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Original Research Paper

# Use of Hi-resolution data for evaluating accuracy of traffic volume counts collected by microwave sensors

David K. Chang [a], Mitsuru Saito [b,*], Grant G. Schultz [b], Dennis L. Eggett [c]

[a] Hales Engineering LLC, Lehi, UT 84043, USA
[b] Department of Civil & Environmental Engineering, Brigham Young University, Provo, UT 84602, USA
[c] Department of Statistics, Brigham Young University, Provo, UT 84602, USA

## HIGHLIGHTS

- The number of approach lanes and approach volume level significantly affect the accuracy of traffic volume counts while the sensor installation position does not.
- At a typical 3-lane approach intersection, average accuracy ranged from 99.8% for low approach volume level (less than 100veh/h/ln) to 98.7% for high approach volume level (greater than 250veh/h/ln).
- At a 5-lane approach intersection, average accuracy ranged from 94.6% for low approach volume level to 89.2% for high approach volume level.
- Installing microwave sensors following the manufacturer's specifications is the key for getting reliable data.

## ARTICLE INFO

*Article history:*
Received 9 August 2016
Received in revised form
2 June 2017
Accepted 9 June 2017
Available online 6 September 2017

*Keywords:*
Traffic volume
Microwave
Signal
Performance
Accuracy
Mixed model analysis of variance

## ABSTRACT

Over the past few years, the Utah Department of Transportation has developed the signal performance metrics (SPMs) system to evaluate the performance of signalized intersections dynamically. This system currently provides data summaries for several performance measures, one of them being turning movement counts collected by microwave sensors. As this system became public, there was a need to evaluate the accuracy of the data placed on the SPMs. A large-scale data collection was carried out to meet this need. Vehicles in the Hi-resolution data from microwave sensors were matched with the vehicles by ground-truth volume count data. Matching vehicles from the microwave sensor data and the ground-truth data manually collected required significant effort. A spreadsheet-based data analysis procedure was developed to carry out the task. A mixed model analysis of variance was used to analyze the effects of the factors considered on turning volume count accuracy. The analysis found that approach volume level and number of approach lanes would have significant effect on the accuracy of turning volume counts but the location of the sensors did not significantly affect the accuracy of turning volume counts. In addition, it was found that the location of lanes in relation to the sensor did not significantly affect the accuracy of lane-by-lane volume counts. This indicated that accuracy analysis could be performed by using total approach volumes without comparing

* *Corresponding author*. Tel.: +1 801 422 6326; fax: +1 801 422 0159.
E-mail address: msaito@byu.edu (M. Saito).

Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2017.06.002

specific turning counts, that is, left-turn, through and right-turn movements. In general, the accuracy of approach volume counts collected by microwave sensors were within the margin of error that traffic engineers could accept. The procedure taken to perform the analysis and a summary of accuracy of volume counts for the factor combinations considered are presented in this paper.



## 1. Introduction

The Utah Department of Transportation (UDOT) has developed the signal performance metrics (SPMs) system for realizing automatic performance evaluations using the extensive traffic flow data collection infrastructure for signalized intersections consisting mainly of microwave sensors (UDOT, 2015). The system currently provides data summaries for several performance measures, including 1) Purdue coordination diagram, 2) speed, 3) approach volume, 4) Purdue phase termination charts, 5) split monitor, 6) turning movement volume counts, 7) arrivals on red, 8) approach delay. These performance measures provide signal engineers and others, including the public, immediately access to the data, which in turn allow them to respond quickly to traffic related problems and to collect traffic data for modeling, planning, and other traffic studies. Though the SPMs is operating and functional, UDOT did not have data to provide the accuracy of performance measures to its users. Therefore, this study was conducted from October 2013 to June 2015 to evaluate accuracy of turning volume counts and to provide calibration factors so that the users of SPMs can be informed to properly interpret the turning volumes reported in the SPMs.

To meet the goal of the study, a large-scale data collection was carried out. Then, a procedure was developed to match vehicles in the Hi-resolution (Hi-res) data created by microwave sensors and the ground-truth turning vehicle counts collected in the field or through UDOT's CCTVs, accessible from the research team's transportation laboratory. A mixed model analysis of variance (ANOVA) was then performed to evaluate the effects of controlling factors on turning volume count accuracy. A summary of the accuracy of microwave sensors used in the SPMs has been published and available in the literature (Chang et al., 2016; Saito et al., 2015). It reported that two factors, approach volume level and number of approach lanes, significantly influenced the accuracy of the approach volume counts and that sensor position did not have significant effect on the accuracy of approach volume counts. The effect of approach speed limit on approach volume accuracy was found inconclusive. In general, as the intersection become larger, the accuracy of approach volume counts decreases and as the approach volume level increases, the accuracy decreases. In the paper by Chang et al. (2016), the process of data collection, data reduction, and statistical analyses to reach the conclusions were only briefly mentioned due to the limit on paper length. A spreadsheet-based analysis procedure was developed during the course of the study to carry out the task. The data reduction to match vehicles from the two data sets was the most time-consuming activity of this study and required much engineering.

The focus of this paper is on the procedure taken to match vehicles in two data sets. It begins with a brief summary of the literature review on traffic volume count tools, followed by the study method used in the study, and describing the site selection and data collection, and data reduction process, then, a brief summary of the results of statistical analysis, and conclusions are obtained.

## 2. Literature review

This paper briefly presents a summary of two categories of roadway traffic sensors and the way in which a microwave sensor works. Referred to Saito et al. (2015), more information on microwave and other roadway traffic sensors were discussed. There have been a number of studies on microwave traffic sensors (Edgar, 2002; Medina et al., 2012, 2013a, 2013b; Prevedouros, 2004). They reported that microwave sensors provide practically accurate traffic counts in normal weather conditions (Edgar, 2002; Medina et al., 2012), however, their accuracy may decrease significantly in adverse weather conditions, especially under strong winds that might cause oscillation of the traffic signal mast arm to which they were attached (Medina et al., 2013a, b). For such cases, installation of damping plates or microwave sensors on the vertical pole were suggested (Medina et al., 2013b).

### 2.1. *Roadway traffic sensor types*

Traffic sensors are grouped into two categories: non-intrusive (or over-roadway) and intrusive (or in-roadway). The definition of a non-intrusive sensor “is traffic detection sensors that cause minimal disruption to normal traffic operations during installation, operation and maintenance compared to conventional detection methods” (SRF Consulting Group, 2010). Examples of these types of sensors include infrared, magnetic, radar, ultrasonic, acoustic, and video imaging (FHWA, 2016; Jeon et al., 2014; Windmill Software Ltd, 2016).

On the opposite side of the non-intrusive sensors are intrusive sensors, or traditional sensors, which are defined as “devices … that involve (the) placement of the sensor technology on top of or into the lane of traffic being monitored”