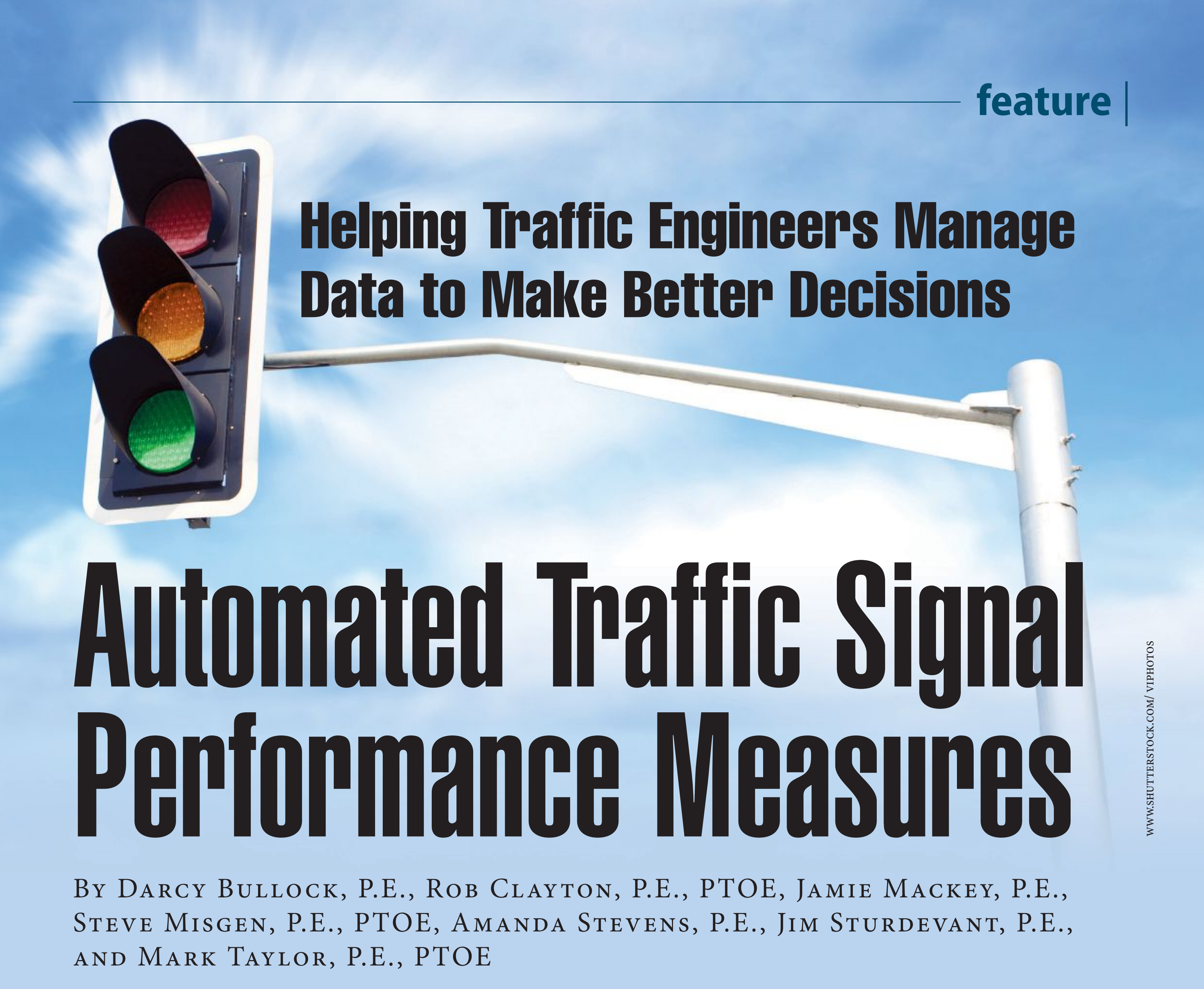

Helping Traffic Engineers Manage Data to Make Better Decisions

Automated Traffic Signal Performance Measures

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Improved signal operations with smooth and equitable traffic flow are goals for most traffic engineers; however the limited snapshot-view retiming methods that involve manual data collection, traffic signal modeling, and field fine-tuning are resource intensive and unresponsive to changes in traffic patterns. The National Transportation Operations Coalition's 2012 National Traffic Signal Report Card has led agencies to focus resources on these activities and develop methodologies to examine all the components of traffic signal operations.[1] These data-driven program management plans provide objective methods for identifying shortcomings and encourages coordination with neighboring jurisdictions. In addition, agencies need tools to prioritize activities when resources are constrained.

Automated Traffic Signal Performance Measures are innovative new traffic signal tools used extensively by the Indiana Department of Transportation (INDOT), the Utah Department of Transportation (UDOT), and the Minnesota Department of Transportation (MNDOT). The signal performance measures help agencies effectively manage traffic signals without the need for extensive manual field data collection or a central traffic management or traffic adaptive system. The American Association of State Highway and Transportation Officials Technology Implementation Group (AASHTO TIG) has recently recognized Automated Traffic Signal Performance Measures as a 2013 focus technology and is investing time and money to accelerate its adoption by agencies nationwide.[2]

Background

Traditional signal timing practices use modeling software with dozens of input parameters, such as estimated speeds, roadway geometrics, and assumed vehicle and driver characteristics. Traffic counts are very labor intensive, and as a result count data are typically aggregated into 15 minute bins while models are typically run using traffic counts obtained from a single day. Developing signal timing plans based upon one day of data is not ideal, but historically it has not been practical or cost effective to obtain additional data.

In 2005, Indiana initiated research to develop a portfolio of new performance measures that characterized flow rates, quality of coordination, and split failures using logged time-stamped detectors, phase state changes, and controller events.[3,4,5] During the development of these performance measures, a team of three vendors (Econolite, Siemens, and Peek) participated in the development of enumeration definitions for approximately 125 controller events, such as "phase begin of green," "phase gap out," "phase max out," "phase begin of yellow," "detector off," and "detector on."[6] Henry X. Liu, et al., characterized this new data as "High Resolution Data."[7] New performance measures derived from this high-resolution data provide an important tool for traffic engineers to make informed and highly accurate decisions in optimizing and managing mobility, rather than having to rely on models, field observations, and public complaints.

What Are Automated Traffic Signal Performance Measures?

Automated Traffic Signal Performance Measures are a series of visual aids that display the high-resolution data from traffic signal controllers. They are a valuable asset management tool, aiding technicians and managers in the control of both traffic signal hardware and traffic signal timing and coordination. They allow analysis of data collected 24 hours a day, 7 days a week, improving the accuracy, flexibility, and performance of signal equipment and the system as a whole. Signal performance measures provide a clear framework for performance analysis and decision-making, while helping to educate and facilitate good dialogues with the public, agency leadership, public officials, first responders, and other mobility partners.

The Purdue Phase Termination Chart (PTC)[8] and Split Monitor (SM) metrics require only data from a signal controller capable of collecting high-resolution data. The Purdue Coordination Diagram (PCD)[9] requires detection in advance of the intersection to record vehicle arrivals as a function of time into the cycle. The Purdue Travel Time Diagram (PTTD)[10] uses vehicle probe data to evaluate corridor performance and does not require the high-resolution data collected by the controller. If lane-by-lane volumes or volume to capacity (v/c) ratios are desired, then lane-by-lane stop bar detection is required. None of the metrics require central traffic signal system software.

How Are Automated Traffic Signal Performance Measures Generated?

Signal controllers with high-resolution data logging capability log controller events with a tenth-of-a-second resolution timestamp and store the events in temporary data files on the controller. A file transfer protocol (FTP) connection is made periodically (about every 15 minutes for UDOT) from a central server to the traffic signal controller to retrieve the data files.[3, 11] If communications do not exist to the traffic signal, it is possible to retrieve data in the field by connecting a laptop computer to the controller using a CAT5 cable. Modern traffic signal controllers have the ability to buffer at least 24 hours of high-resolution controller events. Many controller manufacturers have implemented external storage devices, such as USB drives or memory cards that can be used if longer storage intervals are desired for signals without communication.

Once collected, the data files are translated into a database, where they can be interpreted manually or with an automated graph, analyzed visually or with an optimization algorithm, and archived for comparative analysis. An efficient means of presenting the information is to use a web interface that allows all users—such as agency, consultants, academia, executive leaders, and public officials—the chance to view the information without requiring special software or needing to manage firewalls and network connections.

Helping Traffic Engineers Manage Data To Make Better Decisions

Automated traffic signal performance measures show real-time and historical functionality at signalized intersections. Engineers can use the signal performance measures to directly measure what they previously could only estimate and model. Using the measures allows traffic signal personnel to target and prioritize problem areas. The measures are used to identify problems such as malfunctioning vehicle and pedestrian detection, improper split allocation, and coordination failures. They are valuable tools for troubleshooting customer complaints and for evaluating signal performance during special events. Automated traffic signal performance measures can be used to optimize cycle lengths, offsets, and splits for both recurring and occasional traffic patterns. They can provide a platform for comparing arterial performance on corridors. The measures can help prioritize signal timing needs and eliminate the arbitrary nature of retiming at regular intervals.

Operations Example

New signal coordination plans were installed for the northbound direction of Bangerter Highway at 5400 South in Salt Lake City, UT, USA on March 7, 2013. Figure 1 shows the Purdue Coordination Diagram for that intersection on that day. The diagram is an effective way to show the quality of progression for vehicles arriving at the intersection. Each black dot on the diagram is a vehicle arriving at the intersection. Vehicles arriving above the green line arrive during the green or yellow portions of the phase. Vehicles arriving below the green line arrive during the red time for that movement. At a glance, an analyst can see if vehicles are arriving during green or red, and how long vehicles arriving on red are being delayed.

Figure 1 shows that the offset used for the updated coordination plan that starts at 9:00 a.m. had 76 percent of the vehicles arriving on red between 9:00 a.m. to 11:45 a.m., indicating a mistake was

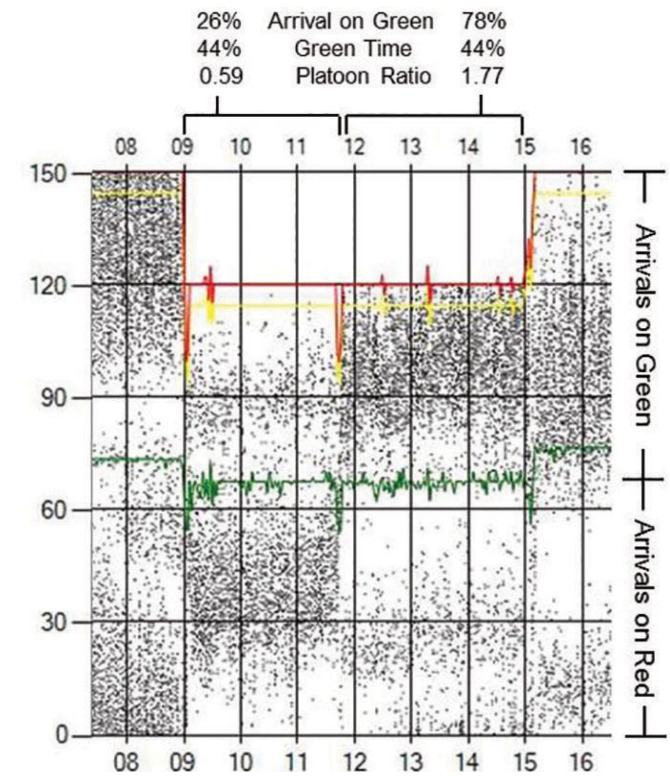


Figure 1: Purdue Coordination Diagram. Northbound Bangerter Hwy & 5400 South (Continuous Flow Intersection) in Salt Lake City, Utah. March 7, 2013

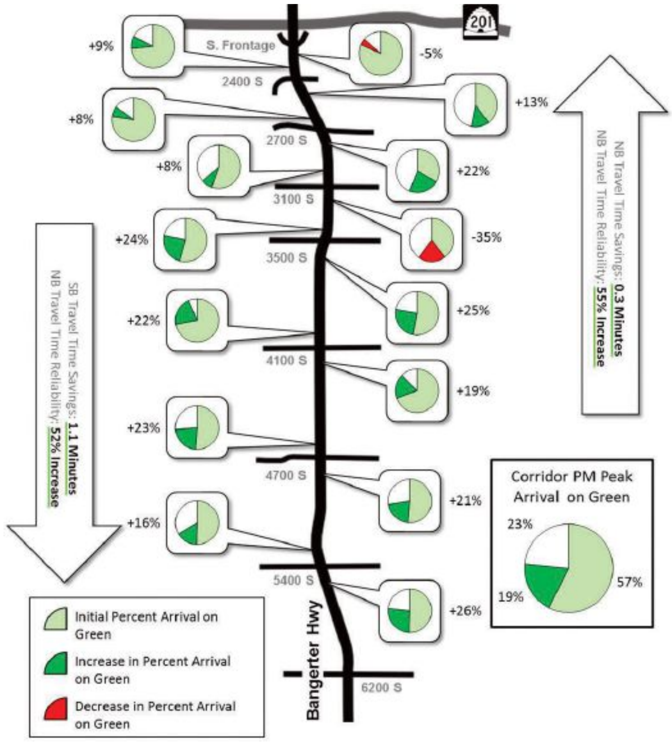


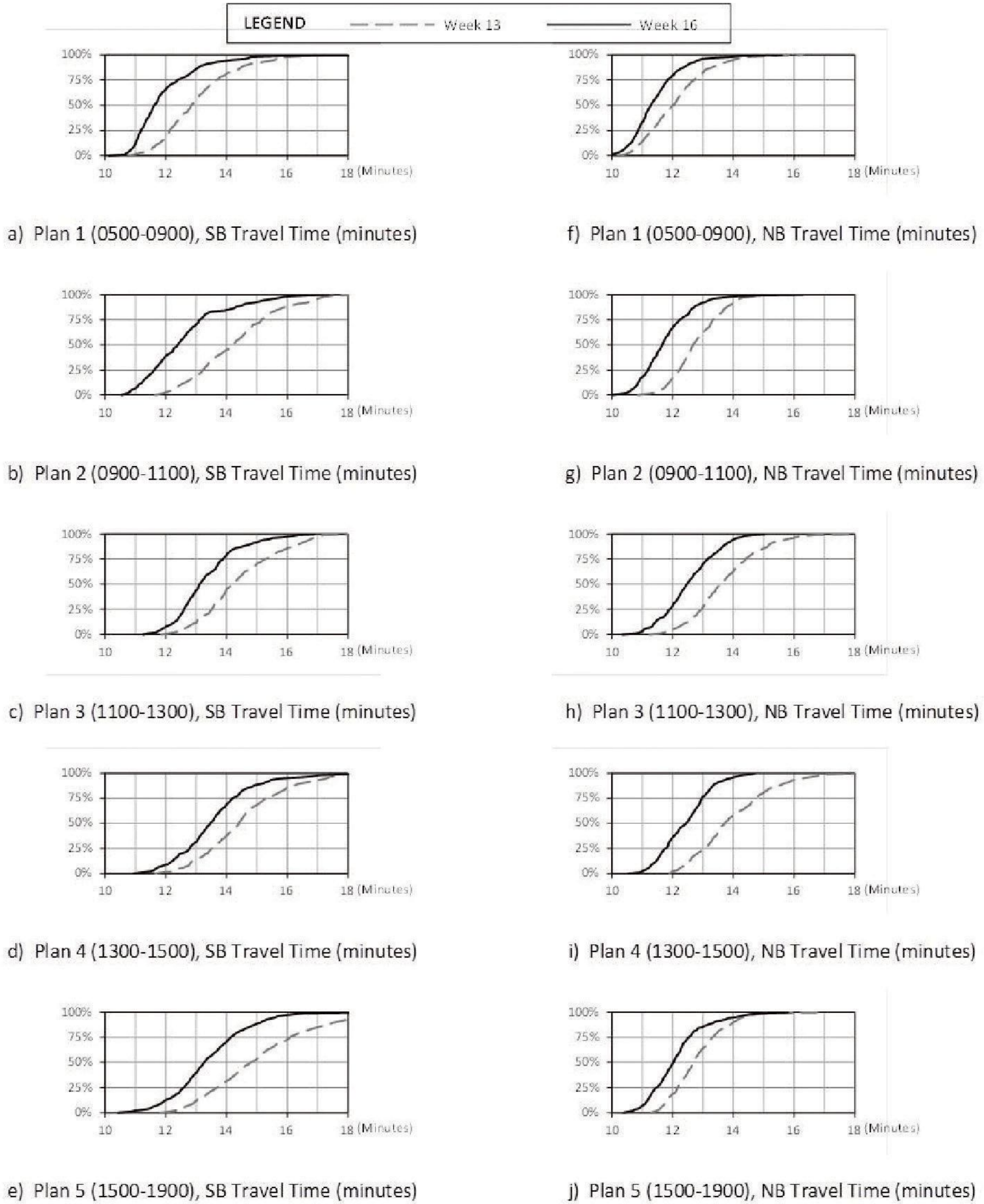
Figure 2: Bangerter Highway re-timing project from SR-201 to 6200 South in Salt Lake City, Utah showing percent arrivals on green and travel-time reliability. March 2013

made when the offset was entered into the controller. Using the Purdue Coordination Diagram in real-time, the mistake was realized and corrected at 11:45 a.m. Vehicle arrivals on green immediately improved (78 percent arriving on green) to the levels anticipated when the coordination plan was designed.

Figure 2 shows the results of the Bangerter Highway re-timing project for the afternoon peak in March 2013, where automated traffic signal performance measures were used for optimization improvements and measures of effectiveness performance comparisons. Overall, the percent arrivals on green increased 19 percent. Probe data showed a travel time improvement for southbound of 1.1 minutes and an improvement in travel time reliability of 52 percent.

Probe Data Outcome Assessment Tools Example

Historically, before-after travel time assessment of corridors was done by agencies or contractors driving the corridor with stop watches or instrumented vehicles. Figure 2 provides a comprehensive summary graphic of a corridor progression and travel time. The travel time information is derived from commercial probe data, which now makes it feasible to obtain thousands of data points characterizing travel time in both directions along an arterial over multiple time plans.11 To further illustrate how this emerging data can be used, Figure 3 shows before and after travel



a) Plan 1 (0500-0900), SB Travel Time (minutes)

f) Plan 1 (0500-0900), NB Travel Time (minutes)

b) Plan 2 (0900-1100), SB Travel Time (minutes)

g) Plan 2 (0900-1100), NB Travel Time (minutes)

c) Plan 3 (1100-1300), SB Travel Time (minutes)

h) Plan 3 (1100-1300), NB Travel Time (minutes)

d) Plan 4 (1300-1500), SB Travel Time (minutes)

i) Plan 4 (1300-1500), NB Travel Time (minutes)

e) Plan 5 (1500-1900), SB Travel Time (minutes)

j) Plan 5 (1500-1900), NB Travel Time (minutes)

Figure 3. US 31 through Kokomo, Indiana signal timing improvement

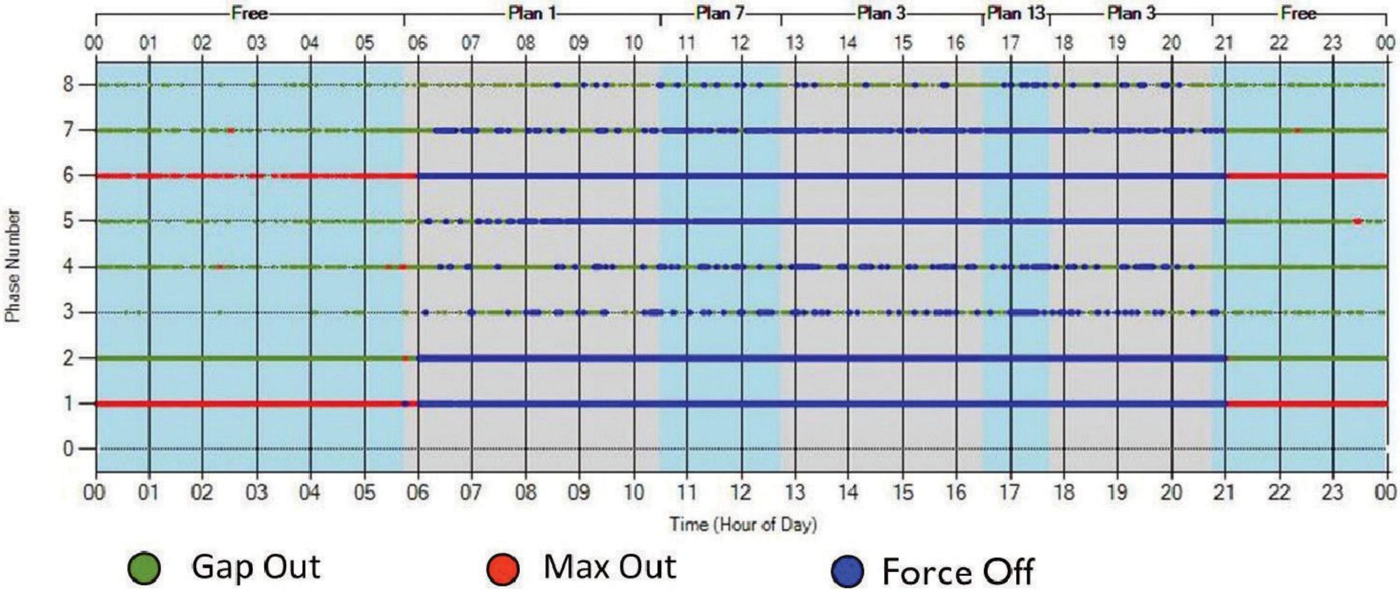


Figure 4: Purdue Phase Termination Chart. SR-77 (400 South) and 1750 West, Springville, Utah. October 23, 2013.

time distributions for an 8.7 mile segment of the US 31 corridor retimed in Kokomo, IN, USA in 2012. Figure 3a-3e shows the statistical distribution of southbound travel times for five different timing plans, and Figure 3f-3j shows similar information for the northbound direction. Perhaps Plan 2-SB (0900-1100) and Plan 4-NB (1300-1500) exhibited the most decrease in median travel time (just under 2 minutes). However, all five timing plans exhibited a decrease in travel time in both directions after the corridor was retimed. An analysis of approximately 3,000,000 commercial probe data records collected over 6 months showed the retiming resulted in approximately $2.7M in user cost savings.

Maintenance Example

Agencies commonly struggle to monitor the health of vehicle detection, frequently relying on complaints from the public to identify problems. The high-resolution controller data logger reports how a phase terminates over time (gap out, max out, or force off), so the Phase Termination Chart can show detection problems at a glance. Figure 4 shows the chart over a 24-hour period for the intersection of 1750 West and 400 South in Springville, UT, USA on October 23, 2013. The graph shows that phases 1 and 6 are utilizing all of the programmed green time every cycle, which indicates a detection problem. A work order was created to repair the vehicle detectors for phases 1 and 6. The chart, in conjunction with the split monitor, also helps with timing maintenance. Since phase 7 was forcing off and phase 8 was frequently gapping out during coordination, some split time from phase 8 was reassigned to phase 7. During 2013, UDOT identified and fixed more than 185 detector issues using automated traffic signal performance measures.

Timing Plan Development Example

MNDOT uses the Systematic Monitoring of Arterial Road Traffic Signals (SMART Signal) System developed by Henry Liu at the University of Minnesota, Twin Cities. The system uses the same high-resolution data collected by the signal controllers at the intersections. Using the data collected, MNDOT developed a complete set of timing plans for a five-intersection arterial, US 10 in Ramsey, MN, USA. Five timing plans were developed that included determination of cycle lengths, splits, offsets, and sequencing. The arterial is now being monitored to determine how the timing plans lose their efficiency over time, and what adjustments can be made to maintain efficiency.

Executive Reporting and Prioritizing Example

Executive leaders and public officials are interested in program-wide signal performance and trends. They want to know if signal operations are getting worse, getting better, or staying the same and by how much. They also want to know how an agency most effectively prioritizes resources and workload. If the percent of vehicles arriving during green and red is known at intersections, the results can be aggregated for various levels of interest within the agency (executive, department, region, division, and technical). UDOT's signal performance measures executive reports for December 2013, collected from 333 intersections and 680 approaches, show on average 29 percent of vehicles arrive on red statewide in Utah at intersections with the required advance detection. Similar measurements are also aggregated for various regions, cities, corridors, and intersections. The agency also knows where the signal timing is in the greatest need of retiming projects. For UDOT, the December 2013 metrics show that 10400

South in South Jordan, UT, USA between I-15 and Bangerter Highway was one of the worst coordinated arterials in the state, with an average 41 percent of vehicle arrivals on red.

Similarly, the use of emerging commercial probe data to independently calculate $2.7M in user cost reductions along US 31 (Figure 3) in Indiana provides an important performance measure to report to elected officials and decision makers demonstrating the impact they have when they invest in traffic signal operations and maintenance.

Moving Forward to Implementation

There are a number of features in central and closed loop systems that work well and are needed for traffic management success, such as controller database management; paging and alarm functions; traffic responsive and adaptive control; manual override of plan selections for special events/incidents; and real-time intersection graphic displays. Some central traffic signal systems have or are in the process of incorporating some of the metrics presented in this paper. However, part of the success of the automated traffic signal performance measures is the web-based access to the metrics without network access rules, passwords, or the need to purchase specific central or closed loop systems, which also increases transparency. Other successes of automated traffic signal performance measures are that the agency can be self-sufficient in analyzing raw data, the reports and alarms can be easily tailored to an agency's specific needs, and there is an open-source component so users can innovate, build upon the original technology, and share their ideas and research. Agencies interested in pursuing these metrics outside of a central or closed loop system can contact a member of the AASHTO TIG Lead-States Committee. The website www.tig.transportation.org has a full listing of signal performance measures committee members and additional information about the AASHTO TIG program.

ITE Webinar Series on Automated Traffic Signal Performance Measures

The Institute of Transportation Engineers will host a 3-part webinar series on the automated traffic signal performance measures discussed in this article featuring presentations by INDOT, UDOT, MNDOT, and Purdue University. For complete details and to register, visit www.ite.org/education.

Achieve Your Agency's Objectives Using Automated Traffic Signal Performance Measures

April 9, 2014 | 12:00 p.m. to 1:30 p.m.

Automated Traffic Signal Performance Measures Case Studies

May 7, 2014 | 12:00 p.m. to 1:30 p.m.

Critical Infrastructure Elements for Automated Traffic Signal Performance Measures

June 11, 2014 | 12:00 p.m. to 1:30 p.m.

Conclusion

Innovation, creativity, risk, and increased transparency are necessary to meet a growing society's transportation needs. The automated traffic signal performance measures discussed in this article allow for agencies to effectively optimize and manage traffic signals without extensive field data collection, a central traffic management or adaptive system, or a signal communications infrastructure. In addition, these measures allow agencies to visualize data in an easy-to-understand format that is web-based and easily accessible by a diverse group of users. Using automated traffic signal performance measures, agencies will be able to improve mobility, increase safety, and use resources more effectively. To see how signal performance measures work, visit UDOT's website at: www.udottraffic.utah.gov/signalperformancemetrics. **itej**

Acknowledgments

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Resources

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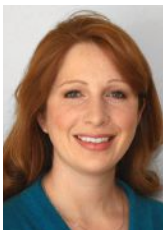

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