout a network.

7 to 8 am , weekday, September 2021 Bluetooth Loadings



Distribution and Presentation

Analysis and data management is done using ESRI GIS tools. There are very large capabilities available for cloud based data libraries (ARCGIS.COM), mapping sites and servers, collaboration sites, story books, development tools, and other resources, that can support the approach presented.

Conclusion

As demonstrated, traffic data and travel demand data of many kinds can be integrated and related in a spatial data system. For traffic data this supports getting the most out of measures but will also focus collection efforts through a better understanding of what is available. Those in traffic will be considerably more aware of travel demand. For travel demand, to more easily examine measures and estimates of performance allows for more informed trip generation estimates and study of travel. Everyone gets a richer information resource and a foundation for new measures and analysis.

Progress will continue to be made in developing a dynamic and comprehensive view of the performance of Delaware's transportation system through a combination of measures and estimates. Estimation efforts will include management and consolidation of available measures and constraints of the network connectivity. Extending our information and developing estimates where there are no measures is a focus on the direction of travel flow throughout the network. Direction as can be extracted from traffic counts, loop detections, orgin-destination loadings and other measures or derived measures provides information about the relationships of the network, and greatly enhances estimation. It is also a further use of the information we have. With measures and estimates in a consistent format, analysis resources can be employed including a very wide range of network analysis for route and origin-destination studies, as well as linear referencing tools to consolidate and aggregate linear measures.