Georgia Department of Transportation

Automated Traffic Signal Performance Measures

Reporting Details

Prepared for:

Georgia Department of Transportation

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List of Acronyms and Abbreviations

AoG/AOG ....Arrivals on Green

AoR/AOR ....Arrivals on Red

ATSPM ....Automated Traffic Signal Performance Measures

GDOT ....Georgia Department of Transportation

GOR ....Green Occupancy Ratio

GT ....Green Time

f_{LU}...Lane Utilization Factor

MOE..Measures of Effectiveness

MPH ....Miles Per Hour

PA ....Pedestrian Activation

PCD..Purdue Coordination Diagram

PHF ....Peak Hour Factor

PHV..Peak Hour Volume

ROR ....Red Occupancy Ratio

VPH...Vehicles per Hour

WCF...Windows Communication Foundation

Introduction

This is the third of three documents that comprise the full Georgia Department of Transportation (GDOT) Automated Traffic Signal Performance Measures (ATSPM) documentation package. Together, the three documents detail the installation and use of the Automated Traffic Signal Performance Measures website, including site navigation, reporting components, and report interpretation. This document is a detailed compilation of what is necessary to create reports and how to interpret reports within the ATSPM website.

# 1.	Approach Delay

Approach Delay provides data regarding the delay experienced at an approach to an intersection. The calculated delay figure is simplified. It does not account for start-up delay, deceleration, or queue length exceeding the detection zone.

Note: The Approach Delay Chart has not been thoroughly quality-checked.

## 1.1.	Requirements for Approach Delay Chart

The Approach Delay chart depicts the time between a detector activation during the red portion of the phase, and when that phase turns green. Not all intersections within the ATSPM are capable of providing the **Approach Delay** chart. In order to display this chart, applicable phases of an intersection must include properly configured parameters as listed below:

- Vehicle count detection, set back 350 to 400 feet from the stop bar (beyond the area where vehicle queues are common)
- Signal controller must track all events using the standard event codes, including the timing of red and green
- Controller logs must be retrievable by the ATSPM web server

## 1.2.	Approach Delay Data

### 1.2.1.	How Data is Gathered and Compiled

When the user generates this chart, the Measures of Effectiveness (MOE) Windows Communication Foundation (WCF) Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type ApproachDelayOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID

- Y-axis maximums
- Bin size
- Flags for showing:
  - Plan statistics
  - Delay per vehicle
  - Total delay per hour

Using these parameters, a SignalPhaseCollection object is generated within the MetricOptions object.

Within this SignalPhaseCollection, the phases in use during the period and the associated detector events are analyzed. Data is gathered from the Controller_Event_Logs table. Delay is calculated for each individual arrival during red, then aggregated based on the analysis period.

1.2.2.   How Data is Displayed

The MetricOptions object creates a chart object, generated by the web rendering engine provided in the .NET Framework. All the delay data is rendered to the chart as lines, based on the per-hour and per-vehicle preferences. The chart is then saved as an image file displayed on the website.

1.3.   Interpreting the Approach Delay Chart

Plots are generated after selecting **Create Metrics**, one for each movement meeting the requirements. In the example (Figure 1), the northbound approach (Phase 2) is displayed with the duration from 1:00 PM to 2:00 PM and 5-minute intervals. For the purpose of this interpretation, all options (check boxes) were selected before chart creation.

- Left side is the legend:
  - ——— **Approach Delay**, a red line that graphically represents the total duration of delay for all vehicles during the interval.
  - ——— **Approach Delay Per Vehicle,** a blue line that graphically represents the average duration of delay per vehicle during the interval.
- The first line of text at the top of the chart is the name of the road, the signal number, and the direction (phase).
- The second line is the date and time range specified during criteria selection.
- The third line is the Average Delay Per Vehicle for the complete duration of the chart, not per interval.
- The fourth line is the Total Delay For Selected Period, not per interval.
- Above each chart section in standard text is the plan (timing) the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the example, the chart has one section (and plan) between 13:00 and 14:00.
- Above each chart section in Blue Text is the numerical value in seconds for the Average Delay Per Vehicle for that section of the chart.

- Above each chart section in Red Text is the numerical value in seconds for the Total Delay for that section of the chart.
- The X-axis (above and below the chart) is the time of day in 24-hour format.
- The Y-axis title (Left Side: Blue Text) and scale is the delay per vehicle. For instance, at 13:05 along the northbound approach, the average per vehicle delay was 26 seconds.
- The Y-axis title (Right Side: Red Text) and scale is the total delay. For instance, at 13:20 along the northbound approach, the total delay was approximately 15000 seconds.
- The disclaimer that the chart is simplified and the data represents the duration between detector activation (during red) and initiation of the green phase is included at the bottom of the chart.
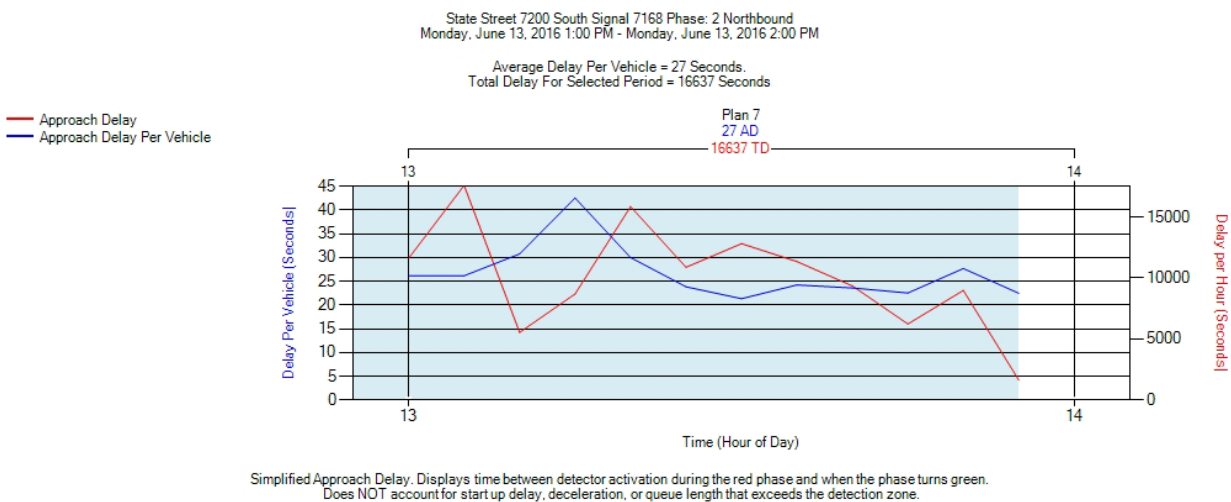
Figure 1: Approach Delay (1-hour duration/5 minute intervals)

2. Approach Speed

The **Approach Speed** charts provide feedback regarding the posted speed limit, average speed, and 85th percentile speed. The speed calculation is generated from vehicles approaching during the green phase, not including the first X seconds of green, defined by the Movement Delay parameter in the detector configuration.

2.1. Requirements for Approach Speed Charts

This data requires the use of advance radar detection that can detect the speeds of vehicles at a setback distance between 350 and 400 feet from the stop bar. The detector used for this application is typically a Wavetronix SmartSensor™ Advance detector. In order to display this chart, the intersection must include properly configured parameters as listed below:

- Setback count detection (350 to 400 feet or beyond the initial queue of vehicles).
- Signal controller must track all events using the standard event codes, including the start of green phase.

- Signal controller logs must be retrievable by the ATSPM web server.
- The Speed Listener component is installed, running, and configured to connect to the detector.

2.2. Approach Speed Data

2.2.1. How Data is Gathered and Compiled

When the user generates this plot, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common) which is of type ApproachSpeedOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximum and minimum
- Bin size
- Flags for showing:
  - Plan Statistics
  - Average Speed
  - Posted Speed
  - 85th Percentile Speeds

Using these parameters, one or more SpeedApproachDirection objects are generated within the MetricOptions object. Typically, one will be generated for each approach supporting speed detection. These will then be filtered by start date, end date, and signal ID.

Within these SpeedApproachDirection objects, vehicle detections are gathered from Controller_Event_Logs table, and cross-referenced against the signal phase number and timeframe.

2.2.2. How Data is Displayed

Each of the SpeedApproachDirection objects creates a chart object, generated by the web rendering engine provided in the .NET Framework. All the speed data is rendered to the chart as lines based on user preferences.

2.3. Interpreting the Approach Speed Chart

The **Approach Speed** chart, shown in Figure 2, is a line graph generated for each movement meeting the requirements. It includes the following components:

- Left side is the legend:
  - ───── Posted Speed, a green line that depicts the speed limit in miles per hour (MPH).

- o ⎯⎯⎯ 85th Percentile Speed, a blue line that depicts the 85th percentile speed. If there are insufficient vehicles during the period, the percentile will be zero.
    - o ⎯⎯⎯ Average MPH, a red line that depicts the average speed.
- The first line of text at the top of the chart is the name of the road, the signal number, the phase, and direction.
- The second line is the date and time range of this chart as specified during the criteria selection.
- The third line is the distance from the detector to the stop bar along with the minimum speed filter.
- The fourth line displays the current time filter after the start of the green, when data inclusion begins.
- The fifth line is the speed accuracy of +/- 2 MPH for average speed and +/- 1.5 MPH for 85th percentile speed (*Source: Report No. UT-16.05 - May 2016 https://www.udot.utah.gov/main/uconowner.gf?n=28384521790001597*).
- Directly above the chart (first line) is the timing plan (Plan) the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the example shown in Figure 2, the chart has one section (and plan) between 04:00 and 09:00.
- The second line above each chart section shows the 85th percentile speed during the respective plan.
- The third line above each chart section shows the average speed during the respective plan.
- The fourth line above each chart section shows the standard deviation from the average speed to the 85th percentile speed during the respective plan
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is the speed in MPH; for instance at 5:00 AM, the 85th percentile speed was approximately 46 MPH and the average speed was approximately 43 MPH.
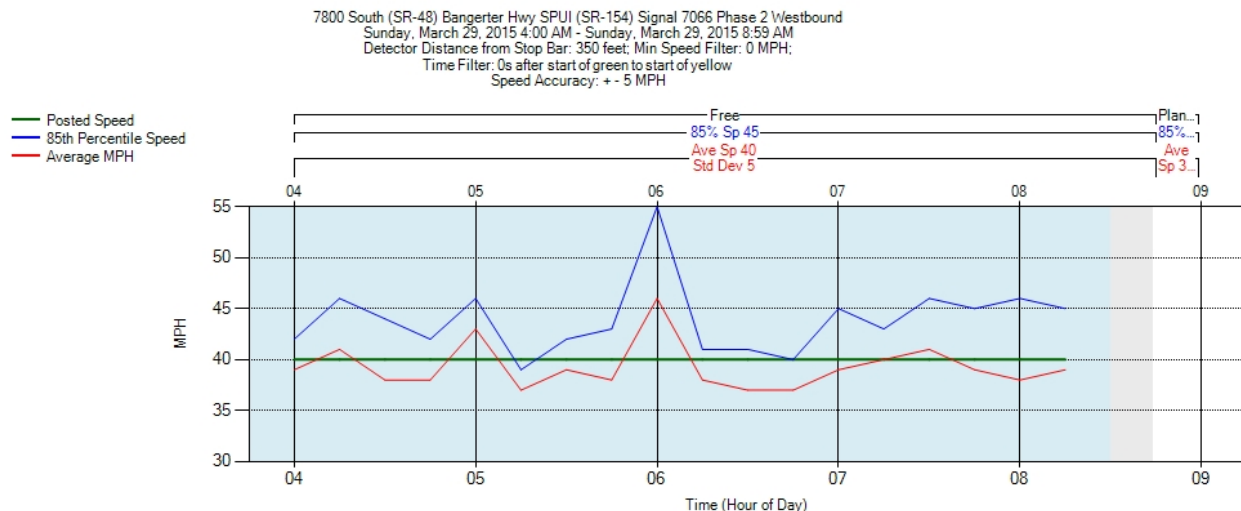
Figure 2: Approach Speed Chart

3. Approach Volume

The **Approach Volume** chart plots the traffic traveling toward the selected intersection. It utilizes both advance and stop bar detection (if available) to display comparisons between volume and flow factor for opposing directions. (A Wavetronix SmartSensor Advance detector typically provides advance detection). The results also include a table with metrics and values represented by the chart.

3.1. Requirements for Approach Volume Chart

Not all intersections in the ATSPM are capable of supporting the Approach Volume chart. In order to display this chart, the intersection must include properly configured parameters as listed below:

- Vehicle count detection: The detector(s) may be located either at the stop bar or set back (advanced). Advanced detection is typically provided using Wavetronix SmartSensor Advance.
- Signal controller must track all events using the standard event codes.
- Signal controller logs must be retrievable from the ATSPM web server.

3.2. Approach Volume Data

3.2.1. How Data is Gathered and Compiled

When the user generates this chart the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common) which is of type ApproachVolumeOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximums
- Bin size
- Flags for showing:
  - Directional Split
  - Total Volume
  - SB/EB Volume
  - NB/WB Volume
  - Traffic Message Channel Detection
  - Advance Detection

Using these parameters, one or more ApproachVolumeChart objects are generated within the MetricOptions object. Typically, one will be generated for each pair of directions (north/south, east/west) and for type of detection (stop bar, advance).

Within these ApproachVolumeChart objects, vehicle detections are gathered from the Controller_Event_Logs table and cross-referenced with the approach direction, detector ID, and timeframe.

3.2.2.   How Data is Displayed

Each of the ApproachVolumeChart objects creates a chart object, generated by the web rendering engine provided in the .NET Framework. All the volume data is rendered to the chart as lines based on user preferences. The ApproachVolumeChart object also contains a table object where the numeric statistics are recorded.

3.3.   Interpreting the Approach Volume Chart and Table

Once the **Approach Volume** metrics are generated, one chart for each supported movement will be created. Each chart will include a table for the respective representative data. The chart includes the following components:

- Left side is the legend:
    - ────── Solid blue line graphically represents the volume of northbound or westbound approaching traffic.
    - ────── Solid red line graphically represents the volume of southbound or eastbound approaching traffic.
    - ─ ─ ─ Dotted blue line is the D-Factor, graphically representing the northbound to southbound (or westbound to eastbound) ratio.
    - ─ ─ ─ Dotted red line is the D-Factor, graphically representing the southbound to northbound (or eastbound to westbound) ratio.
- The first line at the top of the chart is the name of the road and the signal name along with the directions.
- The second line is the date and time range and the type of detection used.
- The Y-axis title (Left Side or primary Y-axis) and scale is the Volume (vehicles per hour [VPH]); for example, in the chart in Figure 3, at approximately 12:30 the northbound volume is approximately 800 and the southbound is approximately 1200.
- The Y-axis title (Right Side or secondary Y-axis) and scale is the Directional Split (D Factor); for example, using the same 12:30 values, the northbound split is approximately .4 and the southbound split is approximately .6.
- The X-axis (below the chart) is the hour in 24-hour format.
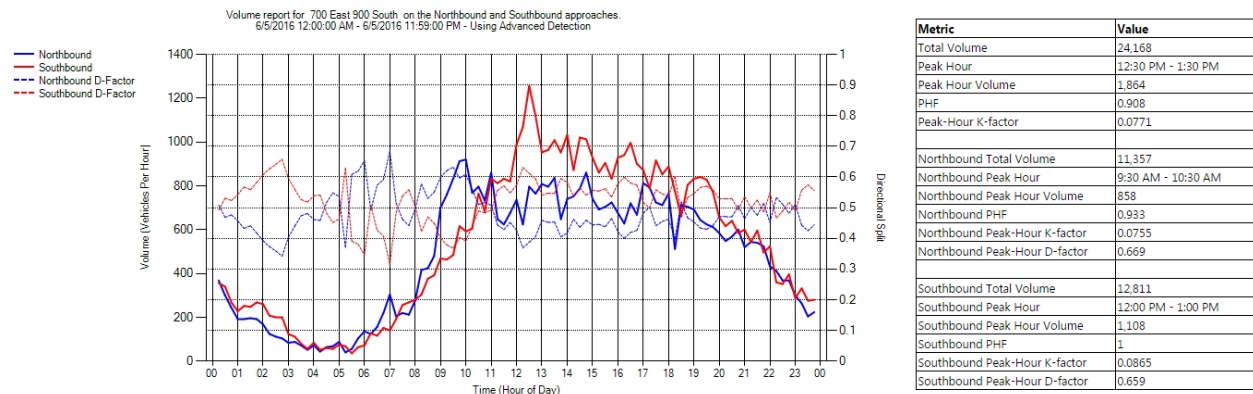
Figure 3: Approach Volume Chart using Advanced Detection

The table to the right of the chart includes additional information regarding data illustrated by the chart. Northbound and southbound information is replaced with westbound and eastbound information for tables with charts depicting west/east approaches. The table provides information regarding the volume for the prescribed period for the total volume as well as for each direction.

These metrics are:

- Total Volume – The total vehicles approaching both directions for the duration of the chart
- Peak Hour – The hour with the highest total volume within the duration of the chart
- Peak Hour Volume – The total vehicles in both directions approaching the intersection
    - When the bin size is 15 minutes, this is the cumulative value of the four bins
- Peak Hour Factor (PHF) – The ratio between the peak hour volume (PHV) and the highest bin of that period
- Peak Hour K Factor – The ratio between the peak hour and the total volume for the day
- Northbound Total Volume – The total northbound vehicles for the duration of the chart
- Northbound Peak Hour – The hour with the highest northbound volume within the duration of the chart
- Northbound Peak Hour Volume – The number of northbound vehicles during the Northbound Peak Hour
- Northbound PHF – The PHF as calculated on the northbound peak hour
- Northbound Peak Hour K-Factor – The K-Factor as calculated on the northbound peak hour
- Northbound Peak Hour D-Factor – The ratio between the northbound and southbound volume during the northbound peak hour
- Southbound Total Volume – The total southbound vehicles for the duration of the chart
- Southbound Peak Hour – The hour with the highest southbound volume within the duration of the chart
- Southbound Peak Hour Volume – The number of southbound vehicles during the Northbound Peak Hour
- Southbound PHF – The PHF as calculated on the southbound peak hour
- Southbound Peak Hour K-Factor – The K-Factor as calculated on the southbound peak hour

- Southbound Peak Hour <u>D-Factor</u> – The ratio between the southbound and northbound volume during the southbound peak hour

4.   Arrivals on Red

The **Arrivals on Red (AoR)** metric plots the quantity of vehicles that arrive on the red phase as well as the percentage of vehicles that arrive on the red phase compared to vehicles arriving on green or yellow.

4.1.   Requirements for Arrivals on Red

This metric requires count detection that is set back from the stop bar between 350 and 400 feet (or beyond the initial queue of vehicles at the intersection). In order to display this chart, the intersection must include properly configured parameters as listed below:

- Setback count detection (350 to 400 feet). This advanced detection is typically provided using Wavetronix SmartSensor Advance.
- Signal controller must track all events using the standard event codes.
- Signal controller logs must be retrievable from the ATSPM web server.

4.2.   Report Data

4.2.1.   How Data is Gathered and Compiled

When the user generates this plot, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type AoROptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximum
- Bin size
- Flag for showing plan statistics

Using these parameters, a SignalPhaseCollection object is generated within the MetricOptions object.

Within this SignalPhaseCollection, the phases in use during the period, and the associated detector events, are analyzed. Data is gathered from the Controller_Event_Logs table, in this case, detector actuations during the red portion of the cycle.

The detector timestamps are projected ahead to vehicle arrivals at the stop bar using the Speed and Distance from Stop Bar in the detector configuration. The configuration parameter Decision Point can be used to offset the vehicle arrival back X number of seconds. This is typically left at zero seconds.

4.2.2. How Data is Displayed

The MetricOptions object creates one or more chart objects generated by the web-rendering engine provided in the .NET Framework. All the delay data is rendered to the chart as lines based on user preferences. The chart is then saved as an image file displayed on the website.

4.3. Interpreting the Arrivals on Red Chart

Once the AoR metrics are created, as shown in Figure 4, there will be one chart for each supported movement. The example below is the northbound approach set to display the AoR from 6:45 AM to 9:30 AM with a 5-minute volume bin. The chart components are:

- Left side legend:
    - – – – Dotted red line for AoR, graphically representing the number of vehicles arriving on red phase.
    - ——— Solid red line for Percent AoR, graphically representing the percentage of AoR versus all vehicles.
    - – – – Dotted black line for Total Vehicles, graphically representing the number of vehicles approaching the intersection in all phases.
- At the top of the chart, the first line includes the name of the road, the signal number, and the directional approach.
- The second line is the date and time range for the analysis period.
- The third line is the numerical value of the total detector hits (all phases) and the numerical value of AoR.
- The fourth line is the percent of AoR during the analysis period.
- Directly above the chart, in standard text, is the timing plan that the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the example shown in Figure 4, 6:45 to 7:00 was Free operation and 7:00 to 9:30 was Plan 1.
- Above each chart section in Blue Text is the numerical value for the Percent AoR for this plan of the prescribed time period.
- Above each chart section in Red Text is the numerical value for the percentage of time the signal is in Red Time, the red phase, for this plan of the prescribed time-period.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side or primary Y-axis) and scale is the Volume (VPH); for example, in Figure 4 at 8:00 the AoR volume is approximately 440 and the total vehicles are just over 1000.
- The Y-axis title (Right Side or secondary Y-axis) and scale is the Percent AoR; for example, at 8:00, the AoR is approximately 43%.
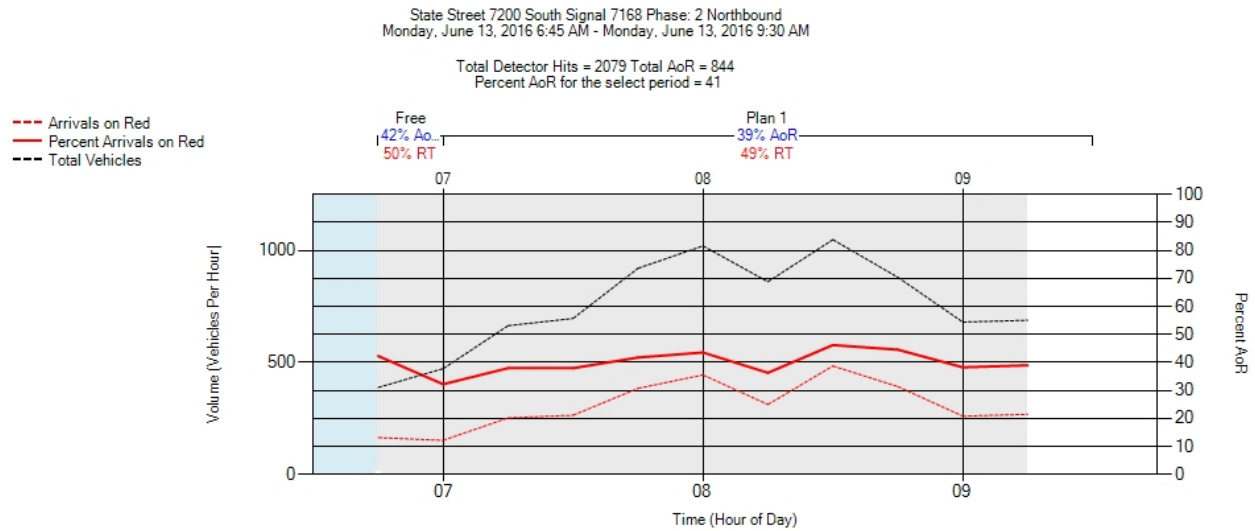
Figure 4: Arrivals on Red Chart

5. Pedestrian Delay

The **Pedestrian Delay** chart displays the duration a pedestrian waits to receive the walk indication after actuation of the pedestrian call.

5.1. Requirements for Pedestrian Delay

This metric requires that the intersection is set up as shown below. No special configuration is necessary to run this metric.

- One or more movements must have pedestrian actuation.
- Signal controller must track all events using the standard event codes, including pedestrian actuation and the subsequent start of walk.
- Signal controller logs must be retrievable by the ATSPM web server.

5.2. Report Data

5.2.1. How Data is Gathered and Compiled

When the user generates this chart, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common).

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID

- Y-axis maximums

Using these parameters, a PedDelaySignal object is generated within the MetricOptions object.

Within this PedDelaySignal, data is gathered from the Controller_Event_Logs table, in particular, pedestrian events (pedestrian call, pedestrian detection, begin walk, begin don't walk). The phases in the signal cycle containing pedestrian events are determined. Finally, for each phase "cycle" objects are created that contain datestamped pairs of pedestrian calls and begin walk indications.

5.2.2.   How Data is Displayed

The MetricOptions object creates one or more chart objects generated by the web rendering engine provided in the .NET Framework. All the delay data (for each cycle, the difference between call and walk) is rendered to the chart as bars. The chart is then saved as an image file displayed on the website.

5.3.   Interpreting the Pedestrian Delay Chart

Once **Create Metrics** is selected, a chart for each approach with a crosswalk is created. The data included in each chart is:

- Left side is the legend:
    - Blue bars, Pedestrian Display by Actuation, graphically represent the duration in minutes after actuation until the pedestrian receives a walk indication.
- The first line at the top is the title of the chart.
- The second line is the name of the road and the signal number along with the phase and direction.
- The third line is the date and time range of the analysis period as specified during the criteria selection.
- The fourth line is the phase associated with the pedestrian movement.
- Next is a summary line for the analysis period, including:
    - Number of pedestrian actuations (PA)
    - Minimum delay is displayed in minutes:seconds
    - Maximum delay is displayed in minutes:seconds
    - Average delay is displayed in minutes:seconds
- The first line, directly above the chart, is the timing plan that the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the below example, there is one signal plan active (Free) for the analysis period.
- Above each chart section, the second line is the number of PAs for this plan.
- Above each chart section, the third line is the average delay for this plan.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is the Pedestrian Display by Actuation [minutes]; for instance, the pedestrian delay around 3:30 PM in Figure 5 was approximately 1 minute and 50 seconds.
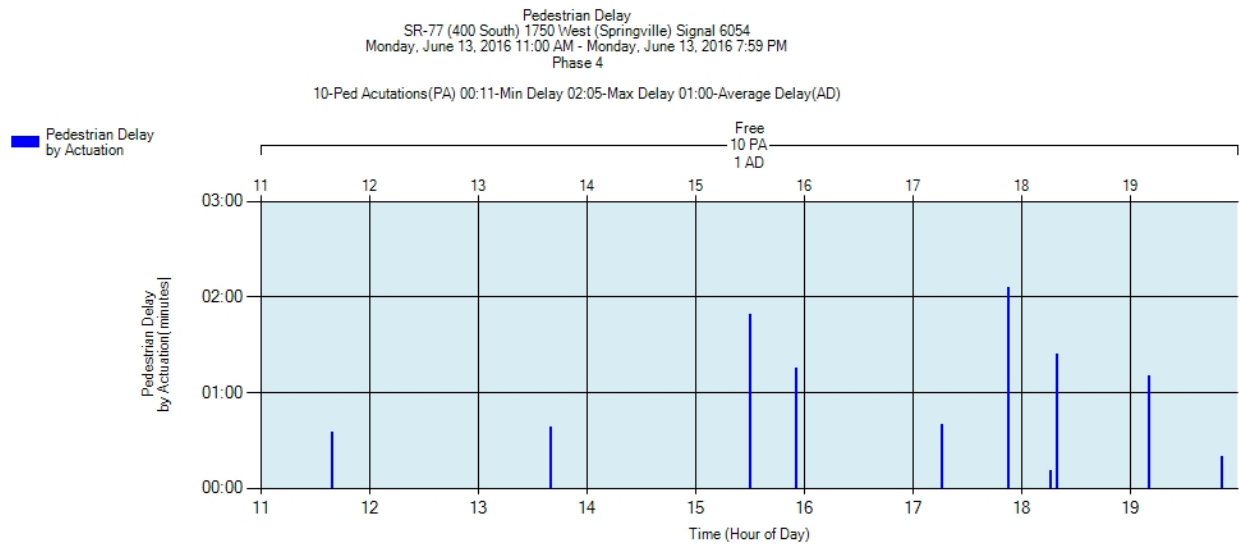
Figure 5: Pedestrian Delay Chart

6. Preemption Details

After generating the **Preemption Detail** report, the ATSPM provides feedback via three separate charts. The data represented depicts preemption from the request through end of preemption service. Preemption can occur for both rail and emergency requests. Both rail and emergency preemption metrics include multiple charts. These reports have the same legends regardless of preemption type, but some data are not available on the emergency charts.

6.1. Requirements for Report

To support the Preemption Detail metric, the intersection must meet these requirements. No special configuration is necessary to run this metric.

- The intersection controller must be configured for preemption.
- The intersection must include preemption detection hardware.
- The controller log must include instances of preemption where a preemption request was received and serviced by the controller.
- Signal controller must track all events using the standard event codes, including Preemption events.
- Signal controller logs must be retrievable by the ATSPM web server.

6.2. Report Data

6.2.1. How Data is Gathered and Compiled

When the user generates these plots, the MOE WCF Service creates a MetricGenerator object. This object is linked to three MetricOptions objects on the client side (MOE.Common), which are of types PreemptServiceMetricOptions, PreemptServiceRequestOptions, and PreemptDetailOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximums

For each chart, data is gathered from the Controller_Event_Logs table for all preemption event codes (99-131).

For the Preempt Request and Preempt Service charts, data is compiled as timestamp and event parameter pairs.

For the Preempt Details charts, the phases in the signal cycle containing preemption events are determined. Finally, for each phase "cycle" objects are created, which contain time to service, dwell time, entry delay, end call, call max out, track clear, and gate down data paired with their respective timestamps.

6.2.2. How Data is Displayed

The MetricOptions objects create one or more Chart objects, generated by the web rendering engine provided in the .NET Framework. All the preemption data is rendered to the chart as bars and points. The chart is then saved as an image file displayed on the website.

6.3. Interpreting the Preemption Details

After selecting **Create Metrics**, the **Preemption Details** charts are displayed if the time-period includes preemption event codes. A set of charts will be generated for each movement supporting the metric. The top two charts display only the number of preempt requests and preempt services. Next, there will be a detailed chart for each preemption number (phase) that includes the appropriate event code.

Chart properties are described in detail below.

Preempt Request Chart (both types):

- Left side is the legend:
    - ◆ Preempt Request, a black dot, graphically represents each time a request for preemption was received by the controller.

- The first line at the top contains the name of the chart, the road name, and the signal number.
- The second line is the date and time range as specified during the criteria selection.
- The Y-axis title (Left Side) and scale is the Preempt Number; for instance, all preempt requests for Figure 6 and Figure 9 were made on Preemption 1.
- The X-axis (below the chart) is the hour in 24-hour format.

**Preempt Service** Chart (both types):

- Left side is the legend
  - ◆ Black dot, Preempt Request, graphically represents each time there is a service for preemption.
- The first line at the top contains the name of the chart, the road name, and the signal number.
- The second line is the date and time range as specified during the criteria selection.
- The Y-axis title (Left Side) and scale is the Preempt Number; for instance, all preempt services for Figure 7 and Figure 10 were received on Preempt 1.
- The X-axis (below the chart) is the hour in 24-hour format.

Preempt Details Chart, see Figure 8 and Figure 11 (both types):

- Left side is the legend (* = both; ᵗ = rail only):
  - ▮ Time to Service, a yellow bar, graphically represents the elapsed time from call to service*
  - ▮ Dwell Time, a green bar, graphically represents the elapsed time during preempt service*
  - ▮ Entry Delay, a red bar, graphically represents when a failure occurs ᵗ
  - • End Call, a black dot, graphically represents when a preempt call ends *
  - x Call Max Out, a red X, graphically represents when a preempt call times out (no service) ᵗ
  - ◆ Track Clear, a green marker, graphically represents when the rail is clear ᵗ
  - • Gate Down, a black dot, graphically represents gate arm is down ᵗ
- The first line at the top is the name of the chart.
- The second line is the road name and the signal number.
- The third line is the date and time range as specified during the criteria selection.
- The fourth line is the preempt number shown in the duration of the chart.
- The Y-axis title (Left Side) and scale is the elapsed time in seconds; for instance, in Figure 8, the Time to Service for the emergency preempt at 2:00 PM was approximately 25 seconds.
- The X-axis (below the chart) is the hour in 24-hour format.

6.3.1.   Emergency Preemption Charts

Note that for the complete details chart, there are no Entry Delay occurrences.
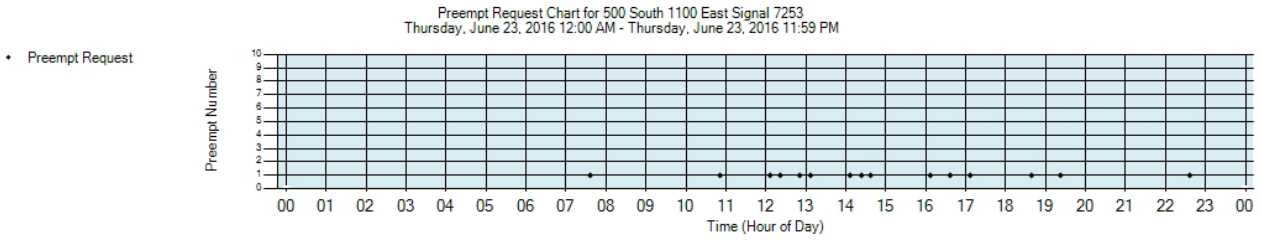
Figure 6: Preemption Request (Emergency)
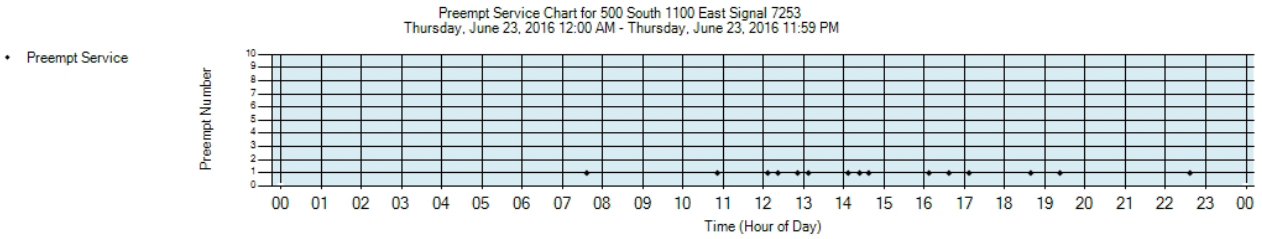
Figure 7: Preemption Service (Emergency)
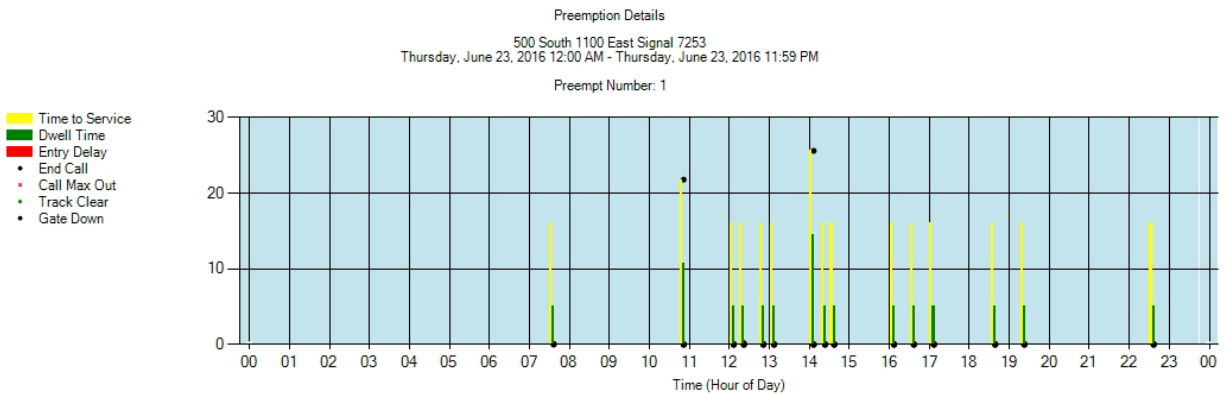
Figure 8: Preemption Details (Emergency)

6.3.2.   Rail Preemption Charts

Unlike the Emergency chart above, the Rail Preemption Details chart includes Entry Delay.
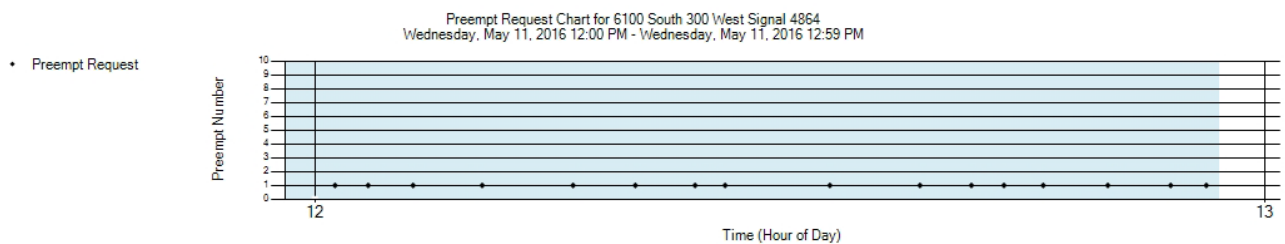
Figure 9: Preemption Request (Rail)
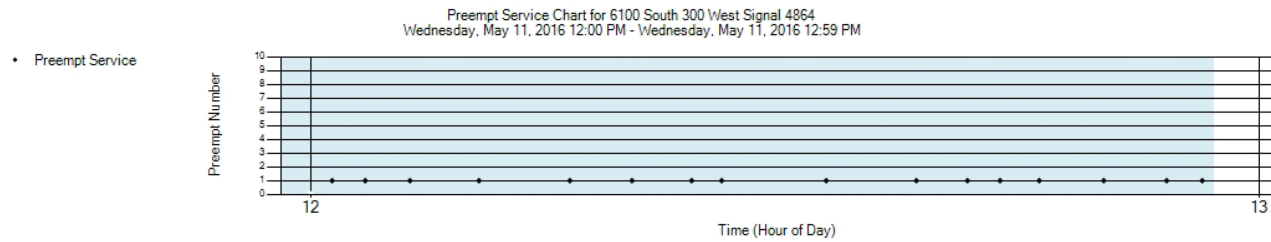
Figure 10: Preemption Service (Rail)
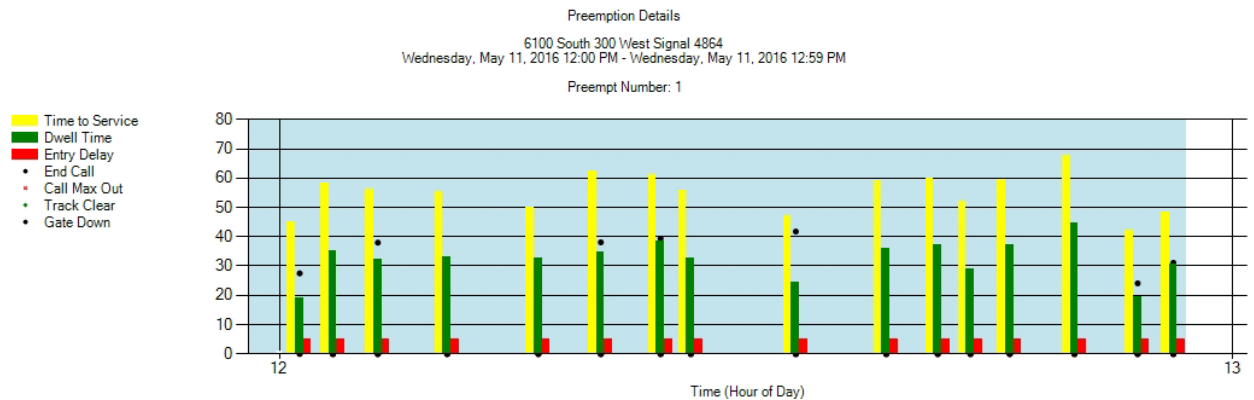
Figure 11: Preemption Details (Rail)

7.   Purdue Coordination Diagram

The **Purdue Coordination Diagram** (PCD) is a diagram that depicts all phases (green, yellow, and red) and traffic arrivals during each movement of the cycle. Each cycle is depicted separately as a series of vehicles (dots). It starts at the bottom of the diagram during AoR, and tracks up and to the right until the next change to red. By these means, the diagram depicts vehicle arrivals in a spatial manner and allows for platoon analysis.

7.1.   Requirements for the Purdue Coordination Diagram

The PCD requires count detection at a setback between 350 and 400 feet from the stop bar (beyond the typical queuing of vehicles at the intersection). In order to display this diagram, the intersection must include properly configured parameters as listed below:

- Vehicle detection capable of counting vehicles approaching the intersection (setback of 350-400 feet).
- Signal controller must track all events using the standard event codes, including the timing of red, yellow, and green phases.
- Signal controller logs must be retrievable by the ATSPM web server.

7.2. Report Data

7.2.1. How Data is Gathered and Compiled

When the user generates this diagram, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type PCDOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximums
- Volume bin size
- Dot size
- Whether or not to show plan statistics
- Whether or not to show volumes

Event Data is gathered from the Controller_Event_Logs table. Data is then compiled into Change to Green, Change to Yellow, Change to Red, Detector Activation, and possibly Volume per Hour chart series.

The detector timestamps are projected ahead to vehicle arrivals at the stop bar using the Speed and Distance from Stop Bar in the detector configuration. The configuration parameter Decision Point can be used to offset the vehicle arrival back X number of seconds. This is typically left at zero seconds.

7.2.2. How Data is Displayed

The MetricOptions objects create one or more Chart objects, generated by the web rendering engine provided in the .NET Framework. All the PCD data is rendered to the chart as bars and points. The chart is then saved as an image file displayed on the website.

7.3. Interpreting the Purdue Coordination Diagram

Like many of the other charts, the **PCD** will generate a diagram for each supported movement of the intersection. The diagram itself includes:

- Left side is the legend:
  - · Detector Activation, black dots, graphically represent each time a vehicle arrives.
  - —— Change to Green, a green line, graphically represents when the phase changes to green.
  - —— Change to Yellow, a yellow line, graphically represents when the phase changes to yellow.
  - —— Change to Red, a red line, graphically represents when the phase changes to red.

- o ━━━ Volume Per Hour, a black line, graphically represents the volume per hour.
- o ▉ AoG (arrival on green), percentage for AoG and color of this text above each chart plan section.
- o ▉ GT (green time), percentage for GT and color of this text above each chart plan section.
- o ▉ PR (platoon ratio), definition for PR and color of this text above each chart plan section.

- At the top of the chart, the first line is the name of the road and the signal number along with the direction.
- The second line is the date and time range as specified during the criteria selection.
- The third line is the overall percentage of detection that occurred on green for the duration displayed.
- Directly above the chart in standard text is the plan (timing) the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the example shown in Figure 12, Plan 1 is active through about 8:45, then Plan 7 is active.
  - o Above each chart section in Blue Text (first blue line) is the percentage of the AoG for this plan.
  - o Above each chart section in Blue Text (second blue line) is the percentage of the cycle length that was green for this plan.
  - o Above each chart section in Brown Text is the Platoon Ratio for this plan. The platoon ratio is calculated by dividing AoG by GT.
  - o The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side or primary Y-axis) and scale is the cycle time in seconds. In Figure 12, at 8:30 the cycle total time is approximately 150 seconds, with the red split lasting approximately 90 seconds before the following green begins. This is followed by yellow clearance at approximately 145 seconds into the cycle (55 seconds after change to green).
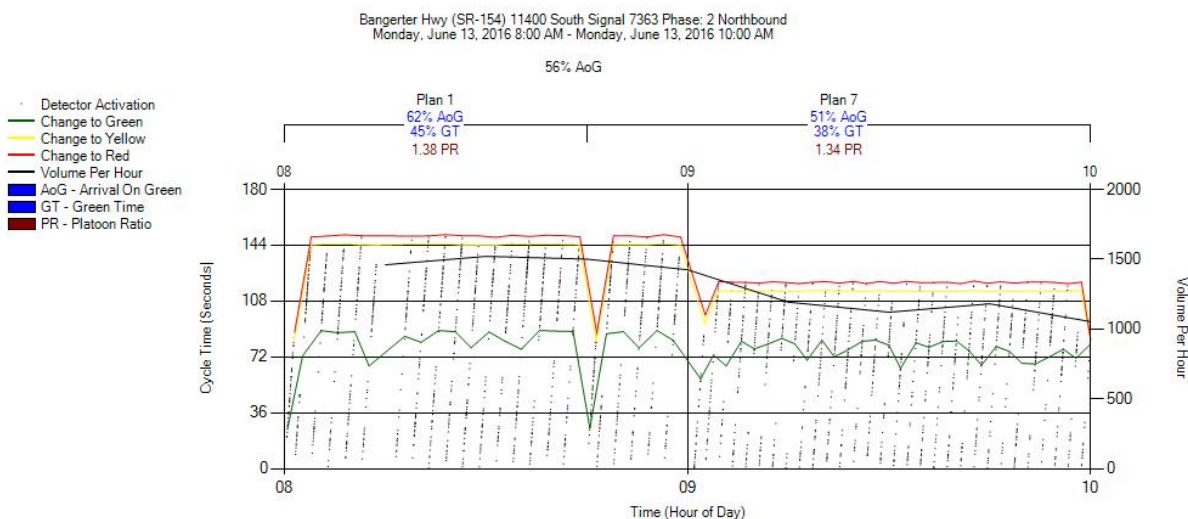- The Y-axis title (Right Side or secondary Y-axis) and scale is the Volume per Hour.

Figure 12: Purdue Coordination Diagram

8. Purdue Phase Termination

The **Purdue Phase Termination** chart is a graphical representation of why each phase terminated during a user-selected period.

8.1. Requirements for Purdue Phase Termination Chart

The intersection must be equipped as followed to support the Purdue Phase Termination chart. No special configuration is necessary to run this metric.

- Signal controller must track all events using standard event codes, including phase termination reasons.
- Additional vehicle detection other than that done by the controller is not necessary for this metric.
- Signal controller logs must be retrievable from the ATSPM web server.

8.2. Report Data

8.2.1. How Data is Gathered and Compiled

When the user generates this chart, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type PhaseTerminationOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Minimum number of consecutive terminations to be displayed

Using these parameters, an AnalysisPhaseCollection object is generated within the MetricOptions object.

Within this AnalysisPhaseCollection, the phases in use during the period and the associated phase termination events are analyzed. The termination events meeting the consecutives threshold are gathered from the database for the Controller_Event_Logs table. The events tracked are Gap Out, Max Out, Force Off, and Pedestrian.

8.2.2. How Data is Displayed

The MetricOptions object creates a chart object, generated by the web rendering engine provided in the .NET Framework. All the termination events are rendered to the chart as data points, and the chart is then saved as an image file displayed on the website.

8.3. Interpreting the Purdue Phase Termination Chart

The **Purdue Phase Termination** chart includes a representation for each phase, the controller plan, and the time of day. A chart is generated for each supported movement. The legend (shown in Figure 13) is displayed above the chart and includes:

- ![green] <u>Gap Out</u>. If a phase is terminated due to gap out, a green dot is displayed along the line of that phase.
- ![red] <u>Max Out</u>. If a phase is terminated due to max out, a red dot is displayed along the line of that phase.
- ![blue] <u>Force Off</u>. If a phase is terminated due to force off, a blue dot is displayed along the line of that phase
- ![gray] Unknown. Although included in the legend, it is not currently graphed.
- ![gold] Ped Activity. If a pedestrian activation for a phase occurs, a gold dot is displayed <u>above</u> the line of that phase.

Figure 13: Purdue Phase Termination Legend

The chart for the **Purdue Phase Termination** data is displayed below the legend. It includes:

- The first line at the top is the name of the road and signal number.
- The second line is the selected date and time range as specified during the criteria selection.
- The third line provides an indication of how some of the data are displayed; for instance, in Figure 14, force-offs, max-outs, and gap-outs with consecutive occurrences are displayed as 1 instance.
- The fourth line is a constant text that states "Pedestrian events are never filtered."
- Directly above the chart is the plan (timing) the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the example shown by Figure 14, Plan 10 is active for the entire analysis period.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is the phase number; for Figure 14, during phase 4 at approximately 10:15, the phase has a few gap out terminations as well as two pedestrian activations displayed.
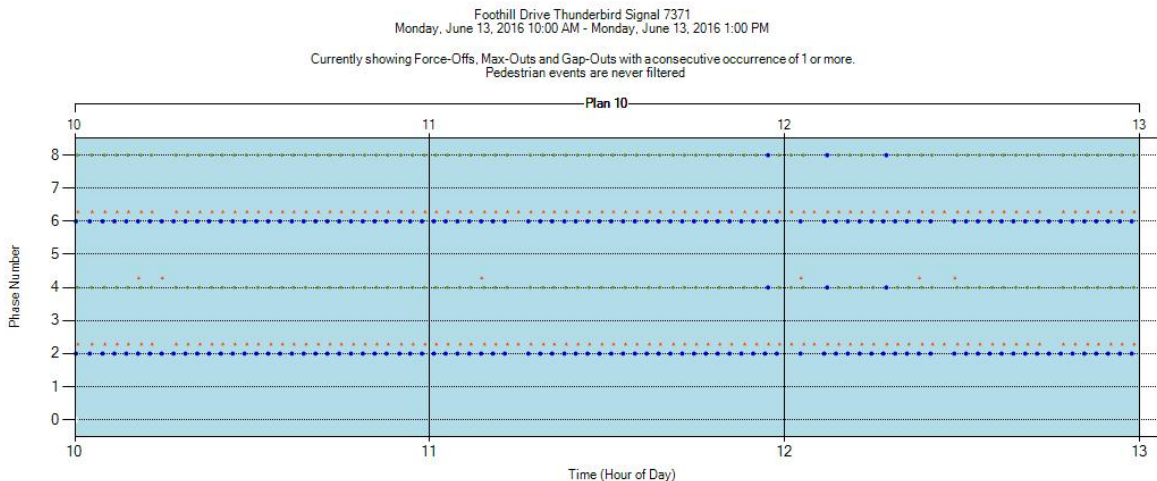
Figure 14: Purdue Phase Termination Chart

9. Purdue Split Failure

The **Purdue Split Failure** chart includes a great deal of information, the culmination of which is the reporting of the count, percentages, and classifications of split failure. It utilizes stop bar presence detection to calculate the green occupancy ratio (GOR) and red occupancy ratio (ROR). When both are above 80 percent, the phase is considered a split failure for that cycle.

9.1. Requirements for the Purdue Split Failure Chart

To support the Purdue Split Failure chart, the intersection must support the following:

- Traffic detection at the stop bar, either by lane group or individual lane. It's important that detection channels are not shared across signal phases.
- Signal controller must track all events using standard event codes, including phase terminations.
- Signal controller logs must be retrievable by the ATSPM web server.

9.2. Report Data

9.2.1. How Data is Gathered and Compiled

When the user generates this chart, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type SplitFailOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID

- Y-axis maximums
- First Second of Red
- Show Fail Lines
- Show Average Lines
- Show Percent Failure Lines

Event Data is gathered from the Controller_Event_Logs table. Data is then compiled into split fail, GOR gap out, GOR force off, ROR gap out, ROR force off, average ROR, average GOR, and percent fails series.

9.2.2.   How Data is Displayed

The MetricOptions objects create one or more chart objects, generated by the web rendering engine provided in the .NET Framework. All split failure data is rendered to the chart as lines and points. The chart is then saved as an image file displayed on the website.

9.3.   Interpreting the Purdue Split Failure Chart

Once **Create Metrics** is selected, a chart for each movement supporting the metric will be created. The data included on the chart is:

- Left side is the legend
    - o   Split Fail, a yellow vertical line representing when a failure occurs.
    - o   GOR Gap Out, a green dot graphically representing each time a GOR gap out occurs.
    - o   GOR Force Off, a green dot graphically representing each time a GOR force off occurs.
    - o   ROR Gap Out, a red triangle graphically representing each time a ROR gap out occurs.
    - o   ROR Force Off, a red dot graphically representing each time a ROR force off occurs.
    - o   Average ROR, a solid red line depicting the average percentage of ROR.
    - o   Average GOR, a solid green line depicting the average percentage of GOR.
    - o   Percent Fails, a dotted blue line depicting the average percentage of failures.
- The first line at the top of the chart is the name of the road and the signal number along with the phase and direction.
- The second line is the date and time range as specified during the criteria selection.
- The third line is total split fails of the chart over the entire analysis period.
- Above each chart section, the first line shows the timing plan(s) the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the Figure 15 example, it is in Plan 10 from Noon until 2:45 PM and is in Free from 10:30 PM until Midnight.
- Above each chart section, the second line is the number of split fails during the plan.
- Above each chart section the third line is the percentage of split fails during the plan.
- The X-axis (above and below the chart) is the hour in 24-hour format.

- The Y-axis title (Left Side) and scale is the Occupancy Ratio (percent); in Figure 15, the average GOR percentage from 12:15 PM to 12:30 PM was approximately 75 percent.
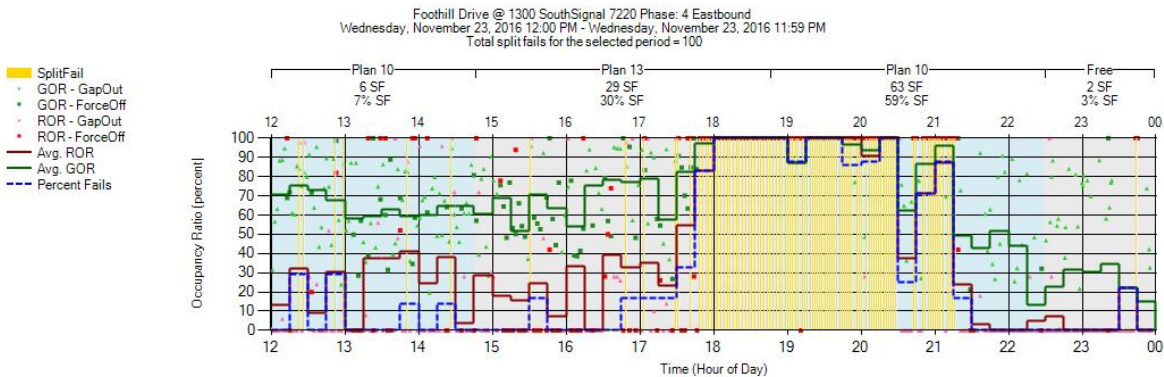
Figure 15: Purdue Split Failure Chart

10.   Split Monitor

Similar to the **Purdue Phase Termination**, the **Split Monitor** depicts the factor that terminates the phase. The **Split Monitor** report separates the data into charts for each phase and adds the phase duration in seconds. Each chart depicts the reason the phase terminated over a user-selected time frame.

10.1.   Requirements for the Split Monitor Chart

To support the Split Monitor chart, the intersection must support the following. No special configuration is necessary to run this metric.

- Signal controller must track all events using standard event codes, including phase terminations.
- Signal controller logs must be retrievable by the ATSPM web server.

10.2.   Report Data

10.2.1.   How Data is Gathered and Compiled

When the user generates this chart, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type SplitMonitorOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID

- Y-axis maximums
- Selected Percentile Split
- Show Plan Stripes
- Show Pedestrian Activity
- Show Average Split
- Show Percent Max Out and Force Off
- Show Percent Gap Outs
- Show Percent Skip

Event Data is gathered from the Controller_Event_Logs table. Data is then compiled into programmed split, gap out, max out, force off, unknown, and pedestrian activities series.

10.2.2. How Data is Displayed

The MetricOptions objects create one or more chart objects, generated by the web rendering engine provided in the .NET Framework. All the split monitoring data is rendered to the chart as lines and points. The chart is then saved as an image file displayed on the website.

10.3. Interpreting the Split Monitor Chart

Once the **Split Monitor** charts are generated, the user will see a legend followed by the chart(s). The legend (Figure 16) is displayed at the top and includes:

- **■** Programmed Split. When applicable, the programmed split length is displayed as an orange line.
- **■** Gap Out. When a phase is terminated due to gap out, a green dot is displayed along the line of that phase.
- **■** Max Out. When a phase is terminated due to max out, a red dot is displayed along the line of that phase.
- **■** Force Off. When a phase is terminated due to force off, a blue dot is displayed along the line of that phase.
- **■** Unknown. When a phase is terminated and the termination cause is unknown, a black dot is displayed along the line of that phase.
- **■** Ped Activity. When a pedestrian activation for a phase occurs, a bronze/gold dot is displayed.

Figure 16: Split Monitor Legend

For each supported movement, a chart for the **Split Monitor** data is displayed below the legend. It includes:

- The first line at the top of the chart is the name of the road along with signal number and phase.
- The second line is the selected date and time range as specified during the criteria selection.
- Directly above the chart, the first line displays the timing plan the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the first example, shown in Figure 17, Plan 10 is active for the entire analysis period. In Figure 18, multiple signal plans are active over the 18-hour analysis period.
- Above each chart section, the second line is the 85th percentile (if available) speed during this plan.
- Above each chart section, the third line is the average split during this plan.
- Above each chart section, the fourth line is the percentage of force offs during this plan.
- Above each chart section, the fifth line is the percentage of gap outs during this plan.
- Above each chart section, the sixth line is the percentage of skips (phase skipped due to lack of demand) during this plan.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is the phase duration in seconds; for instance, in Figure 17 at approximately 10:15, phase 2 was terminated at approximately 220 seconds with a force off. A pedestrian activation is also displayed approximately at 220 second mark.
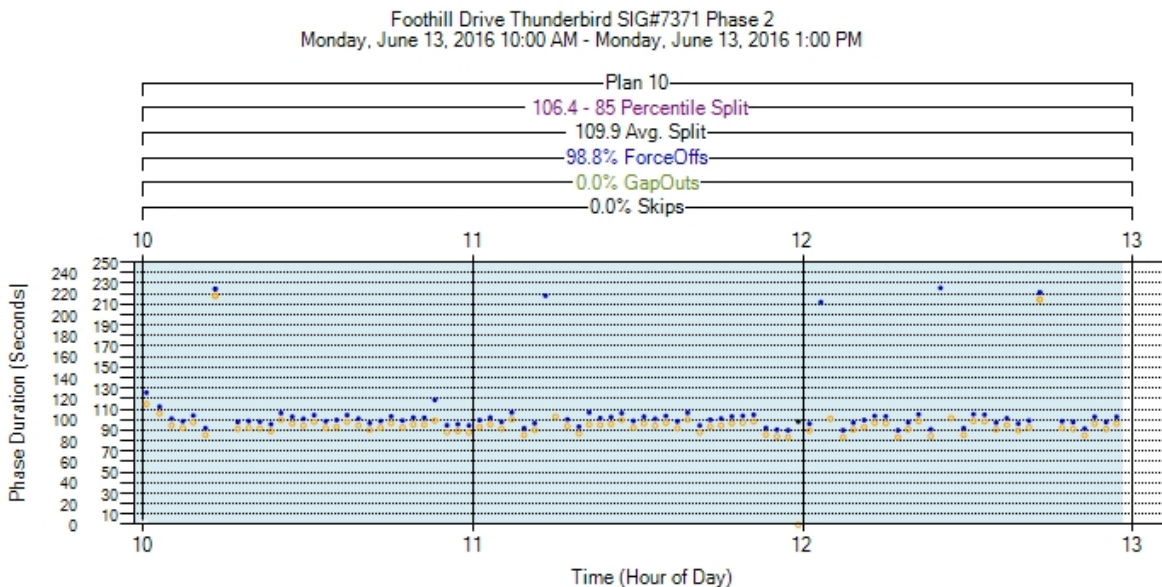
Figure 17: Split Monitor Time Comparison to Purdue Phase Termination
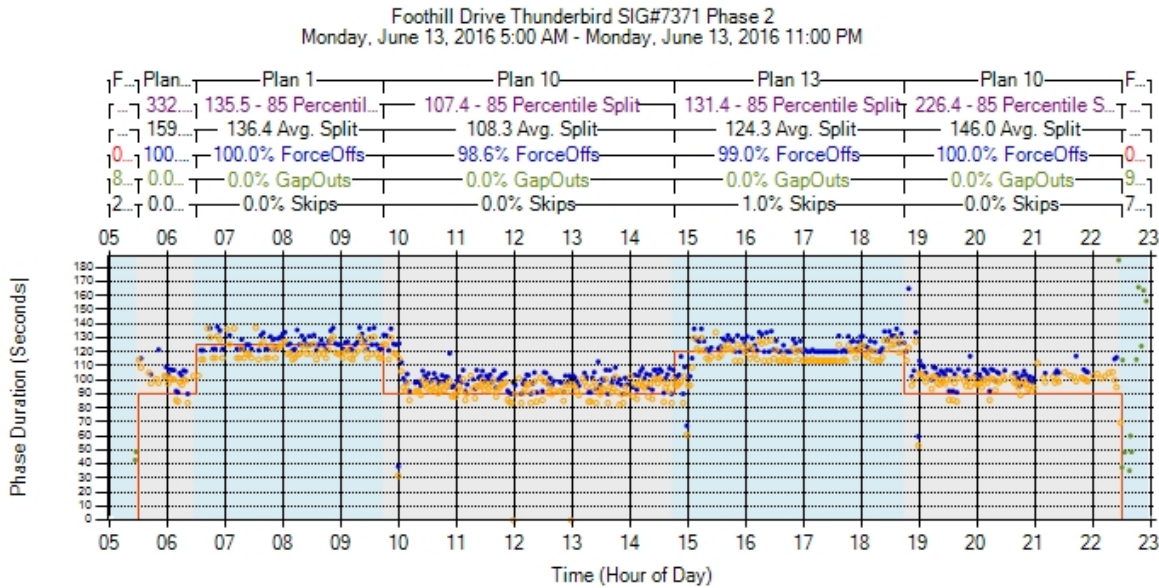
Figure 18: Split Monitor (includes Programmed Split)

11. Turning Movement Counts

The **Turning Movement Counts** metric displays counts for all supported turn and through movements. Once the user selects the appropriate intersection and time period, and clicks **Create Chart**, a separate graph for each dedicated movement for each approach is generated. If there is no dedicated right or left turn lane, there will not be a chart for that movement; however, if there is a shared through-turn lane, that lane will be indicated as "Thru Right" or "Thru Left."

11.1. Requirements for Turning Movement Counts

This data requires stop bar detection with count for each travel lane. In order to display this chart, the intersection must include properly configured parameters as listed below:

- Stop bar/count detection for each lane in movement(s) to be analyzed.
- Signal controller must track all events using standard event codes.
- Signal controller logs must be retrievable by the ATSPM web server.

11.2. Report Data

11.2.1. How Data is Gathered and Compiled

When the user generates this plot, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type TMCOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximums
- Volume bin size
- Flags for:
  - o Showing per-lane volume
  - o Showing total volume

Using these parameters, separate charts for each movement direction, and then vehicle, exit ramp, and bicycle lane usages are created within the MetricOptions object. The Controller Event Log is queried on a per-detector basis for each chart.

11.2.2. How Data is Displayed

The MetricOptions object creates a chart object, generated by the web rendering engine provided in the .NET Framework. All of the per-lane and total volumes are rendered to the chart as data points. The chart is then saved as an image file displayed on the website.

11.3. Interpreting Turning Movement Counts

The **Turning Movement Counts** chart is a line graph over the analysis period. Two charts are included below to illustrate the metric. All charts include the following components:

- The first line at the top of the chart is the name of the road and the signal number.
- The second line is the date and time range as specified during the criteria selection.
- The third line is the movement and direction; for instance, the Figure 19 example chart is the **Southbound Thru.**
- The fourth line details statistics of the selected time for total volume. This includes peak hour and PHV in VPH.
- The fifth line details statistics of the selected time for PHF and lane utilization factor (f_{LU}).
- Above the chart is the timing plan the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In the examples shown in Figure 19 and Figure 20, Plan 7 is active for the entire analysis period.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is the volume in VPH.

There are many varieties of formatted charting, depending on lane count and configuration. Two charts from different intersections are displayed as examples, each with multiple lanes. One is for southbound through movement along an exit ramp, returning motorists to the expressway. The other is for westbound through lanes.

For the southbound through example, Figure 19, the following applies:

- The legend is at the bottom:
  - ──── Total Volume, if there is more than one lane, the total for all lanes is depicted with a black line.
  - - - - - Thru left, for a travel lane that is shared left and through, the chart will display a dotted gold line that depicts the VPH for that lane.
  - ──── Lane 2, for a travel lane that is dedicated to that specific movement, the chart will display a gold line that depicts the VPH for that lane.
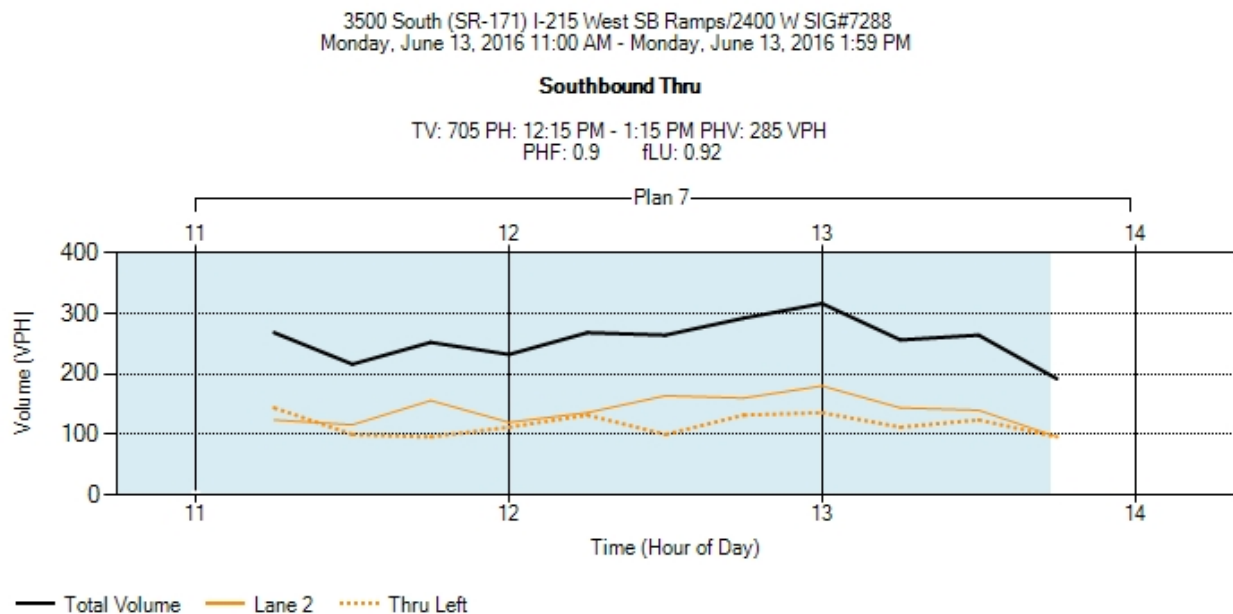
Figure 19: Turning Movement Counts (Southbound Thru)

For the westbound through example, Figure 20, the following applies:

- The legend is at the bottom:
  - ──── Total Volume, if there is more than one lane, the total for all lanes is depicted with a black line
  - ──── Lane 1, all movement reports will include at minimum lane 1, which depicts the VPH for the first lane; depicted as solid maroon.
  - ──── Lane 2, similar to Lane 1 and depicted as a solid gold line.
  - - - - - Lane 3, similar to Lane 2 and depicted as a dotted blue line.
  - - - - - Lane 4, similar to Lane 3 and depicted as a dotted maroon line.
  - ──── Thru Right, a through movement shared with right turn; displayed as a blue line that depicts the VPH for that lane.
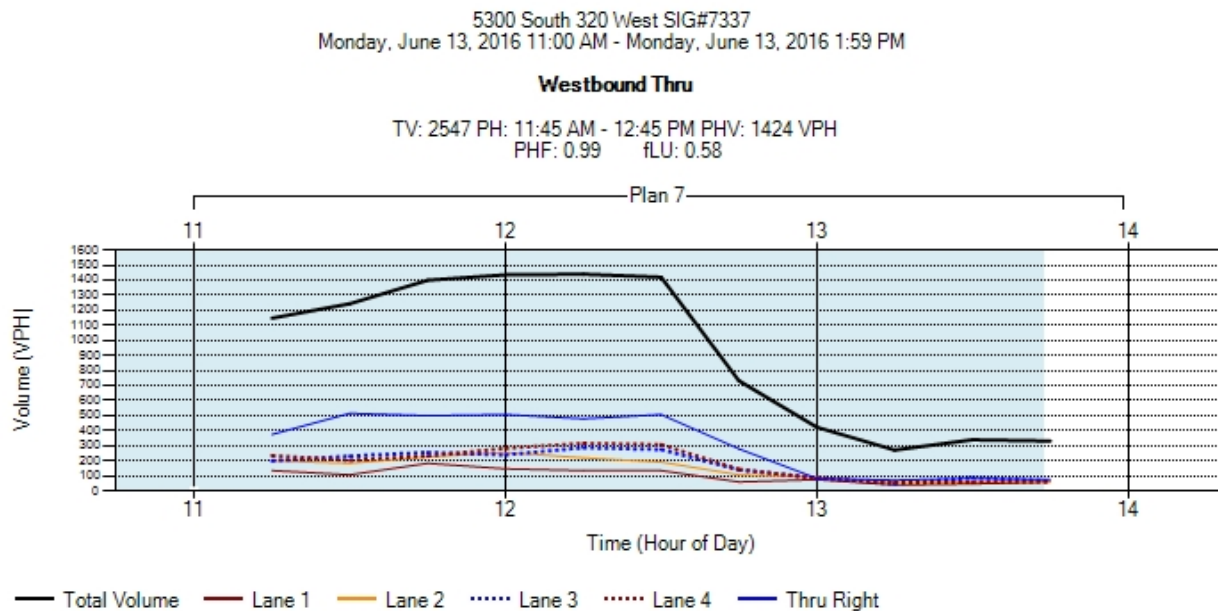
Figure 20: Turning Movement Counts (Westbound Thru)

12.   Yellow and Red Actuations

Yellow and Red Actuations is a graphical representation of when vehicles enter the intersection during the yellow and red indications for each phase. This is based on analyzing vehicle speed and its distance from the intersection to predict whether the vehicle can stop. With additional configuration parameters, vehicles could also be counted as they cross the stop bar and enter the intersection (if the detection system is configured for this purpose).

The overarching purpose of this metric is to identify when engineering countermeasures might be needed to deal with red-light running.

Note: This metric can occasionally flag vehicles that are probably passing through on green or yellow as violations.

12.1.   Requirements for Yellow and Red Actuations

In order to produce the Yellow and Red Actuations chart, there must be a determination if a vehicle either: 1) passes beyond the stop bar into the intersection, or 2) can or cannot stop before the stop bar. These measures determine whether the vehicle likely entered the intersection during the yellow and red indications of each phase. The Utah ATSPM site mostly utilizes radar detection (Wavetronix SmartSensor Matrix) with a count sensor at or slightly in front of the stop bar. A minimum speed threshold, usually 5 mph, is set in the sensor software and vehicles traveling less than this speed are omitted (https://udottraffic.utah.gov/ATSPM/Images/WavetronixMatrixLatencyInformation.pdf). In addition, UDOT often uses a detector latency of 1.2 seconds when using Wavetronix Matrix that is further

discussed in the pdf listed above. Radar detection or a loop that collects data within the intersection itself would be optimal. In order to display this chart, the intersection must include properly configured parameters as listed below:

- Detection (multiple methods) to determine entrance beyond the stop bar into the intersection.
- Signal controller must track all events using standard event codes.
- Signal controller logs must be retrievable by the ATSPM web server.

12.2. Report Data

12.2.1. How Data is Gathered and Compiled

When the user generates this plot, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type YellowAndRedOptions.

These MetricOptions are bound by:

- Y-axis maximum
- Severe Red Light Violations
- Flags for:
  - Red Light Violations
  - Severe Red Light Violations
  - Percent Red Light Violations
  - Percent Severe Red Light Violations
  - Average Time Red Light Violations
  - Yellow Light Occurrences
  - Percent Yellow Light Occurrences
  - Average Time Yellow Occurrences

Using these parameters, separate charts for each signal phase are created within the MetricOptions object. Approach data is queried for all approaches relevant to the signals selected.

12.2.2. How Data is Displayed

The MetricOptions object creates a chart object, generated by the web rendering engine provided in the .NET Framework. The chart is then saved as an image file to later be displayed on the website.

12.3. Interpreting Yellow and Red Actuations

After the report generates, there will be a separate chart for each movement available. The abbreviations for the "Yellow and Red Actuations" metric are defined in the Component Details document. Each graph includes these components:

- The first line at the top of the chart contains the name of the road, the signal number, the phase, and direction.
- The second line is the date and time range as specified during the criteria selection.
- The third line is the total violations (entering on red clearance or red) during the plan.
- The fourth line is the percentage of violations during the displayed time.
- The fifth line is the percentage of severe violations (calculated based on the **Severe Red Light Violations** input).
- The sixth line is the number of vehicles entering the intersection during the yellow indication.
- The seventh line is the percentage of vehicles entering the intersection during the yellow indication.
- The Legend is to the right of the graph
    - o   Red, the duration of the red indication, represented by solid pink.
    - o   Red Clearance, the duration of the all red clearance, represented by solid red.
    - o   Yellow Clearance, the duration of the yellow clearance, represented by solid yellow.
    - o •   Detector Activation, a detector activation where the vehicle cannot stop in time to keep from entering the intersection during the yellow, all red, or red indications; represented by black dots.
- Directly above the chart, the first line displays the timing plan the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale. In Figure 21, Plan 1 is active for the entire analysis period.
- Above each chart section, the second line is TYLO (Average Time Yellow Occurrences), which is the average time in seconds that vehicles enter the intersection during the plan.
- Above each chart section, the third line is %YLO (Percent Yellow Light Occurrences), which is the percentage of vehicles entering the intersection during the plan, relative to the total flow.
- Above each chart section, the fourth line is #YLO (Yellow Light Occurrences), which is the number of vehicles entering the intersection during the plan.
- Above each chart section, the fifth line is Ave TRLV (Average Time Red Light Violations), which is the average time in seconds when red light violations occur during the plan.
- Above each chart section, the sixth line is %SRLV (Percent Severe Red Light Violations), which is the percentage of severe red light violations during the plan, relative to the flow.
- Above each chart section, the seventh line is %RLV (Percent Red Light Violations), which is the percentage of red light violations during the plan, relative to the flow.
- Above each chart section, the eighth line is SRLV (Severe Red Light Violations), which is the total number of severe red light violations that occurred during the plan.
- Above each chart section, the ninth line is RLV (Red Light Violations), which is the total number of red light violations (entering on red clearance or red) that occurred during the plan.
- The X-axis (above and below the chart) is the hour in 24-hour format.
- The Y-axis title (Left Side) and scale is Yellow Red Time [Seconds]. For instance, in Figure 21, the last detector activation before the 8:00 hour is approximately 3.5 seconds and is just prior to all red clearance; thus, it is defined as an occurrence rather than a violation because it happened during yellow.
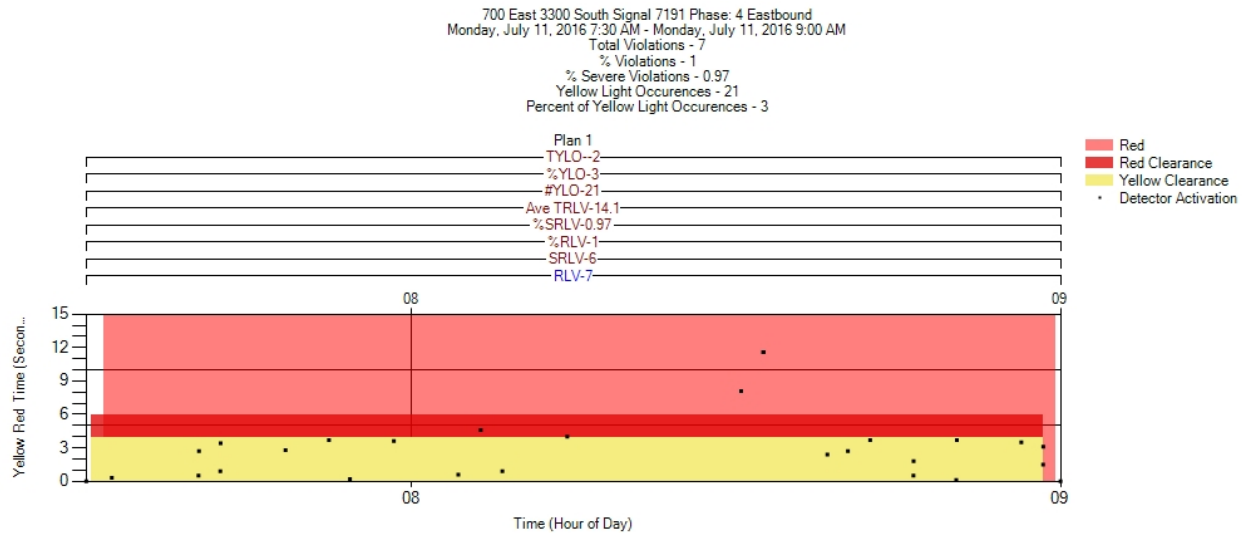
Figure 21: Yellow and Red Actuations Graph

13. Purdue Split Failure

Purdue Split Failure provides a detailed view of signal operations. The metric relies on existing stop bar presence detection either by lane group or lane-by-lane. The metric calculates the percent of time stop bar detectors are occupied during the green phase and then during the first five seconds of red. These numbers are called the Green Occupancy Ratio (GOR) and Red Occupancy Ratio (ROR). If the occupancy ratios are both more than 80 percent, the phase is considered a split failure in that cycle-a threshold based on previous field studies (Day, C.M., D.M. bullock, H. LI, S.M. Lavrenz, W.B. Smith, and J.R. Sturdevant. Integrating Traffic Signal Performance Measures into Agency Business Processes. West Lafayette, Indiana: Purdue University, 2016). When multiple consecutive split failures occur, it can indicate that queued vehicles are not being served in one cycle.

13.1. Requirements for Purdue Split Failure

The Purdue Split Failure requires presence detection either by lane group or lane-by-lane (preferred). In order to produce the Purdue Split Failure charts, the intersection must include properly configured parameters as listed below:

- Vehicle detection capable set up in the presence mode at the stop bar that is also used to call and extend the signal phase.
- Signal controller must track all events using standard event codes.
- Signal controller logs must be retrievable by the ATSPM web server.
-

13.2.   Report Data

13.2.1. How Data is Gathered and Compiled

When the user generates this plot, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type PurdueSplitFailure.

These MetricOptions are bound by:

- First Seconds OF Red (default is 5)
- Flags for:
  - Show Fail Lines
  - Show Average Lines
  - Show Percent Fail Lines

Using these parameters, separate charts for each signal phase are created within the MetricOptions object. Data is queried for all phases relevant to the signals selected.

13.2.2. How Data is Displayed

The MetricOptions object creates a chart object, generated by the web rendering engine provided in the .NET Framework. The chart is then saved as an image file to later be displayed on the website.

13.3.   Interpreting Purdue Split Failure

After the report generates, there will be a separate chart for each phase available. The abbreviations for the "Purdue Split Failure" metric are defined in the Component Details document. Each graph includes these components:

- The first line at the top of the chart contains the name of the road, and the signal number.
- The second line is the date and time range as specified during the criteria selection.
- The third line is the phase number and phase description.
- The fourth line is the total split failures for the phase for the analysis period.
- The Legend is to the right of the graph (See Figure 22).

Figure 22: Purdue Split Failure Legend

- Directly above the chart (See Figure 23), the first line displays the timing plan the intersection signal controller was using for each bracketed section of the chart. Charts may have multiple sections/plans depending on the time scale.
- The second line down shows the number of split failures for each time-of-day period.
- The third line down shows the percentage of split failures for each time-of-day period.
- The X-axis (below the chart) is the hour in 24-hour format (or whatever start and end time was chosen).
- The Y-axis title (Left Side) and scale is Occupancy Ratio [percent].
- The red lines are showing the average ROR in 15-minute intervals.
- The green lines are showing the average GOR in 15-minute intervals.
- The red squares are showing the ROR for each cycle.
- The green squares are showing the GOR for each cycle.
- The vertical yellow lines are showing a split failure for that cycle, defined as a GOR 80% or above and a ROR of whatever is shown in the Purdue Split Fail Options (default is first 5 seconds of red), indicating that queued vehicles are not being served in one cycle.
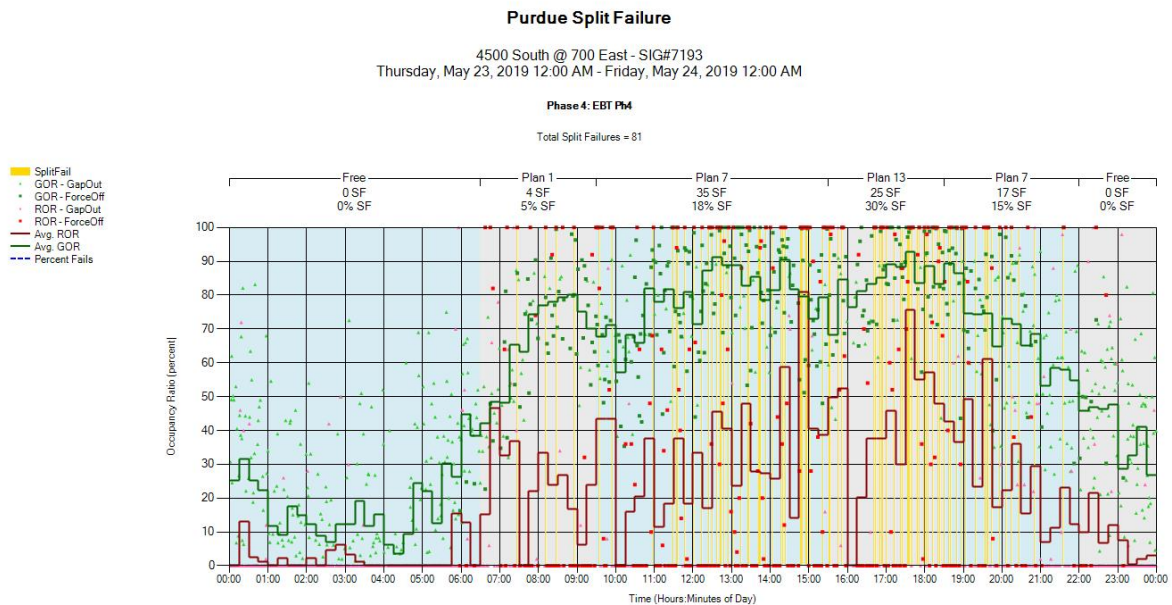

Figure 23: Purdue Split Failure Graph

14. Timing and Actuation

The **Timing and Actuation** metric depicts a detailed view of the vehicle and pedestrian cycles for each phase overlaid with detection actuations. In addition, this metric allows custom enumeration codes to be plotted for further analysis. This metric is most useful for mesoscopic level (≈<60 minutes) of detail.

Since mesoscopic level of analysis will most likely be used with this metric, the algorithm will look back 6 minutes for cycle (green, yellow, red) data behind the specified start time. If no enumerations are found, it will then go back as far as 60 minutes and then 24 hours looking for data. If none is found, it will gray it out or not show any data.

14.1. Requirements for Timing and Actuation

This metric requires that the intersection is set up as shown below.

- Configuring the phases in ATSPM Signal configuration is necessary to see data for this metric (unless "Raw Data Display" is enabled). If "Raw Data Display" is enabled, the algorithm will ignore the signal configuration and will look for up to 16 phases and 16 overlaps for active phase and pedestrian events.
- Without "Raw Data Display" enabled, to see timing and detection actuation charts, the phase needs to be assigned and detectors mapped to the phase.
- Signal controller must track all events using the standard event codes, including pedestrian actuation and the subsequent start of walk.
- Signal controller logs must be retrievable by the ATSPM web server.

14.2. Report Data

14.2.1. How Data is Gathered and Compiled

When the user generates this chart, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common).

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Various Timing and Actuation Options

Using these parameters, a TimingAndActuation object is generated within the MetricOptions object.

Within this TimingAndActuation, data is gathered from the Controller_Event_Logs table, in particular:

- Active Phase Events: phase begin green [1], phase min complete [3], phase begin yellow clearance [8], phase end yellow clearance [9], phase end red clearance [11]
- Overlap Events: overlap begin green [61], overlap begin trailing green [62], overlap begin yellow [63], overlap begin red clearance [64], overlap off [65], pedestrian overlap begin walk [67], pedestrian overlap begin clearance [68], pedestrian overlap begin solid don't walk [69].
- Detector Events: detector off [81], detector on [82], ped detector on [90], ped detector off [89].

Custom Codes

- Three boxes are available under "Custom Codes".
  - Phase Event Codes – Enumeration codes entered will display under each phase that is displayed. For the data to be relevant, it is up to the user to consult with the Indiana Traffic Signal Hi Resolution Data Logger Enumerations (https://docs.lib.purdue.edu/jtrpdata/3/) and to select the event codes that have an event parameter defined as "Phase #".
  - Global Event Codes – Enumeration event codes entered will display on a separate blue chart at the bottom of the phase charts, if data is available.
  - Global Event Parameters – Enumeration Event Parameters entered will display on a separate blue chart with the global event codes at the bottom of the phase charts, if data is available.

14.2.2. How Data is Displayed

The MetricOptions object creates one or more chart objects generated by the web rendering engine provided in the .NET Framework. All the delay data (for each cycle, the difference between call and walk) is rendered to the chart as bars. The chart is then saved as an image file displayed on the website.

14.3. Interpreting the Timing and Actuation Chart

Once **Create Metrics** is selected, a chart for each phase that is configured is created. The data included in each chart is:

- If the "Legend" box is checked, a legend will show at the bottom of all the charts. Please see Figure 24 below for a detailed description of colors and codes used for this metric.

Legend For Timing And Actuation Charts

|	
Dark Green Fill Box: Phae Begin Green, Event Code 1	
Medium Spring Green Fill Box: Phase Min Complete, Event Code 3	
Lime Green Fill Box: Overlap Begin Green, Event Code 61	
Light Green Fill Box: Overlap Begin Trailing Green (Extension), Event Code 62	
Light Yellow Fill Box: Phase Begin Yellow Clearance, Begin Overlap Yellow, Event Codes 8 & 63	
Dark Red Fill Box: Phase End Yellow Clearance, Overlap Begin Red Clearance, Event Codes 9 & 64	
Light Red Fill Box: Phase End Red Clearance, Overlap off (Inactive with Red indication) Event Codes 11 & 65	
Light Gray Fill Box: No Vehicle Display Cycles Found	
Light Blue Fill Box: Pedestrian Begin Walk, Event Codes 21 & 67	
Deep Blue Fill Box: Pedestrian Begin Clearance, Event Codes 22 & 68	
Gray Fill Box: Pedestrian Begin Solid Don't Walk, Event Codes 23 & 69	
Black Triangle: Detector On, Code 82	▲
Light Gray Square: Detector Off, Code 81	▪
Line Connecting Detector On, (Code 82) to Detector Off (Code 81)	——
Dark Purple Triangle: Advanced Count with Time Offset, Detector On, Event Code 82	▲
Medium Purple Square: Advanced Count with Time Offset, Detector Off, Code 81	▪

Figure 24: Legend for Timing and Actuation Charts

- The first line at the top (if "Header For Each Phase" is checked) is the title of the chart.
- The second line is the name of the road and the signal number.
- The third line is the date and time range of the analysis period as specified during the criteria selection.
- The fourth line is the phase number.
- The X-axis (below the chart) is the time from start time to end time that was selected for analysis.
- The Y-axis (if the options are enabled) will show the following:
    - Vehicle signal display
    - Pedestrian Intervals
    - Pedestrian Detector Actuations
    - Lane Detection
    - Phase Event Codes (if entered).
- There is a box titled, "Show Lane Detection". Under this box are several options, one of the options to show the "on/off lines". If enabled (default is on), a line will be drawn connecting the detection on and off codes (See Figure 25).
- Figure 25 below shows phase 2 for signal 7220. The time range is from 11:30 AM to 11:35 AM. The diagram shows the green, yellow and red clearance time of the vehicle signal display, as well as the pedestrian interval timing (walk, flashing don't walk, solid don't walk) and detector actuations.
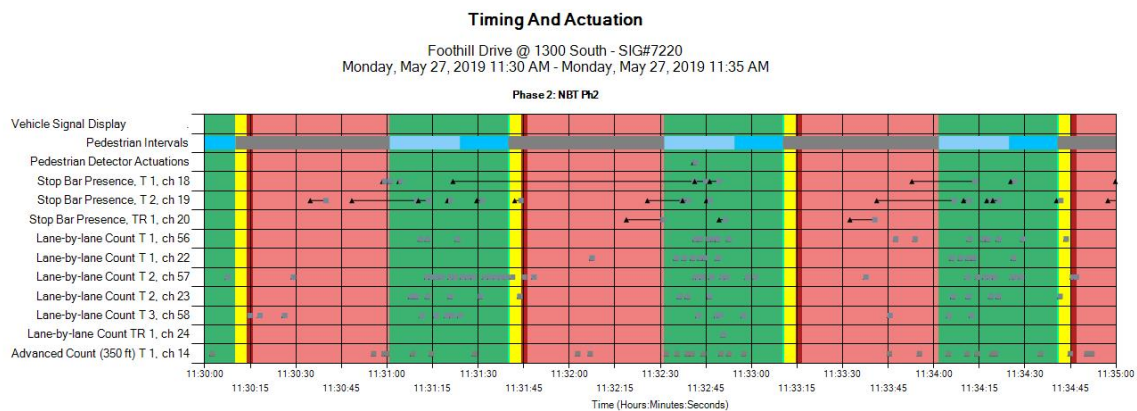
Figure 25: Timing and Actuation Chart

- There are many options available for analysis with this metric as described in more detail in the Component Details manual. One of the options includes the option for "Custom Codes". Figure 26 below shows the same data as found in Figure 25 with the addition of Phase Event code 6 at the bottom. Figure 27 shows the global event codes and parameters that display on a separate chart.
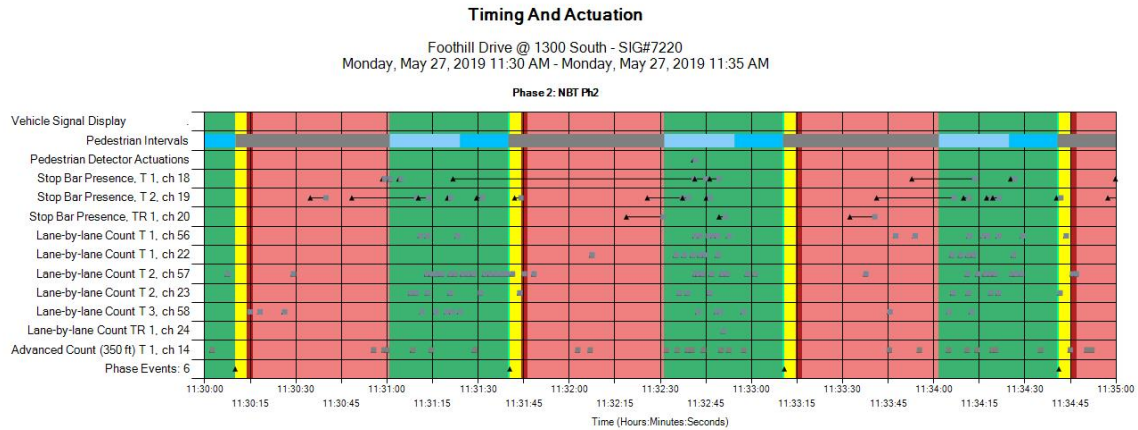
Figure 26: Timing and Actuation Chart - Phase Event Codes
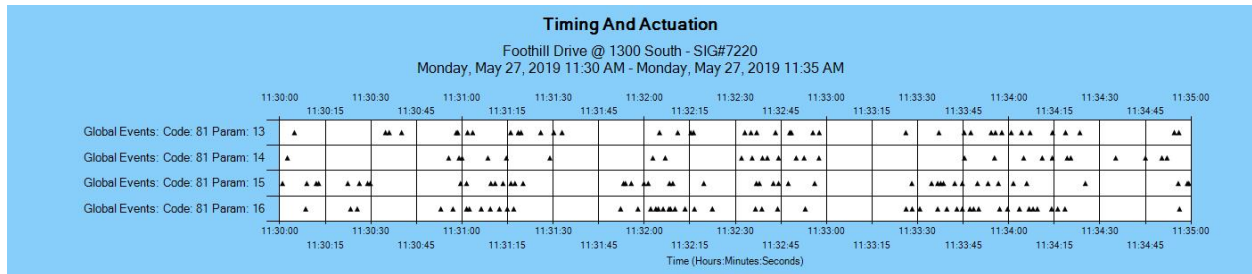

Figure 27: Custom Global Event Codes & Parameters

15.   Chart Usage

The **Chart Usage** charts tabulate the cumulative entries agencies submitted via the **Log Action Taken** form on the ATSPM website.

Access **Chart Usage** from the **Reports** tab, select the desired start and end dates, and click **Create Chart**. After the page loads, the charts are ready for viewing. There are two usage pie charts, two metric tabulation bar charts, and 15 metric action bar charts. If there is no data during the selected time period for a specific chart, a blank chart will display as a placeholder.

15.1. Report Data

15.1.1. How Data is Gathered and Compiled

When the user generates these charts, the Usage.js script makes a web request with the GetMetricsUsage, GetAgencyUsage, GetReportRuns, GetActionsCharts, and GetActionsByMetric functions to the ActionLogController. These requests have two arguments, start date and end date.

The GetMetricsUsage function gathers all data between the start and end date from the action log and groups it by metric type. The GetAgencyUsage function gathers all data between the start and end date from the action log and groups it by agency. The GetReportRuns function gathers all logged chart generated events from the application event log. The GetActionCharts function gathers all data between start and end date and creates a chart for each action listing the metrics used for that action. The GetActionsByMetric function gathers all data between the start and end date from the action log and creates a chart for each metric type grouped by action type.

15.1.2. How Data is Displayed

The functions described above then create chart objects generated by the web rendering engine provided in the .NET Framework. The charts are then saved as an image file to later be displayed on the website.

15.2. Pie Charts

The **Chart Usage** pie charts are typical pie charts, as shown in Figure 28, showing a relative percentage of each component. When the mouse pointer is hovered over a section of the chart, that section highlights and displays the number associated with the metric for the corresponding item.
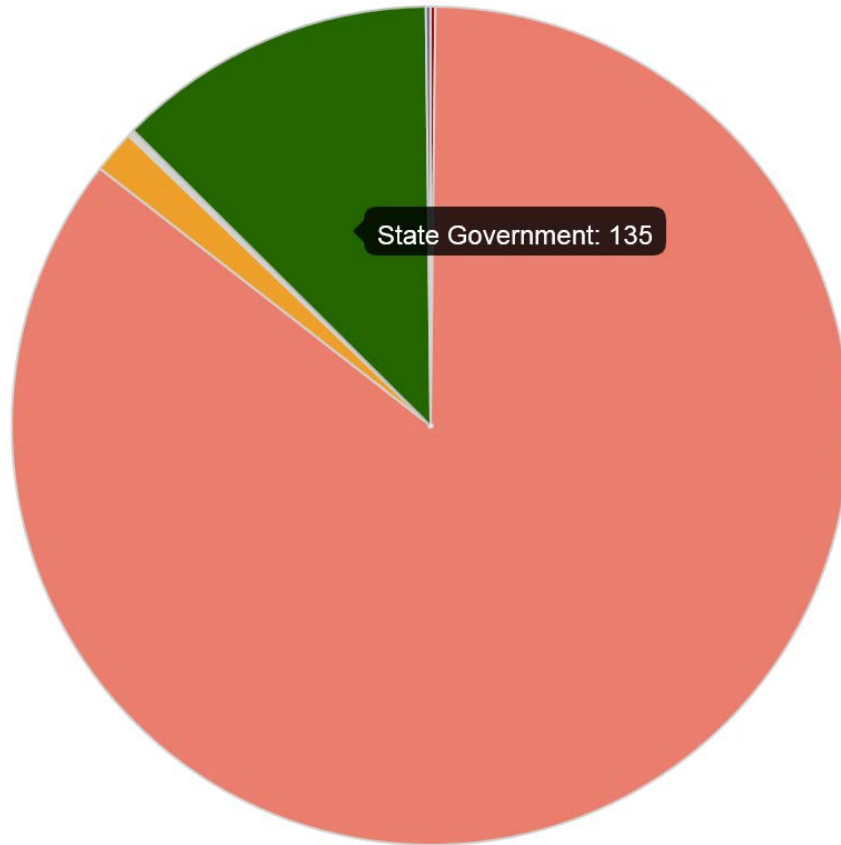
State Government: 135

Figure 28: Example Pie Chart

15.2.1. Chart Usage

The **Chart Usage** pie chart tabulates the total usage of each chart during the defined period. The chart legend, as shown in Figure 29, lists all available chart types, though some may not be included or discernable while viewing the chart.
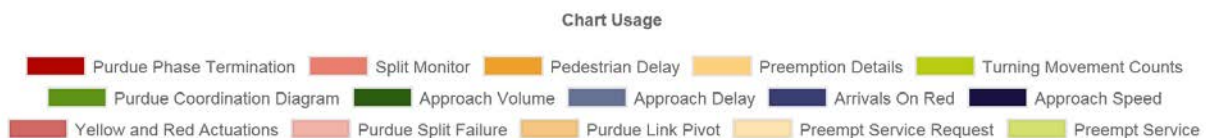

Figure 29: Chart Usage Legend

15.2.2. Agency Usage

The **Agency Usage** pie chart tabulates each agency's usage during the defined period. The chart legend, as shown in Figure 30, lists all available chart types, though some may not be included or discernable while viewing the chart.
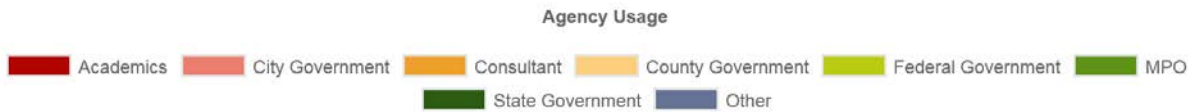
Figure 30: Agency Usage Legend

15.3. Metric Tabulation Bar Charts

The Metric Tabulation bar charts are typical bar charts, as shown in Figure 31, showing bars with height-relative components. When the mouse pointer is hovered over a section, that section highlights and displays the number associated with the metric for the corresponding item. Both of the Metric Tabulation charts, **Reports Run** and **Actions By Metric**, have the same categories, which are: Purdue Phase Termination, Split Monitor, Pedestrian Delay, Preemption Details, Turning Movement Counts, Purdue Coordination Diagram, Approach Volume, Approach Delay, AoR, Approach Speed, Yellow and Red Actuations, Purdue Split Failure, Purdue Link Pivot, Preempt Service Request, and Preempt Service.
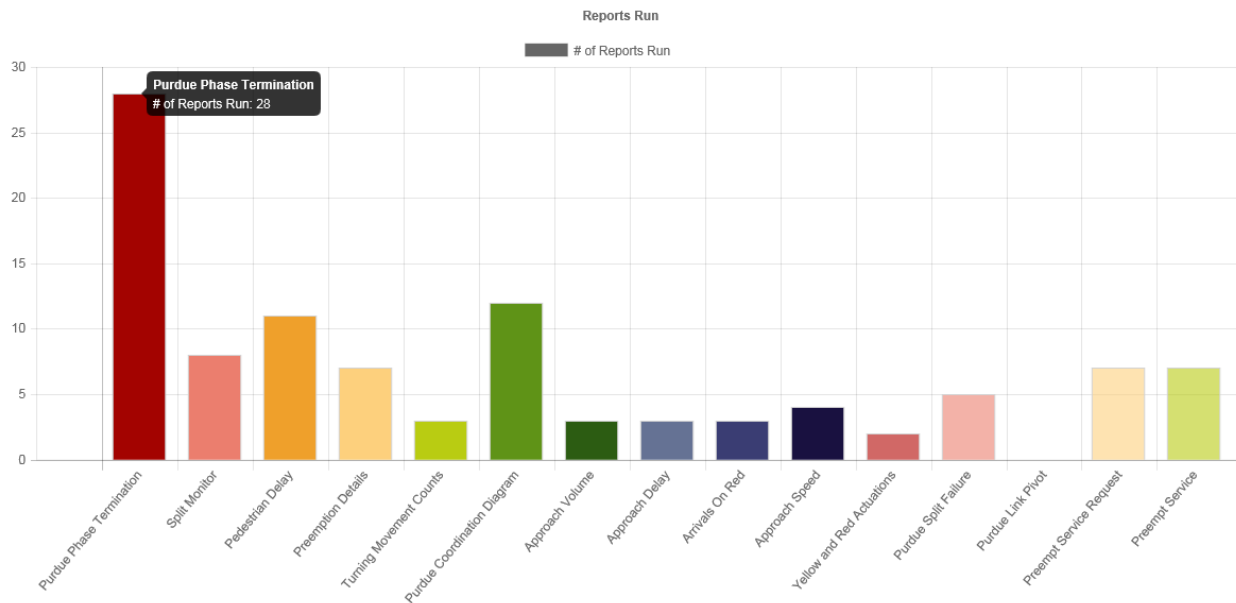

Figure 31: Example Bar Chart

15.4. Metric Action

The **Metrics Action** bar charts (Figure 32) tabulate the actions for 15 metrics. These metrics are those listed in the tabulation bar charts and the number of actions (e.g. Detector Issue, Offset, or other) that were required for each metric.
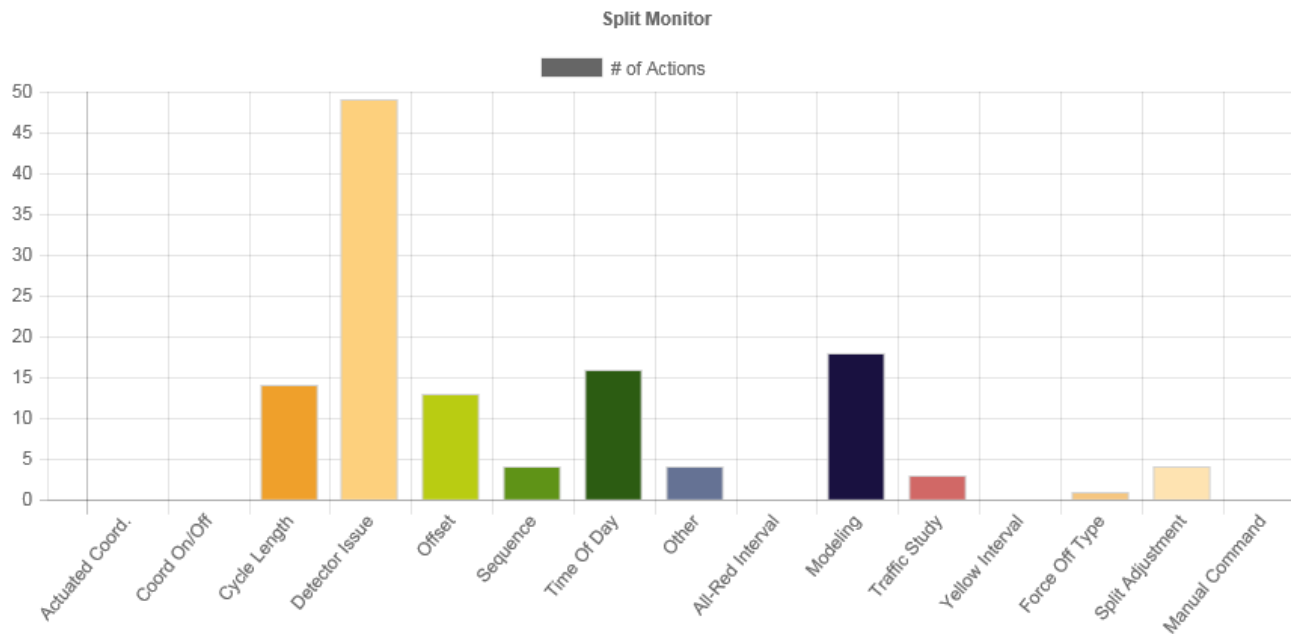
Figure 32: Example Metric Action Chart

16.   Purdue Link Pivot

The **Purdue Link Pivot** report is a compilation of data in two separate reports and includes links to additional graphs. The data is presented in relation to the AoG for the corridor regarding upstream/downstream traffic flow and can be used to interpolate possible outcomes by editing offset.

16.1.   Adjustments

The first report displayed after running the report is the **Adjustments** table. This report includes offset data for each signal in the route.

16.1.1.   Requirements for Report

The **Offset Adjustments** table requires that one or more link pivot routes be set up (via **Charts > Purdue Link Pivot Route Setup**). The routes must consist of consecutive traffic signals with advanced count vehicle detection along the route. PCDs must be configured for all approaches on the route.

16.1.2.   Report Data

16.1.2.1.   How Data is Gathered and Compiled

When the user generates a Purdue Link Pivot report, a LinkPivotController object is created. This object connects to the LinkPivotService which generates all report content including the adjustments section. The user selected options are contained in a LinkPivotViewModel.

This LinkPivotViewModel object is bound by:

- Start date and time
- End date and time
- Route
- Cycle Length
- Days to Include
- Starting Point
- Bias
- Bias Direction

Next, the GetLinkPivot function is called which gathers data from the Approach Route Details table with a matching route id. This data is compiled into a list of link pivot pairs. Each pair is then enhanced with the statistics data found in the final adjustments table.

16.1.3. How Data is Displayed

The LinkPivotController object creates a link pivot diagram, generated by the web rendering engine provided in the .NET Framework. All adjustment data is rendered to a table defined in the LinkPivotViewModel.

16.1.4. Interpreting Adjustments

The **Adjustments** table (Figure 33) represents recommended offsets for coordinated operation along a pre-defined route of consecutive signals.

This table includes eight columns as follows:

- **Link** – the sequential number for the link within the route.
- **Signal ID** – the number assigned to the signal during setup.
- **Location** – the main and side streets where the signal is located.
- **Link Delta** – the recommended delta (change) to the offset for that portion of the link.
- **Edit Link Delta** – a change field to simulate adjustments to the offset; default is zero.
- **Offset(+ to Offset)** – a calculated value adding **Link Delta** and **Edit Link Delta**.
- **Existing Offset** – a change field to enter the programmed offset for the link; default is zero.
- **New Offset** – a calculated value adding **Offset(+ to Offset)** and **Existing Offset**.

Adjustments

Link	Signal	Location	Link Delta	Edit Link Delta	Offset(+ to Offset)	Existing Offset	New Offset
1	7371	Foothill Drive Thunderbird	0	0	0	0	0
2	7223	Foothill Drive 2100 South	0	0	0	0	0
3	7222	Foothill Drive 1700 South	0	0	0	0	0
4	7221	Foothill Drive 2300 East	0	0	0	0	0
5	7220	Foothill Drive 1300 South	0	0	0	0	0
6	7503	Foothill Drive 2100 East	0	0	0	0	0
7	7219	Foothill Drive Sunnyside	0	0	0	0	0
8	7218	Foothill Drive Wakara Way (660 S.)	0	0	0	0	0
9	7217	Foothill Drive Mario Capecchi Dr (1950 E.)	0	0	0	0	0

Figure 33: Adjustments Table

16.2.   Approach Link Comparison

The **Approach Link Comparison** table displays segment (signal-to-signal) data from the corridor and provides AoG data, upstream and downstream, for existing and predicted flow.

16.2.1.   Requirements for Report

This report has the same requirements as the **Offset Adjustments** table. See Section 14.1.1.

16.2.2.   Report Data

16.2.2.1.   How Data is Gathered and Compiled

When the user generates a Purdue Link Pivot report, A LinkPivotController object is created. This object's LinkPivotResult function is used to generate all report content including the approach link comparison section. The user selected options are contained in a LinkPivotViewModel.

This LinkPivotViewModel object is bound by:

- Start date and time
- End date and time
- Route
- Cycle Length
- Days to Include
- Starting Point
- Bias
- Bias Direction

Next, the GetLinkPivot function is called which gathers data from the Approach Route Details table with a matching route id. This data is compiled into a list of link pivot pairs. Each pair is then enhanced with the statistics data found in the final adjustments table.
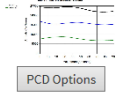
16.2.3. How Data is Displayed

The LinkPivotController object creates a link pivot diagram, generated by the web rendering engine provided in the .NET Framework. All adjustment data is rendered to a table defined in the LinkPivotViewModel.

16.2.4. Interpreting Approach Link Comparison

The **Approach Link Comparison** table (Figure 34) is comprised of seven major columns. These columns are:

- **Link**, which is a sequential number to define each segment.
- **Approaches** is split into two columns. The first column is **Upstream**, which lists the Signal ID and direction in the first row and the main and cross streets in the second row for the upstream signal. Next is **Downstream**, which lists the Signal ID and direction in the first row and the main and cross streets in the second row for the downstream signal.
- **Upstream AoG** is split among three columns:
    - **Existing** – the number of arrivals on green computed with existing data;
    - **Predicted** – the number of vehicles predicted to arrive on green at the chosen delta; and
    - **Change** – the pie chart shows the existing percent arrivals on green (light green) and the predicted gain in arrivals on green (dark green) or predicted loss (red).
- **Downstream AoG** is split among three columns, which are the same as the Upstream.
- **Total Link AoG** is split among three columns, which are the same as and tabulate the Upstream and Downstream numbers.
- **Delta**, which corresponds to the delta in the Offset Adjustments table.
- **AoG Chart** displays a thumbnail image for the Results Graph (see Figure 35) of traffic through the intersection.

Figure 34: Approach Link Comparison Table

The last row in the **Approach Link Comparison** table (Figure 36) is the Corridor Summary that tallies the Upstream, Downstream, and Total Link AoG for the corridor.
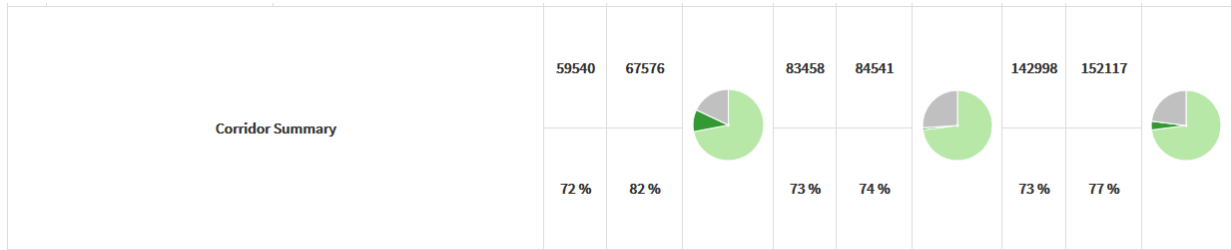
Figure 35: Corridor Link Summary

 In the **AoG Chart** column, below the thumbnail, is a **PCD Options** link, which displays the Purdue Coordination Diagrams for that link, if selected. See PCD Options below.

16.3.   Max Arrivals On Green Chart

Clicking on the thumbnail image in the **AoG Chart** column of the **Approach Link Comparison** table displays the Max Arrivals On Green By Second chart. This chart is an interpolative representation on what the AoG would be if the offset were adjusted.

16.3.1.   Requirements for Report

This report has the same requirements as the Offset Adjustments table. See Section 14.1.1.

16.3.2.   Report Data

16.3.2.1.   How Data is Gathered and Compiled

When the user generates this diagram, the MOE WCF Service creates a MetricGenerator object. This object is linked to a MetricOptions object on the client side (MOE.Common), which is of type PCDOptions.

These MetricOptions are bound by:

- Analysis period start date
- Analysis period end date
- Signal ID
- Y-axis maximums
- Volume bin size
- Dot size
- Whether or not to show plan statistics
- Whether or not to show volumes

Event Data is gathered from the Controller_Event_Logs table. Data is then compiled into Change to Green, Change to Yellow, Change to Red, Detector Activation, and possibly Volume per Hour chart series.

16.3.2.2. How Data is Displayed

The MetricOptions objects create one or more Chart objects, generated by the web rendering engine provided in the .NET Framework. All the PCD data is rendered to the chart as bars and points. The chart is then saved as an image file displayed on the website.

16.3.3. Interpreting Max Arrivals On Green By Second

The **Max Arrivals On Green By Second** chart displays the cumulative AoG volume of the selected time period for each direction as well as the total AoG (both directions). Additionally, it calculates the projected AoG per direction based on adding seconds to the offset. The X-axis is limited to the cycle length as defined when selecting the route, starting point, date, and time. The components of the chart are:

- Chart Title, "Max Arrivals On Green By Second."
- Left side is the legend:
    - ——— Total AOG, depicts the total of upstream and downstream AoG for the selected time duration.
    - ——— Downstream AOG, depicts the total downstream AoG for the selected time duration.
    - ——— Upstream AOG, depicts the total upstream AoG for the selected time duration.
- The Y-axis title and scale is AOG. The scale is automatically expanded to display the total vehicles from each direction that arrive on green; e.g. – Figure 34 is an example chart. These are the initial Downstream and Upstream values on the Y-axis, and are combined for the Total AOG. These numbers are affected by analytics based on what the AOG would be if the offset were adjusted (X-axis).
- The X-axis title and scale is Adjustment (seconds) and is the range from zero to cycle length.

The point in time (X-axis) where the projected total AOG is the highest becomes the recommended "delta" in both the Offset Adjustments and Approach Links tables.
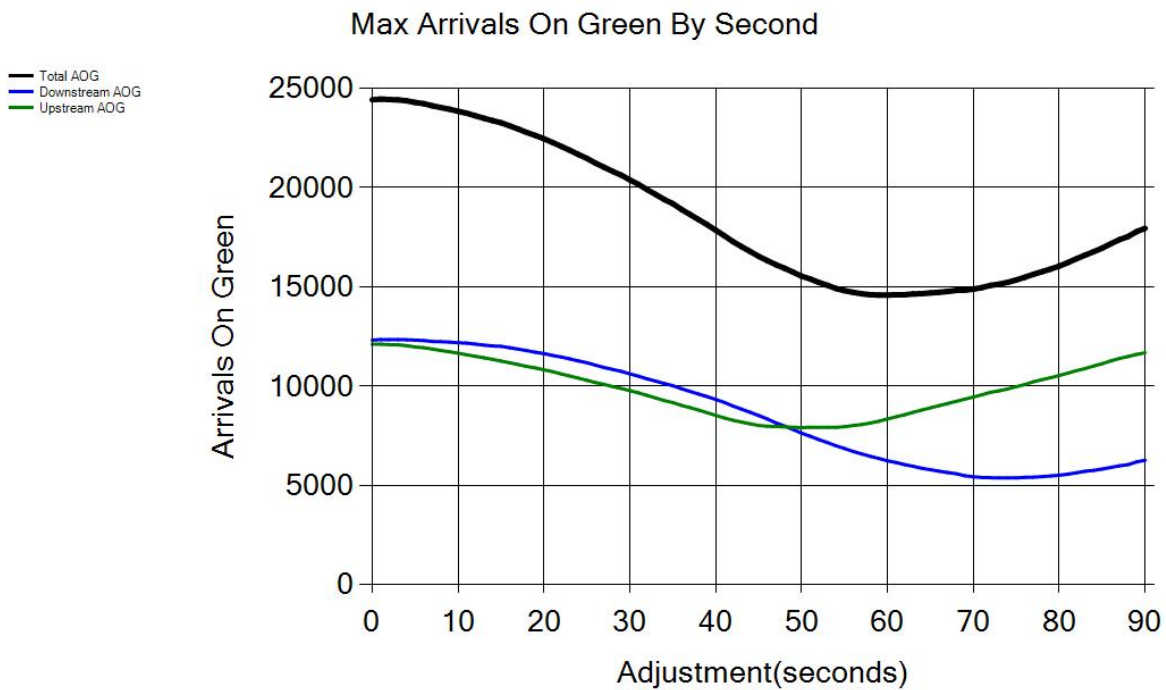
Figure 36: Max Arrivals On Green By Second

16.4.   PCD Options

After selecting a segment of the corridor in the **Approach Links** table, clicking **PCD Options** in the **AoG Chart** column, and choosing the desired PCD choices, the metric is displayed. Except for the delta, the requirements, components, and interpretation are the same as the PCD from the signals menu. See the Purdue Coordination Diagram for complete instructions. The legend is not included, but the graph itself is the same. As shown in Figure 37, there will be two PCD charts side by side. These charts are the Existing and Predicted AoG as presented in PCD. The left side (existing) is the same as though selected in Purdue Coordination Diagram from Signals. Additionally, the right side (predicted) displays the PCD with the delta applied. The delta can be manipulated and reapplied to view varying results.
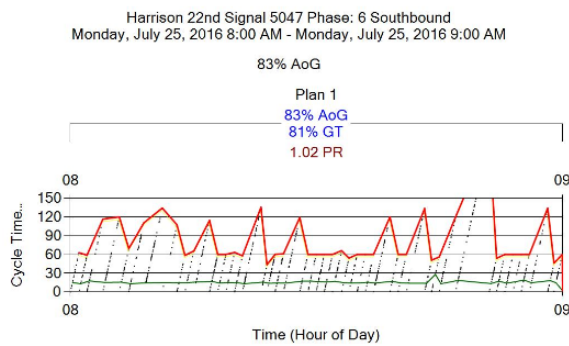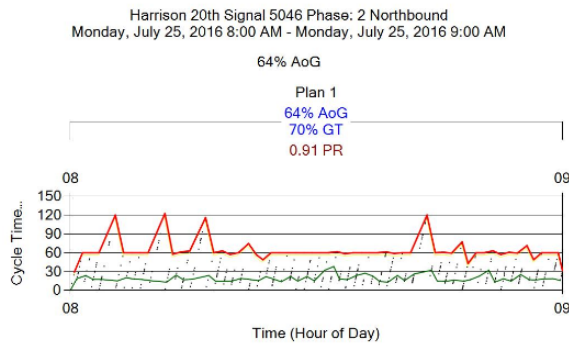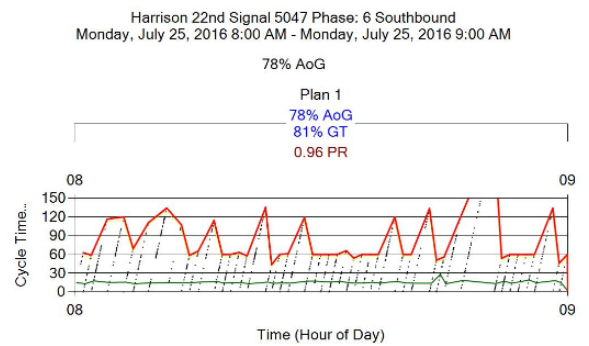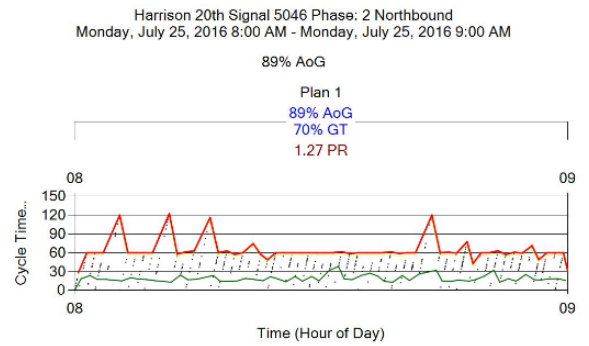
Figure 37: PCD (Existing & Predicted) for Purdue Link Pivot

Appendix A. Glossary

This Appendix lists and defines the technical terms used throughout the document.

A.1. Actuation (pedestrian)

Actuation is another term for a pedestrian pressing the button at the crosswalk to request the crossing signal.

A.2. Approach Delay

Approach delay is defined as the time starting when the vehicle begins to decelerate at an intersection, and ending when it crosses the stop bar.

On the ATSPM website, this figure is simplified as the time starting when the advance detector is actuated, and ending when the phase turns green.

A.3. D (Directional) Factor

D Factor indicates the directionality of flow when comparing opposing directions (east vs. west, north vs. south). It can be the ratio of one direction to the other, or of one direction to their sum (directional split).

A.4. Dwell Time

On signal controllers supporting preemption, dwell time is the time elapsed while preemption is activated and servicing the emergency movement. For example, dwell time applies when the railroad gates are down and the train is present.

A.5. Entry Delay

On signal controllers supporting preemption, entry delay is a timing delaying the onset of preemption.

A.6. Force Off

Force Off occurs when the controller's split timer expires, terminating the phase. This only occurs under coordinated operation. A force off indicates that a phase is over-capacity.

A.7. Gap Out

Gap Out occurs when the signal controller terminates the phase because its minimum time has been served and the vehicle extension timer has expired. A gap out can indicate that a phase has excess capacity.

A.8.   Green Occupancy Ratio

The GOR is the proportion of green time that a detector is occupied. On the ATSPM website, the detector is at the stop bar.

A.9.   Green Time

The time, in seconds, that a phase (or overlap) has the green light.

A.10.   K Factor

On the ATSPM website, the K Factor denotes the ratio of the PHV to the total traffic for the day. It is non-applicable when the analysis period is shorter or longer than 24 hours.

A.11.   Lane Utilization Factor

The f_{LU} reflects the degree of variation of traffic flow between lanes in a lane group. According to the *Highway Capacity Manual 2000*, it is calculated as:

$$f_{LU} = v_g/(v_{g1}N)$$

V_g is the unadjusted demand flow rate for the lane group in vehicles per hour. V_{g1} is the unadjusted demand flow rate on the single lane in the lane group with the highest volume. A f_{LU} of 1.0 indicates that all lanes in the group have the exact same flow rate.

A.12.   Max Out (phase)

Max Out occurs when, under high traffic demand, a phase has been extended to its maximum length. This only occurs under non-coordinated operation. A max out indicates that a phase is over-capacity.

A.13.   Max Out (preemption)

On signal controllers supporting preemption, max out refers to a timer that expires after the initiation of the preempt call. The max out timer covers cases where the emergency movement was never actually serviced (a false alarm).

A.14.   Peak Hour

Peak Hour is the hour within a time period (typically a day) with the maximum volume. The hour is measured with a 15-minute resolution. Thus, the peak hour might be 4:15-5:15 PM.

A.15.   Peak Hour Volume

PHV is the vehicle count recorded during the peak hour.

A.16.   Peak Hour Factor

PHF measures the relationship between the PHV, and the maximum rate of flow within that hour.

PHF for the standard 15-minute volume resolution is described as:

$$PHF = \frac{V_h}{4 \cdot V_{15\,max}}$$

V_h is the PHV, and V_{15max} is the highest 15-minute volume recorded during that hour. A PHF of 1.0 indicates perfectly uniform traffic flow within the peak hour.

A.17.   Preemption

Preemption is a function in most signal controllers, whereby an external source sends the controller a request that triggers a change in operating conditions for a special event. Preemption is often used for emergency vehicles and railroad crossings.

A.18.   Platoon Ratio

Platoon ratio is a metric describing the quality of vehicle progression through an intersection. Higher ratios denote higher degrees of platooning, or AoG.

Platoon ratio R_p is calculated as:

$$R_p = \frac{P}{g/C} = \frac{CP}{g}$$

P is the proportion of vehicles arriving on green, *g* is the length of green in the cycle, and *C* is the overall cycle length.

A.19.   Red Occupancy Ratio

ROR is the proportion of time that a detector is occupied during the beginning of red (default, five seconds). On the ATSPM website, the detector is at the stop bar.

A.20.   Split

Split is the fraction of the overall cycle time the signal controller assigns to a particular phase.

A.21.   Split Failure

Split failure occurs when a signal controller is unable to serve all the demand on a phase within a cycle. Split failure imposes delay on vehicles passing through the intersection.

A.22.   Time to Service

On signal controllers supporting preemption, time-to-service elapses between the initiation of the preempt call, and the actual servicing of the emergency movement.