# USING PRE-EXISTING INFRASTRUCTURE TO CREATE A NOVEL SIGNAL PERFORMANCE MEASURE

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## ABSTRACT

This paper presents a novel traffic signal performance measure (NSPM) that combines vehicle speed detection with an established signal performance measure along the US 1 arterial roadway in New Jersey, USA. Arterial roadways utilize several effective, yet costly, technologies to improve traffic flow and safety while minimizing delay and assuring travel time reliability. Vehicle speed detectors, known as advanced detectors, collects speed data in excess of 1,000 feet before the stop bar, providing a means to assess vehicle progression. This research combined advance detector speed data with traffic signal controller cycle data to create a visually intuitive graph that plots vehicle trajectories with respect to the signal cycle time. The presence data collected from the advanced detectors also indicate queue buildup by lane, providing a means to evaluate safe braking distances. A performance measure was created using data collected from the existing infrastructure equipment (speed detector and traffic signal controllers) named Modified Vehicle Arrival (MVA). By applying this performance measure, a better understanding of the intersection operation is realized without additional capital investment.

## INTRODUCTION

Data driven traffic control methods based on traffic sensors are being employed to improve safety and efficiency at signalized traffic intersections. There are several commercially available sensors in production that can obtain a variety of data to include vehicle speed, trajectory, presence, headway, time of arrival, etc. [*1, 2, 3*]. These data are instrumental in creating data driven measures that are used to assess signalized intersection performance. Unfortunately, it is cost prohibitive to provide all the necessary sensors to optimize safety and efficiency.

The purpose of this study is to evaluate the ability to use preexisting infrastructure to develop a novel signal performance metric (NSPM). For this research, an existing speed radar detector is used to predict vehicle trajectories at the approach of an adaptive traffic signal. The detector, placed ahead of the intersection (advanced detector), collects speed data that is combined with the existing traffic signal controller data to define a new performance measure. An advanced vehicle detector provides speed, time of vehicle presence, and a vehicle length on a lane-by-lane basis in advance of the intersection. By combining existing traffic signal controller data with advance speed detector data, the performance metric, Modified Vehicle Arrival (MVA), is defined. This measure aims to provide a numerically sound, yet visually intuitive vehicle trajectory with respect to the adaptive traffic signal controller data to allow an agency to better assess vehicle progression as well as safety.

## DATA AND TEST BED

An established test site located at the intersection of Carnegie Center Boulevard and US-Route 1 (Figure 1) was used to develop the performance measure. The site has 3 lanes southbound and 4 lanes northbound. Only the northbound traffic, particularly lane 8, was evaluated in this study. The period observed is July 30, 2020, at 11:15 am to July 31, 2020. The intersection is running an adaptive controller software (Insync) with a Wavetronix [*4*] advance detector (AD) located approximately 1,200 feet south of the northbound stop bar. This intersection is also employing the federally funded Automated Traffic Signal Performance Measures (ATSPM) software, which can graphically represent data from the adaptive traffic signal and AD. ATSPM is an established suite of performance measures and data analysis tools that are traditionally used with high resolution controller data, but have been recently combined with adaptive traffic controller data [*5*, *6*]. The Purdue Coordination Diagram (PCD) is a specific graphical performance measure used within the ATSPM suite. The PCD graphically shows the signal phase with respect to the vehicle detection times and volume to evaluate intersection performance [7, *8*]. By manipulating vehicle detection inputs from the AD, vehicle trajectories are produced in the PCD, where previously only the detection was represented. This provides a quantitative representation of the vehicle speed for a particular detection with respect to the signal cycle time.

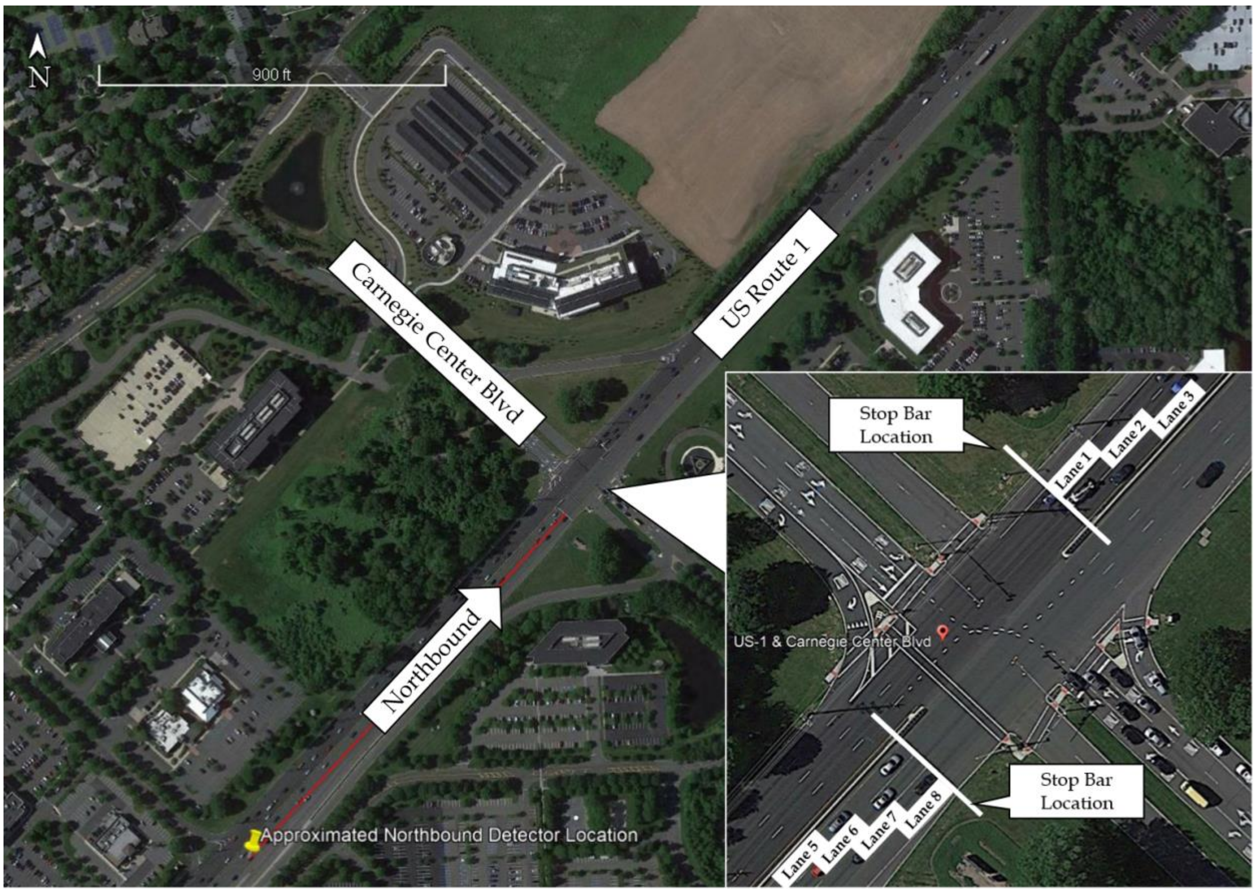


Figure 1. US Route 1 and Carnegie Center Boulevard with Approximated Advance Detector LocatiModified Vehicle Arrival Methodology

The main takeaway from the PCD is that it relates vehicle detections to signal phases. Vehicle detections are traditionally displayed as individual points seen in Figure 2. To display vehicle detections from the AD, traffic controller event code 81 signals the presence of a vehicle in the ATSPM [8]. This code is manipulated to represent the trajectory for the MVA. Instead of each dot representing just the vehicle with respect to the signal phase as it does with the PCD, a series of dots is produced in close proximity to represent the detected vehicle's trajectory. The first dot represents the vehicle detection, while a series of subsequent dots represents vehicle speed in increments of 5 mph. For example, if a vehicle is traveling at 50 mph in lane 8, lane 8 will have the initial dot detection, followed by 9 more dots shortly after. The spacing used between dots for the vectors can vary depending on desired vector appearance. To avoid overlapping data, 0.5 second spacing with respect to the time in cycle was used for vector points. This arrangement provides both a quantitative vehicle speed along with the time of occurrence in the signal phase. For cases where not enough time passed, the data became part of the previous vector. After creating a vector, 5 seconds must pass before another vector can start, and any data points taken during this time are displayed as a single point. This process is repeated for all 7 lanes of the intersection seen in Figure 1, however the results of lane 8 are further analyzed in this paper. The ATSPM software displays traffic controller data from the study site and creates signal performance graphs. In these graphs, the vectors represent the magnitude of the velocity of the vehicle, whose direction goes from the start to the end of the phase. This process is visualized in Figure 3, where some of the data behind the resulting PCD is broken down.

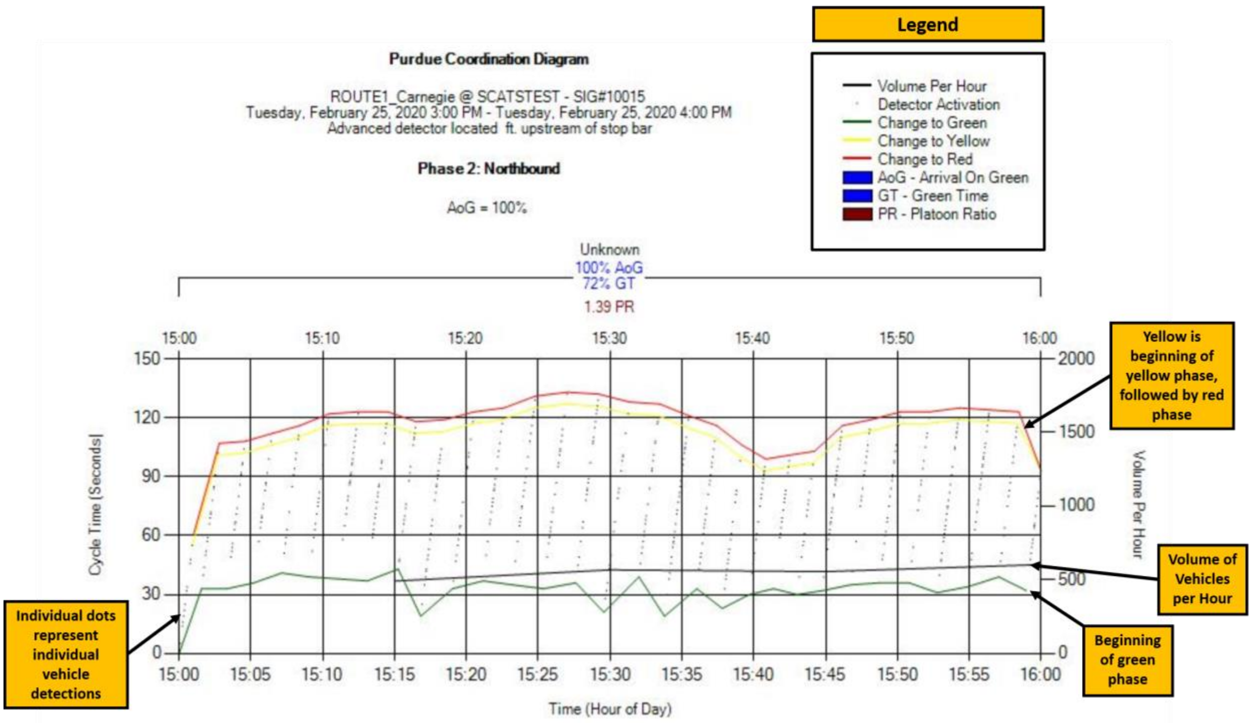


Figure 2. Unmodified Purdue Coordination Diagram

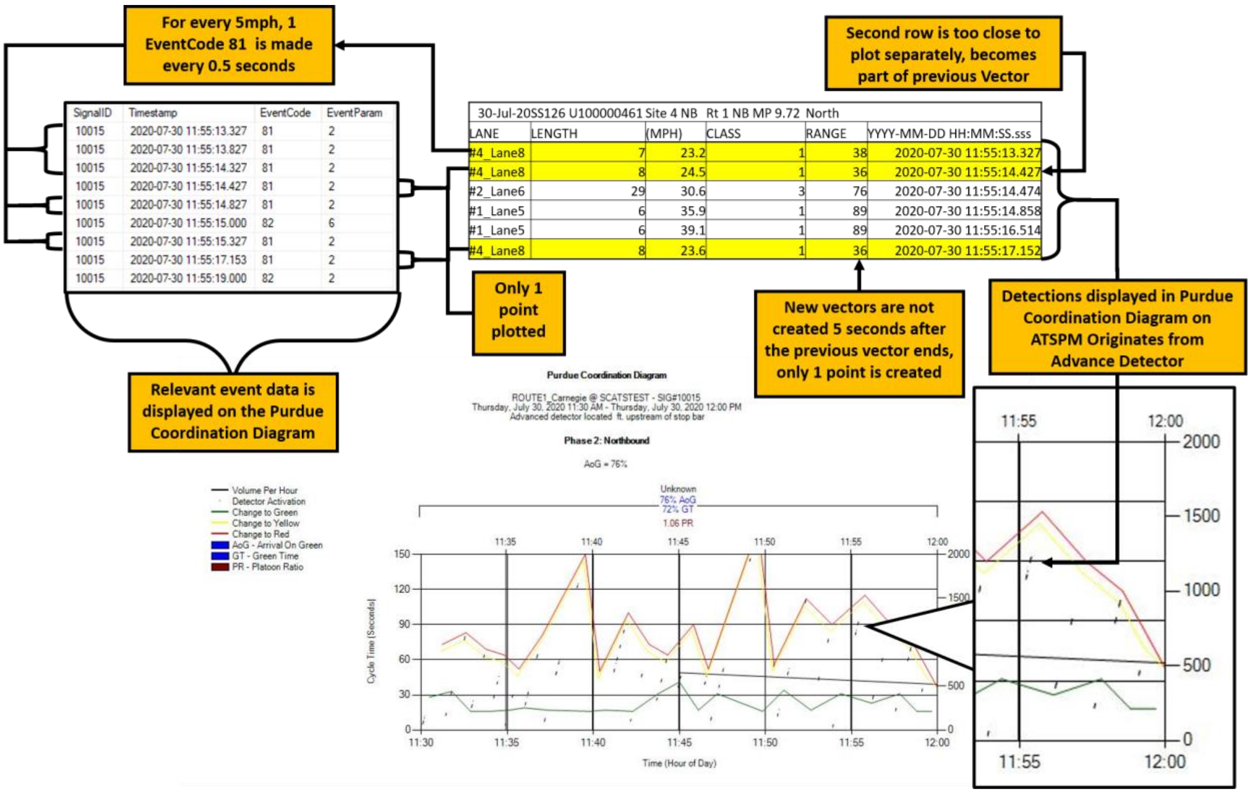


Figure 3. Modified Purdue Coordination Diagram Data Process

## RESULTS OF PROJECTING SPEEDS INTO ATSPM BASED ON DETECTION

The results from the MVA improve upon the PCD by displaying the relationship between vehicle velocity and vector length with respect to the signal phase. It is found that velocities could not directly be understood from the length of the vectors created in the PCD, however velocities relative to one another could be understood. It is demonstrated that smaller vectors represent slower speeds while longer vectors represent faster speeds. From this, a relationship is established that the shorter vectors throughout the day occur during times of heavy traffic, with there being queue build up at the intersection. This would explain the frequency of short vectors near each other. Inversely, longer vectors indicate down time in traffic where queue size is at a minimum. The issue with the MVA is that the vehicle detection points displayed are limited as vectors overlap other detections. Vector lengths are then adjusted so that an excessive number of detections would not be hidden by vectors. This resulted in **Error! Reference source not found.**, where vectors are too short to notice without magnifying the image.

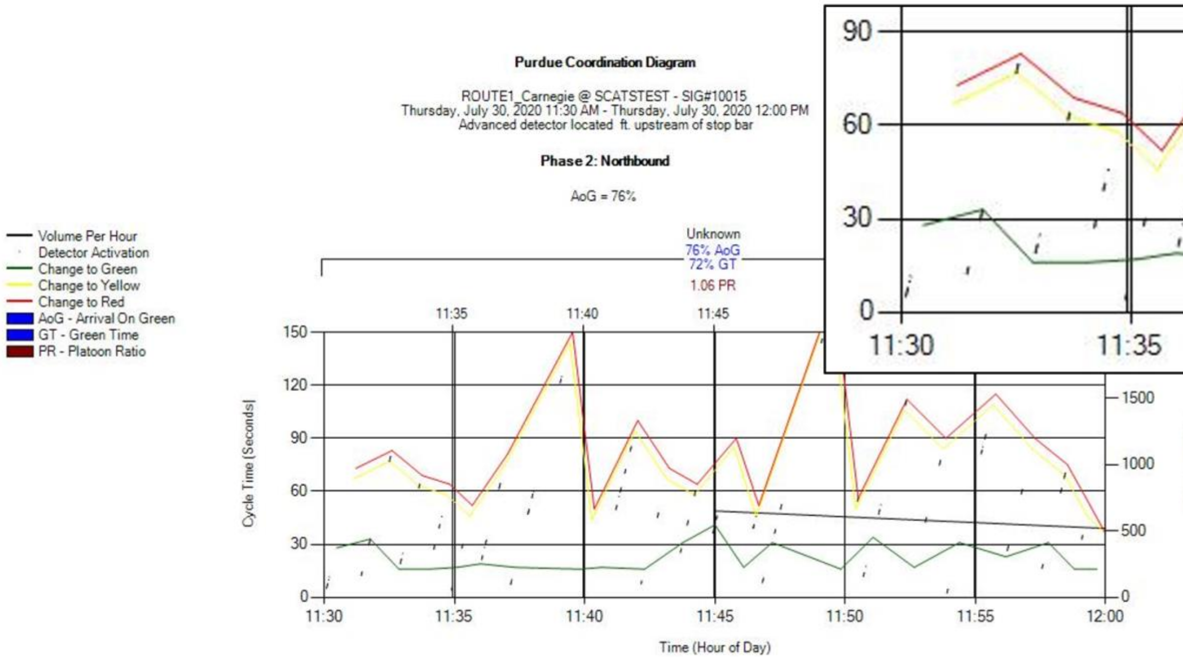


Figure 4. Lane 8 Northbound, Purdue Coordination Diagram ATSPM Result

## CONCLUSIONS

Existing infrastructure is viable across multiple applications beyond its intended use. With ADs, individual detections across multiple lanes and speed data are useful beyond gaining an understanding of vehicle behavior. It allows for intersection performance to be understood more so by integrating speeds into ATSPM by manipulating preexisting metric displays. As a NSPM, the MVA showed that it is possible for the PCD to be adapted to also show speeds relative to one another throughout the day. As a NSPM however, it could still be improved upon. Instead of creating vectors based on the start and end of signal phases, vertical lines placed on the bottom of the PCD output could be used. Considering multiple vehicles at a single time stamp cannot be detected when separated by lane, the individual vertical lines would be capable of showing all detections and speeds, whereas the MVA as is, would not show all detections due to overlapping lines. However, if detections are not a main concern, vector lengths could be increased so that variances in speed between detections could become more noticeable with respect to the signal timing. Subsequently, by knowing the speed of a vehicle when a traffic signal goes red, a quantifiable method for evaluating the potential of red-light running can be realized. Even with its limitations, the MVA still shows that the PCD within ATSPM can still be improved using existing sensor infrastructure.

## REFERENCES


1. Haydin, V. (2021, February 25). *How Big Data in Autonomous Vehicles Defines the Future*. Intellias. https://www.intellias.com/how-big-data-in-autonomous-vehicles-defines-the-future/.
2. *Autoscope Vision*. Image Sensing Systems, Inc. (n.d.). https://www.imagesensing.com/solutions/video-detection/video-detection-products/autoscope-vision.html.
3. Federal Highway Administration Research and Technology. (n.d.). *Chapter 2, Traffic Detector Handbook: Third Edition-Volume I*. U.S. Department of Transportation/Federal Highway

Administration.
https://www.fhwa.dot.gov/publications/research/operations/its/06108/02.cfm.
4. Wavetronix LLC. (n.d.). wavetronix.com. https://www.wavetronix.com/.
5. U.S. Department of Transportation Federal Highway Administration. (2020, August 7). *Automated Traffic Signal Performance Measures*. Traffic Signal Performance Measures - Arterial Management Program - FHWA Office of Operations.
https://ops.fhwa.dot.gov/arterial_mgmt/performance_measures.htm.
6. Lattimer, C. R. (2021, February 21). Automated Traffic Signal Performance Measures. Washington, DC; U.S. Department of Transportation Federal Highway Administration.
7. Mackey, J. (2014, July 1). Automated Traffic Signal Performance Measures, 2014 Joint Western/Midwestern District ITE Annual Meeting. Institute of Transportation Engineers.
8. Sturdevant, J. R. (2012, November). Indiana Traffic Signal Hi Resolution Data Logger Enumerations. Indiana Department of Transportation.