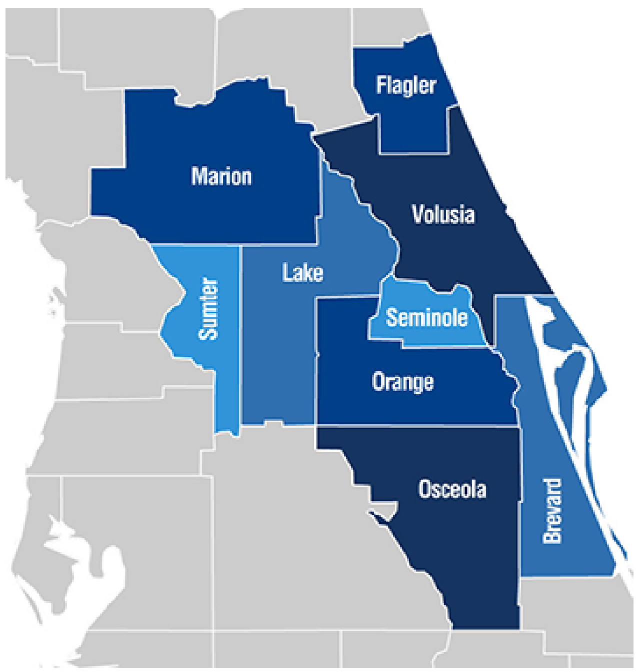
Real-Time Signal Operations

Improving Real-Time Data Accuracy for Smarter Operations with HEIDI

Florida Department Of Transportation and Flow Labs Work Together to Improve Data Accuracy for Real-Time Traffic Insights

Managing one of Florida's most complex transportation networks, the Florida Department of Transportation District 5 (FDOT D5) oversees a rapidly growing region that serves over four million residents—a population that grows by the size of a small city (40,000–120,000 new residents) every year. Adding to the challenge, Orlando, the heart of District 5, is the nation's top visitor destination, drawing over 75 million tourists annually—more than the entire population of France.



FDOT District 5 serves a 4m+ population surrounding the Orlando Metropolitan Area.

With limited space for new roadways and the high cost of arterial expansion, FDOT D5 prioritizes Transportation System Management and Operations (TSM&O) strategies, including Integrated Corridor Management (ICM), to maximize the efficiency of existing infrastructure. However, a major challenge persists: accurately estimating real-time intersection turning movement counts and traffic volumes.

Traditional data collection methods, including detection systems, often introduce biases and inaccuracies, making it difficult to optimize signal timings to real-time incidents and conditions, proactively manage congestion, and improve roadway safety. Without reliable real-time data, decision-making remains reactive, limiting the effectiveness of operational strategies.

To solve this challenge, FDOT D5 partnered with Flow Labs to deploy the High-Definition Engineering Intersection Data via Integrative Modeling (HEIDI) system. This hybrid on-premise and cloud-based solution integrates real-time data from FDOT's existing detection systems with high-penetration connected vehicle probe data from TomTom. By fusing these data sources, HEIDI provides unparalleled visibility into intersection dynamics, enabling data-driven signal optimization, congestion mitigation, and safety enhancements.

With HEIDI, FDOT D5 is pioneering a new era of real-time traffic management, proving that smart data—not just more roads is the key to transforming mobility in high-growth regions.

> "For years, we've attempted to get accurate, real-time turning movement counts, especially in areas without full detection coverage. With HEIDI, we have a solution that delivers consistent, reliable, low latency data—even in places where we haven't updated our signal infrastructure."

Jeremy Dilmore
FDOT District 5
TSMO Program Manager

Problem

Every transportation decision begins with data, and for FDOT District 5 (FDOT D5), real-time accuracy is critical to managing traffic efficiently. However, FDOT's detection-dependent architecture faces significant challenges that undermine data reliability, making it difficult to optimize signal timing, manage congestion, and enhance roadway safety.

System reliability is a primary challenge

Power outages, network failures, and weather conditions frequently disrupt detection devices, while equipment malfunctions and obstructions create gaps and inaccuracies in traffic data. These blind spots leave engineers working with incomplete or outdated information, limiting their ability to make proactive decisions.

Infrastructure constraints add another layer of difficulty.

Budget limitations restrict the expansion of detection technology, leaving many intersections and corridors under-monitored. Without comprehensive coverage, FDOT D5 must rely on fragmented data, making it harder to identify and address traffic issues across the entire network.

Data fragmentation remains a persistent problem.

FDOT D5 collects traffic data from multiple sources, but these systems often operate in silos. Detection-based counts are inconsistent, probe vehicle data lacks full coverage, and integration between sources is limited. As a result, traffic operations teams struggle to get a clear, unified view of real-time conditions.

These integration challenges result in data inconsistencies, reduced confidence in traffic insights, and an inability to make timely, informed decisions about roadway operations.

Solution

To address critical data reliability challenges, **FDOT District 5 partnered with Flow Labs** to develop **HEIDI**—a **hybrid cloud architecture solution** that delivers high-resolution, real-time traffic insights. By integrating data from **FDOT's existing traffic signal infrastructure**, including **signal controllers and detection devices**, with **high-penetration probe data from vehicles**, HEIDI eliminates blind spots and significantly enhances data accuracy.

Built on **Flow Labs' state-of-the-art Integrated Signal Performance Measures (ISPM) platform**, HEIDI combines the best elements of ATSPM (Automated Traffic Signal Performance Measures) and PBSPM (Probe-Based Signal Performance Measures), offering a more **comprehensive and precise** approach to traffic monitoring.

HEIDI fuses **multiple data sources** together to create a unified, high-fidelity view of real-time traffic conditions. It leverages:

Multi-Source Data Integration.

HEIDI combines FDOT's existing detection system data with high-penetration probe data from **TomTom**, vastly improving coverage and accuracy.

Advanced Machine Learning Algorithms.

The solution compares detection data with probe data to identify inconsistencies and corrects inaccuracies in FDOT's detection systems, reducing systematic undercounting bias by up to 39%.

A Cloud-Native and On-Premise Architecture.

It ensures low-latency, high-uptime data processing that seamlessly integrates with FDOT's operational platforms.

Scalability for Large-Scale Deployment.

The system is designed to support **over 2,000 signalized intersections** across the region, enabling FDOT D5 to transition from **reactive** to **proactive** traffic management.

With HEIDI, FDOT D5 is pioneering a new standard for **real-time intersection intelligence**, transforming how agencies optimize signals, manage congestion, and improve roadway safety—without the need for costly infrastructure expansion.

Outcomes

The HEIDI project has demonstrated a groundbreaking, **infrastructure-agnostic** approach to generating **high-accuracy real-time turning movement counts (TMCs)**, surpassing traditional detection-based methodologies. By integrating FDOT's existing detection infrastructure with Flow Labs' high-penetration probe vehicle data, this initiative validated a scalable and precise system for real-time traffic monitoring and decision-making.

Unmatched Volume Accuracy with Infrastructure-Agnostic Capability

The accuracy of HEIDI's turning movement count estimates was rigorously validated through a comprehensive study using **13,860 real-time traffic volume data samples**, benchmarked against independently collected ground truth video data. The study confirmed that both **integrated and probe-only estimation methods achieved high accuracy**, with integrated estimates maintaining a **Mean Absolute Percentage Error (MAPE) below 10%**, exceeding existing federal standards.

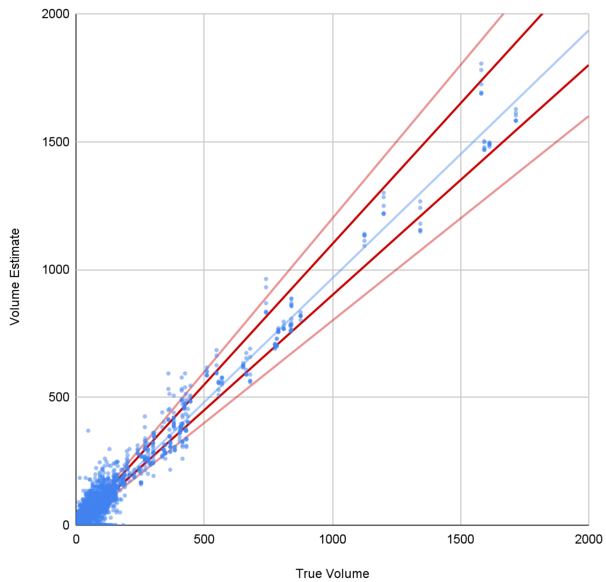


Figure 1: Probe Only Correlation Analysis

0.970*x + -3.59 R2 = 0.960

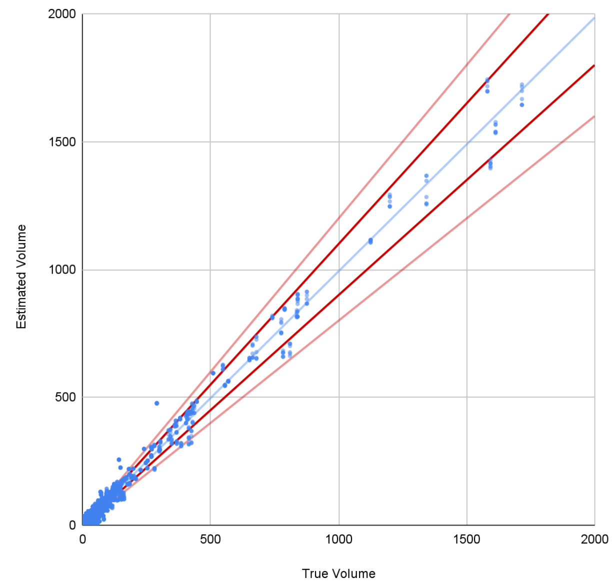


Figure 2: Integrated Correlation Analysis

0.993*x + 0.699 R2 = 0.985

Notably, probe-only estimates also demonstrated strong accuracy, with performance improving as penetration rates increased. **When probe sample sizes reached 20 vehicles per period, accuracy exceeded 80%, and at 90 vehicles per period, accuracy surpassed 90%**. These results validate **probe data as a viable alternative for turning movement counts in locations with limited detection infrastructure**, making it a cost-effective solution for rural intersections, temporary work zones, and low-instrumentation environments.

Low-Latency, High-Uptime Real-Time Processing

HEIDI successfully delivered real-time turning movement counts at **low latency levels**, optimized at **15-minute intervals** to balance speed and accuracy. The cloud-native and on-premise hybrid architecture enabled real-time processing with **99.9%+ uptime**, ensuring continuous, uninterrupted traffic monitoring. This level of reliability establishes HEIDI as a highly scalable solution, capable of maintaining **stable real-time traffic insights even in large-scale deployments across thousands of intersections**.

		Time Interval (minutes)					
		1	3	5	15	30	60
Latency (minutes)	1	100.00%	107.27%	89.49%	24.68%	10.59%	7.28%
	3	103.22%	96.23%	62.61%	24.33%	9.79%	7.63%
	5	94.84%	73.28%	46.12%	19.25%	9.86%	7.87%
	10	89.17%	44.64%	26.87%	15.11%	8.93%	7.50%
	15	32.74%	21.72%	18.15%	13.33%	8.58%	7.46%
	30	32.18%	21.33%	18.25%	13.25%	8.36%	7.29%
	60	32.22%	21.34%	18.31%	13.29%	8.37%	7.29%

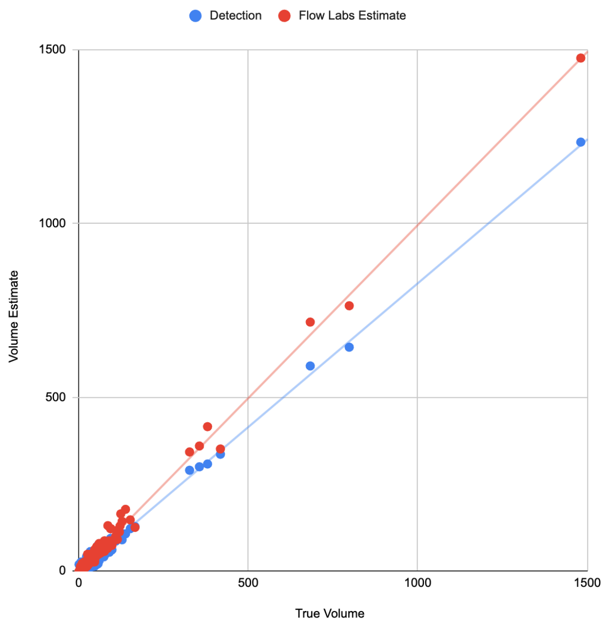
Table 1: Interval-Latency Accuracy Levels - Probe Only - MAPE

		Time Interval (minutes)					
		1	3	5	15	30	60
Latency (minutes)	1	35.09%	16.61%	13.82%	9.84%	7.71%	5.80%
	3	35.09%	16.61%	13.81%	9.57%	7.52%	5.95%
	5	35.09%	16.59%	13.62%	9.35%	7.08%	5.87%
	10	35.04%	16.48%	13.48%	8.53%	5.88%	6.14%
	15	34.07%	15.61%	11.93%	7.83%	6.07%	6.36%
	30	34.08%	15.54%	11.94%	7.90%	5.96%	6.27%
	60	34.08%	15.54%	11.95%	7.90%	5.97%	6.28%

Table 2: Interval-Latency Accuracy Levels - Integrated - MAPE

Detecting and Correcting Systematic Detection Bias

Detection-based traffic monitoring often suffers from persistent errors caused by sensor drift, occlusion, and hardware failures. The HEIDI project successfully identified and corrected significant detection bias, reducing systematic undercounting errors in key detection systems. **One detector originally undercounted traffic volumes by 18.1%, while another showed a more severe 39% undercounting bias**. HEIDI's advanced machine learning algorithms **reduced these biases to just -0.4% and -7.4%**, respectively, restoring accuracy and ensuring reliable real-time traffic estimates. These corrections demonstrate the platform's ability to continuously self-calibrate and improve infrastructure-based detection reliability without manual intervention.



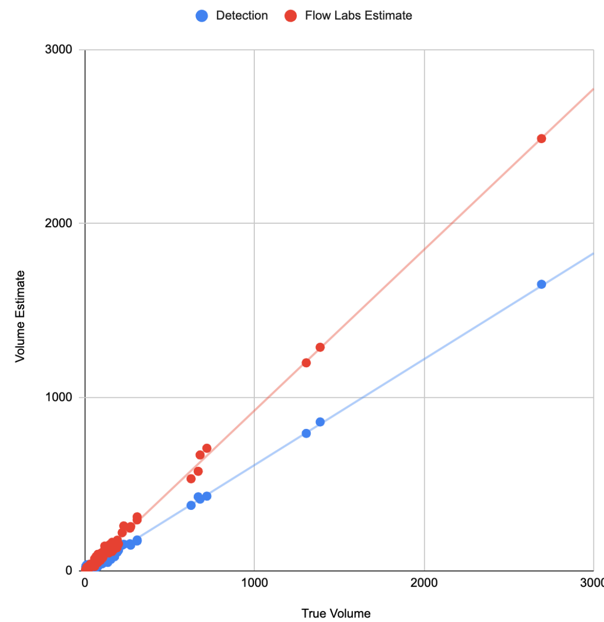


Figure 3: Detector A Correlation Analysis - Detection vs Flow Labs 0.996*x + -0.796 R2 = 0.992

Figure 4: Detector D Correlation Analysis - Detection vs Flow Labs 0.926*x + -2.23 R2 = 0.997

Validating Real-Time High-Penetration Probe Data

This study also validated the penetration rates of Flow Labs' real-time high-penetration probe vehicle data, confirming its viability as a scalable traffic monitoring tool. **The results demonstrated a 21.7% penetration rate, significantly higher than industry benchmarks, which typically range between 2% and 8%.** This high penetration rate reinforces the robustness of probe-based traffic volume estimation, particularly in areas where detection infrastructure is sparse or absent. The findings suggest that real-time connected vehicle data can serve as a standalone methodology for turning movement counts, reducing reliance on traditional sensor-based monitoring.

		Time Interval (minutes)					
		1	**3**	**5**	**15**	**30**	**60**
Latency (minutes)	**1**	0.00%	0.02%	0.31%	9.89%	15.40%	18.92%
	3	0.03%	0.30%	2.33%	12.53%	17.24%	19.80%
	5	0.86%	2.81%	5.87%	14.91%	18.37%	20.28%
	10	13.97%	15.26%	17.07%	19.37%	20.79%	21.36%
	15	20.53%	20.91%	21.21%	21.46%	21.59%	21.65%
	30	21.65%	21.67%	21.67%	21.68%	21.70%	21.70%
	60	21.67%	21.69%	21.69%	21.69%	21.70%	21.70%

Table 3: Penetration Rates by time Interval and Latency

The HEIDI project has proven that real-time, multi-source traffic data fusion can outperform conventional detection-based approaches while offering a scalable, infrastructure-agnostic alternative for turning movement counts. **With the potential to scale across 2,000+ signalized intersections, HEIDI paves the way for FDOT to leverage real-time, AI-enhanced traffic analytics for smarter signal timing, congestion management, and predictive safety applications.**

Future Impact

With Phase II, **HEIDI is set to expand across 2,000 signalized intersections, bringing unprecedented data accuracy and scalability to FDOT D5's traffic management efforts**. This expansion will enhance critical applications, from automating turning movement count collection to supporting signal retiming projects with real-time, high-accuracy traffic volume estimates. By delivering more precise data, HEIDI will also improve signal warrant studies, ensuring that new traffic signals are justified with reliable traffic flow insights.

Beyond operational improvements, HEIDI will play a key role in evaluating the impact of infrastructure changes. The system's ability to conduct before-and-after analyses will allow FDOT D5 to quantify the effects of signal timing adjustments, corridor modifications, and safety interventions. By identifying which intersections would benefit most from retiming, HEIDI will help agencies prioritize investments where they will have the greatest impact.

HEIDI's high-penetration probe data also opens new possibilities for enhanced safety applications. Future expansions will enable data-driven enforcement of Red Light Running policies, as well as the deployment of predictive safety models to mitigate high-risk conditions before crashes occur.

To further improve accuracy and adaptability, upcoming research efforts will focus on adaptive model selection, allowing HEIDI to dynamically determine when to rely on probe-only versus integrated data estimation based on real-time conditions. The system will also incorporate automated anomaly detection, ensuring that detection drift and hardware malfunctions are identified and corrected instantly. Future integration of stop bar detection, transit movement data, and crowdsourced GPS data will provide a more comprehensive view of traffic conditions, making HEIDI an even more powerful tool for modern traffic management.

Why HEIDI Matters

The FDOT D5 HEIDI project has redefined how traffic volumes are measured and managed, setting a new national benchmark for real-time turning movement counts—particularly in low-traffic conditions where no prior standard existed. By fusing detection-based and probe data, this initiative proves that a multi-source approach delivers superior accuracy, resilience, and scalability over relying on aging infrastructure or incomplete datasets.

Flow Labs

A Blueprint for the Future of Traffic Management

HEIDI's ability to correct detection errors, provide highly accurate low-latency traffic volume estimates, and support real-time decision-making empowers FDOT engineers to optimize signal timing, proactively reduce congestion, and enhance roadway safety with confidence. With planned expansion to 2,000 signalized intersections, HEIDI is poised to become a foundational tool for data-driven traffic operations, ensuring more efficient mobility and safety improvements at scale. This project serves as a model for transportation agencies nationwide, demonstrating the power of AI-driven, multi-source data integration in modern traffic management.

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