DCT 186

Application of Global Positioning System (GPS) to Travel Time And Delay Measurements

Summer 2005

by

ARDESHIR FAGHRI
MICHAEL FRY
JOOST VAN BOEKHOLD
EVY VLAHOS
AARON DENTEL-POST
HARRY SHENTON

Department of Civil and Environmental Engineering
College of Engineering
University of Delaware

August 2005

Delaware Center for Transportation
University of Delaware
355 DuPont Hall
Newark, Delaware 19716
(302) 831-1446

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DELAWARE CENTER FOR TRANSPORTATION
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Introduction

Since 1996, the Global Positioning System (GPS), a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations, has collected travel time and delay data on major roadways throughout Delaware. The GPS statistically matches manual data collection in accuracy and efficiency and therefore continues to effectively collect data within Delaware today. Every year, a report is compiled documenting and summarizing the collected data. The *Application of Global Positioning System (GPS) to Travel Time and Delay Measurements – 1997 Phase* report describes the testing of the applicability and accuracy of the GPS system, while the *1998 Phase* report provides step-by-step instructions for data collection.

In past years, travel data was collected during peak-travel times between mid-September and Thanksgiving. In 2002, data collection expanded to include summer peak-travel times as well. In 2003, the summer mileage covered increased from 652 to 896 miles, and in 2004, this mileage increased again from 896 to 1006 miles. This report describes the methodology used to collect summer peak-travel time data and includes a summary and conclusion of the collected data.

Methodology

The continued success of the travel time and delay data collected over the past nine years in monitoring congestion trends along Delaware roadways in the fall months has led the Delaware Department of Transportation (DelDOT) to include the major travel routes to and from the shore points during the summer months in the annual data collection. This data has become critical to the analysis of travel patterns surrounding the Delaware beaches and to the monitoring of congestion along these major routes.

All major routes leading to and from the Delaware beaches were covered. Routes and numerous additional segments were added in 2003 and even more have been added in 2004. No new segments were added in 2005. All of the routes covered can generally be divided into two groups:

- North-South roads: SR 1, US 13, US 113, SR 896, SR 71, SR 9 (new), I-95, and I-495. These routes are primarily used by travelers coming to and from the main northern points, including New Castle County, Pennsylvania, New Jersey, Cecil County (in Maryland), etc.
- East-West roads: SR 404, SR 14, SR 16, SR 20, SR 24, SR 26, SR 30, SR 36, SR 54, I-295. These roads are generally used by travelers from Maryland, Virginia, and Washington, D.C. entering the Delaware shore points.

For each route that was covered, control points were selected between the segments of the roadway. The control points were positioned at major intersections or where road characteristics, such as the number of lanes, speed limit, or development type changed. Once the control points were selected, they were entered into data dictionary files using the Pathfinder editing system, which allows control points and specific attributes to be added, deleted, or edited. Data dictionary files allow control points and other roadway attributes, such as the speed limit and number of lanes, to be collected and stored with only a click of the mouse.

A major feature that was added to data collection in 2004 was the addition of a background map with corresponding control points to the Aspen software used while driving. This background map would allow the data collector to view where the car was in relation to the next control point as well as the surrounding roads and intersections. The control points were represented by red crosses throughout the background map and were placed exactly where the next segment began. Both the background map and control points were added by layering two shape files extracted from the Geographic Information Systems (GIS) network. By adding these features, the data collector no longer had to rely on the car odometer and predetermined distances to anticipate the next control point.

As for data collection times, data was collected on summer weekends between June 19th and August 19th. Generally, the majority of beach-goers travel to and from the shore points on Friday afternoons, Sunday afternoons, and throughout the day on Saturday. Thus, data was collected heading toward the beach (southbound and eastbound) on Friday evenings from 3 to 7 PM and from 9 AM to noon on Saturday mornings. Data was also collected heading away from the beach (northbound and westbound) on Saturday evenings from 4 to 8 PM and on Sunday afternoons from 4 to 7 PM. These periods were chosen based on DelDOT's recommendations and on observations made during the summer 2003 data collection. In addition, contact was made with certain toll plazas, located along some of these beach routes, including those in Dover, Odessa, and on I-95. The information obtained highlighted specific times during the weekend when traffic volume was at its peak but only confirmed the time intervals mentioned above.

Due to the number of routes to be covered and the need for at least 2 successful runs of each route, it was necessary to use two vehicles to complete the project on time. Two people rode in each car: a driver and a data collector. The latter operated the laptop computer and noted each attribute, while the former attempted to approximate the average driver. While one person might feasibly drive and collect data at the same time, this would present a serious safety hazard.

Each route was driven at least twice in each direction to guarantee the accuracy of the data that was collected. In the event of problems, whether due to equipment failure, weekend-long inclement weather, or large irregularities in the travel patterns, the roads were traveled again to ensure that peak beach-traffic patterns were captured. Also, in the event of heavy rain or very poor weather conditions, which happened twice, data was not collected at all, in order to avoid the collection of inaccurate data, which would not fully represent particular travel and delay times, as well as ensure the safety of data collectors. Where more than two runs were completed, only the results of the two or more that best captured the peak volume were used and averaged. Once all the data was collected, exported, and printed, it was analyzed and summarized on a segment-by-segment basis.

Differences between Fall and Summer Projects

The same basic methodology is used in both the fall and summer GPS Travel Time projects. In addition, many of the roads covered are the same. However, there are some key differences separating the projects:

1. Some of the roads covered were different than those covered in the fall. The fall project emphasizes commuter routes, particularly in New Castle County, while the summer project covers major beach routes throughout the state.
2. Instead of weekday morning and afternoon collection times as in the fall, the summer data was collected on weekends.
3. In the fall, data is collected separately for both morning (AM) and afternoon (PM), and at least two runs of each route are completed in each direction at each time of day. Results are then tabulated separately for AM and PM. In the summer, there is no AM/ PM division. Thus, roads are covered only twice in each direction.

4. Because the summer project focuses primarily on statewide, long-distance beach traffic rather than short intra-county commuter trips, the roads are not separated by county as they are in the fall.

Interpretation of 2005 Summer Data

This report includes a data table with all of the collected information arranged by route name. The leftmost column contains the name of the route being covered. Each route is then divided into the different segments and data is provided in each direction. To the right of the segment names, the table contains the following information:

- Distance (Miles) – This is the distance in miles for the given segment of roadway shown to the left. When the term "Total" is specified, the distance corresponds to the total length from the first control point to the last.

- Mean Peak Travel Time (Seconds) – This is the average time in seconds that was required to travel the length of the segment.

- Mean Peak Travel Speed (mph) – The average speed of the test vehicle from one point to the next is the Mean Peak Travel Speed. This value is given in miles per hour and is obtained by dividing the Distance of the segment by the Mean Peak Travel Time.

- Total Peak Delay (Seconds) – This is the time, in seconds, spent in delay on the given segment. By DelDOT's definition, delay is the time during which the vehicle speed drops below five miles per hour.

- Peak Delay Source – This is the reason for the delay noted in the previous column. Reasons for delay include signals, construction, accidents, congestion, pedestrian crossings, train crossings, etc. Traffic signals are the primary cause of delay.

- Mean Peak Running Speed (mph) – This is the average speed in miles per hour that a vehicle would travel through the section of roadway if delay were not experienced. The running speed, R, is obtained by the following equation:

$$R = \frac{\text{Distance}}{\text{Mean Peak Travel Time - Total Peak Delay}}$$

- Percent Time in Delay – This is the percentage of time spent in delay for the route segment shown. The percentage is found by dividing the Total Peak Delay by the Mean Peak Travel Time, then multiplying the quantity by 100. Example:

$$\text{Percent Time in Delay} = \frac{82.08\,\text{sec}}{360\text{sec}} \times 100 = 22.8\%$$

- Number of Lanes – This represents the number of lanes during the given segment. For those segments that have a varying number of lanes, two or more values will appear in this column.

- Posted Speed (mph) – This represents the posted speed limit for the given segment of the roadway shown. For segments with more than one posted speed, two or more values will appear in this column.

Conclusion

Beach traffic congestion during the summer of 2005 was again collected both precisely and effectively by the GPS Travel Time and Delay project teams. Although no new roads received attention, all roads covered in 2004 were again covered in 2005. This allowed for the continuing collection and analysis of travel time and delay time along the existing summer routes.

Data collection using a GPS unit is an advancement to manual data collection. The system, however, is not perfect and some problems arose. A minor, but continuing problem, the notebook computers occasionally malfunctioned during data collection, which would shut off the GPS units. Also, one GPS unit stopped working for a brief period and had to be sent for maintenance. At times the satellite signal was lost, due to inclement weather or tree obstruction. Nonetheless, manual data collection was always feasible and was used in the few instances when necessary.

Poor road markings and unforeseen road conditions made recollection of delay data on some roads necessary. On SR 24, a train crossing blocked the road when no train was coming causing traffic to stand still. Flooding also occurred during a brief rain storm on SR 24 between SR 1 and SR 23. The road signs to follow SR 20 south along US 13 are poorly marked, indicating turns incorrectly, or not at all. Trucks driving north on SR 26 block road signs which are too close to the edge of the road. On Northbound US 13, part of the road was used for the use of the Delaware State Fair.

Drivers to the beach appeared to be driving faster than in previous years, and drivers were aggressive on the longer north and south bound roads. Speeds exceeding 70 miles per hour on roads with 55 mph speed limits was not uncommon. In addition, drivers were observed along I-95 and I-495 driving down the breakdown lane in order to avoid the congestion. Most of the time the drivers on the breakdown lane were trying to turn off onto an exit and in some cases caused fender benders from people turning off appropriately. In addition, the development of large shopping centers along SR 1 have caused excessive delays near the beach. Drivers appear to be using US 113 to circumvent the signalization along the last few segments of SR 1.

Variability in the time of peak traffic volume also caused difficulties. There are numerous factors that cause variation in this peak time, some of which are current weather, predicted weather, and holidays. If weather is predicted to be poor, fewer vacationers go to the beaches, or if the weather is sunny and then turns rainy, people usually leave early. Consequently, while the data collection periods generally coincided with major peak periods, it was difficult to capture the best peak time, especially during the Saturday runs. On the other hand, traffic peak times on Friday evenings remained consistent, with travel and delay times appearing considerably high, especially on I-95 and I-495. However, when analyzing and observing this data, one must recognize the possibility of business travel mixing with beach travel during this period. Lastly, minimal human error might have occurred during driving, data collection, and computations, possibly affecting the outcome of certain data results.

Ideally, in the future, a computerized process to extract the GPS results and travel data is expected to yield greater accuracy and efficiency. Additionally, observations noted that data collection beyond US 13 on the East-West routes, not including SR 404, does not provide strong travel time and delay data and may be unnecessary in future projects. It was determined that hardly any congestion or even volume was observed past this point and up until the Maryland state line. Thus, the last control point on these roads could be placed at the intersections with US 13, as such a change would result in more resources being concentrated on more heavily traveled segments of other routes. The possible addition of SR 9, however, has continued to be an unsuccessful addition. After several runs of SR 9 both northbound and southbound, it was discovered that there is no sufficient necessity to include this route in the data collection. This was concluded from the result that no considerable delay was experienced, and, in fact, no congestion or even moderate volume was observed at all beyond Wilmington in New Castle County.

For the most part, data is collected every day of the weekend with no specification given to which day, only which direction. Thus, data collected on Friday evenings is averaged with data collected on Saturday mornings, since both times represent southbound traffic to the shore points. So far, there has been no serious problems or inaccuracies with this method; however, it may be more beneficial to collect and analyze this data on more of a day-to-day basis, with possibly two runs being completed for each route in each direction as well as on each day, in order to allow for a more direct analysis of the data and a more specific account of when beach roads are most congested. Also, after careful observation along with direct contact with the toll plazas, as mentioned earlier, it was discovered that congestion northbound on Saturday mornings can be just as high as congestion southbound at this time. Methods of collection including Saturday morning north bound routes may be a possible addition to future projects, and it may contribute to the accuracy and development of a successful travel time and delay study during the summer, when traffic peak times do vary considerably. In order to allow for these additions and the time constraints put on summer data collection, it may be necessary to include a third car, as well as a third set of data collectors, in accomplishing this summer project in the future. This summer project was very successful in capturing an accurate picture of travel time and delay all over Delaware and its shore points, and these changes would not only continue the success of the project but allow for a more detailed and comprehensive approach to GPS data collection and its application to such travel time and delay measurements.

An unusually high improvement rate was observed along the ten most improved segments. Four segments improved from LOS F to LOS A, while another four segments improved from an LOS E to an LOS A. While, the numbers seem high, there is a rationale explanation. Segment 'SR 273 (exit 162) to Christiana Mall (exit 164)' experienced construction during the summer of 2004. In the past year, EZ Pass express lanes were installed on segments 'Exit 1 (SR 896) to MD Line', 'MD Line to Exit 1 (SR 896)' and 'Exit 98 to Scarborough Rd (104),' improving a driver's ability to circumvent the toll booths. While analysis of 2004 data reveals no further explanation for the drastic improvement, two segments, 'US 9 (non truck route) to SR 404/18' and 'SR 20 West to SR 24' were classified as LOS B and A respectively in 2003. In 2004 these same two segments were classified as two of the most degraded segments between 2003 and 2004.

Appendix A

<u>Notable Segments:</u>

This is a listing of segments which appear to require special attention.

Equations:

$$\%\_PS\_TS = \frac{MeanPeakTravelSpeed - WeightedAverageSpeed}{WeightedAverageSpeed}$$

$$\%\_D\_PS\_TS = \%\_PS\_TS_{2005} - \%\_PS\_TS_{2004}$$

A_1: 10-Most Degraded Segments

Segments are selected by taking the difference between the LOS of 2005 and the LOS of 2004 and taking the segments which indicated the most drastic decline. If two or more segments had the same level of degradation, the segment with the least %_D_PS_TS took priority.

A_2: 10-Most Improved Segments

Segments are selected by taking the difference between the LOS of 2005 and the LOS of 2004 and taking the segments which indicated the most notable improvement. If two or more segments had the same level of improvement, the segment with the greatest %_D_PS_TS took priority.

A_3: 20-Worst Segments

The 20 segments with the greatest LOS are selected and displayed in this table.

A_1: 10-Most Degraded Segments:

ROUTE_NAME	DIR	SEGMENT	LOS_04	LOS_05	%_D_PS_TS
DuPont Hwy	NB	SR 72 (152) to SR 1/US 13 Split	A	F	-54.09%
SR 26	WB	SR 30 to SR 54 split	A	C	-42.76%
US 13	SB	SR 9 West to SR 24	A	D	-39.04%
DuPont Hwy	NB	SR 896 to C&D Canal	A	D	-35.60%
DuPont Hwy	SB	C&D Canal to SR 896	B	E	-29.76%
DuPont Hwy	SB	SR 273 to US 40	C	E	-25.90%
SR 896	SB	I-95 to Old Baltimore Pike	B	D	-22.83%
Relief Route	SB	US 40 (exit 160) to US 13 North (exit 156)	A	E	-19.90%
US 113	SB	US 13/113 Split to 1/113 Merge (SR 1 Exit 95)	B	D	-17.38%
Relief Route	SB	SR 24 to Rehoboth Avenue	B	E	-13.14%

A_2: 10-Most Improved Segments:

ROUTE_NAME	DIR	SEGMENT	LOS_04	LOS_05	%_D_PS_TS
Relief Route	NB	SR 273 (exit 162) to Christiana Mall (exit 164)	F	A	119.41%
US 113	NB	US 9 (non truck route) to SR 404/18	F	A	55.90%
I-95	SB	Exit 1 (SR 896) to MD Line	E	A	55.61%
I-95	NB	MD Line to Exit 1 (SR 896)	F	A	54.71%
I-495	SB	Exit 1 (US 13) to I-95	F	A	53.66%
Relief Route	NB	Exit 98 to Scarborough Rd (104)	E	A	51.18%
I-95	SB	SR 141 to Merge with SR 1	E	A	50.38%
US 113	NB	SR 20 East to SR 24	F	B	45.14%
US 113	SB	SR 20 West to SR 24	F	B	42.49%
I-95	NB	Merge with I-95 N to SR 141	E	A	38.13%

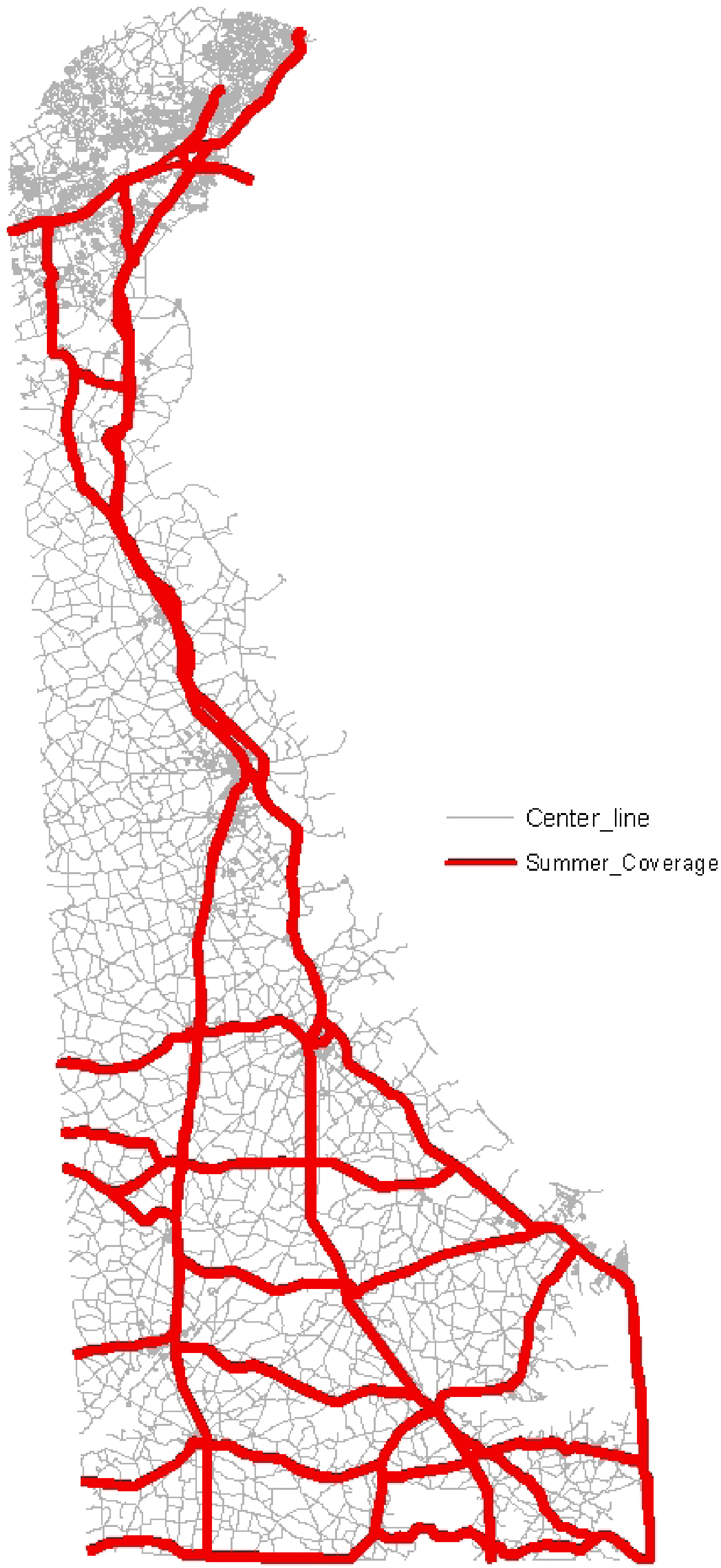
A_3: 20-Worst Segments:

ROUTE_NAME	DIR	SEGMENT	LOS	LOS %	Av. Speed (mph)
DuPont Hwy	SB	I -495 to I-295	F	84.55%	7.7
SR 896	NB	SR 1 to US 13	F	84.18%	7.9
I-95	NB	Exit 3 (SR 273) to Exit 4 (SR 1)	F	79.17%	11.5
SR 20	EB	US 13 / SR 20 W to US 13 / SR 20 E	F	79.03%	8.7
I-295	WB	SR 9 to US 13	F	77.89%	11.1
I-295	WB	US 13 to I-95	F	75.80%	12.1
US 13	SB	SR 20 West to SR 20 East	F	72.89%	13.4
I-95	SB	I-495 JCT to Exit 5 (SR 141/I-295 JCT)	F	72.21%	15.3
DuPont Hwy	SB	SR 8 to US 13/113 Split	F	57.98%	19.5
Relief Route	SB	James St. to SR 54	F	57.85%	15.5
DuPont Hwy	NB	SR 72 (152) to SR 1/US 13 Split	F	55.63%	25.0
Relief Route	NB	King Charles Ave (DE) to Rehoboth Avenue	F	51.65%	16.7
I-95	SB	I-295 to Exit 4 (SR 1/Churchmans)	F	50.76%	26.7
Relief Route	NB	Rehoboth Avenue to SR 24	F	50.16%	19.1
DuPont Hwy	SB	SR 141 to SR 273	E	69.84%	15.1
SR 24	WB	SR 30 to US 113	E	67.95%	10.7
DuPont Hwy	SB	SR 273 to US 40	E	67.55%	16.8
DuPont Hwy	SB	I-295 to SR 141	E	61.04%	19.5
Relief Route	NB	Christiana Mall (exit 164) to Merge with I-95 N	E	46.49%	29.4
DuPont Hwy	NB	US 13/113 Merge to SR 8	E	46.41%	18.8

Appendix B:

Summer Coverage:

The following GIS drawing displays in red all the routes that are covered by the Summer 2005 GPS data collection.


Center_line
Summer_Coverage

Appendix C:

Mean Peak Travel Speed:

The following GIS drawing displays the mean peak travel time in miles per hour in both directions for every segment of the Summer 2005 GPS data collection.

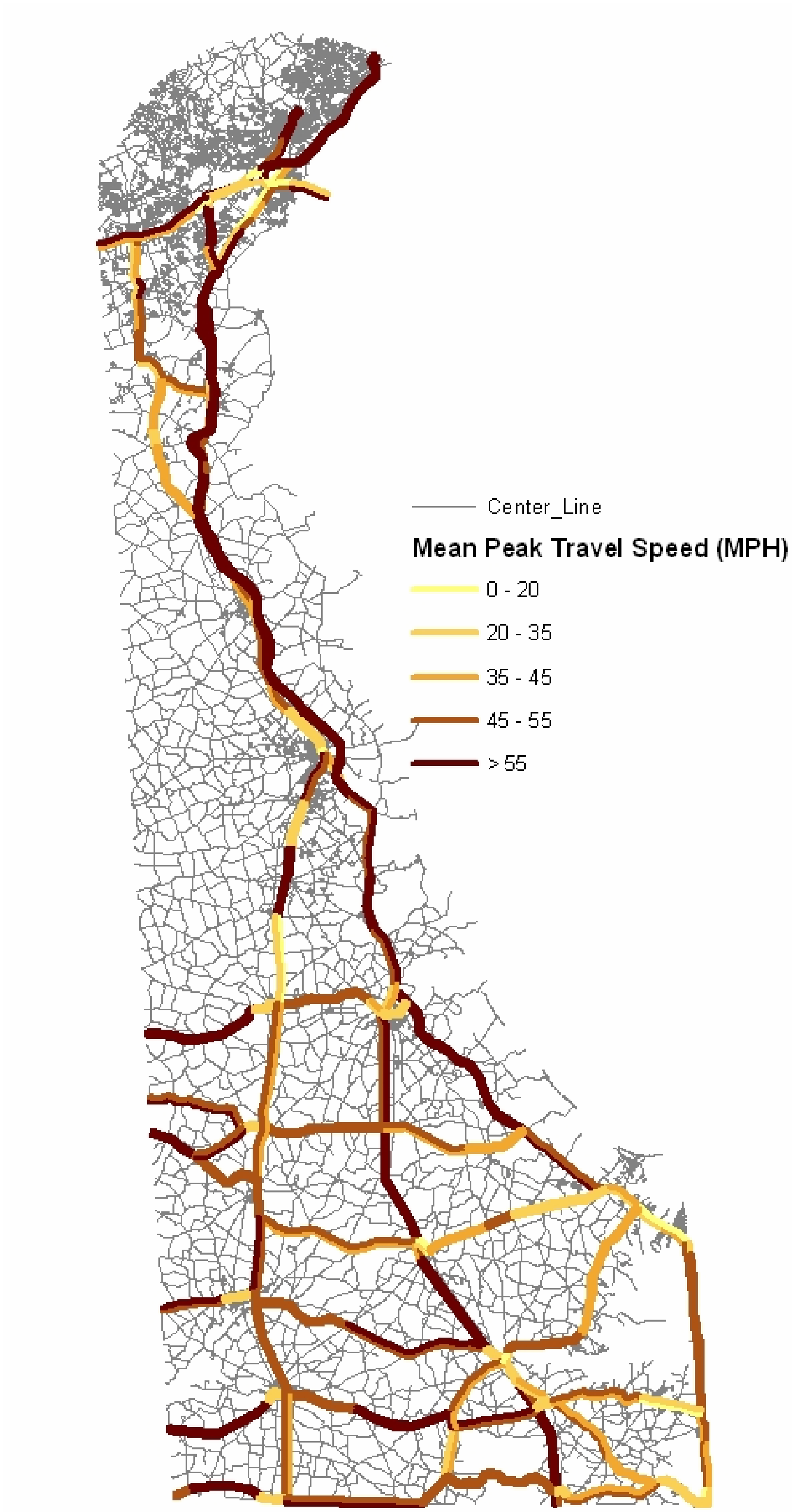
Methodology:

The mean peak travel speed for every segment is calculated by averaging the total time required to travel the length of each segment of all runs (mean peak travel time), and dividing the segment length by that time.

Equations:

$$MeanPeakTravelTime = \frac{\sum_{1}^{n} TotalTravelTime\_Run(x)}{n}$$

$$MeanPeakTravelSpeed = \frac{SegmentDistance(Miles)}{MeanPeakTravelTime(Seconds)} * \frac{3600\,seconds}{1\,hour}$$



Center_Line
Mean Peak Travel Speed (MPH)
0 - 20
20 - 35
35 - 45
45 - 55
> 55

Appendix D:

<u>Mean Peak Delay:</u>

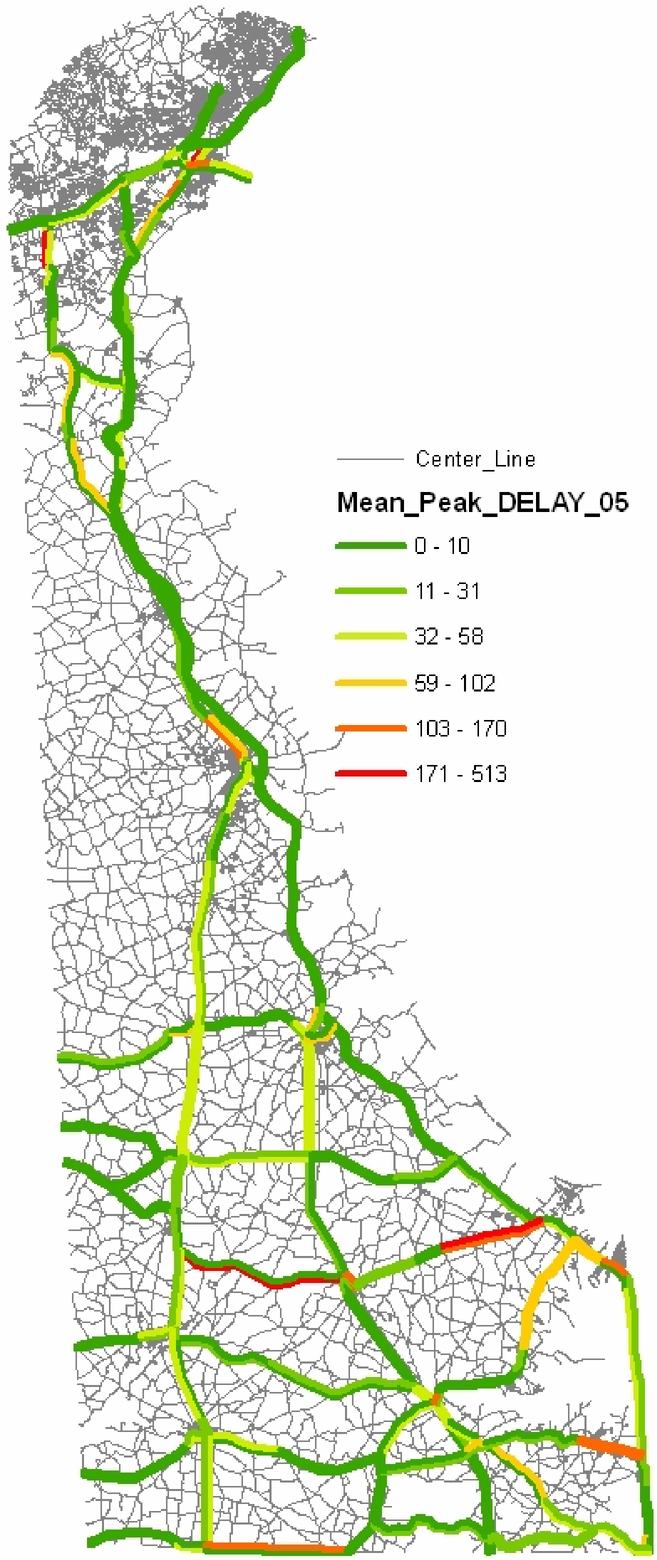
The following GIS drawing displays the average delay along each segment in both directions for every segment of the Summer 2005 GPS data collection.

Methodology:

Average delay is calculated by adding together the delay measured in each run and dividing the total by the number of runs. The result is displayed in seconds of delay.

Equations:

$$AverageDelay(\sec onds) = \frac{\sum_{1}^{n} Delay(\sec onds)\_run(x)}{n}$$


Center_Line
Mean_Peak_DELAY_05
0 - 10
11 - 31
32 - 58
59 - 102
103 - 170
171 - 513

Appendix E:

Posted Speed vs. Average Speed Difference:

The following GIS drawing displays the percent difference between the posted speed and the average speed for every segment of the Summer 2005 GPS data collection.

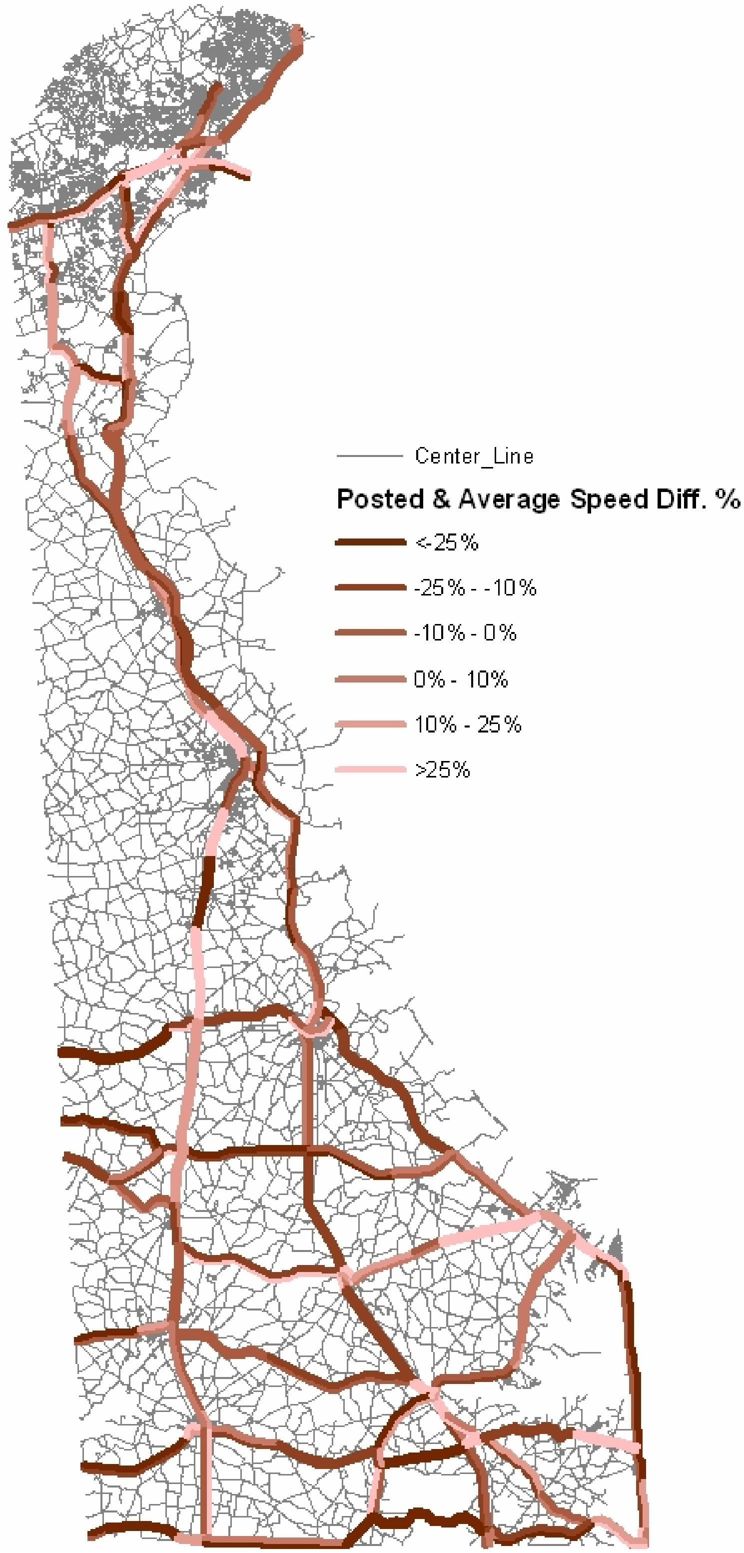
Methodology:

The percent difference between the posted speed and the average speed is calculated be subtracting the average speed of all runs from the posted speed and dividing the difference by the posted speed. This is done for all segments.

Equations:

$$AverageSpeed = \frac{\sum_{1}^{n} AverageSpeed\_run(x)}{n}$$

$$Posted\ \&\ AverageSpeedDiff.\% = \frac{(PostedSpeed - AverageSpeed)}{PostedSpeed} * 100\%$$


Center_Line
Posted & Average Speed Diff. %
<-25%
-25% - -10%
-10% - 0%
0% - 10%
10% - 25%
>25%

Appendix F:

Level of Service 2004:

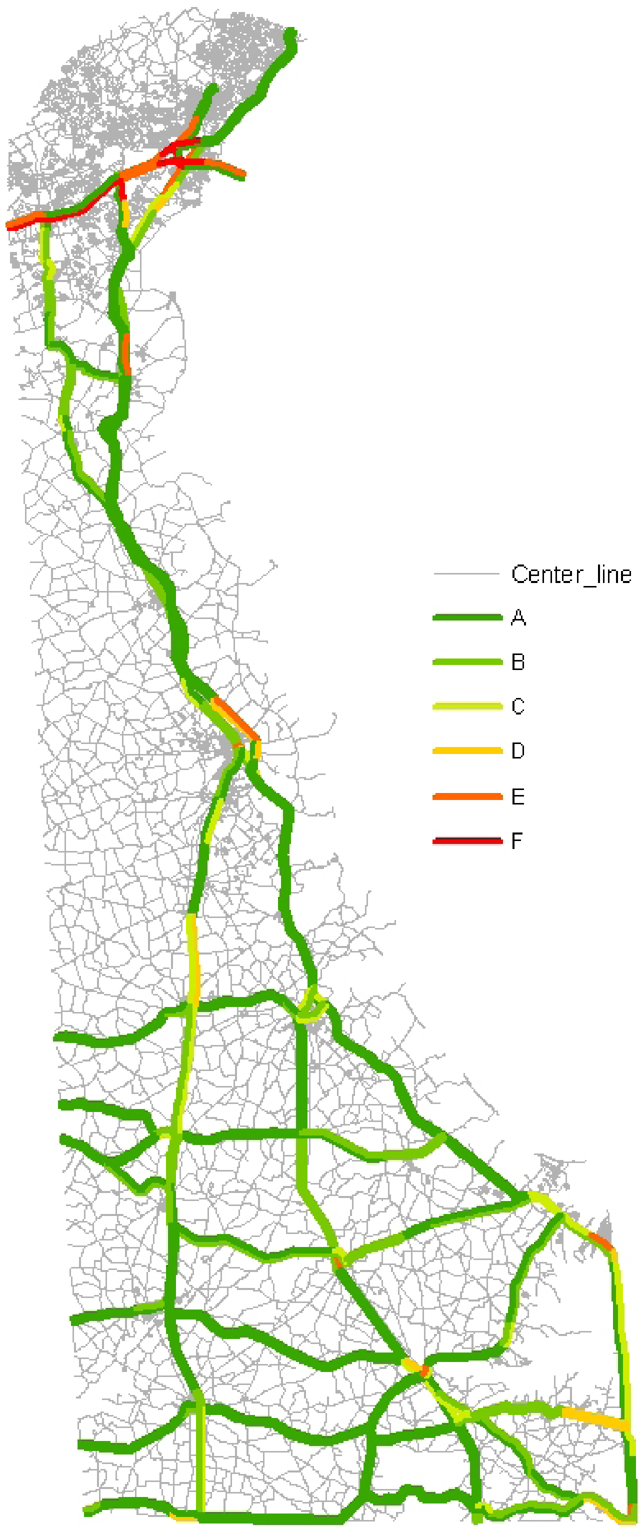
The following GIS drawing displays the calculated level of service for each direction of all segments for every segment of the Summer 2004 GPS data collection.

Methodology:

Using the percent difference between the posted speed and average speed, the level of service is calculated. By first identifying segments that are interstates or interstate/freeways and roads that are arterials in 2004, the following tables are used to classify the appropriate level of service.

Percentage of speed below the posted speed limit:

For Interstate or Interstate/Freeways:	Arterials:
LOS A: 0-14%	LOS A: 0-10%
LOS B: 14-18%	LOS B: 10-30%
LOS C: 18-20%	LOS C: 30-45%
LOS D: 20-30%	LOS D: 45-60%
LOS E: 30-50%	LOS E: 60-70%
LOS F: 50% +	LOS F: 70% +


Center_line
A
B
C
D
E
F

Appendix G:

Level of Service 2005:

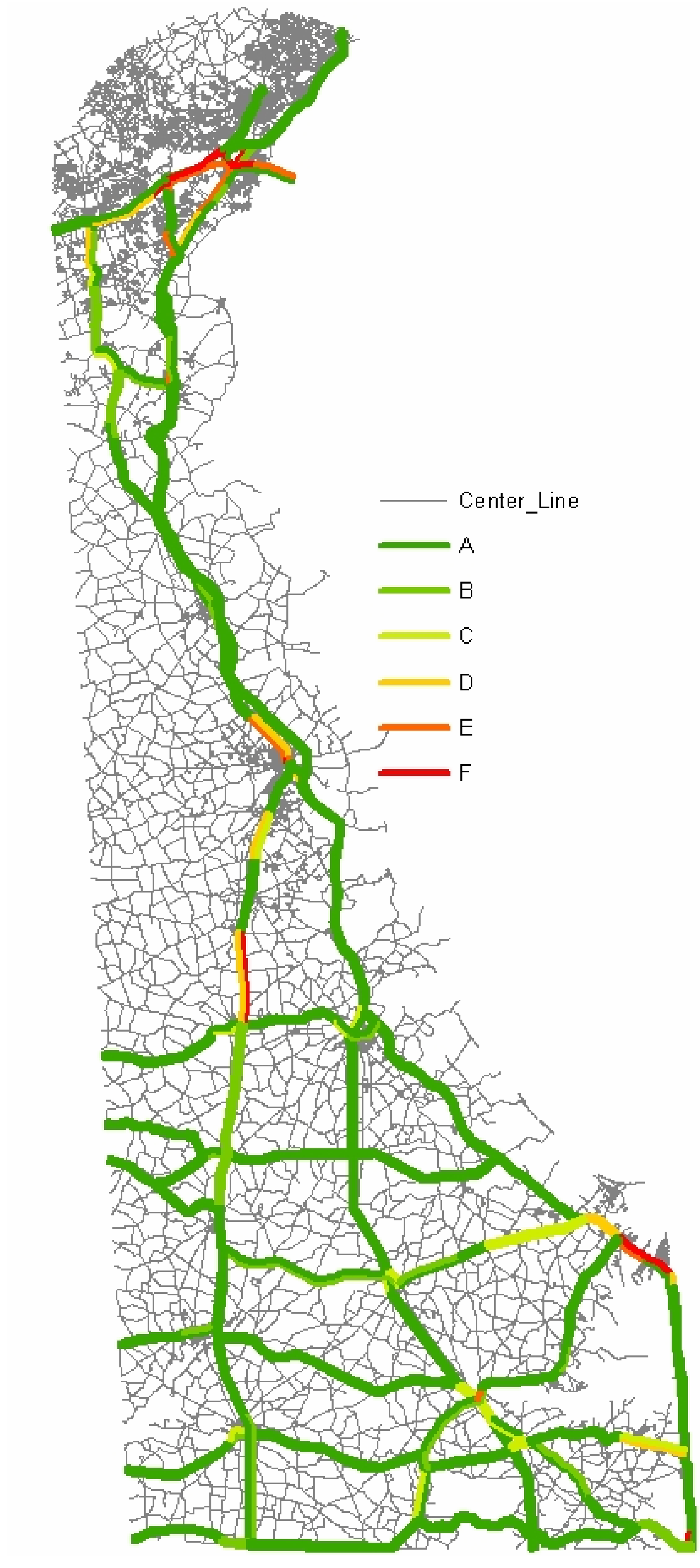
The following GIS drawing displays the calculated level of service for each direction of all segments for every segment of the Summer 2005 GPS data collection.

Methodology:

Using the percent difference between the posted speed and average speed, the level of service is calculated. By first identifying segments that are interstates or interstate/freeways and roads that are arterials in 2005, the following tables are used to classify the appropriate level of service.

Percentage of speed below the posted speed limit:

For Interstate or Interstate/Freeways:	Arterials:
LOS A: 0-14%	LOS A: 0-10%
LOS B: 14-18%	LOS B: 10-30%
LOS C: 18-20%	LOS C: 30-45%
LOS D: 20-30%	LOS D: 45-60%
LOS E: 30-50%	LOS E: 60-70%
LOS F: 50% +	LOS F: 70% +



Center_Line
A
B
C
D
E
F

Appendix H:

Peak Travel Time Data – Summer 2005:

The following table is the averaged data for all segments analyzed during the summer 2005 GPS data collection. The table includes the route number, route name, segment direction, segment distance, mean peak travel time, mean peak travel speed, total delay, peak delay source, mean peak running speed, percent time in delay, number of lanes and the posted speeds.

Delaware Center for Transportation
University of Delaware
Newark, Delaware 19716