NATIONAL INSTITUTE FOR CONGESTION REDUCTION

FINAL REPORT
May 2022

Evaluating Regional Traffic Signal Performance Measures Using Crowd-Sourced Data in 2021 Urban Mobility Report

Appendix A: Methodology

Kartikeya Jha
Luke Albert
Debbie Albert
David Schrank

For:
National Institute for Congestion Reduction
University of South Florida
Center for Urban Transportation Research | University of South Florida

4202 E. Fowler Avenue, ENG030, Tampa, FL 33620-5375

NICR
NATIONAL INSTITUTE FOR CONGESTION REDUCTION

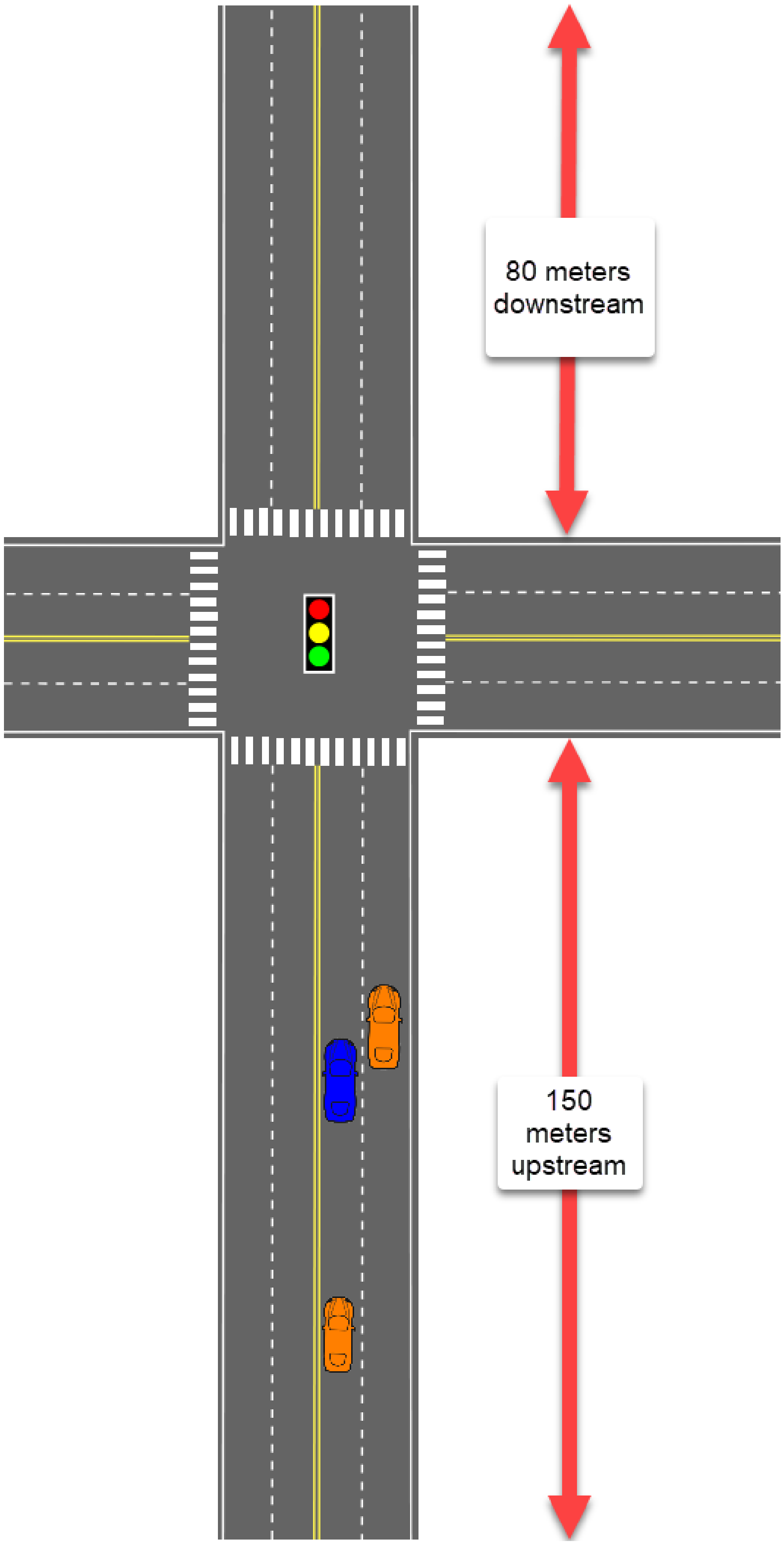
INRIX Traffic Signal Performance Data

INRIX developed a method to obtain traffic signal analytics data without needing to install field detection equipment. To obtain this data, INRIX collects anonymous vehicle waypoint "breadcrumbs" at 3 to 5 second intervals from probe vehicles. Individual vehicle waypoints are used to calculate travel times through intersections. Within the Traffic Signal Analytics application, INRIX uses the following assumptions when estimating vehicle attributes such as turning movements, vehicle stops, approach speed, and traffic signal split failures.

1. Shown in Exhibit A-1, the intersection influence area is 150 meters upstream and 80 meters downstream of the intersection. All data are aggregated together at the node (signal) for all intersecting roadways.
2. The 5th percentile travel time is used to define the limit of unimpeded travel time, so vehicles traveling slower than the 5th percentile travel time are considered to be delayed.
3. Vehicles that slow below 6 MPH for 3 seconds or more are considered stopped vehicles. This metric aligns with Advanced Traffic Signal Performance Measures (ATSPMs) in a detector-based system.

NICR NATIONAL INSTITUTE FOR CONGESTION REDUCTION
4202 E. Fowler Avenue, ENG 030
Tampa, FL 33620-5375
www.nicr.usf.edu

Exhibit A-1. INRIX Signal Analytics Intersection Influence Area



NICR
NATIONAL INSTITUTE FOR CONGESTION REDUCTION
4202 E. Fowler Avenue, ENG 030
Tampa, FL 33620-5375
www.nicr.usf.edu

This data is aggregated by intersection and summarized over time periods (*1*).

For this analysis, one week of traffic signal data in October 2020 was obtained for approximately 210,000 signals across the United States. The sample rate for this dataset was approximately 2% to 8%, and the data was aggregated into 15-minute time periods over the seven days. The following information was included for each intersection:

- X and Y coordinates of each intersection
- Delay per vehicle – Seconds of delay per vehicle for each 15-minute time period
- Count (not scaled) – Actual count of each vehicle sampled
- Count (scaled) – Estimated count of total vehicles based on vehicles sampled and sample rate for that intersection. Each intersection's count of actual vehicle crossings over each rolling hour in 15-minute increments is scaled up using INRIX volume profiles. Then, all scaled values are added together for a national total (*2*).
- Percent arrival on green – Percentage of vehicles sampled that did not slow down below 6 MPH for at least 3 seconds
- Split failures – Count of vehicles that slowed below 6 MPH for at least 3 seconds multiple times before clearing intersection.
- Level of service for each 15-minute time period.

TTI utilized the X and Y coordinate information to assign the intersections to urban areas from the Urban Mobility Report, so that traffic signal performance measure data could be summarized for each urban area.

Data Considerations

While this dataset is excellent for a high-level comparison of traffic signal performance between urban areas, there are some limitations that must be considered when evaluating performances measures produced from this specific dataset. This data includes approximately 80% of traffic signals in the US covering one week in 2020 with a sample rate between 2% and 8%. There is a robust amount of information included in the dataset, but there are gaps in duration of data collection, intersection coverage and sample penetration that must be contemplated when assessing the data. Moreover, as alluded to earlier in the discussion, the data may be biased towards the major road performance because of lack of adequate data on lower volume routes/private driveways. Example events and/or activities that could affect traffic signal performance for all or a portion of an urban area include:

- major construction;
- special events;
- incidents;
- seasonal activities such as fall foliage viewing;
- weather events including hurricanes;
- community goals;
- major changes in travel patterns such as during the COVID-19 pandemic;
- traffic signal spacing and network.

For example, major construction projects, special events, or major incidents that took place during the week could affect traffic signal performance for a portion of an urban area. Only weekday data was used in the analysis in order to minimize the possibility of construction events or special events impacting the performance measure calculations.

In addition, areas with Fall seasonal events (e.g., New England Fall foliage, major sporting events, etc.) have significantly different traffic patterns over a short period of time than the rest of the year. Further, severe weather events such as hurricanes can have significant effects on traffic. By aggregating data for the entire urban area, impacts of some major events in a small portion of the urban area are absorbed and may not be noticeable in calculations for the entire area.

Another element for consideration is that community goals regarding non-motorized transportation vary depending on the needs of the community. An urban area with a major college campus or heavy bicycle and pedestrian traffic amongst the general population might have lower traffic signal performance measures than communities that are car-centric. Since this is a measure of traffic signal performance, lower signal performance could be a result mode priority rather than poor signal timing efforts. One item of note regarding college towns and the October 2020 dataset is that most college classes were still virtual in Fall 2020 as a result of the COVID-19 pandemic. As a result, vehicle and pedestrian activity during the study week was much lower than typical traffic during school semester, so traffic signal performance around college campuses was generally much higher than during an otherwise normal Fall traffic.

Two final key considerations that affect the ability to coordinate traffic signals are signal spacing and network topology. Traffic signal spacing is discussed in more detail in the main report, but the closer the traffic signals are spaced, the more challenging it is for traffic engineers to coordinate traffic signals, particularly in multiple directions. Arrivals on green are generally lower and delay is typically higher on corridors which have closely spaced traffic signals. However, the observation on effect of signal density can be different depending on whether the analysis is performed at the corridor level or the urban area level. In the latter case, other confounding factors such as resources (funds, personnel), maintenance routine, equipment, etc., may impact results. Network topology (grid network vs non-uniform roadway network) is also a key consideration, but was not quantifiable for this evaluation.

Traffic Signal Performance Measures

The INRIX traffic signal analytics data was used to both summarize data provided for each urban area, and to calculate additional traffic signal performance measures. When choosing traffic signal performance measures, it is important to use multiple measures to gain a full understanding of traffic signal operations of an urban area. This section of the report outlines the calculation methodology of performance measures. Each of the equations outlined below represents the calculation for one 15-minute time period that was used to aggregate for the week and for the urban area.

Total Delay

Total delay is a good measure of the magnitude of delay at an individual signalized intersection because locations with more vehicles have more delay than intersections with fewer vehicles when operating at a similar level of service. Equations A-1 and A-2 illustrate the total weekly and annual delay calculation for each 15-minute time period that is summed for all time periods for all intersections in the urban area.

$$\text{Total Delay (Weekly)} = \sum(\text{Scaled Count X Delay Per Vehicle}) \qquad \text{(Eq. A 1)}$$

$$\text{Total Delay (Annual)} = \text{Total Delay (Weekly) X 52} \qquad \text{(Eq. A 2)}$$

Average Delay Per Vehicle

Average delay per vehicle is a measure of operation of a traffic signal that is useful to understand the mean wait time for each vehicle at an intersection. Commonly, motorists wait longer at intersections with a higher delay per vehicle regardless of traffic volume at the intersection. This could be attributed to poor signal timing, preemption, or other factors that influence signal operation. In order to calculate delay per vehicle, first the total number of vehicles must be estimated. The calculation for total scaled count is shown in Equation A-3, which sums the scaled count across all time periods and intersections. Calculation of delay per vehicle is shown in Equation A-4.

$$\text{Total Scaled Count} = \sum \text{Scaled Count} \qquad \text{(Eq. A 3)}$$

$$\text{Average Delay Per Vehicle} = \frac{\text{Total Delay (Weekly)}}{\sum \text{Scaled Count}} \qquad \text{(Eq. A 4)}$$

Vehicle Arrivals on Green

Percentage of vehicle arrivals on green is a measure of traffic signal progression, which is a calculation of the percentage of vehicles that proceed through the intersection without stopping. Below are equations used to calculate total arrivals on green (Eq. A-5) and percent arrivals on green (Eq. A-6).

$$\text{Total Arrivals on Green} = \sum(\text{Percent Arrivals on Green} \times \text{Scaled Count}) \qquad \text{(Eq. A 5)}$$

$$\text{Percent Arrivals on Green} = \frac{\text{Total Arrivals on Green}}{\text{Total Scaled Count}} \qquad \text{(Eq. A 6)}$$

Vehicle Arrivals on Red

Percentage of vehicle arrivals on red is also a measure of traffic signal progression and is the opposite of vehicle arrivals on green. Vehicles that stopped before proceeding through the intersection are included in this calculation. Calculations for total arrivals on red and percent arrivals on red are shown in equations A-7 and A-8.

$$\text{Total Arrivals on Red} = \text{Total Scaled Count} - \text{Total Arrivals on Green} \qquad \text{(Eq. A 7)}$$

$$\text{Percent Arrivals on Red} = \frac{\text{Total Arrivals on Red}}{\text{Total Scaled Count}} \qquad \text{(Eq. A 8)}$$

Split Failures

Split failure count can be a measure of excessive delay, as it measures the number of vehicles that stopped at least twice before proceeding through the intersection – meaning that a vehicle was not able to get through the signal on one or more green indications. Although split failures can be an indication of poor signal timing, there are often other contributing factors, such as high traffic volumes relative to intersection capacity, emergency pre-emptions, and traffic incidents. The calculation of total split failures and percentage of split failures are depicted in equations A-9 and A-10. One way to separate arrivals on red potentially due to poor signal timing from arrivals on red due to other factors is to subtract split failures from arrivals on red, as shown in Equation A-11. Lastly, the calculation of percentage of vehicles arriving on red that were not split failures is shown in Equation A-12.

NICR NATIONAL INSTITUTE FOR CONGESTION REDUCTION
4202 E. Fowler Avenue, ENG 030
Tampa, FL 33620-5375
www.nicr.usf.edu
CUTR CENTER FOR URBAN TRANSPORTATION RESEARCH
Berkeley UNIVERSITY OF CALIFORNIA
Texas A&M Transportation Institute
UPR Recinto Universitario de Mayagüez

$$\text{Split Failure Count} = \sum\left(\frac{\text{Scaled Count}}{\text{Count (Not Scaled)}} \times \text{Split Failures}\right) \qquad \text{(Eq. A 9)}$$

$$\text{Percent Split Failures} = \frac{\text{Split Failure Count}}{\text{Total Scaled Count}} \qquad \text{(Eq. A 10)}$$

$$\text{Arrivals on Red (Not Split Failure)} = \text{Total Arrivals on Red} - \text{Split Failure Count} \qquad \text{(Eq. A 11)}$$

$$\%\ \text{Arrivals on Red (Not Split Failure)} = \frac{\text{Total Arrivals on Red} - \text{Split Failure Count}}{\text{Total Scaled Count}} \qquad \text{(Eq. A 12)}$$

Traffic Signal Efficiency Index

The traffic signal efficiency index (TSEI) is another performance measure for traffic signal progression that measures the likelihood a driver is to arrive on green versus red. There are two traffic signal efficiency indices (raw and adjusted). The raw traffic signal efficiency index includes all vehicle arrivals, while the adjusted traffic signal efficiency index does excludes split failures in the arrivals on red. The adjusted index is used to measure signal timing efficiency under free flow conditions because split failures can be caused by factors other than signal timing (e.g., capacity constraints, pedestrian activity, emergency pre-emptions, traffic incidents, etc.). Traffic signal efficiency indices calculations are shown in Equations A-13 and A-14.

$$\text{Traffic Signal Efficiency Index (Raw)} = \frac{\text{Percent Arrival on Green}}{\text{Percent Arrival on Red}} \qquad \text{(Eq. A 13)}$$

$$\text{Traffic Signal Efficiency Index (Adjusted)} = \frac{\text{Percent Arrival on Green}}{\text{Percent Arrival on Red (Not Split Failure)}} \qquad \text{(Eq. A 14)}$$

Both raw and adjusted traffic signal efficiency indices are calculated to determine traffic signal efficiency for both normal and free flow conditions. With traffic volumes reduced in 2020 due to COVID, during the week of data collection, there were fewer split failures due to capacity limitations than would be expected in a normal traffic week. It is anticipated that if these measures are re-evaluated with traffic data in the future, there would be a larger difference between TSEI and adjusted TSEI, which would provide some insight on efficiency of signal timing isolated from other factors that cause intersection inefficiencies.

This report introduces a new metric, TSEI, that is easily understood as the multiplication factor that a vehicle is more likely to arrive on green compared to red (X times more arrivals on green than red). It utilizes data available to calculate metrics similar to Platoon Ratio calculations in the Highway Capacity Manual. The HCM 6th Edition includes details on using Platoon Ratios as a measure to describe signal progression quality. A Platoon Ratio measure is meant to be applied to a specific signal movement group (e.g., major street through movements), however, both metrics are related to arrivals on green.

Orange County Transportation Authority is proactive in measurement of traffic signal performance and uses a combination of measures to develop an index to report the overall signal system. Included in this index is a ratio of arrivals on green to arrivals on red (*4*). Based on the example corridors shown on their website, a 1.8-2.0 ratio resulted in a Corridor Synchronization Performance Index (SCPI) Level Tier 3 which is Fair and the minimum level for which they do not recommend consideration for applying for signal synchronization funding.

Level of Service

The most common measure of delay at an intersection is level of service (LOS) derived from the Highway Capacity Manual. Signalized intersection LOS is defined in terms of average total delay of all movements through an intersection (*3*). Letter grades are applied to LOS delay ranges, from LOS A (10 seconds or less delay per vehicle) to LOS F (greater than 80 seconds per vehicle). LOS D (between 35 and 55 seconds per vehicle) or better is generally considered to be an acceptable level of service, so data was aggregated to determine the percentage of time that each intersection was operating at LOS D or better.

In addition, traffic signal weighted LOS was calculated for each urban area, and the calculation for weighted LOS is shown in Equation A-15 with the following number scores applied to each LOS:

- LOS A = 1
- LOS B = 2
- LOS C = 3
- LOS D = 4
- LOS E = 5
- LOS F = 6

$$\text{Traffic Signal Weighted LOS} = \frac{\sum(\text{Level of Service Number Score} \times \text{Scaled Count})}{\text{Total Scaled Count}} \qquad \text{(Eq. A 15)}$$

Weighted LOS is a metric that normalizes LOS for an urban area by considering the amount of traffic at each intersection. Regions with a weighted LOS score of less than or equal to 4 have weighted LOS for the region of D or better, which is considered to be an acceptable level of service.

Traffic Signal Density

Traffic signal density was calculated by dividing the number of signalized intersections analyzed in the urban area by the centerline miles of arterial roads (principal and minor arterials from FHWA statistics dataset). This calculation is shown in Equation A-16.

$$\text{Traffic Signal Density} = \frac{\text{Number of Traffic Signals}}{\text{Miles of Arterial Roads}} \qquad \text{(Eq. A 16)}$$

NICR NATIONAL INSTITUTE FOR CONGESTION REDUCTION
4202 E. Fowler Avenue, ENG 030
Tampa, FL 33620-5375
www.nicr.usf.edu

References

Intersections, Corridors, and More New Features in Signal Analytics Webinar, INRIX, 2021

The INRIX U.S. Signals Scorecard, INRIX website https://inrix.com/signals-scorecard/ Accessed May 2022

Highway Capacity Manual, Sixth Edition: A Guide for Multimodal Mobility Analysis, Transportation Research Board, 2016

Orange County Transportation Authority website https://www.octa.net/ Accessed February 2022

The National Institute for Congestion Reduction (NICR) will emerge as a national leader in providing multimodal congestion reduction strategies through real-world deployments that leverage advances in technology, big data science and innovative transportation options to optimize the efficiency and reliability of the transportation system for all users. Our efficient and effective delivery of an integrated research, education, workforce development and technology transfer program will be a model for the nation.

www.nicr.usf.edu