DCT 169

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

Summer 2004

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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 equals manual data collection in accuracy and efficiency and therefore continues to effectively collect data within Delaware today. Every year, a report is compiled documenting this study 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 typically collected during peak-travel times between mid-September and Thanksgiving. In 2002, data collection in the summer as well as in the fall began. In 2003, the summer mileage covered increased significantly, from 652 to 896 miles, and in 2004, this mileage increased even further from 896 to 1006 miles. This report describes the methodology used to collect these 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 eight years in monitoring congestion trends along Delaware roadways 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. Several routes and numerous additional segments were added in 2003 and even more have been added in 2004. 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 (new), and I-495 (new). 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 (new). 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, it was necessary to select control points between the segments of the roadway. Control points were located at major intersections or where road characteristics, such as the number of lanes, speed limit, or development type changed. Some control points were added, deleted, or changed between 2003 and 2004 based on last year's observations. 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 18th and August 15th. 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 occurred 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 2004 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:

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

- 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

The summer 2004 GPS Travel Time and Delay project continued to ascertain the validity and effectiveness of using GPS to monitor beach traffic congestion during the summer. Data was collected again on all of the roads that were covered in 2003 as well as some new ones, allowing for comparisons and continuing the summer data collection and analysis of the general travel and delay times along these routes.

While data collection using a GPS unit is a considerable advancement to manual data collection, the system is not flawless and some problems arose. In a few instances, problems with the notebook computers rendered them useless. Occasionally the satellite signal was lost, due to inclement weather or tree obstruction. However, the inaccuracy experienced last year from the GPS taking readings only every five seconds was improved by updating the system to take readings every one second, which greatly decreased the amount of time and data lost when satellite signals could not be detected. Nonetheless, manual data collection was always feasible and was used in very few instances when necessary.

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. This summer, in particular, has appeared to be exceptionally rainy and muggy, which has definitely been represented in the data during certain runs, with travel and delay times appearing lower when compared to the summer 2003 findings. Also, the completion of SR 1 at the end of last summer has appeared to contribute to some differences between the 2004 and 2003 data. Fortunately, many travelers have appeared to make use of the availability of a newly completed SR 1, while some other travelers are still using US 13 to reach the shore points, and thus both routes may show heavy volumes though not high congestion. 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, particularly along the newly added routes, I-495, I-295, and I-95. However, when analyzing and observing this data, one must recognize the possibility of business travel mixing with beach travel during this time. 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, it was observed 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. On the other hand, the addition of I-295, I-95, and I-495 have been successful improvements to this project. These routes have provided strong and accurate data regarding Delaware summer traffic, with high congestion and large delays having been experienced consistently along these routes. Also, the control points along these routes are exactly the same ones used in the fall data collection and the useful data collected this summer has actually appeared very similar to that collected in the fall for these segments, which further supports the success of these additions to the 2004 summer project. The possible addition of SR 9, however, has not been as successful. 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.

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. This information lead data collectors to begin data collection earlier on a few Saturday mornings in order to collect data northbound along major beach routes. However, only a few runs were completed, and there is not a sufficient amount of data to completely display such traffic. On the other hand, this method 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.

Appendix A:

10-Most Degraded Segments:

ROUTE_NAME	DIR	SEGMENT	LOS_03	LOS_04	%_D_PS_TS
SR 26	WB	SR 1 to SR 17	A	D	-122.16%
DuPont Hwy	SB	SR 8 to US 13/113 Split	A	E	-65.95%
US 113	SB	SR 20 West to SR 24	B	F	-53.18%
US 13	SB	SR 14 to SR 12	A	D	-48.04%
US 113	NB	US 9 (non truck route) to SR 404/18	B	E	-47.83%
Relief Route	NB	SR 26 to Collins St.	A	C	-45.00%
SR 20	EB	US 13/20 W merge to US 13/20 E	C	F	-42.00%
SR 24	WB	SR 30 to US 113	B	E	-40.98%
SR 20	EB	SR 20 W/US 113 Merge to SR 24	A	C	-38.93%
Relief Route	NB	SR 896 (exit 142) to C&D Canal	A	E	-37.22%

10-Most Improved Segments:

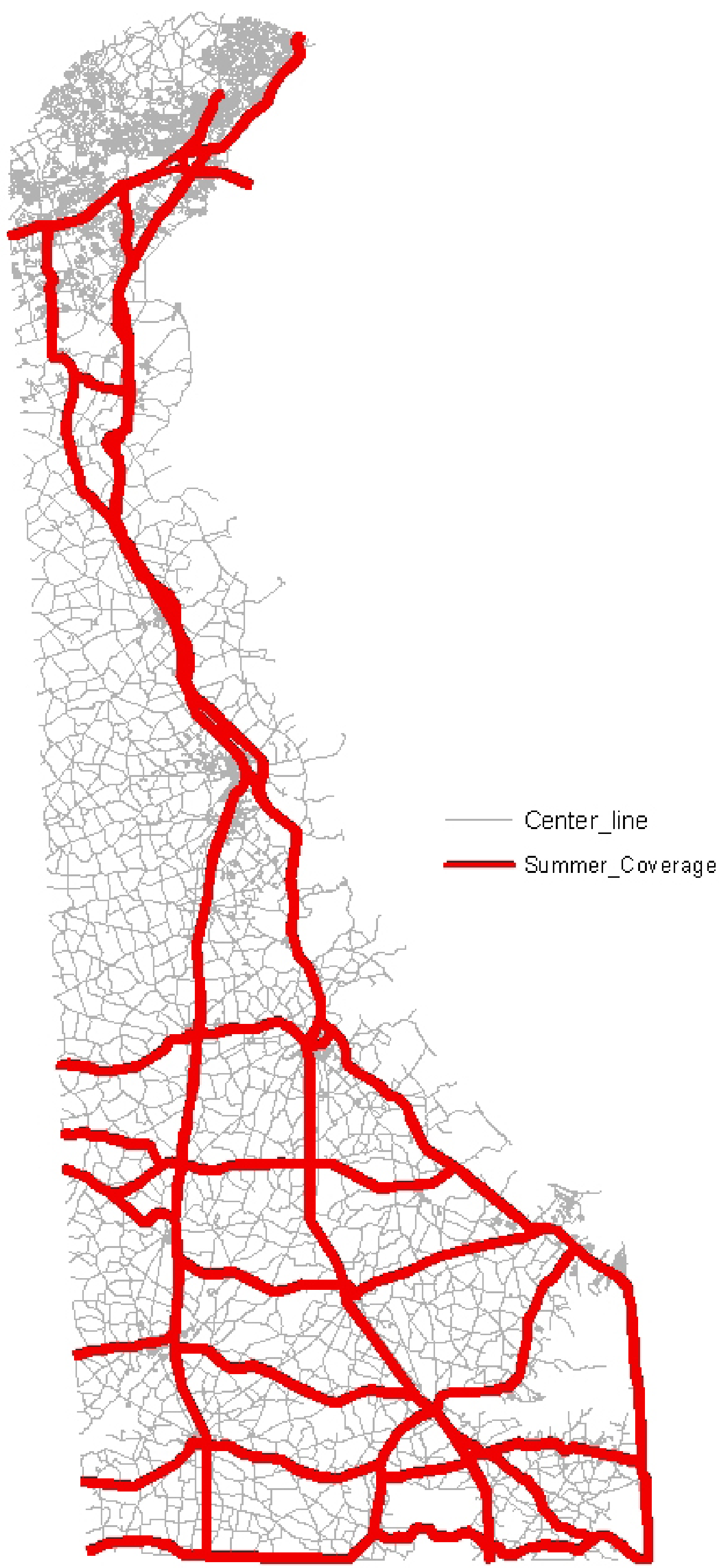
ROUTE_NAME	DIR	SEGMENT	LOS_03	LOS_04	%_D_PS_TS
DuPont Hwy	SB	SR 299 to SR 71	D	A	57.53%
Relief Route	NB	Combo w/ US 113 (95) to Exit 97	E	A	48.08%
Relief Route	SB	US 9 West / SR 404 to SR 24	F	C	47.91%
Relief Route	SB	SR 24 to Rehoboth Avenue	E	B	45.77%
Relief Route	NB	US 40 (exit 160) to SR 273 (exit 162)	F	D	43.18%
Relief Route	NB	US 13 North (exit 156) to US 40 (exit 160)	D	A	42.48%
US 113	SB	SR 404/18 to US 9 (non truck route)	D	B	36.60%
SR 896	SB	SR 15 to SR 896 / SR 71 Split	D	B	33.94%
SR 71	NB	US 301Split to 896 / 71 Split	D	B	33.65%
SR 24	EB	US 13 to Road 449	C	A	33.27%

Appendix A:

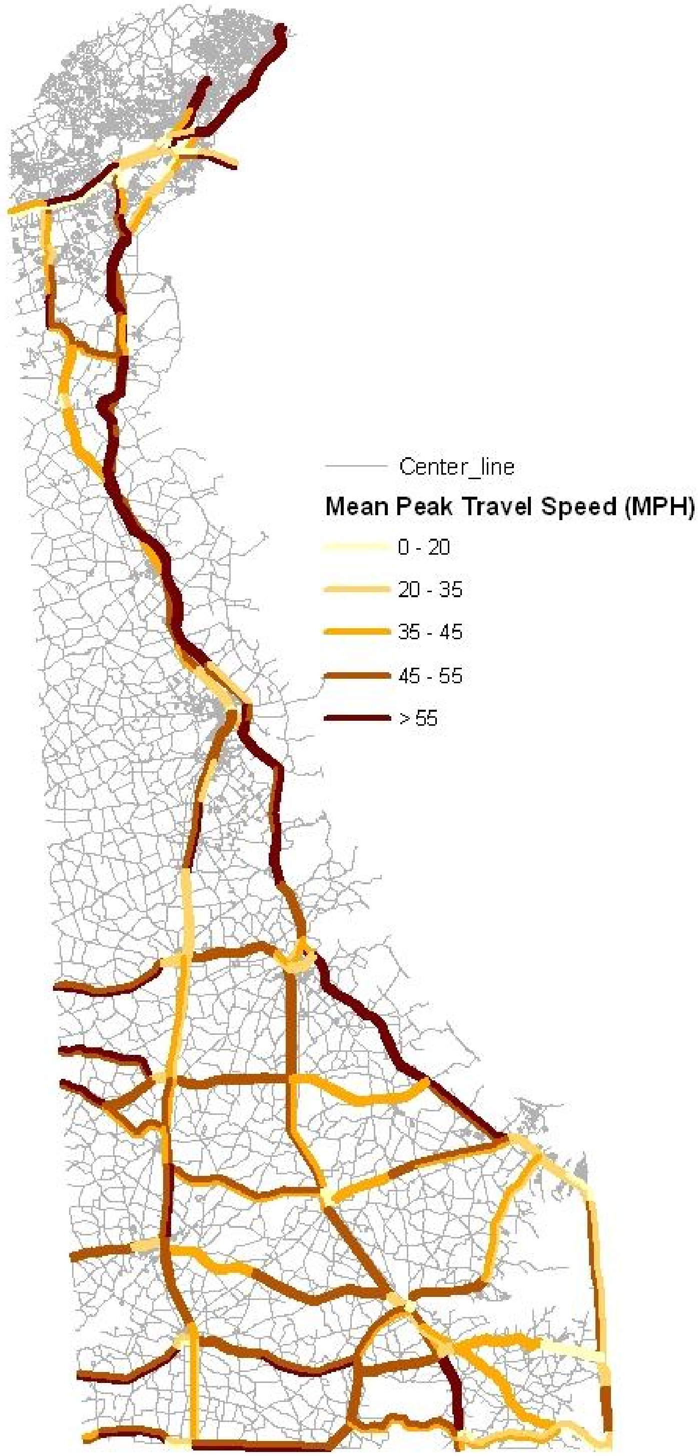
20-Worst Segments:

ROUTE_NAME	DIR	SEGMENT	LOS	LOS %	Av.Speed (mph)
SR 896	NB	SR 1 to US 13	F	84.43%	7.8
Relief Route	NB	SR 273 (exit 162) to Christiana Mall (exit 164)	F	82.99%	9.4
Relief Route	NB	Christiana Mall (exit 164) to Merge with I-95 N	F	81.94%	9.3
I-295	WB	SR 9 to US 13	F	80.60%	10
I-95	NB	Exit 3 (SR 273) to Exit 4 (SR 1)	F	77.04%	12.6
I-295	WB	US 13 to I-95	F	76.79%	12
SR 20	WB	US 13/20 E to US 13/20 W split	F	74.14%	11.6
I-95	SB	I-495 JCT to Exit 5 (SR 141/I-295 JCT)	F	72.93%	14.9
SR 20	EB	US 13/20 W merge to US 13/20 E	F	72.15%	12.5
I-95	NB	Exit 1 (SR 896) to Exit 3 (SR 273)	F	71.03%	15.9
US 113	SB	SR 20 West to SR 24	F	70.39%	15.2
I-95	NB	MD Line to Exit 1 (SR 896)	F	64.33%	19.6
I-495	SB	Exit 1 (US 13) to I-95	F	53.46%	27
I-295	EB	I-95 to US 13	F	51.20%	26
SR 24	WB	SR 30 to US 113	E	67.15%	8.2
I-95	SB	I-295 to Exit 4 (SR 1/Churchmans)	E	43.76%	30.9
I-95	NB	Exit 4 (SR 1/Churchmans) to Exit 5 (I-295)	E	40.14%	32.9
I-95	SB	Exit 6 (Maryland Ave) to I-495 JCT	E	33.68%	36.5
I-95	SB	Exit 1 (SR 896) to MD Line	E	31.73%	37.5
I-295	WB	D.M.B. to SR 9	E	31.34%	34

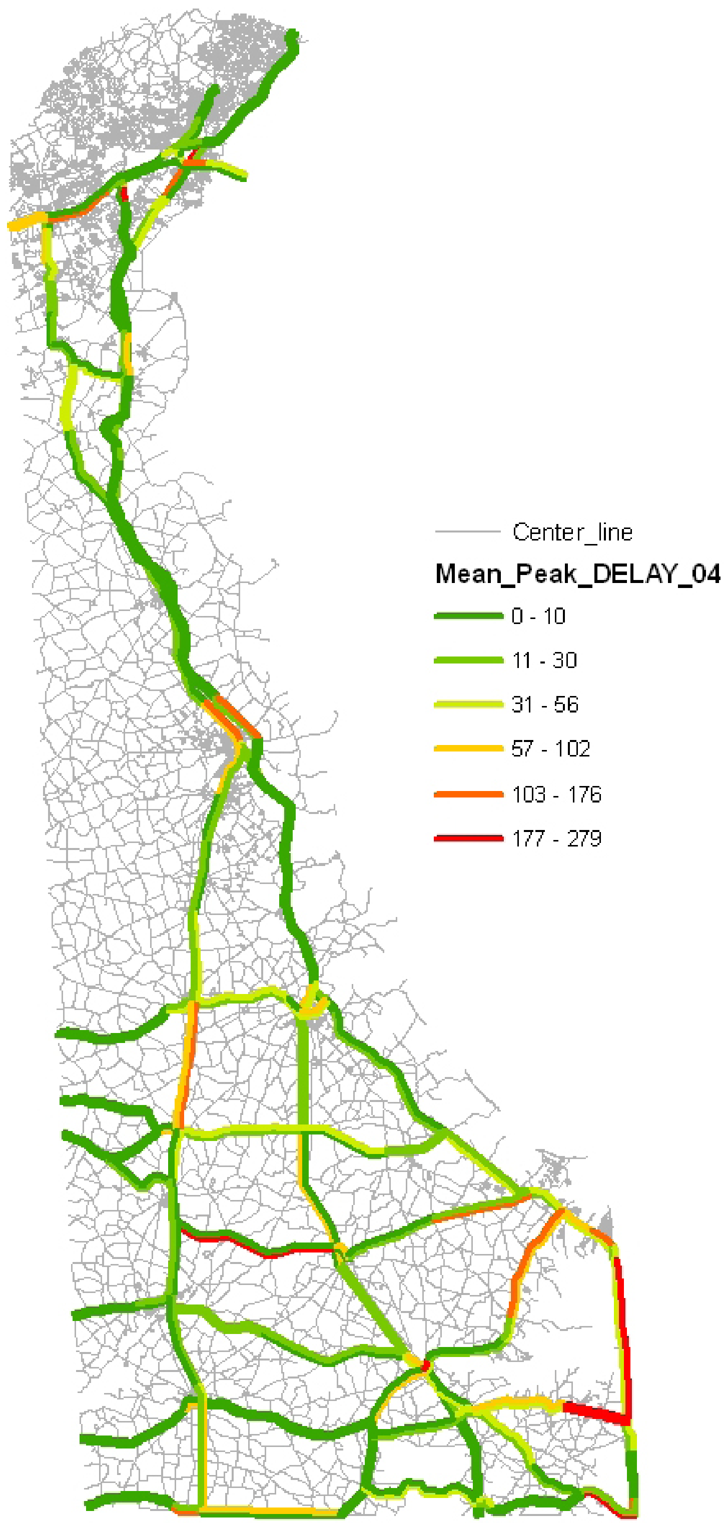
Appendix B:



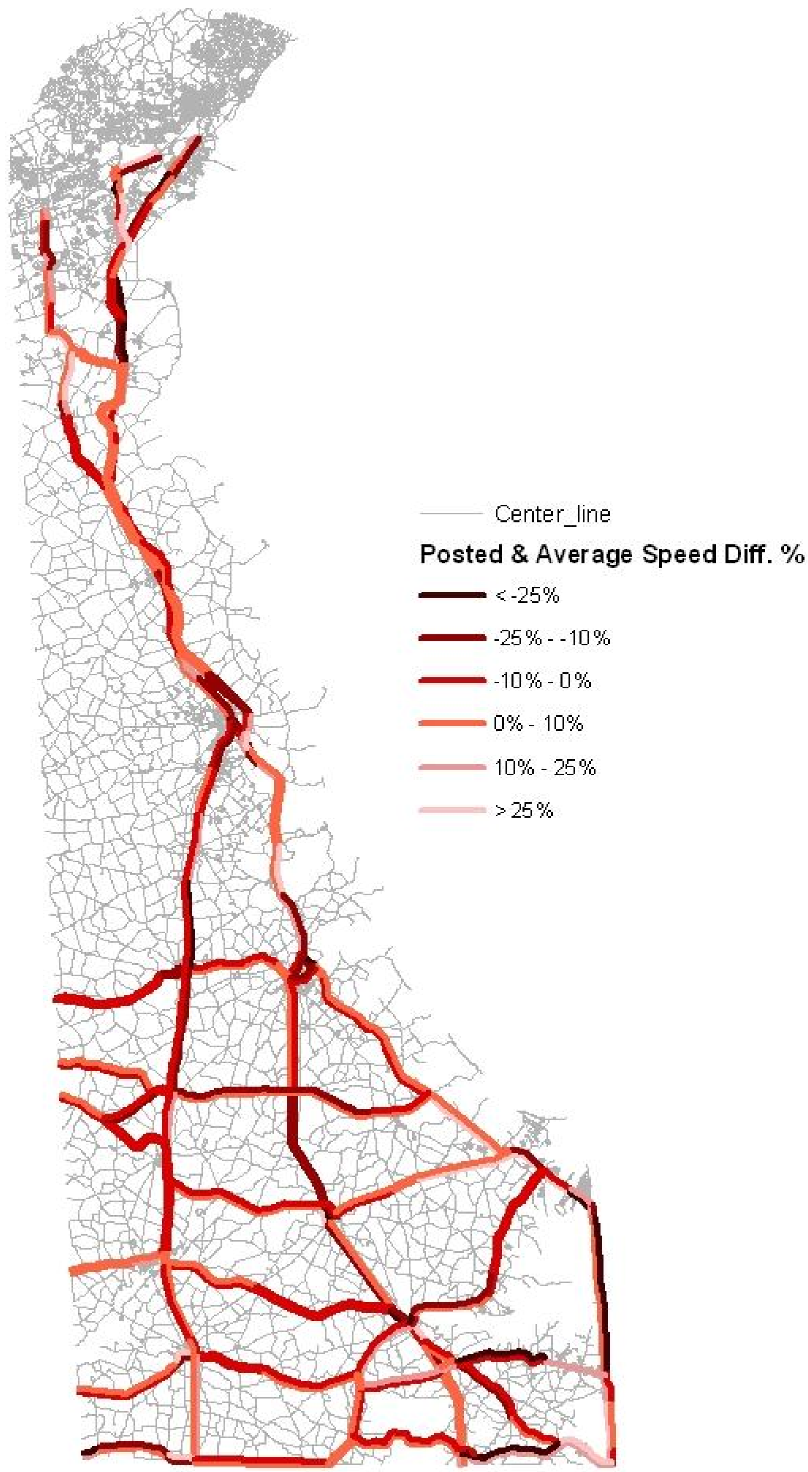
Appendix C (Mean Peak Travel Speed):



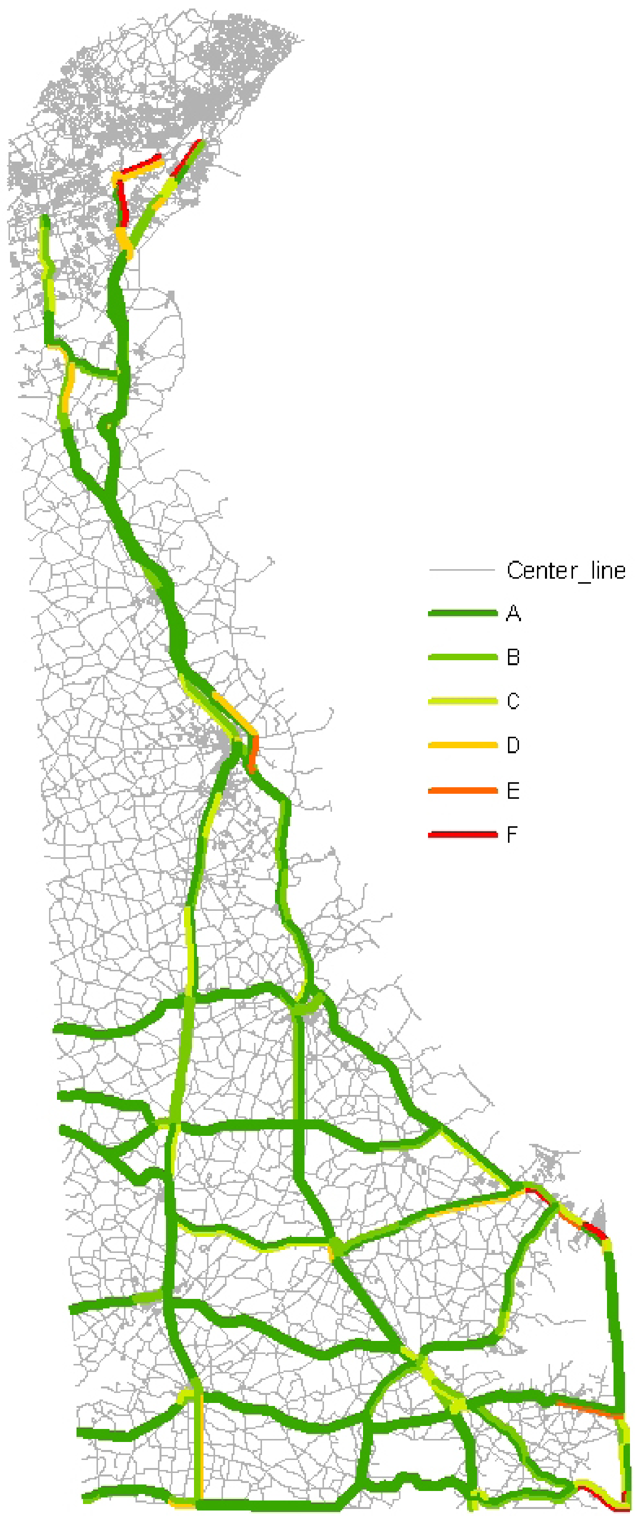
Appendix D (Mean Peak Delay):



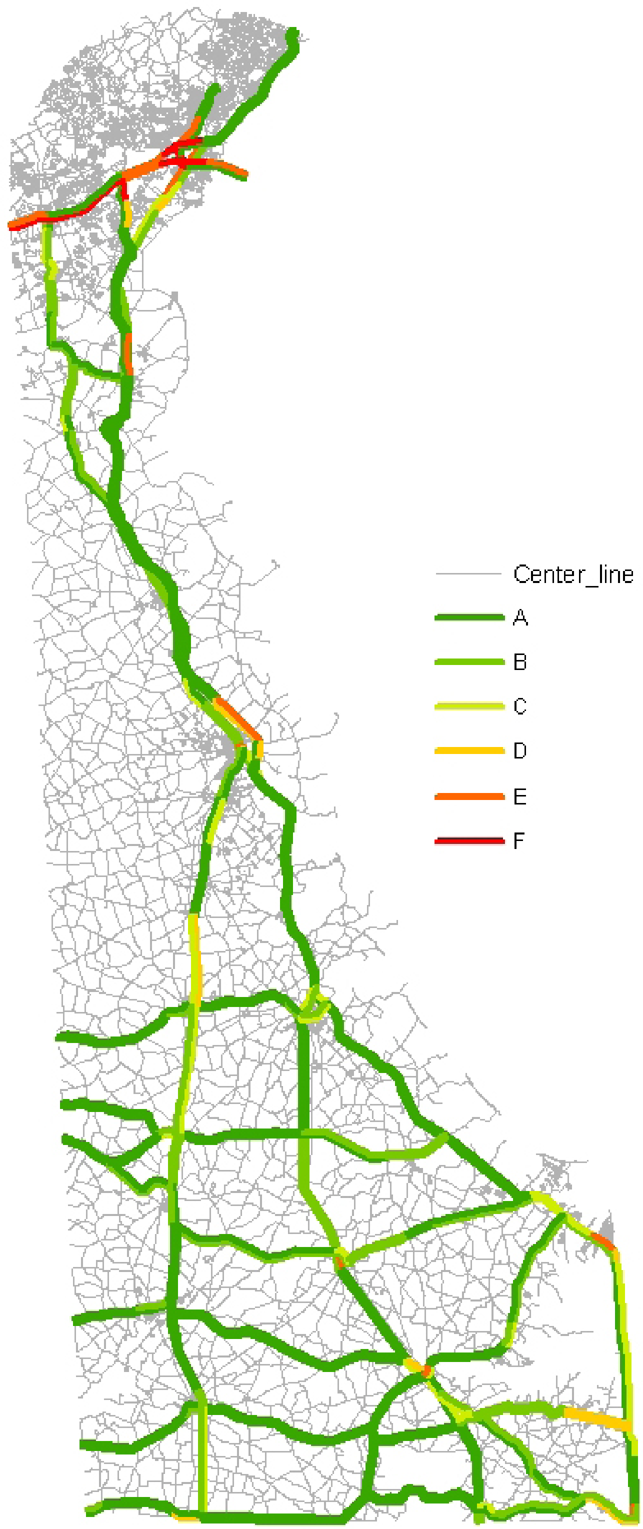
Appendix E (Posted Speed vs. Average Speed Difference):



Appendix F (Level of Service 2003):



Appendix G (Level of Service 2004):



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