JACOBS

Memorandum

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To Ashwin Patel, P.E.
PennDOT Engineering District 6-0

From Steve Cunningham, P.E., PTOE

Subject SR 202 Before-After Travel Time Comparison

Before-After Study Overview

In order to enhance traffic flows along SR 6202 between County Line Road and Memorial Drive in Doylestown, the Pennsylvania Department of Transportation (PennDOT) specified and installed an adaptive traffic signal system at thirteen (13) intersections along this corridor. These signal improvements were made as part of the larger SR 0202, Section 7IT construction project which included various Intelligent Transportation System (ITS) deployments along area roadways.

The travel time and delay study corridor included thirteen (13) signalized intersections along SR 6202, between County Line Road in Montgomery Township, and Memorial Drive in Doylestown. The study area is approximately 5.68 miles in length, and signal spacing varies from 200 feet (between Memorial Drive and Hospital Drive), to over 6,000 feet (between Tamanend Avenue and Iron Hill Road). The study area includes the following intersections with SR 6202:

1. County Line Road[1]
2. Schoolhouse Road
3. Brittany Drive/Skyline Drive
4. Limekiln Pike
5. Bristol Road
6. Sand Road
7. Tamanend Avenue
8. Iron Hill Road
9. New Britain Road
10. PA 611 Southbound Ramps
11. PA 611 Northbound Ramps
12. Hospital Drive
13. Memorial Drive

Field travel data was collected on a typical weekday during the AM, midday, and the PM peak periods. The “Before” data was collected on May 17 and 18, 2012, prior to the adaptive traffic signal system field installation and modification of signal operation and timing plans. Data collected during this period was used as the “Before” implementation travel time surveys for comparing the measures of effectiveness of the traffic signal modifications. Data was collected again May 15, 2013, after activation and optimization of the adaptive traffic signal system. These “After” implementation travel time surveys were carried out for the same AM, midday, and PM peak

[1] Although County Line Road was part of the adaptive system installation associated with the 202-7IT project, the adaptive functionality was not active at the time of this study due to conflicting schedules and PennDOT priorities at this intersection.

periods for the study corridor to determine the efficacy of the implemented and fine-tuned adaptive system. The measures of effectiveness (travel time, delay, and average speed) for the "After" study were compared with that of the "Before" study.

As these results are further discussed in this memorandum, it is important to note that the signal timings **were not** optimized prior to the adaptive system installation. A corridor re-timing program is not currently planned by the Department or the local municipalities in the foreseeable future. Optimization of the signal system prior to the adaptive installation would likely have yielded significant travel time benefits. However, with this step not having occurred, it is impossible to discern the additional travel time and delay benefit that can be attributed solely to the adaptive system. Also, the side street delays and queues were not measured nor evaluated as part of these study efforts. With a lack of data for side street delays and queues we cannot definitively say that the overall intersection delays were not simply shifted from the main street (SR 6202) approaches to the side streets. It should be noted, however, that field observations and feedback received from motorists and the local municipalities do not indicate significant side-street delay or queuing issues. Furthermore, in the time between the "before" and "after" data collection runs, the US 202 Parkway was opened to traffic, which effectively doubled roadway capacity for regional traffic between Montgomeryville and Doylestown. With these considerations in mind, it is not possible to evaluate the effectiveness of the adaptive system alone, but rather provide an overall comparison of travel data between these two time periods.

Travel Time Runs

The travel time and delay study involved measuring the time required for each of a series of vehicle runs through the corridor. Vehicle runs in each direction of travel were conducted during the "Before" and "After" periods on a typical weekday during each of the following time periods:

- AM peak (6:00 AM to 9:00 AM);
- Midday Peak (11:00 AM to 2:00 PM); and
- PM peak (3:00 PM to 6:00 PM).

The drivers conducting the travel time runs were instructed to use the "floating car method," in which the drivers attempt to travel with the flow of traffic, changing lanes so as to pass as many cars as they are passed by. This method is used so that the travel times collected are representative of the travel time of the average vehicle traveling through the corridor. When intersections are closely spaced and traffic is heavy, lane change opportunities become limited. Traffic in the right and left through lanes may flow at different speeds, depending on the number of vehicles planning to turn at upcoming intersections, and the driver performing the travel time run may be "stuck" in a lane. While this condition may result in travel times that do not represent the average car, averaging many travel time runs for the same time period will help eliminate the bias that may be present in individual runs. **Table 1** shows the number of travel time runs that were completed during each of the time periods, in each direction, for each study period.

Table 1: Number of Travel Time Runs Completed During Each Study Period

Direction	Time of Day	Before	After
Northbound	AM Peak	4	7
	Midday	3	6
	PM Peak	3	6
Southbound	AM Peak	3	6
	Midday	3	6
	PM Peak	3	5

These travel times were measured using a laptop computer running Tru-Traffic® software connected to a GPS receiver mounted on the roof of the vehicle. The driver was able to stop and start the data collection from safe locations while the vehicle was stopped and was not required to take any additional action while the vehicle was moving. The software gathered location information from the GPS receiver at 1-second intervals and calculated vehicle speed and location through the corridor based on this information.

Analysis and Results

Travel Time Comparison
Table 2 presents the summary statistics for the travel runs described in the previous section. The statistics include the travel time for each segment averaged over all the runs for a given time period and direction of travel, as well as other measures of effectiveness such as average speed and total system delay.

The measures of effectiveness for the corridor include:

- ***Average Travel Time*** - the average travel time in seconds for the vehicle to travel through the corridor from the center of the first intersection to the center of the last intersection, calculated separately for each direction of travel.

- ***Average System Delay*** - the travel time through the corridor for each run minus the time it would have taken the vehicle to travel through the corridor if it were able to travel at the normal speed of traffic, averaged over all runs for a given time period in each direction of travel. The normal speed of traffic is defined here as the posted speed limit.

- ***Average Travel Speed –*** the speed of the vehicle averaged over the length of the study area.

- ***Number of Stops -*** the number of times the vehicle's speed drops below 5mph after exceeding 15mph, averaged per direction for all runs.

Table 2: SR 6202 Travel Time Comparison

Direction	Time of Day	Data Set	Average Travel Time (sec)	Average System Delay (sec)	Average Travel Speed (mph)	Average Number of Stops
Northbound	AM Peak	Before	741	220	27.6	5.0
		After	605	84	34.0	2.7
		Δ	135	135	6.3	2.3
		% Change	**-18%**	**-62%**	**+23%**	**-46%**
	Midday	Before	734	213	28.0	6.0
		After	646	125	31.4	3.7
		Δ	88	88	3.5	2.3
		% Change	**-12%**	**-41%**	**+12%**	**-39%**
	PM Peak	Before	817	296	25.0	7.0
		After	663	142	30.7	3.5
		Δ	154	154	5.7	3.5
		% Change	**-19%**	**-52%**	**+23%**	**-50%**
Southbound	AM Peak	Before	868	347	23.9	7.3
		After	697	176	29.3	4.7
		Δ	171	171	5.4	2.7
		% Change	**-20%**	**-49%**	**+23%**	**-36%**
	Midday	Before	808	287	25.2	5.7
		After	699	178	29.2	4.3
		Δ	110	110	4.0	1.4
		% Change	**-14%**	**-38%**	**+16%**	**-24%**
	PM Peak	Before	1141	620	17.9	8.7
		After	901	380	22.9	6.0
		Δ	240	240	5.0	-2.7
		% Change	**-21%**	**-39%**	**+28%**	**-31%**

Average Travel Time Analysis
The total travel time for each run through the corridor was used as the primary measure of effectiveness. Travel time was measured from the center of the first intersection to the center of the last intersection encountered during the run. **Figure 1** shows the comparison in travel time along the corridor for the eastbound and the westbound directions during all study periods. As shown in **Table 2**, the evaluation shows that the adaptive signal operation offers significant improvement over the existing timing plans as reflected by the percent reduction in average travel times.

The average travel time is observed to be reduced by 12 to 21 percent.

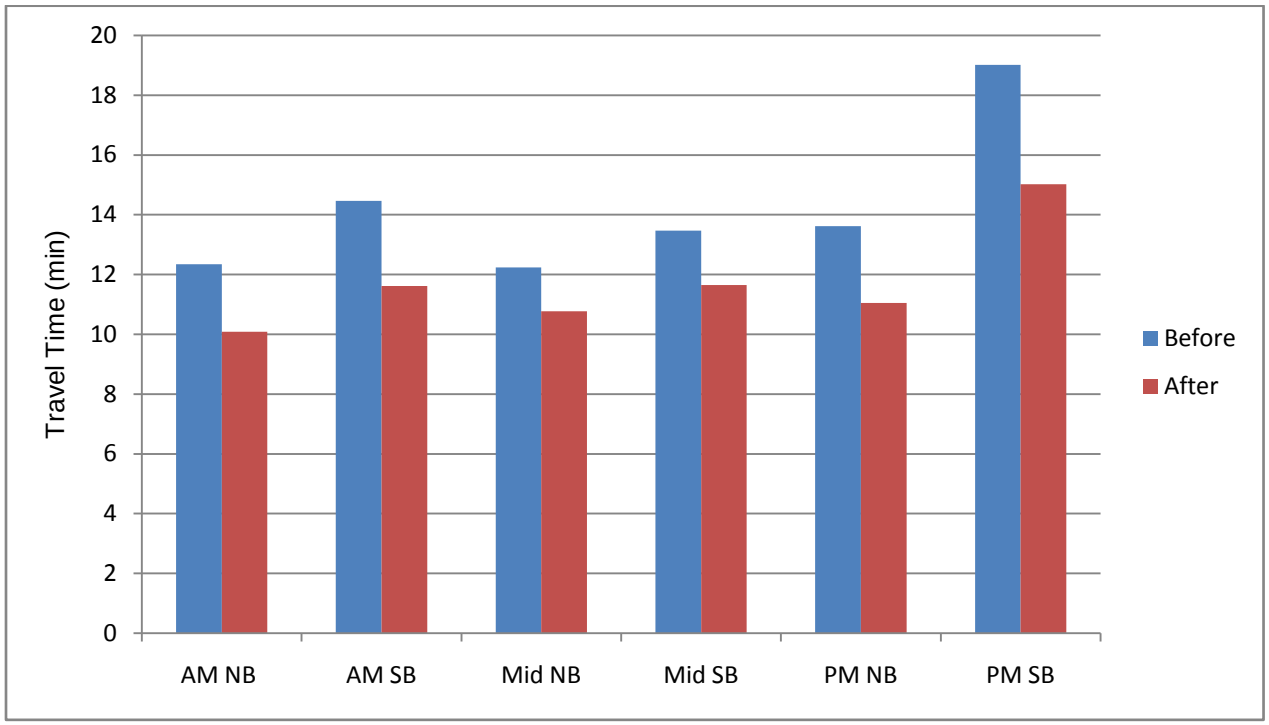

Figure 1: Travel Time Improvements

Average System Delay Analysis
Delays along the study corridor were evaluated for both the "Before" and "After" scenarios. This was completed by comparing the actual travel time observed in the field to a theoretical "unconstrained" vehicle traveling at the speed limit along the study corridor. The comparison between the system delays "Before" and "After" condition provides a relative measure of system performance improvement through the corridor. It is also noted that the average system delay goes down with the reduction in the number of stops along the corridor. **Figure 2** shows the decrease in the System Delay with the implementation of the adaptive signal operation.

The average system delay was reduced by 38 to 62 percent.

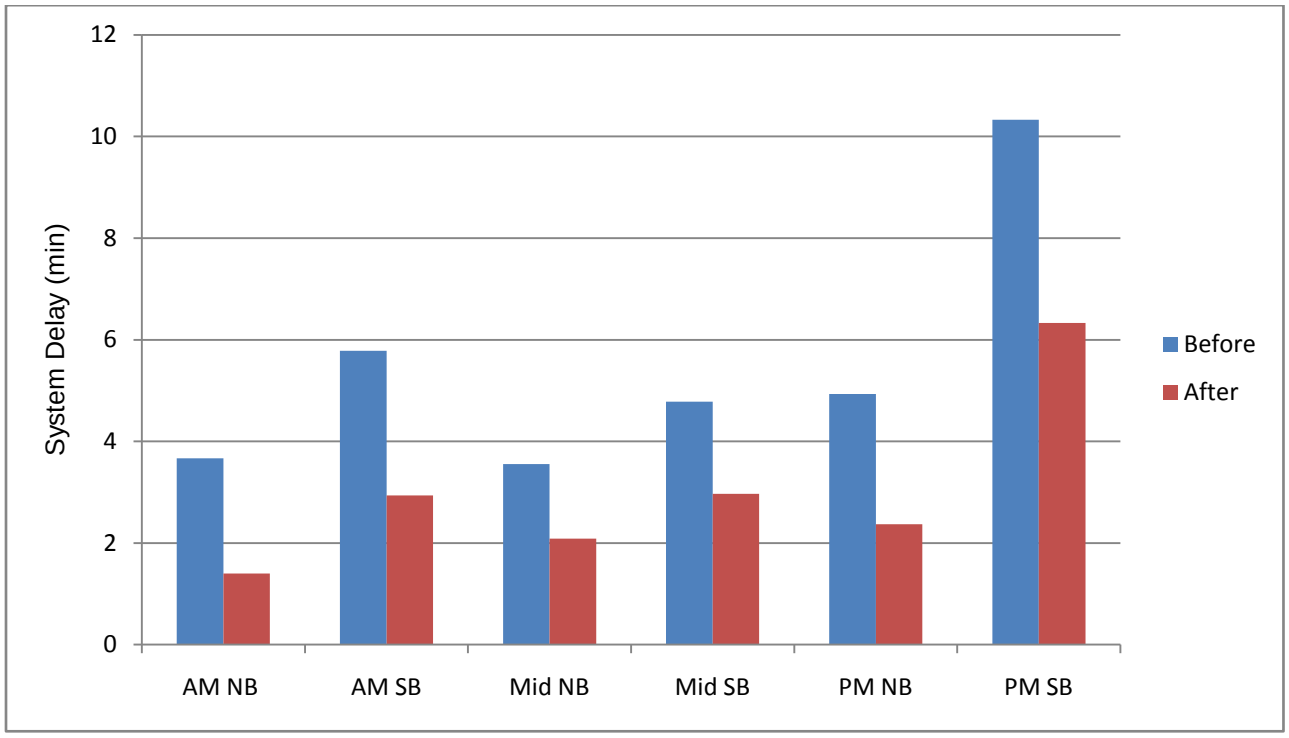

Figure 2: Average System Delay Improvements

Time-Space Analysis
Attachment A offers an alternate way to visualize the corridor travel time improvements by showing speed and cumulative travel time by distance through the entire corridor. These figures represent the time-space diagrams for each of the analysis periods, with both directions of travel represented. The red lines in the figures represent the average travel time runs in the "Before" data, and the blue lines represent the "After" data. The black dashed line represents an unconstrained vehicle traveling at the speed limit along the corridor. These graphs use the same horizontal axis, which shows the distance along the corridor in feet, and the graphs track the average study vehicle as it moves through the corridor. The vertical axis represents time, therefore the vertical distance between the various lines represents the travel time differences at various points along the corridor. Using these figures, the data can be used to verify that unexpected delays or decreases in traffic flows are not occurring. Similarly, intersections should be evaluated simultaneously for both directions of travel.

Other MOE's
Attachment B offers the output files from the Tru-Traffic Analysis, and details other Measures of Effectiveness collected through the GPS data. Also provided electronically are the Google Earth .kml files of the individual travel runs which can be used to visualize travel conditions through the color-coded map overlay data, and additional Travel Time and Delay Analyses with information for each intersection along the corridor.

cc: 202-7IT Jacobs Project Team