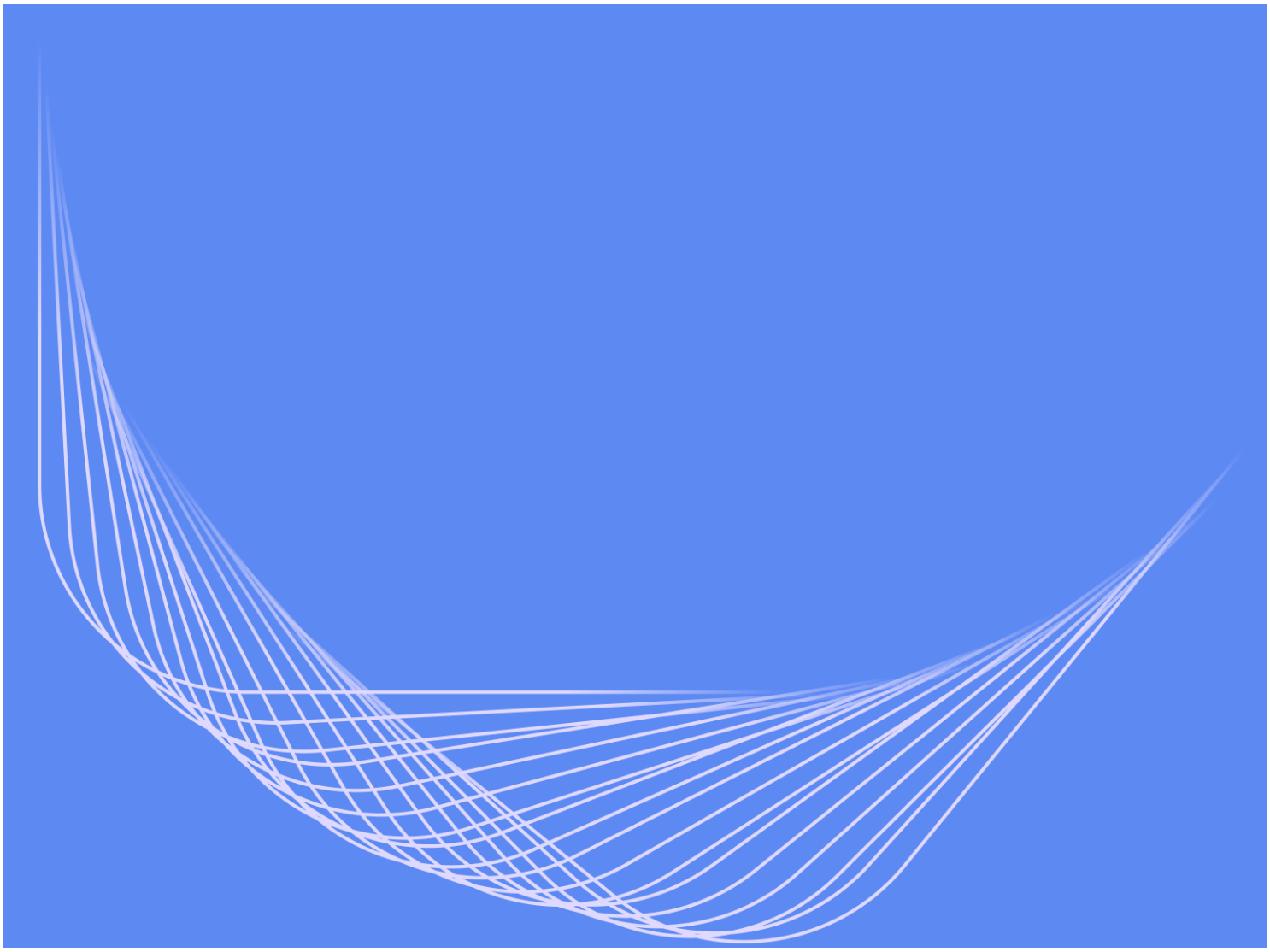
CASE STUDY

Virtual Sensors

TECHNOLOGY VALIDATION

Flow Labs Virtual Sensor technology is proven to generate 94.4% accuracy in field conditions offering a scalable, affordable approach to accurate data collection.



Abstract

Traditionally, agencies are dependent on physical detectors to accurately estimate volumes on roadways. Despite the numerous types of technologies including inductive loops, radar detectors, bluetooth detectors and video, the reliability of these detectors in day-to-day field conditions as well as different light and weather conditions remains a concern.

This study investigates the accuracy of Flow Labs Virtual Sensor technology. **Virtual Sensor technology is a hardware-free approach which utilizes connected vehicle data alongside existing sensor data to estimate turning movement counts at intersections.**

5 intersection approaches in Utah were used as part of this study exploring a variety of different conditions including different volumes (high and low volume movements), different types of movements (thru, left and right turn movements), and varying levels of detection coverage (high coverage to zero coverage).

The results of this study show that **Virtual Sensors offer 94.4% accuracy** in field conditions versus 86.7% for Physical Detectors. Not only do Virtual Sensors reduce volume error by more than 56%, they also are capable of generating these levels of accuracy where there isn't any existing detection at all. This offers a more affordable and scalable approach to traffic data collection than ever before.

INTRODUCTION

Traffic volumes are usually measured on road segments, or at intersections - where they are commonly known as turning movement counts (TMCs).

The current standard practice involves either (1) collection from the field using manual methods (2) collection from physical detectors (e.g. inductive loops, radar detectors, wifi detectors) (3) manual counts based on video. Whilst manual counts offer the highest levels of accuracy, they are often time intensive and costly. Whilst counts from physical detectors are more scalable, they have questionable and variable reliability.

Probe-data from connected vehicles, cell phones and other connected devices have provided a novel dataset which can aid engineering, and planning. These datasets offer deeper insights into travel times, routes, and delay, and are also beginning to be used for volume estimates. However, given low penetration rates they have offered limited reliability for volume estimation.

Flow Labs have developed Virtual Sensors, a novel methodology which leverages proprietary artificial intelligence algorithms for data collection from numerous sources on a given roadway, integrates and processes this data, and subsequently provides high-fidelity information including TMCs.

This study compares TMCs generated by physical detectors with TMCs generated by Flow Labs Virtual Sensors.

SET UP

Flow Labs acquired video data for **5 intersection approaches from Utah Department of Transportation (UDOT), covering 11 distinct turning movements, for 30-minute periods.** The time periods were chosen by UDOT and the approaches were selected by Flow Labs.

The approach selection was based on the desire to capture a variety of different types of approach and movement including a variety of different volumes (high and low volume movements), a variety of different types of movements (thru, left and right turn

Figure 1: Intersections and approaches used for this study

Intersection 6145
SR-73 / Foothill Blvd
WB Approach

Intersection 7801
SR-36 / Mills Junction
SB Approach

Intersection 6035
Pioneer Crossing / Millpond Dr
WB Approach

Intersection 5026
Riverdale Rd / I-15
WB & EB Approach

Flow Labs generated turning movement count estimates from Virtual Sensors. The turning movements from detectors were acquired from UDOT ATSPM. The turning movements for these videos were counted manually.

A variety of measures were used to quantify accuracy including:

- Volume-Weighted Error
- GEH

RESULTS

Table 1 shows a summary of the results.

Table 1: Summary of detection accuracy

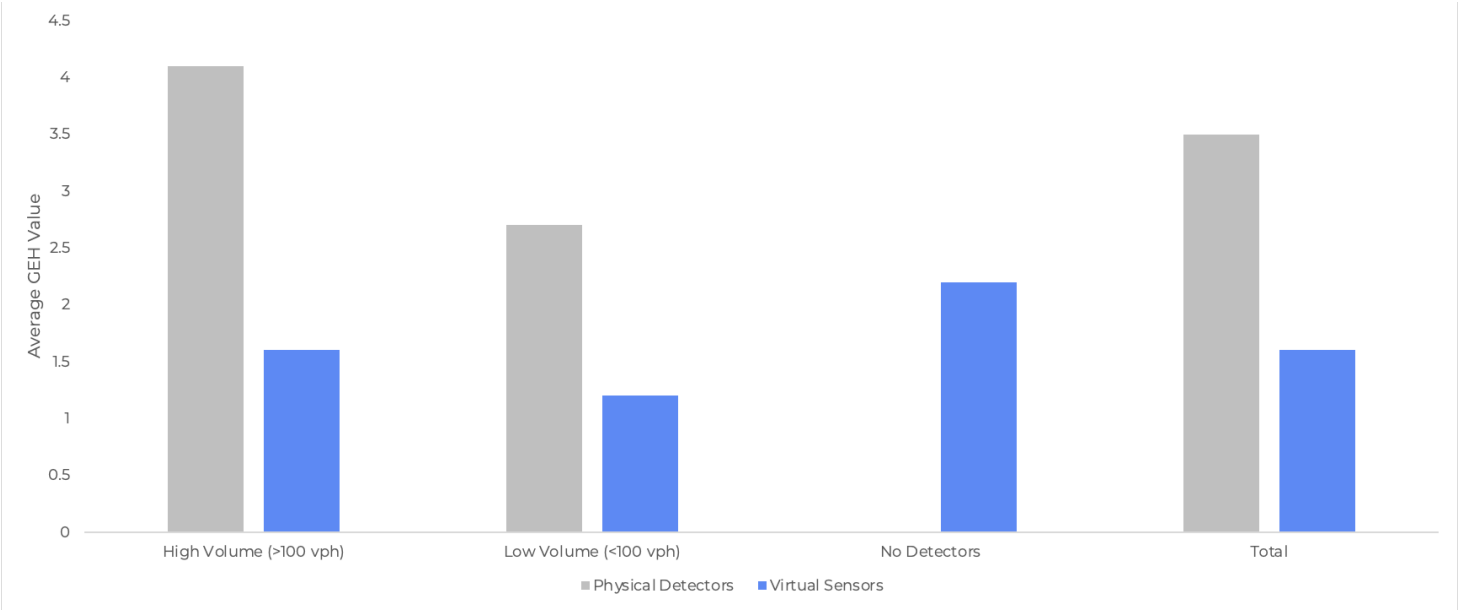
	GEH			Average Error		
Detector Type	Physical Detectors	Virtual Sensors	Error Reduction	Physical Detectors	Virtual Sensors	Error Reduction
High Volume (>100 vph)	4.1	1.6	59.9%	12.4%	5.2%	58.1%
Low Volume (<100 vph)	2.7	1.2	56.2%	30.7%	14.2%	53.8%
No Detectors	--	2.2	--	--	5.5%	--
Total	3.5	1.6	54.8%	13.3%*	5.6%	57.9%

Flow Labs Virtual Sensors were shown to achieve substantially higher accuracy than physical detectors across all movements. On average they achieved an accuracy of 94.4% (versus 86.7% for physical detectors) and a GEH value of 1.6 (versus 3.5 for physical detectors).

GEH Comparison

Typically a GEH of less than 5.0 is considered a good match between modeled and observed volumes. GEHs in the range of 5-10 warrant further investigation. If GEH is greater than 10 then there is an issue with the model or the data.

Figure 2: Comparison of average GEH values for Physical Detectors and Virtual Sensors

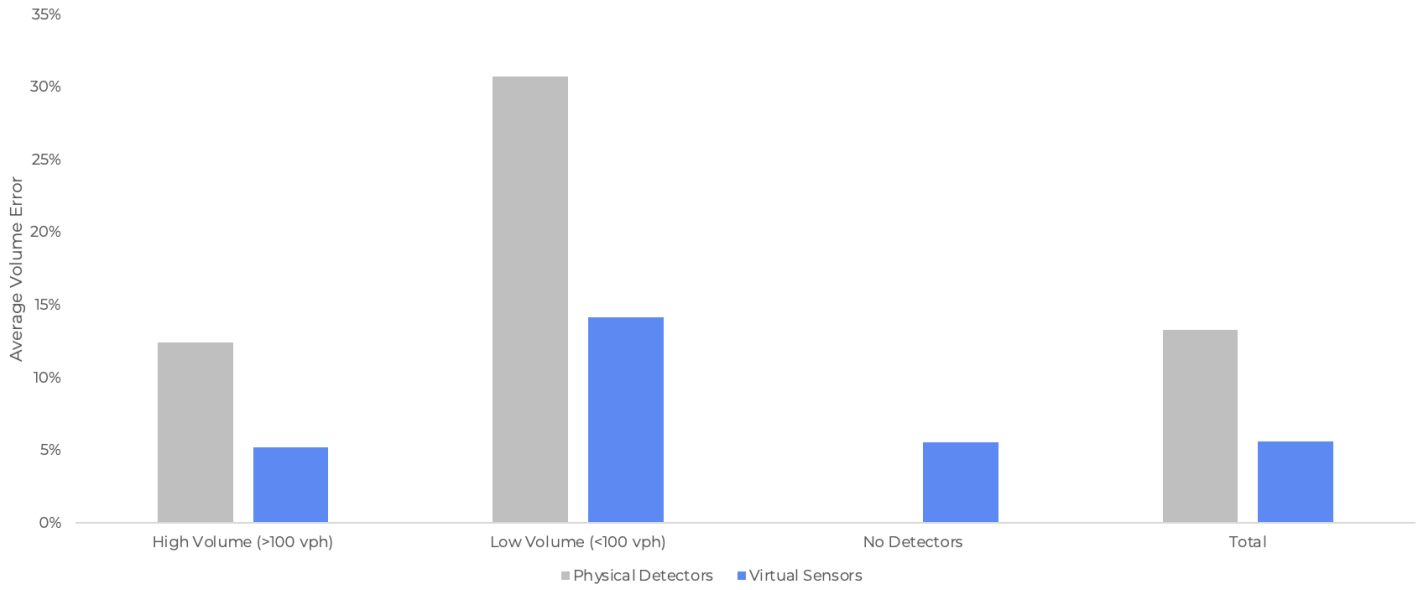


Out of the 11 approaches, 3 physical detectors were in the 5.0 - 10.0 range, and overall the average GEH was 3.5. In comparison **for Flow Labs Virtual Sensors, all of the results were comfortably lower than 5.0 with a maximum of 3.7 and an average of 1.6 - a substantial improvement in accuracy.** In addition, Flow Labs achieved a GEH of 2.3 on the approaches that had no existing detection.

Volume Weighted Error Comparison

According to manufacturer guidance, the volume accuracy of the detectors should be comfortably above 90% (for approaches with less than 4 lanes).

Figure 3: Comparison of average volume error for Physical Detectors and Virtual Sensors

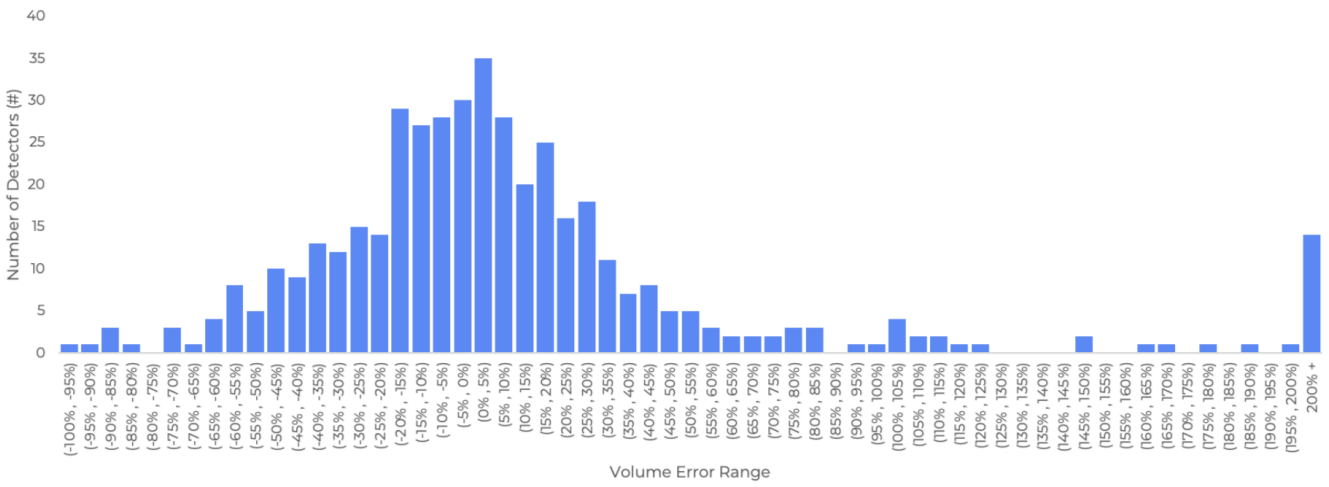


Out of the 11 approaches, only 3 detectors actually met this criteria, whilst the volume weighted average error across all TMCs where detection existed was 13.3%. In comparison, for Flow Labs Virtual Sensors, 6 out of 11 TMCs were within the 10% range, and the volume-weighted average error was 5.6%. In addition, Flow Labs achieved an average error of 5.5% on the approaches that had no existing detection.

FURTHER WORK

Flow Labs conducted a larger scale study on detector health across 438 detectors. Estimated turning movements counts were generated using Virtual Sensors, comparing them to existing physical detectors. Counts were compared over a 28-day period (29th July 2021 - 25th August 2021).

Figure 4: Histogram of volume error across a large sample of detectors



Across 435 detectors, **only 121 detectors (27.6% of detectors) were estimated to be within 10% volume accuracy.** The average absolute error was 42.1%, the volume-weighted average error was 27.3%. The average GEH across all detectors studied was 5.1. These error numbers are slightly higher than the smaller scale study and are possibly due to the longer time frame studied, however, they are within the confidence levels of Virtual Sensors.

IMPLICATIONS

Physical detectors are the dominant source of data for automated systems including Traffic Management Systems, Signal Performance Analytics, Adaptive Systems, Traffic Simulation. They provide the data for numerous traffic management decisions. **With poor quality data, automated systems cannot operate reliably** - which has been the experience for most transportation agencies who have deployed automated traffic control systems. In addition, transportation professionals cannot accurately validate key decisions.

Virtual Sensors offer a reliable, affordable and scalable approach to generating data across transportation systems. This data can be used to build a foundation for automated tooling with greater reliability and improve roadway performance, **empowering transportation agencies to achieve their mobility, safety and environmental goals.**

CONCLUSION AND FURTHER WORK

Based on this study, **integrated data from Virtual Sensors would be suitable for volume estimation across a variety of situations and offer a more accurate and complete data source than physical detectors.**

These results were achieved with **connected vehicle penetration rates (during the specified time periods) of between 0% and 3.2%. These levels of accuracy represent a major technical breakthrough** proving that Virtual Sensor technologies offer the ability to generate higher accuracy and insight than traditional physical detection, and provide a more scalable alternative to in-field collection.

To date, Flow Labs has integrated data from Virtual Sensors into numerous automated applications including:

- Roadway and Intersection Analytics: Leveraging Virtual Sensors to generate accurate operational, mobility, safety and environmental metrics for given roadways and intersections.
- Proactive Signal System Health and Safety Monitoring: Including monitoring of signal performance and detector performance on a continuous basis.
- Signal Optimization: Leveraging Virtual Sensors to automatically optimize traffic signal timing plans.

In future, Flow Labs will be looking to integrate data from additional sources, such as larger volumes of connected vehicles, and additional sensors, to improve accuracy and insight further.