



Vehicle Speed Detection at Signalized Intersections Using High-Resolution Data

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Abstract

Transportation agencies are increasingly adopting advanced technologies to monitor and operate surface transportation systems. This study evaluates the accuracy of high-resolution speed data collected from traffic signal-mounted radar sensors by comparing it to speed data collected from pneumatic road tubes and handheld LiDAR at two signalized intersections in Portland, Oregon.

The analysis demonstrates that traffic signal-mounted radar sensors can provide reliable vehicle speed measurements to evaluate compliance against threshold speed limits, but not in absolute terms. These validated speed measurements can support Intelligent Transportation System (ITS) applications by enabling traffic system performance monitoring, safety assessments, and evaluation of signal timing strategies aimed at reducing speeding and red-light running at signalized intersections.

Introduction

With over 400,000 traffic signals in the United States (Nevers et al., 2020), finding ways to effectively manage and operate these signals is a critical task for transportation agencies.

Today, many agencies are considering how to integrate Automated Traffic Signal Performance Measures (ATSPM) into their workflows. The ATSPM framework allows transportation agencies to collect real-time data from vehicles interacting with traffic signals and processes this data in the form of dashboards and automated alerts.

With ATSPM, transportation agencies can quickly identify important issues such as traffic signals that lost power, intersections experiencing excessive delays, or intersections where vehicles are traveling at very high speeds.

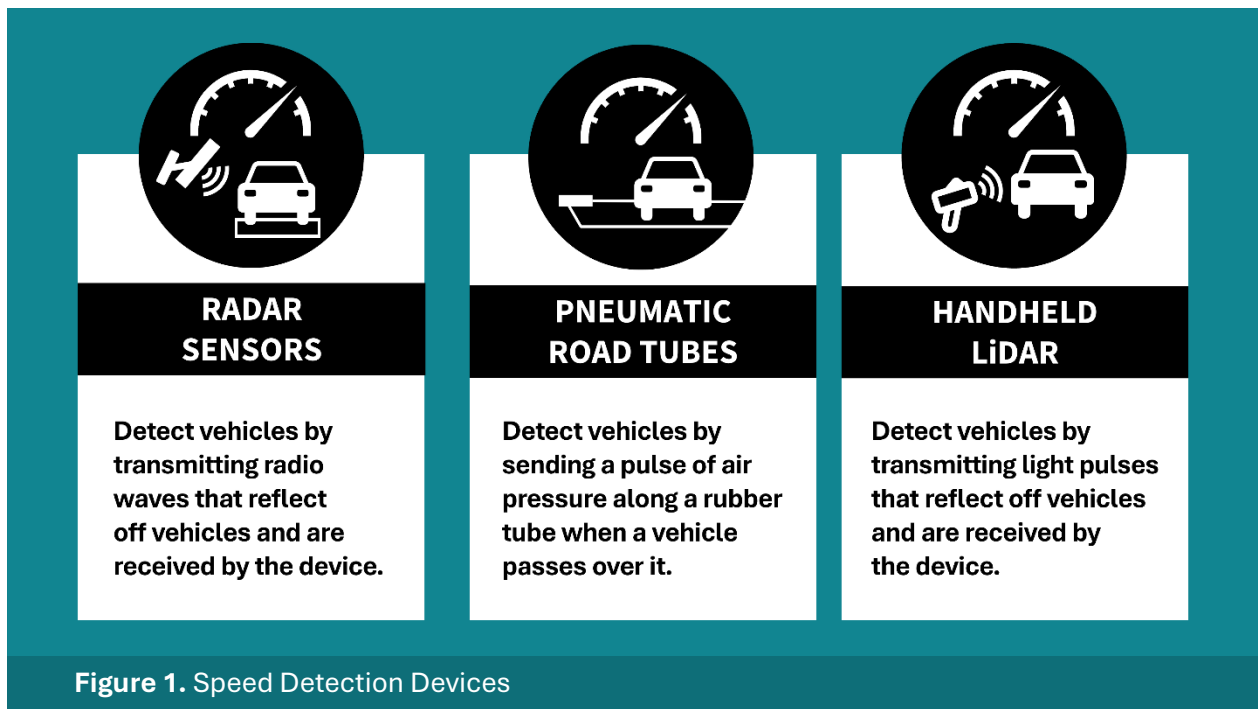
One of the most influential benefits of ATSPM is its ability to promote a culture shift from reactive to proactive management (Day et al., 2020).

The incremental changes enabled by proactive management allow agencies to maintain the performance of traffic signals more consistently over time as compared to reactive management, where performance needs to degrade significantly before it is noticed and addressed (Day et al., 2020). ATSPM offer a wide range of benefits – not only

for traffic signal operators and maintenance staff but also for other key stakeholders like senior managers, planners, designers, policy decision-makers, and the general public (Nevers et al., 2020) – from identifying problems sooner to tracking progress towards goals.

In 2023, there were over 2.4 million people injured and over 40,000 deaths on surface transportation systems in the United States. Of those fatalities, over 11,000 occurred in speeding related crashes (NHTSA, 2025). In 2023, 58% of traffic deaths in Portland, Oregon involved speeding (PBOT, 2024). Speeding is consistently identified as a major factor in traffic fatalities and injuries in Portland and in the U.S. Accurate vehicle speed detection at signalized intersections is essential for ensuring traffic safety.

Since the 1960s, transportation agencies have used inductive-loop detectors as the traditional detection system for traffic signals (Klein et al., 2006). These types of detectors are classified as intrusive, because they consist of long wires buried under the surface of asphalt or concrete pavements. With current advancements in technology, agencies can choose from a variety of speed detection devices. In this research, three speed detection devices were evaluated: radar sensors, pneumatic road tubes, and handheld LiDAR (Figure 1).

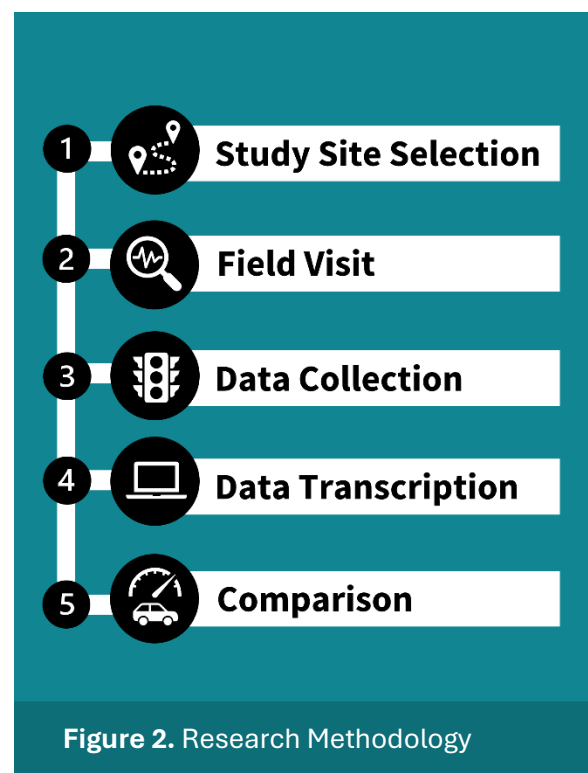


Methodology

In alignment with the City of Portland's commitment to Vision Zero since 2015, the goal of the Portland Bureau of Transportation (PBOT) is to eliminate crashes that result in fatal and serious injuries.

This research was driven by three main motivations: 1) determine if technology already installed in the field can be used to evaluate signal timing interventions, 2) confirm that the speed data sourced from radar sensors is accurate, and 3) test signal timing strategies for reducing speeding. These motivations guided the research objective, which was to validate speed data collected from traffic signal-mounted radar sensors using data collected from pneumatic road tubes and handheld LiDAR (with pneumatic tubes serving as the ultimate ground truth).

This research was organized into five different phases (Figure 2).

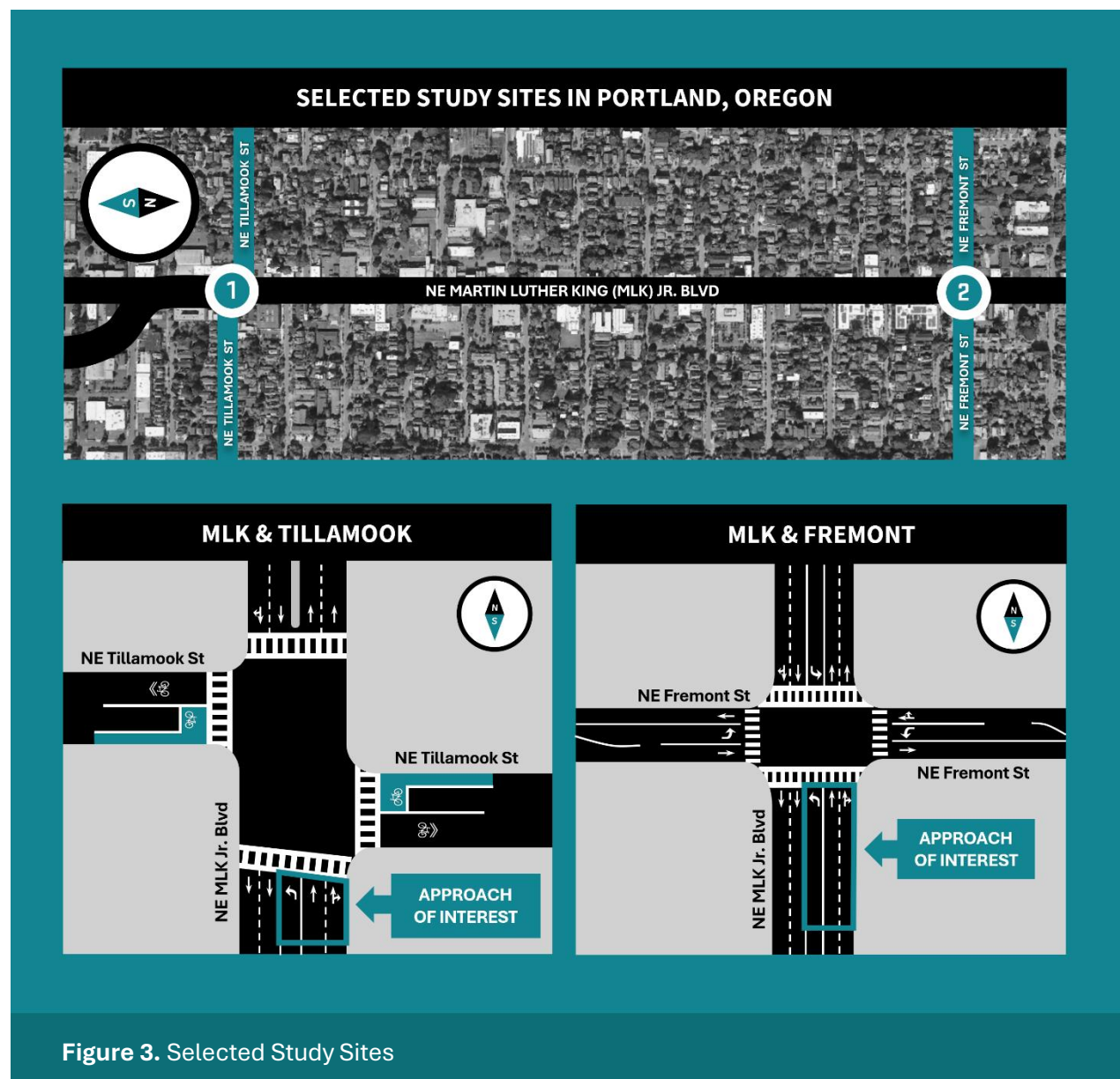


Study Site Selection

Two intersections in Portland, Oregon were selected (MLK & Tillamook and MLK & Fremont). These intersections were selected because they are signalized and coordinated, they are located on Portland's high crash network, and they are equipped with pan-tilt-zoom (PTZ) cameras, radar detection units (RDU), and advanced transportation controllers (ATC) with communication.

Field Visit

The Oregon State University (OSU) research team conducted field visits to assess existing conditions (speed limit at both intersections is 30 mph). Figure 3 shows the location of the intersections with respect to each other (~0.7 miles apart), their individual layouts, and the approaches of interest. The approach of interest for each intersection included all northbound vehicles.



Data Collection

PBOT provided the OSU research team with the tube data and the high-resolution speed data collected from traffic signal-mounted radar sensors (Wavetronix SmartSensor Advance) with speed filters. Data from radar sensors and tubes, for both intersections, was collected for 24 hours across 4 days, from Saturday through Tuesday (June 10-13, 2023).

For MLK & Tillamook, the tube dataset contained 994 vehicle observations from Saturday through Monday, while the radar sensor dataset contained 1,073 vehicle observations. The tube data for Tuesday 06/13 was incomplete, due to a tube failure. Thus, the analysis for MLK & Tillamook did not include a comparison between the tube data and the radar sensor data for Tuesday. For MLK & Fremont, the tube dataset contained 1,981 observations from Saturday through Tuesday, while the radar sensor dataset contained 5,867 observations. The number of observations in the tube dataset were lower due to tube failures.

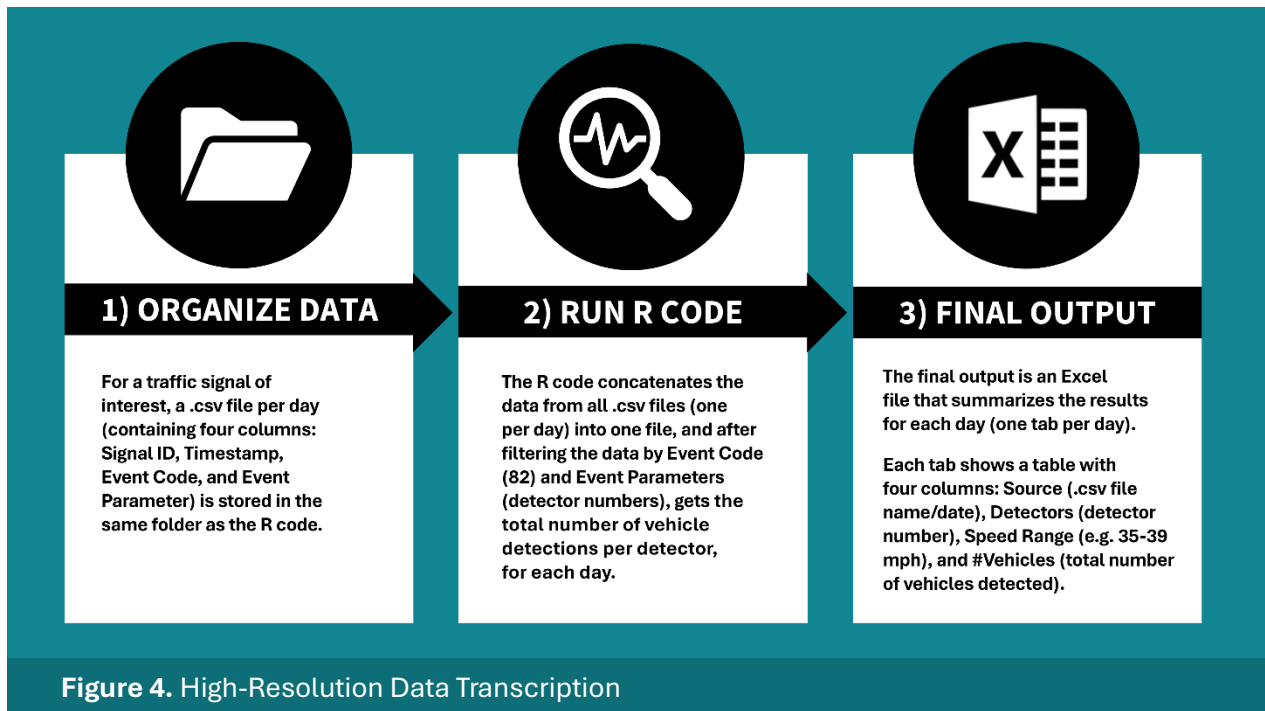
To gain additional insights, the OSU research team visited each intersection on Saturday 06/10 and collected ~2 hours of LiDAR speed data (30+ vehicles) per intersection. Free-flow speeds (Mahmud et al., 2024; Mahmud et al., 2023) at each of the two intersections were recorded using handheld LiDAR guns (ProLaser 4) that were connected to a laptop that recorded the speed and distance of each vehicle within an Excel spreadsheet.

Data Transcription

To transcribe the tube dataset, the raw data was first quality checked and cleaned by removing all observations where tube failures were experienced. Tube failures (e.g., vehicle speeds equal to 0 mph), were stored in Class 14 during data collection. The data was then filtered to include vehicle observations of 35 mph and above to match the speed filters from the radar sensors. Finally, descriptive statistics and visualizations were then generated using Excel and R Studio.

To transcribe the handheld LiDAR dataset, the raw data was also quality checked and cleaned by removing all observations marked with “ignore” during the data collection (e.g. vehicles from which researchers could not get a full capture due to occlusion issues). Then, descriptive statistics were generated, and the speed data was visualized.

Finally, to transcribe the high-resolution dataset (with 200,000+ data points per intersection), a code developed in R Studio, was used. Each intersection was configured with four advance count detectors with speed filters (35-39 mph, 40-44 mph, 45-49 mph, 50-100 mph). The R code filters the high-resolution data by Event Code 82 (On) and generates a vehicle count for each detector, as described in Figure 4. Using the midpoint speed in each speed filter and the vehicle counts, descriptive statistics were generated and the speed data was visualized.



Results

A statistical comparison between the speeds collected by the radar sensors and the speeds collected by the tubes was performed using a Mood's Median Test at a 95% confidence level.

As shown in Table 1, at MLK & Tillamook, there was no statistical difference across all days (p-value > 0.05). And at MLK & Fremont, there was no statistical difference across all days (p-value > 0.05), except for Saturday 6/10.

Table 1. Radar Sensor Speed vs Pneumatic Tube Speed

Intersection	Date	Device	Mean	Std	Median	Mode	N	P-Value
MLK & Tillamook	Saturday 6/10/23	Radar	40.60	4.87	37.50	37.50	290	0.374
		Tube	37.69	3.79	36.00	35.00	347	
	Sunday 6/11/23	Radar	40.60	4.60	37.50	37.50	326	0.052
		Tube	37.40	3.08	36.00	35.00	343	
	Monday 6/12/23	Radar	40.53	4.69	37.50	37.50	457	0.056
		Tube	37.25	2.86	36.00	35.00	304	
MLK & Fremont	Saturday 6/10/23	Radar	39.99	3.79	37.50	37.50	1232	0.012
		Tube	38.15	3.42	37.00	35.00	578	
	Sunday 6/11/23	Radar	40.08	3.78	37.50	37.50	1353	0.685
		Tube	37.71	3.63	37.00	35.00	582	
	Monday 6/12/23	Radar	40.11	3.74	37.50	37.50	1684	0.649
		Tube	37.61	3.09	37.00	35.00	504	
	Tuesday 6/13/23	Radar	40.37	3.90	37.50	37.50	1598	0.468
		Tube	37.53	2.75	36.00	35.00	317	

To gain additional insights, the speeds collected with the tubes were compared with the speeds collected with handheld LiDAR. At MLK & Tillamook, the average speed collected with LiDAR (from 9:45 AM to 12:15 PM) was 6.6 mph higher than the tubes. And at MLK & Fremont, the average speed collected with LiDAR (from 1:30 PM to 3:30 PM) was 4.3 mph higher than the tubes. Comparing spot speeds (tubes) against space speeds (LiDAR) contributed to the differences in speed observed.

Note: The time intervals collected with handheld LiDAR per intersection were selected to avoid peak period traffic.

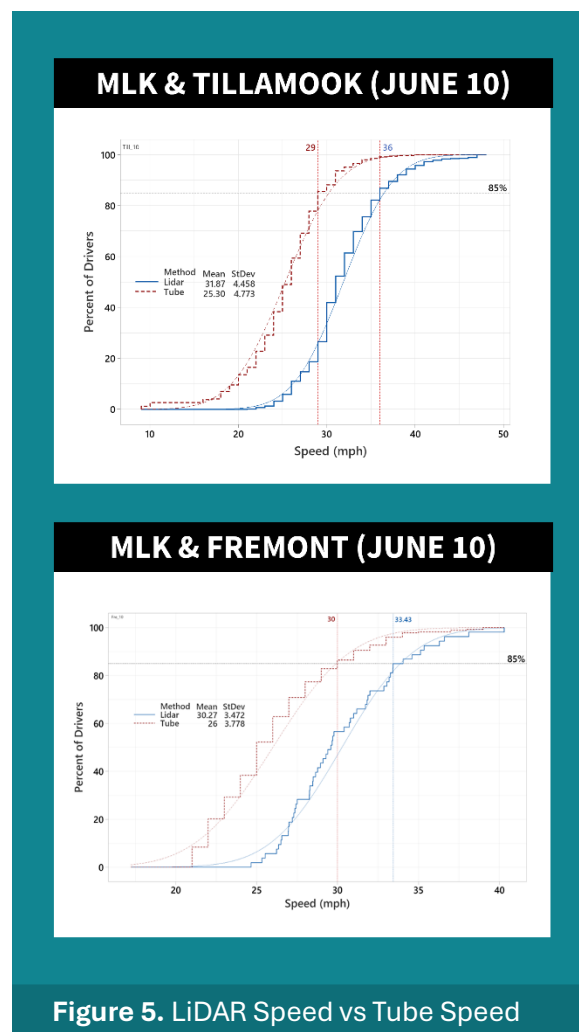
Conclusion

The analysis demonstrates that traffic signal-mounted radar sensors can provide reliable vehicle speed measurements to evaluate compliance against threshold speed limits, but not in absolute terms. For example, the total number of vehicle observations was different between tubes and radar sensors, but speed distributions remained reliable. The findings from this research are aligned with those of previous research that leveraged radar sensors to collect vehicle speed data (Refai et al., 2022; Saito et al., 2016).

Limitations

This research provides a practical methodology to validate speeds obtained from high-resolution data. However, some limitations include the number of study sites, lack of per vehicle speed determination, and the asynchronous function of the data analysis code.

The first limitation is the number of study sites. This study focused on two study sites to develop a proof of concept. Increasing the number of study sites would provide greater variability between sites and would increase the transferability of the results. Second limitation is that the radar sensors employed cannot archive individual speeds for each vehicle in each lane.



And third, the code developed in this research is intended for asynchronous analysis, not for real-time monitoring. Future research could further develop code like this for real-time monitoring applications.

Looking into the future, these validated speed measurements can support ITS applications for monitoring traffic system performance, conducting safety evaluations, and assessing the safety outcomes of signal timing strategies aimed at reducing speeding and red-light violations at signalized intersections.

References

- Day, C., O'Brien, P., Stevanovic, A., Hale, D., Matout, N. (2020). A Methodology and Case Study: Evaluating the Benefits and Costs of Implementing Automated Traffic Signal Performance. United States Federal Highway Administration. FHWA-HOP-20-003. <https://rosap.ntl.bts.gov/view/dot/54064>
- Klein, LA., Mills, MK., Gibson, DRP. (2006). Traffic Detector Handbook: Third Edition. Volume I. United States Department of Transportation. Federal Highway Administration. FHWA-HRT-06-108. <https://rosap.ntl.bts.gov/view/dot/954>
- Mahmud, S. M., Jashami, H., Megat Johari, M. U., Gupta, N., Bamney, A., Gates, T. J., & Savolainen, P. (2024). Effects of Speed Feedback Trailer Positioning and Police Enforcement on Vehicular Speeds in Freeway Work Zone Lane Closures. Transportation Research Record. <https://doi.org/10.1177/03611981241230319>
- Mahmud, M. S., Megat Johari, M. U., Bamney, A., Jashami, H., Gates, T. J., & Savolainen, P. T. (2023). Driver Response to a Dynamic Speed Feedback Sign at Speed Transition Zones Along High-Speed Rural Highways. Transportation Research Record. <https://doi.org/10.1177/03611981221112942>
- Nevers, B., Urbanik, T., Lee, K., Cesme, B., Musselman, J., Zhao, L., Bullock, D., Li, H., Tanaka, A., Day, C., Richardson, L. (2020). Performance-Based Management of Traffic Signals. NCHRP Research Report 954. National Academies of Sciences, Engineering, and Medicine. <https://doi.org/10.17226/25875>
- NHTSA (2025). Traffic Safety Facts 2023 A Compilation of Motor Vehicle Traffic Crash Data. DOT HS 813 738. National Highway Traffic Safety Administration. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813738>
- PBOT (2024). Portland 2023 Deadly Traffic Crash Report - Executive Summary. Vision Zero. Portland Bureau of Transportation. <https://www.portland.gov/transportation/vision-zero/documents/portland-2023-deadly-traffic-crash-report-executive-summary/download>
- Refai, HH., Habib, MA., Li, JQ., Liu, W. (2022). ODOT Radar System for Real-Time Traffic Flow Monitoring. Oklahoma Department of Transportation. FHWA-OK-22-05. <https://rosap.ntl.bts.gov/view/dot/68293>
- Saito, M., Sanchez, GH., Schultz, GG. (2016). Calibration of Automatic Performance Measures – Speed and Volume Data: Volume 2. Utah Department of Transportation. UT-16.05. <https://rosap.ntl.bts.gov/view/dot/30839>