Application of Global Positioning System (GPS) to Travel Time and Delay Measurements – Fall 2014

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**Introduction**

Traffic congestion is a growing problem in many jurisdictions across the country. The travel time data collection method is used to assist the congestion management. The use of traditional sensors (e.g., inductive loops, AVI sensors) or more recent Bluetooth sensors installed on major roads for collecting data is not sufficient because of their limited coverage and expensive costs for installation and maintenance. In order to quantify the severity of congestion, Global Positioning System (GPS) applications have been utilized to collect travel time and delay data for many of Delaware’s principal and minor arterials, collectors, and freeways. Since 1996, the Delaware Department of Transportation (DelDOT), with the help of the Civil and Environmental Engineering Department at the University of Delaware, has been using GPS technology for this purpose. The GPS data has proven to be at least as accurate as the data collected by conventional methods, and is 50% more efficient in terms of manpower. For these reasons, DelDOT has continued to request this annual data each subsequent year. Annual reports documenting the data collection process, its applicability and accuracy, and the collected data have been compiled over the years. 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 report of the 1998 Phase provides a step-by-step procedure for the data collection. The following report describes the data collection methodology, as well as a summary of the collected and processed Fall 2014 data.

**Methodology**

In an effort to quantify congestion related to commuter traffic, travel time and delay data have been collected during morning (7AM – 9AM) and afternoon (4PM – 6PM) peak-hour travel times between September 15, 2014 and November 20, 2014. Data was collected by a minimum of 2 two-person teams, each operating a separate vehicle. Each team consisted of one driver and one data collector. The driver’s
responsibility is to maintain the vehicle’s speed to represent that of the average driver on the road. The data collector is responsible for data collection as the vehicle crosses each specified control point along the route and as the vehicle encounters delay sources. This separation of duties provides for optimal driving safety during data collection and allows each individual to fully concentrate on their respective responsibilities. Each team utilized a Trimble GPS unit with Trimble TerraSync™ and GPS Pathfinder Office software installed. Because of equipment failures experienced in past years, new GPS receivers, new cables, and updated TerraSync software were purchased following data collection in the Fall of 2012. The new Trimble® GeoExplorer 6000® GPS receiver combines submeter accuracy GNSS, high quality photo capture, wireless internet, and connectivity options in a single product, which is able to automatically record time and local coordinates of a probe vehicle every 1 sec along the highways of interest. New units don’t require laptops on site and functions as using the touchscreen feature. The collected data were then snapped to the highway centerlines for use in a GIS database for further analysis.

All major routes surrounding large population centers in Delaware were covered. Those routes can be found below subdivided by county:

- Kent County: SR 1, US 13, US 113, SR 6, SR 8, SR 10, SR 12, SR 14, SR 15, SR 300, State St
- Sussex County: SR 1, US 13, US 113, SR 16, SR 404

With a minimum confidence level of 95% and with permitted errors of 1 to 5 miles per hour in velocity, a minimum of two runs was determined to be sufficient to achieve accurate results. Based on these
findings, each direction of a roadway segment was traveled at least four times: twice during the morning peak hours, and twice during the afternoon peak hours. This was done to ensure that the effects of the traffic directional and temporal fluctuations were captured.

For data collection, all routes and associated control points have been provided to data collection team prior to the trip as Google Maps links. Google Maps links provide visual demonstration of routes and checkpoints as well as overall understanding of location of the routes to be studied. A complete set of all 48 studied roads was included in each vehicle for use by the data collection teams. Starting from Summer 2014, data collection team also prepared specific manual data collection sheets for each route. These sheets include route's name, direction of the road, checkpoint names, distance between checkpoints and cumulative distance from the first checkpoint. Especially, providing cumulative distances in the sheet decreased the possibility of making mistakes for determining the location of checkpoints on site. The new manual data collection sheets improved the efficiency of the team and data collection by providing more information during the data collection.

The Fall 2014 data collection was executed with a group of graduate and undergraduate students in the Civil & Environmental Engineering Department. Prior to the start of the data collection, all data collectors were familiarized with the designated routes and the use of the data collection equipment. The training consisted of preprocessing, a test-run data collection, and postprocessing. Preprocessing included a review of the route to be measured and associated control points, as well as preparation of GPS units, related software and data collection sheets. Postprocessing included a transfer of the data from the portable Trimble GPS units to a main computer, as well as an examination of the data for errors and logged inaccuracies.
The data collectors also conducted a test-run data collection using the manual collection method in the event of equipment failure. To aid in manual data collection, both vehicles were provided with the necessary references and equipment (e.g. manuals, instruction sheets, stopwatches, and printed maps) related to the different procedures and safety measures that would apply. Data collection was closely monitored on a day to day basis, and results were immediately processed after data collection.

**Interpretation of 2014 Fall Data**

This report includes a set of six summary tables containing the collected data segmented by county and time of day. The data in each table is arranged by route name, roadway segments, and direction of travel. The table contains the information explained below:

- **Distance (Miles)** – the length of the given route segment. The distance of each segment is listed and the total of those are summed in the last line of each route.

- **Mean Peak Travel Time (Seconds)** – the average time in seconds that was taken to travel the length of the segment. Again, the mean peak travel time of all segments are summed in the last line of each route.

- **Mean Peak Travel Speed (mph)** – the average speed of the test vehicle traveling from one control point to the next. This value is obtained by dividing the distance of the segment by the mean peak travel time.

- **Total Peak Delay (Seconds)** – the time spent in delay traveling through the given segment. By definition, delay is the time when vehicle speed drops below 5 miles per hour.
• **Peak Delay Source** – the reason for the delay noted in the previous column. Reasons for delay can be due to traffic signals, construction, accidents, congestion, pedestrian crossing, train crossing, etc. Traffic signals are the main cause of delay.

• **Mean Peak Running Speed (mph)** – the average speed that a vehicle would travel through the route segment if delay were not experienced. This value is obtained by the following equation:

\[
\text{MPRS} = \frac{\text{Distance}}{\text{Mean Peak Travel Time} - \text{Total Peak Delay}}
\]

• **Percent Time in Delay** – the percentage of time spent in delay for that route segment. The percentage is obtained by dividing the total peak delay by the mean peak travel time, then multiplying the quantity by 100.

\[
\text{Percent Time in Delay} = \left( \frac{\text{Total Peak Delay}}{\text{Mean Peak Travel Time}} \right) \times 100
\]

• **Number of Lanes** – the number of lanes for the given route segment. Route segments that have more than one value shown designate that the number of lanes change during that segment. This does not include turning bays at intersections.

• **Posted Speed (mph)** – the posted speed limit for the given route segment. Again, for those that have more than one posted speed in this column, this means that the posted speed changes during that segment.
Project Observations and Conclusions

The 2014 data collection was able to be completed accurately within the prescribed time periods. Whenever GPS devices are used for collecting traffic data, it is important to recognize the weaknesses of using GPS devices in urban settings. GPS satellite signals may be deteriorated when a vehicle drives next to buildings or beneath a dense tree canopy. Therefore, manual data also collected during the entire data collection process.

In general, the data collection team observed similar traffic patterns compared to previous years. Higher travel and delay times resulted with lower travel speed in PM peak hours compared to AM peak hours, as expected. It is observed that, traffic flow speed is slow in downtown Wilmington and Newark and some parts of Dover and Middletown in addition to high delay times as expected. Not a significant change observed by data collection team and seen in the data in Fall 2014 compared to previous years except construction and improvement sites along the state’s highways.

As similar to previous years’ results, average travel speed is lower than the posted speed in majority of the Delaware roadways both in AM and PM peak hours. This difference is more significant in New Castle County than Kent and Sussex counties. However, Interstates and freeways such as I-95 and SR 1 show a different pattern in contrast to the majority of the state highways. They present higher average travel speed than posted speed in majority of their segments except accidents and other non-recurring congestion sites.

Additionally, significant congestion and/or multiple traffic signal cycle waiting time observed in mentioned segments below:

- SR141 NB (Brandywine Bridge)
- Dover Area
- US13 between Rt8 and Scarborough
- State Street between Governors Blvd and US 13

**Wilmington Area**
- US 202 between Market Street and I-95
- SR 48/41 between I-95 and Market St
- SR 52 between Overpass and Market Street

**Newark Area**
- Cleveland Ave
- Elkton Road -South Main Street portion
- SR 896 (University of Delaware area)
- SR2 Kirkwood Highway between SR273 and SR72
- SR 72 between SR 4 and Main Street
- SR 72 between Old Baltimore Park and SR 4
- Paper Mill Road between Delaware Ave and Cleveland Ave.

The remainder of this report is organized as follows. Appendix A shows the ten most degraded, the ten most improved, and the twenty worst route segments. These segments are ranked based on changes between the 2013 and 2014 data relating to difference between posted speed and average travel speed. These charts can be used to track changes in land use, system performance, and effects of construction or other improvements.

Appendix B shows a GIS map of full road coverage in the state of Delaware.

Appendix C shows GIS maps of the mean peak travel speed for the routes covered in Delaware for both the AM and PM peak periods. The GIS maps are color-coded based on a range of values.
Appendix D shows GIS maps of the mean peak delay in the AM and PM peak periods. The mean peak delay is the average amount of time, in seconds, that the test vehicle was in delay for a particular segment. The length of delay corresponds to the length of time the test vehicle was traveling at a speed of 5 mph or less.

Appendix E shows GIS maps of the percentage difference between the posted speed and the average travel speed for the AM and PM peak periods. This map is helpful when trying to determine congestion along a particular segment. Even if a particular segment has a low average delay, it does not always mean that there are free-flow conditions. The maps in Appendix E will help to determine additional traffic flow information.

Appendix F and Appendix G show GIS maps of the LOS for the AM and PM peak periods in both 2013 and 2014. LOS was computed based on the following criteria for the percent difference between posted speed and average speed, computed as:

\[
\frac{(\text{Posted Speed} - \text{Average Speed})}{\text{Posted Speed}} \times 100\%
\]

<table>
<thead>
<tr>
<th>Interstate/Freeways (% time under speed limit)</th>
<th>Arterials: (% under speed limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS A: 0-14%</td>
<td>LOS A: 0-10%</td>
</tr>
<tr>
<td>LOS B: 14-18%</td>
<td>LOS B: 10-30%</td>
</tr>
<tr>
<td>LOS C: 18-20%</td>
<td>LOS C: 30-45%</td>
</tr>
<tr>
<td>LOS D: 20-30%</td>
<td>LOS D: 45-60%</td>
</tr>
<tr>
<td>LOS E: 30-50%</td>
<td>LOS E: 60-70%</td>
</tr>
<tr>
<td>LOS F: 50% +</td>
<td>LOS F: 70% +</td>
</tr>
</tbody>
</table>
Finally, Appendix H consists of a summary of the data for each county, as well as the state, in an excel spreadsheet format.
Appendix A

Explanation:
This is a listing of the ten most degraded, ten most improved, and 20 worst route segments in the state as determined by comparing data from 2014 to that of 2013. For all degraded and improved charts %_D_PS_Ts is the percent difference between the posted speed and travel speed between the years 2013 and 2014. The higher the percentage (positive number) the more degraded segment is, and the lower the percentage the more improved segment is. The ten most degraded and 20 worst segments may require further examination.

Variables:
\[ %_D_PS_Ts = \text{The percentage difference between the posted speed and travel speed.} \]
\[ %_D_PS_Ts = \text{The percentage difference between the posted speed and travel speed between years 2013 and 2014.} \]

Equations:
\[ %_PS_Ts = \frac{\text{MeanPeakTravelSpeed} - \text{WeightedAverageSpeed}}{\text{WeightedAverageSpeed}} \]
\[ %_D_PS_Ts = %_PS_Ts_{2014} - %PS_Ts_{2013} \]

A1: 10-Most Degraded Segments
Segments are selected by taking the difference between the LOS of 2014 and the LOS of 2013 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.
**A2: 10-Most Improved Segments**
Segments are selected by taking the difference between the LOS of 2014 and the LOS of 2013 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.

**A3: 20-Worst Segments**
The 20 segments with the worst LOS are selected and displayed in this table. In the table, (*) indicates that route segment was also in worst segment lists of previous year (2013).
### A1: 10-Most Degraded Segments AM/PM:

<table>
<thead>
<tr>
<th>ID</th>
<th>Route Number</th>
<th>Dir</th>
<th>Dist</th>
<th>Segment</th>
<th>2013 LOS</th>
<th>2014 LOS</th>
<th>% Degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>I-95</td>
<td>NB</td>
<td>0.9</td>
<td>Exit 5 (SR 141/I-295 JCT) to I-495 JCT</td>
<td>A</td>
<td>E</td>
<td>69.4%</td>
</tr>
<tr>
<td>299</td>
<td>US 301 &amp; SR 299</td>
<td>EB</td>
<td>1.2</td>
<td>Silver Lake Rd. to SR 1</td>
<td>A</td>
<td>B</td>
<td>64.9%</td>
</tr>
<tr>
<td>442</td>
<td>Silverside</td>
<td>EB</td>
<td>0.9</td>
<td>I-95 to US 13</td>
<td>A</td>
<td>D</td>
<td>55.7%</td>
</tr>
<tr>
<td>151</td>
<td>SR 4</td>
<td>WB</td>
<td>1.0</td>
<td>1st State to SR 7</td>
<td>B</td>
<td>E</td>
<td>51.7%</td>
</tr>
<tr>
<td>119</td>
<td>SR 52</td>
<td>NB</td>
<td>0.8</td>
<td>I-95 to RR Xing</td>
<td>A</td>
<td>C</td>
<td>51.4%</td>
</tr>
<tr>
<td>188</td>
<td>US 13</td>
<td>SB</td>
<td>1.3</td>
<td>I-295 to 141</td>
<td>A</td>
<td>C</td>
<td>50.4%</td>
</tr>
<tr>
<td>297</td>
<td>US 301 &amp; SR 299</td>
<td>EB</td>
<td>1.1</td>
<td>SR 71 to Silver Lake Rd.</td>
<td>B</td>
<td>F</td>
<td>49.7%</td>
</tr>
<tr>
<td>9</td>
<td>US 202</td>
<td>NB</td>
<td>0.7</td>
<td>I-95 to Foulke Rd</td>
<td>A</td>
<td>C</td>
<td>49.0%</td>
</tr>
<tr>
<td>108</td>
<td>SR 141</td>
<td>SB</td>
<td>1.6</td>
<td>I-95 to US 13</td>
<td>A</td>
<td>C</td>
<td>48.0%</td>
</tr>
<tr>
<td>110</td>
<td>SR 141</td>
<td>SB</td>
<td>1.3</td>
<td>US 13 to SR 273</td>
<td>A</td>
<td>C</td>
<td>43.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Route Number</th>
<th>Dir</th>
<th>Dist</th>
<th>Segment</th>
<th>2013 LOS</th>
<th>2014 LOS</th>
<th>% Degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>I-95</td>
<td>SB</td>
<td>1.3</td>
<td>Exit 4 (SR 1) to Exit 3 (SR 273)</td>
<td>A</td>
<td>D</td>
<td>64.8%</td>
</tr>
<tr>
<td>187</td>
<td>US 13</td>
<td>NB</td>
<td>1.3</td>
<td>141 to I-295</td>
<td>A</td>
<td>D</td>
<td>57.2%</td>
</tr>
<tr>
<td>286</td>
<td>SR 72</td>
<td>NB</td>
<td>1.4</td>
<td>Old Baltimore to SR 4</td>
<td>B</td>
<td>E</td>
<td>57.1%</td>
</tr>
<tr>
<td>428</td>
<td>SR 72</td>
<td>NB</td>
<td>1.2</td>
<td>Main St to Kirkwood Hwy</td>
<td>A</td>
<td>C</td>
<td>53.7%</td>
</tr>
<tr>
<td>154</td>
<td>SR 4</td>
<td>EB</td>
<td>1.2</td>
<td>1st State to SR 141</td>
<td>A</td>
<td>D</td>
<td>43.9%</td>
</tr>
<tr>
<td>409</td>
<td>US 113</td>
<td>SB</td>
<td>1.5</td>
<td>SR 20 West to SR 24</td>
<td>A</td>
<td>D</td>
<td>43.8%</td>
</tr>
<tr>
<td>142</td>
<td>SR 4</td>
<td>EB</td>
<td>1.4</td>
<td>Elkton to SR 896</td>
<td>A</td>
<td>B</td>
<td>43.2%</td>
</tr>
<tr>
<td>273</td>
<td>SR 2</td>
<td>WB</td>
<td>1.0</td>
<td>SR 4 to MD Line</td>
<td>B</td>
<td>E</td>
<td>42.6%</td>
</tr>
<tr>
<td>257</td>
<td>SR 261</td>
<td>SB</td>
<td>0.6</td>
<td>PA line to Naamans</td>
<td>B</td>
<td>D</td>
<td>39.9%</td>
</tr>
<tr>
<td>406</td>
<td>US 113</td>
<td>NB</td>
<td>1.2</td>
<td>US 9 to SR 404/18</td>
<td>A</td>
<td>D</td>
<td>39.9%</td>
</tr>
</tbody>
</table>
### A2: 10-Most Improved Segments AM/PM:

<table>
<thead>
<tr>
<th>ID</th>
<th>Route Number</th>
<th>Dir</th>
<th>Dist</th>
<th>Segment</th>
<th>2013 LOS</th>
<th>2014 LOS</th>
<th>% Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>465</td>
<td>SR 71</td>
<td>NB</td>
<td>1.2</td>
<td>SR 7 to US 13</td>
<td>F</td>
<td>A</td>
<td>73.9%</td>
</tr>
<tr>
<td>258</td>
<td>SR 261</td>
<td>NB</td>
<td>0.6</td>
<td>Naamans to PA line</td>
<td>D</td>
<td>A</td>
<td>63.0%</td>
</tr>
<tr>
<td>462</td>
<td>SR 71</td>
<td>SB</td>
<td>4.7</td>
<td>SR 72 to SR 896</td>
<td>C</td>
<td>A</td>
<td>61.9%</td>
</tr>
<tr>
<td>153</td>
<td>SR 4</td>
<td>WB</td>
<td>1.2</td>
<td>SR 141 to 1st State</td>
<td>D</td>
<td>A</td>
<td>59.1%</td>
</tr>
<tr>
<td>207</td>
<td>US 40</td>
<td>WB</td>
<td>0.4</td>
<td>SR 1 to SR 7</td>
<td>F</td>
<td>B</td>
<td>57.9%</td>
</tr>
<tr>
<td>77</td>
<td>SR 1</td>
<td>NB</td>
<td>0.9</td>
<td>SR 273 (162) to Christiana Mall (164)</td>
<td>D</td>
<td>A</td>
<td>57.2%</td>
</tr>
<tr>
<td>432</td>
<td>SR 72</td>
<td>NB</td>
<td>1.3</td>
<td>US 13 to SR 71</td>
<td>D</td>
<td>A</td>
<td>52.7%</td>
</tr>
<tr>
<td>214</td>
<td>US 40</td>
<td>EB</td>
<td>1.4</td>
<td>SR 896 to SR 72</td>
<td>D</td>
<td>A</td>
<td>50.0%</td>
</tr>
<tr>
<td>284</td>
<td>SR 72</td>
<td>NB</td>
<td>1.6</td>
<td>SR 4 to Main St.</td>
<td>D</td>
<td>A</td>
<td>48.8%</td>
</tr>
<tr>
<td>191</td>
<td>US 13</td>
<td>NB</td>
<td>1.0</td>
<td>US 40 to SR 273</td>
<td>D</td>
<td>A</td>
<td>47.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Route Number</th>
<th>Dir</th>
<th>Dist</th>
<th>Segment</th>
<th>2013 LOS</th>
<th>2014 LOS</th>
<th>% Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>434</td>
<td>SR 72</td>
<td>NB</td>
<td>1.7</td>
<td>SR 9 to US 13</td>
<td>D</td>
<td>A</td>
<td>65.4%</td>
</tr>
<tr>
<td>293</td>
<td>US 301 &amp; SR 299</td>
<td>SB</td>
<td>1.0</td>
<td>SR 71 to US 301</td>
<td>C</td>
<td>A</td>
<td>60.7%</td>
</tr>
<tr>
<td>97</td>
<td>SR 141</td>
<td>NB</td>
<td>0.8</td>
<td>SR 52 to Brandywine</td>
<td>F</td>
<td>B</td>
<td>45.2%</td>
</tr>
<tr>
<td>417</td>
<td>Rd 26</td>
<td>WB</td>
<td>0.8</td>
<td>Otts Chapel Rd to MD Line</td>
<td>D</td>
<td>A</td>
<td>43.8%</td>
</tr>
<tr>
<td>528</td>
<td>State St</td>
<td>NB</td>
<td>1.6</td>
<td>SR 10 to US 13</td>
<td>D</td>
<td>A</td>
<td>42.0%</td>
</tr>
<tr>
<td>432</td>
<td>SR 72</td>
<td>NB</td>
<td>1.3</td>
<td>US 13 to SR 71</td>
<td>F</td>
<td>B</td>
<td>41.7%</td>
</tr>
<tr>
<td>302</td>
<td>US 301 &amp; SR 299</td>
<td>WB</td>
<td>0.8</td>
<td>US 13 to SR 1</td>
<td>B</td>
<td>A</td>
<td>41.2%</td>
</tr>
<tr>
<td>299</td>
<td>US 301 &amp; SR 299</td>
<td>EB</td>
<td>1.2</td>
<td>Silver Lake Rd. to SR 1</td>
<td>C</td>
<td>A</td>
<td>40.5%</td>
</tr>
<tr>
<td>283</td>
<td>SR 72</td>
<td>SB</td>
<td>1.6</td>
<td>Main St. to SR 4</td>
<td>F</td>
<td>C</td>
<td>37.2%</td>
</tr>
<tr>
<td>125</td>
<td>SR 2</td>
<td>WB</td>
<td>0.6</td>
<td>PollyD. Hill to SR 72</td>
<td>C</td>
<td>A</td>
<td>36.2%</td>
</tr>
</tbody>
</table>
## A3: 20-Worst Segments AM/PM:

<table>
<thead>
<tr>
<th>ID</th>
<th>Route Number</th>
<th>Dir</th>
<th>Dist</th>
<th>Segment</th>
<th>2014 LOS</th>
<th>%Diff - Posted Speed vs Travel Speed</th>
<th>Avg Travel Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>424</td>
<td>SR 2</td>
<td>WB</td>
<td>0.2</td>
<td>Marrows Rd to SR 273</td>
<td>F</td>
<td>85.0%</td>
<td>5.24</td>
</tr>
<tr>
<td>282</td>
<td>Paper Mill</td>
<td>NB</td>
<td>0.4</td>
<td>DE Ave. to Cleveland Ave.</td>
<td>F</td>
<td>77.3%</td>
<td>7.94</td>
</tr>
<tr>
<td>281*</td>
<td>Paper Mill</td>
<td>SB</td>
<td>0.4</td>
<td>Cleveland Ave. To DE Ave.</td>
<td>F</td>
<td>76.1%</td>
<td>9.50</td>
</tr>
<tr>
<td>297</td>
<td>US 301 &amp; SR 299</td>
<td>EB</td>
<td>1.1</td>
<td>SR 71 to Silver Lake Rd.</td>
<td>F</td>
<td>71.2%</td>
<td>13.02</td>
</tr>
<tr>
<td>97*</td>
<td>SR 141</td>
<td>NB</td>
<td>0.8</td>
<td>SR 52 to Brandywine</td>
<td>E</td>
<td>67.9%</td>
<td>11.25</td>
</tr>
<tr>
<td>274</td>
<td>SR 2</td>
<td>EB</td>
<td>1.0</td>
<td>MD Line to SR 4</td>
<td>E</td>
<td>66.0%</td>
<td>16.98</td>
</tr>
<tr>
<td>131</td>
<td>SR 2</td>
<td>WB</td>
<td>0.6</td>
<td>Best Buy to SR 7</td>
<td>E</td>
<td>65.8%</td>
<td>15.37</td>
</tr>
<tr>
<td>101</td>
<td>SR 141</td>
<td>NB</td>
<td>1.8</td>
<td>SR 2 to SR 48</td>
<td>E</td>
<td>65.6%</td>
<td>14.67</td>
</tr>
<tr>
<td>253</td>
<td>48/41</td>
<td>EB</td>
<td>0.8</td>
<td>SR 2 to I-95</td>
<td>E</td>
<td>64.2%</td>
<td>8.94</td>
</tr>
<tr>
<td>257</td>
<td>SR 261</td>
<td>SB</td>
<td>0.6</td>
<td>PA line to Naamans</td>
<td>E</td>
<td>64.2%</td>
<td>16.12</td>
</tr>
<tr>
<td>89</td>
<td>SR 7</td>
<td>NB</td>
<td>0.9</td>
<td>SR 4 to Route 2</td>
<td>E</td>
<td>64.1%</td>
<td>14.73</td>
</tr>
<tr>
<td>192</td>
<td>US 13</td>
<td>SB</td>
<td>1.0</td>
<td>SR 273 to US40</td>
<td>E</td>
<td>62.5%</td>
<td>19.35</td>
</tr>
<tr>
<td>151</td>
<td>SR 4</td>
<td>WB</td>
<td>1.0</td>
<td>1st State to SR 7</td>
<td>E</td>
<td>62.4%</td>
<td>14.57</td>
</tr>
<tr>
<td>250</td>
<td>48/41</td>
<td>WB</td>
<td>0.9</td>
<td>SR 100 to SR 141</td>
<td>E</td>
<td>61.4%</td>
<td>17.26</td>
</tr>
<tr>
<td>252*</td>
<td>48/41</td>
<td>WB</td>
<td>0.8</td>
<td>SR 2 to SR 100</td>
<td>E</td>
<td>61.1%</td>
<td>15.10</td>
</tr>
<tr>
<td>298</td>
<td>US 301 &amp; SR 299</td>
<td>WB</td>
<td>1.1</td>
<td>Silver Lake Rd. to SR 71</td>
<td>E</td>
<td>61.1%</td>
<td>17.75</td>
</tr>
<tr>
<td>240</td>
<td>SR 896</td>
<td>SB</td>
<td>0.2</td>
<td>Deer Park to Del. Ave @ South Coll</td>
<td>E</td>
<td>61.1%</td>
<td>9.73</td>
</tr>
<tr>
<td>182</td>
<td>Rd 26</td>
<td>EB</td>
<td>2.0</td>
<td>Salem Church Rd. (North) to SR 273</td>
<td>D</td>
<td>59.8%</td>
<td>18.07</td>
</tr>
<tr>
<td>487</td>
<td>SR 10</td>
<td>WB</td>
<td>1.2</td>
<td>SR 10A to US 13</td>
<td>D</td>
<td>59.7%</td>
<td>18.15</td>
</tr>
<tr>
<td>234</td>
<td>SR 896</td>
<td>SB</td>
<td>0.6</td>
<td>Chrysler to SR 4</td>
<td>D</td>
<td>59.3%</td>
<td>14.26</td>
</tr>
<tr>
<td>ID</td>
<td>Route Number</td>
<td>Dir</td>
<td>Dist</td>
<td>Segment</td>
<td>2014 LOS</td>
<td>%Diff - Posted Speed vs Travel Speed</td>
<td>Avg Travel Speed (mph)</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>-----</td>
<td>------</td>
<td>---------------------------------------</td>
<td>----------</td>
<td>--------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>282*</td>
<td>Paper Mill</td>
<td>NB</td>
<td>0.4</td>
<td>DE Ave. to Cleveland Ave.</td>
<td>F</td>
<td>84.8%</td>
<td>5.30</td>
</tr>
<tr>
<td>281*</td>
<td>Paper Mill</td>
<td>SB</td>
<td>0.4</td>
<td>Cleveland Ave. To DE Ave.</td>
<td>F</td>
<td>84.4%</td>
<td>6.19</td>
</tr>
<tr>
<td>239*</td>
<td>SR 896</td>
<td>NB</td>
<td>0.2</td>
<td>Del. Ave @ South Coll. To Deer Park</td>
<td>F</td>
<td>82.1%</td>
<td>4.47</td>
</tr>
<tr>
<td>147</td>
<td>SR 4</td>
<td>WB</td>
<td>1.8</td>
<td>Rt. 58 to SR 273</td>
<td>F</td>
<td>76.4%</td>
<td>11.81</td>
</tr>
<tr>
<td>230</td>
<td>SR 896</td>
<td>SB</td>
<td>0.8</td>
<td>I-95 to Old Baltimore</td>
<td>F</td>
<td>74.6%</td>
<td>12.69</td>
</tr>
<tr>
<td>268*</td>
<td>SR 2</td>
<td>WB</td>
<td>0.6</td>
<td>SR 72 to Paper Mill</td>
<td>F</td>
<td>73.9%</td>
<td>9.13</td>
</tr>
<tr>
<td>424</td>
<td>SR 2</td>
<td>WB</td>
<td>0.2</td>
<td>Marrows Rd to SR 273</td>
<td>F</td>
<td>72.8%</td>
<td>9.54</td>
</tr>
<tr>
<td>207*</td>
<td>US 40</td>
<td>WB</td>
<td>0.4</td>
<td>SR 1 to SR 7</td>
<td>F</td>
<td>71.9%</td>
<td>14.05</td>
</tr>
<tr>
<td>295*</td>
<td>US 301 &amp; SR 299</td>
<td>EB</td>
<td>0.6</td>
<td>US 301 to SR 71</td>
<td>F</td>
<td>71.9%</td>
<td>10.85</td>
</tr>
<tr>
<td>6*</td>
<td>SR 92</td>
<td>WB</td>
<td>0.8</td>
<td>US 13 to I-95</td>
<td>F</td>
<td>70.2%</td>
<td>14.75</td>
</tr>
<tr>
<td>286</td>
<td>SR 72</td>
<td>NB</td>
<td>1.4</td>
<td>Old Baltimore to SR 4</td>
<td>E</td>
<td>69.6%</td>
<td>13.66</td>
</tr>
<tr>
<td>106</td>
<td>SR 141</td>
<td>SB</td>
<td>0.9</td>
<td>SR 4 to I-95</td>
<td>E</td>
<td>69.6%</td>
<td>15.22</td>
</tr>
<tr>
<td>273</td>
<td>SR 2</td>
<td>WB</td>
<td>1.0</td>
<td>SR 4 to MD Line</td>
<td>E</td>
<td>66.3%</td>
<td>14.72</td>
</tr>
<tr>
<td>177*</td>
<td>Rd 26</td>
<td>WB</td>
<td>0.8</td>
<td>SR 72 to SR 896</td>
<td>E</td>
<td>66.1%</td>
<td>11.85</td>
</tr>
<tr>
<td>437*</td>
<td>Silverside</td>
<td>WB</td>
<td>0.7</td>
<td>SR 3 to SR 261</td>
<td>E</td>
<td>65.8%</td>
<td>13.70</td>
</tr>
<tr>
<td>267</td>
<td>SR 2</td>
<td>EB</td>
<td>0.6</td>
<td>Paper Mill to SR 72</td>
<td>E</td>
<td>65.7%</td>
<td>11.77</td>
</tr>
<tr>
<td>454</td>
<td>SR 41</td>
<td>NB</td>
<td>1.0</td>
<td>SR 2 to SR 34</td>
<td>E</td>
<td>65.4%</td>
<td>12.10</td>
</tr>
<tr>
<td>456</td>
<td>SR 58</td>
<td>WB</td>
<td>0.8</td>
<td>SR 7 to SR 4</td>
<td>E</td>
<td>62.7%</td>
<td>14.92</td>
</tr>
<tr>
<td>151</td>
<td>SR 4</td>
<td>WB</td>
<td>1.0</td>
<td>1st State to SR7</td>
<td>E</td>
<td>62.6%</td>
<td>14.52</td>
</tr>
<tr>
<td>89</td>
<td>SR 7</td>
<td>NB</td>
<td>0.9</td>
<td>SR 4 to Route 2</td>
<td>E</td>
<td>62.5%</td>
<td>15.36</td>
</tr>
</tbody>
</table>
Appendix B:

Fall 2014 Coverage:

The following GIS drawing displays all routes that have been covered in the Fall 2014 data collection.
Appendix C:

Mean Peak Travel Speed AM & PM:
The following GIS drawing displays the mean peak travel time in miles per hour in both directions for every segment of the Fall 2014 data collection. This is the average travel speed of the test vehicle across a particular segment.

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:

\[
MeanPeakTravelTime = \frac{\sum_{x=1}^{n} TotalTravelTimeofRun(x)}{n}
\]

\[
MeanPeakTravelSpeed = \frac{SegmentLength(Miles)}{MeanPeakTravelTime(Seconds)} \times \frac{3600(Seconds)}{1(hour)}
\]

C1: Fall 2014 Mean Peak Travel Speed Delaware AM
This GIS map displays the AM mean peak travel speed for the state of Delaware.

C2: Fall 2014 Mean Peak Travel Speed Delaware PM
This GIS map displays the PM mean peak travel speed for the state of Delaware.

C3: Fall 2014 Mean Peak Travel Speed New Castle AM
This GIS map displays the AM mean peak travel speed for New Castle County, DE.

C4: Fall 2014 Mean Peak Travel Speed New Castle PM
This GIS map displays the PM mean peak travel speed for New Castle County, DE.
C5: Fall 2014 Mean Peak Travel Speed Kent AM
This GIS map displays the AM mean peak travel speed for Kent County, DE.

C6: Fall 2014 Mean Peak Travel Speed Kent PM
This GIS map displays the PM mean peak travel speed for Kent County, DE.

C7: Fall 2014 Mean Peak Travel Speed Sussex AM
This GIS map displays the AM mean peak travel speed for Sussex County, DE.

C8: Fall 2014 Mean Peak Travel Speed Sussex PM
This GIS map displays the PM mean peak travel speed for Sussex County, DE.
Travel Time & Delay Study – Fall 2014 – Delaware

Mean Travel Speed (mph) - AM

Legend
- < 20
- 20 - 35
- 35 - 45
- 45 - 55
- > 55

Roadway Centerline
State Boundary

Miles
Travel Time & Delay Study – Fall 2014 – New Castle Co.

Mean Travel Speed (mph) - AM

Legend
- < 20
- 20 - 35
- 35 - 45
- 45 - 55
- > 55
- Roadway Centerline
- New Castle County Boundary

Miles
C5: Fall 2014 Mean Peak Travel Speed Kent AM
Travel Time & Delay Study – Fall 2014 – Kent Co.

Mean Travel Speed (mph) - PM

Legend
- < 20
- 20 - 35
- 35 - 45
- 45 - 55
- < 55

Roadway Centerline
Kent County Boundary

Miles
0 2 4 8 12 16
C7: Fall 2014 Mean Peak Travel Speed Sussex AM

Travel Time & Delay Study – Fall 2014 – Sussex Co.

Mean Travel Speed (mph) - AM

Legend
- < 20
- 20 - 35
- 35 - 45
- 45 - 55
- > 55
- Roadway Centerline
- Sussex County Boundary

Miles
Travel Time & Delay Study – Fall 2014 – Sussex Co.

Mean Travel Speed (mph) - PM

Legend
- < 20
- 20 - 35
- 35 - 45
- 45 - 55
- > 55

Roadway Centerline
Sussex County Boundary

Miles
0 2 4 8 12 16
Appendix D:

Mean Peak Delay AM & PM:
The following GIS drawings display the average delay along each route segment in both directions for every segment of the Fall 2014 data collection. Mean peak delay is the average delay experienced by the test vehicle across a particular segment.

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:

\[
Average\ Delay(\text{seconds}) = \frac{\sum_{i=1}^{n} Delay(\text{Seconds})_{of\ run(i)}}{n}
\]

D1: Fall 2014 Mean Peak Delay Delaware AM
This GIS map displays the AM mean peak delay for the state of Delaware.

D2: Fall 2014 Mean Peak Delay Delaware PM
This GIS map displays the PM mean peak delay for the state of Delaware.

D3: Fall 2014 Mean Peak Delay New Castle AM
This GIS map displays the AM mean peak delay for New Castle County, DE.

D4: Fall 2014 Mean Peak Delay New Castle PM
This GIS map displays the PM mean peak delay for New Castle County, DE.

D5: Fall 2014 Mean Peak Delay Kent AM
This GIS map displays the AM mean peak delay for Kent County, DE.

D6: Fall 2014 Mean Peak Delay Kent PM
This GIS map displays the PM mean peak delay for Kent County, DE.
D7: Fall 2014 Mean Peak Delay Sussex AM
   This GIS map displays the AM mean peak delay for Sussex County, DE.

D8: Fall 2014 Mean Peak Delay Sussex PM
   This GIS map displays the PM mean peak delay for Sussex County, DE.
Travel Time & Delay Study – Fall 2014 – Delaware

Mean Delay (sec) - AM

Legend
- 0 - 20
- 21 - 50
- 51 - 90
- 91 - 170
- 171 - 320

Roadway Centerline
State Boundary

Miles
D2: Fall 2014 Mean Peak Delay Delaware PM
Travel Time & Delay Study – Fall 2014 – New Castle Co.

Mean Delay (sec) - AM

Legend
- 0 - 20
- 21 - 50
- 51 - 90
- 91 - 170
- 171 - 320

Roadway Centerline
New Castle County Boundary

Miles
Travel Time & Delay Study – Fall 2014 – Kent Co.

Mean Delay (sec) - AM

Legend:
- 0 - 20
- 21 - 50
- 51 - 90
- 91 - 170
- 171 - 320

Roadway Centerline
Kent County Boundary
Travel Time & Delay Study – Fall 2014 – Sussex Co.

Mean Delay (sec) - PM

Legend
- **0 - 20**
- **21 - 50**
- **51 - 90**
- **91 - 170**
- **171 - 320**
- Roadway Centerline
- Sussex County Boundary

Miles
Appendix E:

Posted Speed vs. Average Speed Difference AM & PM:
The following GIS drawings display the percent difference between the posted speed and the average speed for every segment of the Fall 2014 data collection. This is the percentage difference between the posted speed of a segment and the average delay of the test vehicle across that segment.

Methodology:
The percent difference between the posted speed and the average speed is calculated by 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: (spd = speed)

\[ \text{AverageSpd} = \frac{\sum_{i=1}^{n} \text{AverageSpd}_{\text{run}(x)}}{n} \]

\[ \text{Posted & AverageSpdDiff.\%} = \frac{(\text{PostedSpd} - \text{AverageSpd})}{\text{PostedSpd}} \times 100\% \]

E1: Fall 2014 Percentage difference between average and posted speed Delaware AM
This GIS map displays the AM percentage difference between average and posted speed for the state of Delaware.

E2: Fall 2014 Percentage difference between average and posted speed Delaware PM
This GIS map displays the PM percentage difference between average and posted speed for the state of Delaware.
E3: Fall 2014 Percentage difference between average and posted speed New Castle AM
This GIS map displays the AM percentage difference between average and posted speed for New Castle County, DE.

E4: Fall 2014 Percentage difference between average and posted speed New Castle PM
This GIS map displays the PM percentage difference between average and posted speed for New Castle County, DE.

E5: Fall 2014 Percentage difference between average and posted speed Kent AM
This GIS map displays the AM percentage difference between average and posted speed for Kent County, DE.

E6: Fall 2014 Percentage difference between average and posted speed Kent PM
This GIS map displays the PM percentage difference between average and posted speed for Kent County, DE.

E7: Fall 2014 Percentage difference between average and posted speed Sussex AM
This GIS map displays the AM percentage difference between average and posted speed for Sussex County, DE.

E8: Fall 2014 Percentage difference between average and posted speed Sussex PM
This GIS map displays the PM percentage difference between average and posted speed for Sussex County, DE.
E1: Fall 2014 Percentage difference between average and posted speed Delaware AM
E2: Fall 2014 Percentage difference between average and posted speed
Delaware PM
E3: Fall 2014 Percentage difference between average and posted speed New Castle AM.
E4: Fall 2014 Percentage difference between average and posted speed New Castle PM
E5: Fall 2014 Percentage difference between average and posted speed Kent AM
E6: Fall 2014 Percentage difference between average and posted speed Kent PM
E7: Fall 2014 Percentage difference between average and posted speed Sussex AM
E8: Fall 2014 Percentage difference between average and posted speed Sussex PM
Appendix F:

Level of Service 2013 AM and PM:
The following GIS drawings display the computed level of service for each segment in both directions for all Fall 2013 data collection.

Methodology:
Using the percent difference between the posted speed and average speed, the level of service is computed. By first identifying segments that are interstates or interstate/freeways and roads that are arterials in 2013, the following tables are used to classify the appropriate level of service.

\[
\frac{(\text{Posted Speed} - \text{Average Speed})}{\text{Posted Speed}} \times 100\%
\]

<table>
<thead>
<tr>
<th>Interstate/Freeways (% time under speed limit)</th>
<th>Arterials: (% under speed limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS A: 0-14%</td>
<td>LOS A: 0-10%</td>
</tr>
<tr>
<td>LOS B: 14-18%</td>
<td>LOS B: 10-30%</td>
</tr>
<tr>
<td>LOS C: 18-20%</td>
<td>LOS C: 30-45%</td>
</tr>
<tr>
<td>LOS D: 20-30%</td>
<td>LOS D: 45-60%</td>
</tr>
<tr>
<td>LOS E: 30-50%</td>
<td>LOS E: 60-70%</td>
</tr>
<tr>
<td>LOS F: 50% +</td>
<td>LOS F: 70% +</td>
</tr>
</tbody>
</table>

F₁: Fall 2013 LOS Delaware AM
This GIS map displays the AM LOS for the state of Delaware.

F₂: Fall 2013 LOS Delaware PM
This GIS map displays the PM LOS for the state of Delaware.
Travel Time & Delay Study – Fall 2013 – Delaware

Level of Service - AM
Travel Time & Delay Study – Fall 2013 – Delaware

Level of Service - PM

Legend
- A
- B
- C
- D
- E
- F

Roadway Centerline
State Boundary

Miles
Appendix G:

Level of Service Fall 2014 AM and PM:
The following GIS drawings display the computed level of service for each segment in both directions for all Fall 2014 data collection.

Methodology:
Using the percent difference between the posted speed and average speed, the level of service is computed. By first identifying segments that are interstates or interstate/freeways and roads that are arterials in 2014, the following tables are used to classify the appropriate level of service.

\[
\frac{(\text{Posted Speed} - \text{Average Speed})}{\text{Posted Speed}} \times 100\%
\]

<table>
<thead>
<tr>
<th>Interstate/Freeways (% time under speed limit)</th>
<th>Arterials: (% under speed limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS A: 0-14%</td>
<td>LOS A: 0-10%</td>
</tr>
<tr>
<td>LOS B: 14-18%</td>
<td>LOS B: 10-30%</td>
</tr>
<tr>
<td>LOS C: 18-20%</td>
<td>LOS C: 30-45%</td>
</tr>
<tr>
<td>LOS D: 20-30%</td>
<td>LOS D: 45-60%</td>
</tr>
<tr>
<td>LOS E: 30-50%</td>
<td>LOS E: 60-70%</td>
</tr>
<tr>
<td>LOS F: 50% +</td>
<td>LOS F: 70% +</td>
</tr>
</tbody>
</table>

G1: Fall 2014 LOS Delaware AM
This GIS map displays the AM LOS for the state of Delaware.

G2: Fall 2014 LOS Delaware PM
This GIS map displays the PM LOS for the state of Delaware.

G3: Fall 2014 LOS New Castle AM
This GIS map displays the AM LOS for New Castle County, DE.
G4: Fall 2014 LOS New Castle PM
This GIS map displays the PM LOS for New Castle County, DE.

G5: Fall 2014 LOS Kent AM
This GIS map displays the AM LOS for Kent County, DE.

G6: Fall 2014 LOS Kent PM
This GIS map displays the PM LOS for Kent County, DE.

G7: Fall 2014 LOS Sussex AM
This GIS map displays the AM LOS for Sussex County, DE.

G8: Fall 2014 LOS Sussex PM
This GIS map displays the PM LOS for Sussex County, DE.
Travel Time & Delay Study – Fall 2014 – Delaware

Level of Service - PM

Legend
- A
- B
- C
- D
- E
- F
- Roadway Centerline
- State Boundary

Miles
Travel Time & Delay Study – Fall 2014 – New Castle Co.

Level of Service - PM

Legend
- A
- B
- C
- D
- E
- F

Roadway Centerline

New Castle County Boundary

0 2 4 8 12 16 Miles
Travel Time & Delay Study – Fall 2014 – Sussex Co.

Level of Service - PM

Legend
- A
- B
- C
- D
- E
- F

Roadway Centerline
Sussex County Boundary

Miles
Appendix H:

Peak Travel Time Data – Fall 2014:
The following table is the averaged data for all segments analyzed during Fall 2014 data collection. The table includes the route number, route name, segment direction, segment distance, mean peak travel time, mean peak delay, 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

AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

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Susan L. Groff, Ed. D.
Director, Institutional Equity & Title IX Coordinator
305 Hullihen Hall
Newark, DE 19716
(302) 831-8063
titleixcoordinator@udel.edu

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact:

Anne L. Jannarone, M.Ed., Ed.S.
Director, Office of Disability Support Services
Alison Hall, Suite 130,
Newark, DE 19716
(302) 831-4643

Abridged Version – with permission by Title IX coordinator (ex: rack cards, etc.)
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