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Developing Data Sources and Standards for Supporting Arterial TSM&O Implementation of the Statewide Arterial Management Program (STAMP)

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16. Abstract
The current research project aimed to evaluate the necessary elements for creating a data management platform for the FDOT districts. To achieve the project objectives, a statewide survey was developed and disseminated to each district in Florida and the findings were used to summarize best practices and areas of opportunity. The literature review in this document not only includes relevant peer reviewed journal articles but also practice-oriented notes and lessons learned from several districts and cities in the nation. Furthermore, numerous data sources and third-part data are investigated in order to guide innovation and direct future investments. The research outcomes can be used to assist districts and decision makers in evaluating strategies for data platform implementation and design. Finally, the project goal is achieved by making recommendations to support uniformity in data collection, utilization, and data sharing in the state of Florida.

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Executive Summary

This final report, prepared for the Florida Department of Transportation, provides a comprehensive analysis and synthesis of the findings from our project, **BED26-977-06**, aimed at developing data sources and standards to support arterial TSM&O implementation for the Statewide Arterial Management Program (STAMP). Over the course of this project, we have extensively reviewed current literature, evaluated existing traffic management software, and consulted with multiple Departments of Transportation across the U.S. to extract best practices and insights that could be adapted to enhance Florida's arterial management capabilities.

Our investigations have led to several key outcomes:

1. Enhanced Data Utilization: We have identified and made recommendations for big data and vendor data applications that can support traffic management operations. These applications are significant in enabling real-time traffic monitoring and management across various districts (detailed recommendations in Chapter 3).
2. Software and Tools Analysis: We have examined traffic management software like NOEMI and ATSPM systems. These tools are essential for improving the accuracy of traffic flow management and enhancing the decision-making processes within TSM&O initiatives (Chapter 1).
3. Best Practices and Recommendations: By analyzing in more depth practices from other state DOTs (Chapter 3), we have drafted a set of actionable recommendations that can be implemented to advance Florida's arterial management systems. These include adopting new data integration techniques, improving data storage and security, and optimizing

traffic signal performance. They also relate to safety metrics, vendor selection, API design, cloud service provider, and platform design (Chapter 3, Section 9).

4. Strategic Recommendations for Districts: Based on comprehensive surveys and stakeholder feedback, we provide tailored recommendations for each district, aimed at addressing specific challenges and leveraging unique opportunities within each area (Chapter 2).
5. Future Directions: Looking forward, we emphasize the importance of continuous data evaluation, the potential integration of emerging technologies, and the ongoing training of personnel to adapt to new TSM&O strategies (Chapter 3).

The forthcoming report serves as a detailed guide for the Florida Department of Transportation to refine and enhance its arterial management operations, ensuring safer, more efficient, and technologically advanced transportation systems across the state.

Report Structure Overview

The report is organized into three distinct chapters, each incorporating insights from previous reports to best describe and connect the findings.

Chapter 1 provides an extensive literature review, exploring big data applications, real-time analytics, SPaT prediction, and cost-benefit analysis related to transportation data management systems. This chapter also showcases practical applications through examples of traffic management software and highlights best practices derived from various state Departments of Transportation, offering a detailed perspective on effective data usage in traffic management.

Chapter 2 provides a comprehensive survey summary and detailed findings from individual FDOT districts, ranging from existing systems and infrastructures to innovative data sources and management practices. Each section ends with tailored recommendations based on the unique needs of the districts, aimed at enhancing arterial management systems and supporting statewide TSM&O strategies.

Chapter 3 focuses on methodology and strategic decision making, emphasizing the integration of STAMP and TSM&O objectives. It discusses enhanced data analysis capabilities, cross-district collaboration, addressing specific district needs, and the development of centralized data management systems. This chapter also synthesizes feedback from stakeholder workshops and provides insights into optimizing traffic management through innovative data integration and analysis strategies.

By this structure of the report, we ensure a comprehensive delivery of the project's scope and the strategic recommendations developed to enhance Florida's transportation management.

Chapter 1

1.1 Introduction

A data management platform (DMP) collects, organizes, and activates first-, second-, and third-party audience data from various sources. Transportation agencies in the United States have been actively procuring DMPs to enhance their operations and improve their decision-making capabilities. These DMPs have various specifications depending on their use case and are used to manage various aspects of transportation operations, such as traffic management, asset management, and maintenance. A well-structured DMP can help transportation agencies improve their decision-making capabilities, efficiently manage their resources, better serve the public, and comply with regulations. By leveraging the power of data, transportation agencies can improve their operations, enhance safety, provide better services to the public, and apply it in the following avenues:

- Improved Decision Making: A good DMP can help transportation agencies make informed decisions by providing them with timely, accurate, and actionable data. With the help of a DMP, agencies can monitor traffic patterns, assess the condition of their assets, and identify potential problems before they become critical.
- Efficient Resource Management: A DMP can help transportation agencies efficiently manage their resources by providing them with a comprehensive view of their operations. With the help of a DMP, agencies can prioritize maintenance activities, allocate resources effectively, and optimize their operations.
- Better Service to the Public: A DMP can help transportation agencies improve their services to the public by providing real-time information on traffic conditions, road closures, and travel times. This information can be shared with the public through various

channels, such as websites, mobile applications, and social media, helping them make informed decisions about their travel plans.

- Compliance with Regulations: Transportation agencies are subject to various regulations related to safety, environmental protection, and data privacy. A good DMP can help agencies comply with these regulations by providing them with the tools they need to collect, store, and manage data in a secure and compliant manner.

State of the art and best practices related to different types of data for TSM&O (Transportation Systems Management and Operations) strategies, performance measures, and procurements for transportation agencies can vary depending on the specific context and needs of each agency.

- TSM&O Strategies: The use of real-time data from sensors, cameras, and other sources can help transportation agencies implement TSM&O strategies such as Active Arterial management (AAM), Integrated Corridor Management (ICM), and Automated Traffic Signal Performance Measures (ATSPM). A comprehensive data management platform that integrates data from multiple sources can help agencies make informed decisions and optimize their operations.
- Performance Measures: Transportation agencies can use data to establish performance measures and assess the effectiveness of their TSM&O strategies. For example, agencies can use data on travel times, congestion levels, and incident response times to evaluate the impact of their TSM&O strategies and identify areas for improvement. Procurements: When procuring TSM&O-related services or technologies, transportation agencies should consider factors such as data interoperability, data privacy and security, and scalability. They should also ensure that their procurement processes are transparent, competitive, and comply with relevant regulations and policies.

An extensive literature review about recent implementations of the state of the art and best practices related to different types of data for TSM&O strategies, performance measures and procurements on an international, national, statewide and district level was conducted. The research team also reviewed outcomes of the previous research using the available data sources on performance measures, safety effectiveness, cost benefit analysis, and improvement in operations after implementation of strategies. This report is organized as follows: the second section includes how different transportation agencies approached TSM&O, where it illustrates the TSM&O strategies are depending on the unique needs of the agency. In addition, advantages and disadvantages of different approaches and implementations were summarized. The third section discusses the uses of the data, such as for developing performance measures, decision support systems (ATSPM and ICM). It will also summarize minimum requirements for accuracy and granularity by the data element. The fourth section includes the key findings from the Department of Transportation meetings. The Florida Department of Transportation District 5 was determined to be the most advanced in DOT from the meetings conducted, and the fifth section goes over the key findings of the meetings. Finally, in the last section an extensive investigation is conducted to identify, summarize, and document all applicable data sources, TSM&O strategies, and performance measures from all districts in Florida.

1.2. Literature review

1.2.1. Big data and vendor data applications in transportation engineering

The transportation industry is essential for the economic growth of a country, and it is crucial to have accurate data to make informed decisions. In order to collect the data, the Department of Transportation (DOT) uses various sources and vendors such as Bluetooth, HERE, INRIX etc. The compatibility and efficiency of these sources can impact the accuracy of the collected data. To assess compatibility and efficiency, researchers have conducted various studies examining the performance measures, safety effectiveness, cost-benefit analysis, and improvement in operations resulting from the implementation of strategies using DOT data sources. In this literature review, we will explore different approaches and implementations used in the past as well as evaluate their advantages and disadvantages, and finally provide insights into the effective data collection methods and analysis. Former research will be also examined to deepen the findings coming from practice with academic knowledge.

The increasing demand for accurate traffic state information for transportation agencies, researchers, and travelers has driven a shift in data collection methods. Traditionally, traffic data have been collected by government agencies using their own sensors, which are limited by high costs, infrastructure demands, and low coverage levels. Consequently, the emergence of private-sector companies selling travel-time and speed data collected using probe vehicles presents an opportunity to outsource traffic data collection (Hu et al., 2016). Various data providers such as INRIX, HERE, and Waze have gained notoriety in this space. As their data sources and related algorithms are proprietary, evaluating the reliability and accuracy of these private-sector data sets is essential for transportation agencies (Hu et al., 2016; Hoseinzadeh et al., 2020).

In the recent times, transportation agencies have increasingly adopted Bluetooth detection systems (BDS) and data provided by the private sector firms such as HERE, INRIX, and TomTom for real-time traffic supervision and extended traffic management strategies (Gong et al., 2021). However, the evaluation of the quality and dependability of these data sources is crucial. Gong, Abdel-Aty, and Park (2021) conducted a comparison of the accuracy and dependability of BDS information and the data from the private sector, specifically HERE, utilizing high-resolution GPS trajectory information along a primary arterial corridor in Orlando, Florida. They discovered that the BDS data surpassed the private sector data in accuracy and reliability, which they ascribed to the improved representation of bimodal traffic flow patterns on signalized arterials.

To improve the quality of data from the private sector, Gong et al. (2021) extracted bimodal traffic flow details from historical BDS information using a finite mixture model and integrated it with real-time data from the private sector employing a Bayesian inference framework. Although the enhancement framework demonstrated its effectiveness throughout the majority of the corridor, it faced challenges in areas significantly affected by traffic originating from or leading to expressway ramps, where the assessment datasets might be biased (Gong et al., 2021).

Other than that, while some of previous studies have assessed the accuracy of private-sector data on freeways (Hu et al., 2016; Sharifi et al., 2017; Hou et al., 2023), others have focused on arterial roads, which pose a more challenging environment due to the presence of traffic signals and other intermediate access points (Zhang et al., 2015; Hu et al., 2016; Hoseinzadeh et al., 2020). These studies have used various validation methods and comparison scenarios, as well as ground truth data sets such as Bluetooth travel-time data (Hu et al., 2016; Hoseinzadeh et al., 2020) and automated vehicle identification (AVI) data (Chung et al., 2018).

Hu et al. (2016) evaluated the quality of the private-sector data on arterials using Bluetooth travel-time data as the ground truth. Their evaluation examined the ability to track real-time conditions and identify long-term traffic state changes. They concluded that the private-sector data evaluated were not suitable for real-time applications but could be used to measure long-term traffic state changes for performance measurement programs. In another study, Sharifi et al. (2017) assessed the effectiveness of the outsourced probe data on signalized arterials for real-time operations and performance measures. Their analysis consisted of several methodologies, including precision and bias speed metrics, slowdown analysis, sampled distribution method, and a review of data from each 24-hour period of data collection. They recommended probe data for arterial roadways with signal densities up to one, to be used with caution for signal densities between one and two, and not recommended when signal density exceeds two.

Hou et al. (2023) carried out a study to compare the quality of travel time data from multiple sources. They employed Bluetooth data as the reference point for actual travel time and contrasted it with data from Waze, HERE, and INRIX. The researchers used three metrics (ATE, TEB, and SEMBS) to assess the performance of vendor data compared to the Bluetooth system under different conditions, overall, by day of the week, and by segment during three-time frames (all-day, morning peak, and afternoon peak). The comparative analysis revealed that HERE and INRIX displayed similar patterns to the Bluetooth travel time data, with data accuracy declining during periods of increasing traffic congestion and differing across various segments (Hou et al., 2023). They attributed this decline to the disparate data collection techniques employed by Bluetooth and GPS, where GPS necessitate a higher sampling rate or frequency to capture speed fluctuations during extreme congestion.

Conversely, Waze data exhibited a distinct pattern compared to the other two datasets, demonstrating the lowest correlation with Bluetooth travel time data and a downward bias in relation to the benchmark Bluetooth data and the other two commercial datasets (INRIX and HERE). The researchers performed a regression analysis to explore the reasons for the discrepancies between the Waze and Bluetooth travel times, discovering that the differences were associated with systematic disruptions, segment length disparities, and available data points. These factors accounted for approximately 70% of the systematic difference between Waze and Bluetooth travel time (Hou et al., 2023).

In summary, INRIX and HERE showed acceptable travel time data quality, while Waze consistently underestimated travel time. The authors acknowledged that other factors might contribute to the differences between Waze and Bluetooth travel time, such as distinct driving behaviors among Waze users or performance variations during recurrent and non-recurrent events. They recommended that future research should examine these factors and further explore performance differences during diverse types of incidents (Hou et al., 2023).

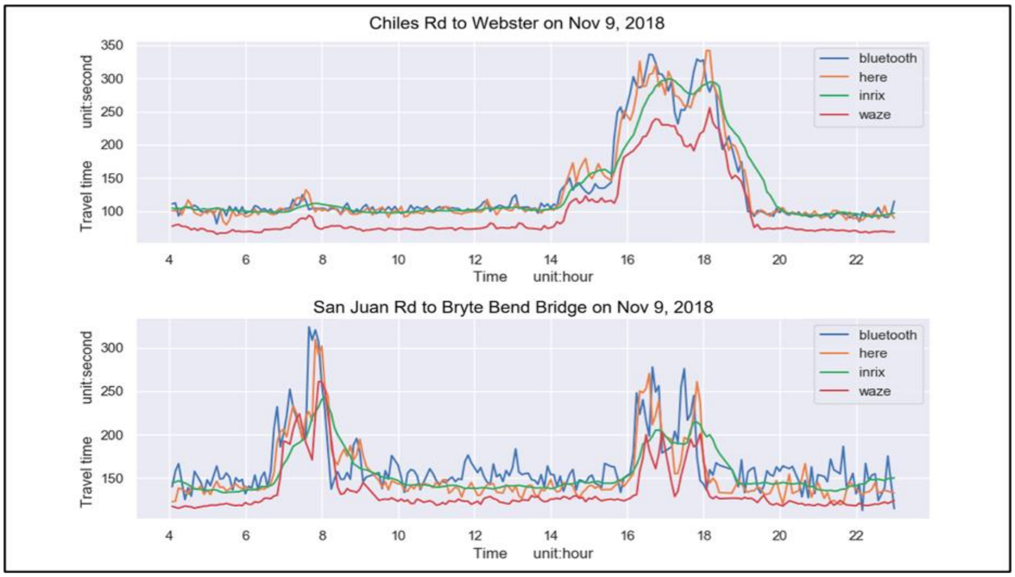

Figure 1. Travel time on Chiles Rd to Webster (top) and San Juan Rd to Bryte Bend Bridge (bottom) on November 9, 2018

Also, research examining Waze speed data for surface streets revealed a slight difference between the Waze and Bluetooth data, suggesting that Waze speed data are a promising data source for surface streets (Hoseinzadeh et al., 2020). However, the study also found that the accuracy of Waze data varied depending on factors such as traffic speed, traffic volume, segment length, and time of day.

Chung et al. (2018) compared the private-sector data to AVI data and carried out research to relate travel time reliability estimates obtained from private-sector data and automated vehicle identification (AVI) data, which relies on radio frequency identification. AVI data, deemed as the ground truth, were gathered using an AVI system with toll tags and compiled into five-minute intervals. Data from HERE, a prominent traffic information supplier, were acquired via the Regional Integrated Traffic Information System and calculated in five-minute intervals.

The researchers chose four types of metrics for comparison, based on the day of the week, specific timeframes, and time of day in five-minute, 15-minute, and one-hour intervals. Paired t-tests were employed to evaluate the statistical difference in travel time reliability between the two data sources. The findings indicated that AVI and HERE data were comparable when considering the day of the week, specific time periods, and time of day at one-hour intervals. However, for five-minute and 15-minute intervals, HERE and AVI data were not generally comparable. This suggests that when estimating travel time reliability in real-time, the travel time reliability derived from HERE data might deviate from the actual travel time. The research implies that when using private-sector traffic data for estimating travel time reliability measures, these metrics should be harmonized based on solid statistics to yield more consistent measures that are closely related to the true travel time reliability (Chung et al., 2018).

Turning to studies conducted by the governmental agencies, research funded by Utah Department of Transportation (UDOT) aimed to understand how the travel-time estimates from HERE compared to the other sources of the travel-time data that were obtained from the Google Directions Application Program Interface (API). The research team analyzed 59 highway segments and compared travel-time estimates for a 36-day period, from January 21 to February 25, 2019. It was found that, under normal operations, travel times from HERE and Google Directions Application Program Interface (API) are very comparable. Furthermore, the analysis of travel-time estimates for work zones also confirms that the estimates from HERE and Google

Directions Application Program Interface (API) are very comparable, though it is noted that the work zones were not field checked for the extent of activity.

Somewhat of a different perspective was taken by the Nebraska Department of Roads who sponsored a study to evaluate the opportunities and challenges of using the INRIX data for real-time performance monitoring. A study performed by AECOM also aimed to understand if there is a relationship between HERE, INRIX, and Bluetooth speed data. The data were collected for four corridors in 2012 and 2013 by the FDOT D4 and FDOT Central Office. It was reported that HERE data required filtering due to high fluctuations in speeds captured in the evening and during the night compared to the daytime speeds. Below are the key findings of the study:

- All three data sources estimated largely similar speed profiles both diurnally and along the roadway segments.
- Bluetooth and HERE data sets estimated remarkably similar “average” time of day travel speeds, even at a segment-level.
- INRIX speed was higher than HERE speed for almost all data points across all five-time periods.
- Bluetooth and HERE travel speeds were in general 5 to 10 miles per hour lower than the INRIX speeds during the day.
- There is a greater variation in the night/early morning travel speeds in the three data sets than the day speeds.

The travel speeds estimates from the local travel demand model are generally higher than all three data sources, especially for the mid-day period.

In summary, the literature on the accuracy and reliability of private-sector traffic data, such as those from INRIX, HERE, and Waze, highlights the importance of evaluating the quality of these data sources before utilizing them for various applications in transportation research and practice. The reliability of these data sources varies depending on the specific road type, traffic conditions, segment length, and time of day. While some private-sector data sources have shown acceptable levels of accuracy and reliability for certain applications, such as long-term traffic state change measurement, they may not be suitable for real-time applications or on specific arterial road segments with high signal densities.

Future research should continue to investigate the factors contributing to the discrepancies between private-sector data and the ground truth sources, as well as the performance of these data sources during recurrent and non-recurrent traffic incidents. Additionally, the development of harmonized measures for travel time reliability estimation is critical for ensuring consistent and accurate representation of true travel time reliability.

1.2.2. Real-time big data analytics and proactive traffic safety management visualization system from UCF SST Lab

In addition to the vendor and in-house data sources, videos have begun to play a substantial role in evaluating safety measures and gaining more insights into the exact interactions of the road users. For the reader’s information, we have incorporated a recent study by Abdel-Aty et al. (2023) in order to further solidify the CCTV applications in traffic safety.

A web-based Proactive Traffic Safety Management (PATM) and Real-time Big Data Visualization tool by Abdel-Aty et al. (2023), which is built upon an award-winning system recognized in the US Department of Transportation (USDOT) Solving for Safety Visualization Challenge was chosen as one of the USDOT Safety Data Initiative (SDI) Beta Tools. Utilizing the data, various modules have been developed, such as real-time crash/secondary crash prediction, CCTV-based expedited detection, PATM recommendation, data sharing, and report generation. To accomplish this, the system also employs real-time CCTV data and integrates them with real-time crash/secondary crash prediction results to oversee traffic conditions and achieve faster crash verification. Ultimately, the reports can be generated from the system outputs to aid decision-makers in long-term planning, and a third-party page is created to share system outputs in real-time.

Real-time CCTV-based expedited detection: This module aims to minimize the time between identifying a crash-prone/secondary crash-prone segment and monitoring the affected locations. The system emphasizes the most relevant cameras and suggests a scanning direction for each camera to oversee road conditions on segments with high crash likelihoods, enabling expedited crash detection. Thus, TMC operators can concentrate on a few cameras at a time instead of attempting to monitor hundreds of CCTVs.

Additionally, upstream and downstream information was incorporated into the base map for the crash likelihood prediction. To achieve rapid crash detection and monitor crash-prone locations using CCTV data, each base map segment was matched with the nearby CCTV cameras based on their latitude and longitude coordinates. The CCTV module is designed to help TMC operators quickly confirm the occurrence of a potential crash and monitor turbulent traffic conditions. The workflow of the CCTV verification module is depicted in Figure 2.

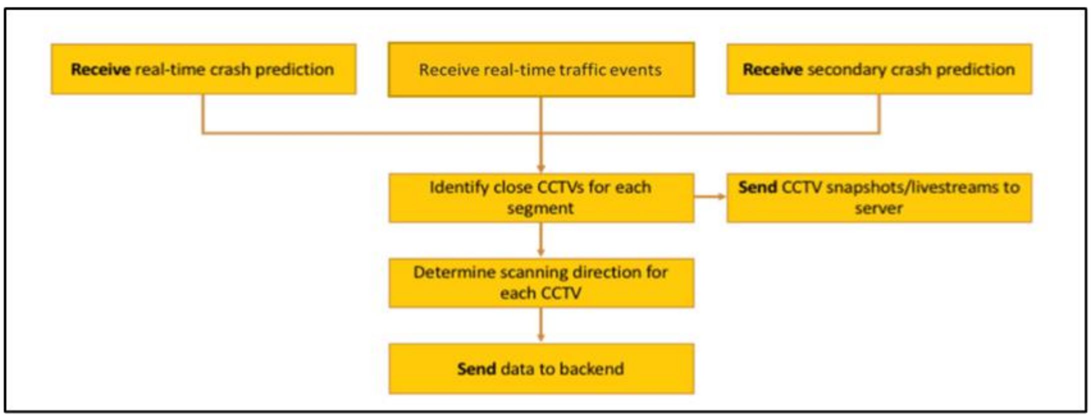

Figure 2. CCTV Module Workflow

The CCTV module receives a list of crash-prone, secondary crash-prone, and ongoing traffic events. For each affected segment, the set of nearby CCTV cameras is identified. A snapshot from each camera is generated and sent to the frontend for visualization. In addition, to facilitate live video monitoring, the RTSP live stream address for each identified camera is collected and sent to the frontend. Furthermore, since PTZ CCTV cameras may not be pointing in the correct direction, the cardinal direction between each camera and the target segment is calculated, and the system provides the operator with a scanning direction recommendation for each camera.

1.2.3 SPaT prediction

Signal Phase and Timing (SPaT) predictions play a crucial role in optimizing traffic signal control systems and improving traffic flow efficiency. By accurately predicting the future state of traffic signal phases and timings, transportation agencies can optimize signal operations, reduce congestion, and enhance the overall traffic management. In the recent years, machine learning techniques have gained significant attention in SPAT prediction due to their ability to capture complex patterns and make accurate predictions. Various studies have explored the application of machine learning algorithms such as artificial neural networks, support vector machines, random forests, and deep learning models for SPAT prediction (Islam et al., 2022; Islam et al., 2023a; Genser et al., 2022; Shafik et al., 2023). Two studies by Islam et al. (2022) and Islam et al. (2023c) used a long short-term memory (LSTM) neural network to predict SPAT intervals based on high-resolution detector data and connected vehicle data. They achieved promising results in terms of prediction accuracy and provided insights into the potential of deep learning models for SPAT prediction.

SPAT predictions rely heavily on traffic flow data, which includes information about traffic volumes, speeds, and occupancy. Inductive loops, while commonly used, are not the only technology used for vehicle detection. Other technologies, such as video detection, thermal detection, radar, LiDAR, and ultrasonic sensors, can also be utilized for this purpose. Each technology has its own advantages and limitations, which may influence their suitability for SPAT (Signal Phase and Timing) prediction models. The following data sources are commonly used to obtain traffic flow data for SPAT prediction:

- Inductive Loop Detectors: Inductive loop detectors are installed on roadways and provide information on vehicle presence, speed, and occupancy. They are widely used in transportation networks and provide real-time data for SPAT prediction models.
- Video Detection: Video detection involves analyzing video feeds from cameras installed at intersections to detect vehicles. It can provide valuable information about vehicle presence, count, and speed. However, video detection may be affected by factors such as poor lighting conditions, camera angles, and occlusions, which can impact its accuracy.
- Thermal Detection: Thermal detection relies on thermal imaging cameras to detect vehicles based on the heat they emit. This technology can be effective in low-light or adverse weather conditions, as it doesn't rely on visible light. However, it may struggle to accurately detect vehicles when there are significant temperature variations in the environment or if the thermal signatures of vehicles are not distinct enough.
- Radar, LiDAR, and Ultrasonic Sensors: Radar, LiDAR, and ultrasonic sensors use various techniques to measure the distance and speed of objects in their vicinity, including vehicles. These technologies are effective at detecting moving objects, and they can provide accurate information about vehicle presence, speed, and sometimes even size. However, they may be more expensive to deploy and maintain compared to inductive loops or video detection systems.

- Bluetooth and Wi-Fi Sensors: Bluetooth and Wi-Fi sensors installed along roadways can detect and track anonymous devices in passing vehicles. These sensors collect data on travel times, speeds, and travel patterns, which can be used for SPAT predictions.
- Probe Vehicle Data: Probe vehicle data provides GPS data from vehicles, which can provide detailed information on vehicle movements and travel times. By aggregating and analyzing the probe vehicle data, researchers can derive valuable insights for SPAT prediction models.

In addition to traffic flow data, SPAT prediction models often incorporate information from traffic signal systems, such as:

- Signal Timing Plans: Signal timing plans define the phase durations and coordination strategies for traffic signals. Historical signal timing plans can be used to analyze the effects of different timing strategies on SPAT predictions and optimize future signal plans.

Signal Controller Data: Signal controllers collect real-time information on signal phase durations, cycle lengths, and current signal states. These data can be used to validate and calibrate SPAT prediction models.

1.2.4 Cost-benefit analysis for data management systems

Effective transportation data management is crucial for government entities involved in traffic planning, infrastructure development, and ensuring transportation safety. To address the complexities of transportation systems and promote safety, many government entities consider implementing a transportation data management system. However, before making this significant investment, it is essential to conduct a comprehensive cost-benefit analysis to assess the financial implications and potential advantages of such a system. This section presents a tailored cost-benefit analysis for a transportation data management system within a government entity context.

1. Objectives of the transportation data management System: The objectives of implementing a transportation data management system in a government entity encompass various safety-related goals, in addition to other transportation management objectives. These objectives include:

    - Enhancing transportation safety by collecting and analyzing accurate and timely data on road conditions, crash occurrences, and hazardous areas.
    - Improving decision-making processes related to safety measures, road infrastructure enhancements, and targeted enforcement activities.
    - Increasing operational efficiency in responding to safety incidents, facilitating emergency management, and reducing incident response times.
    - Enabling better coordination and collaboration among different government departments responsible for transportation safety and emergency services.
    - Ensuring compliance with safety regulations and reporting requirements in the transportation sector.

2. Cost assessment: Assessing the costs associated with implementing a transportation data management system involves considering both direct and indirect expenses. The direct costs may include:

    - Software licenses for the data management system.
    - Hardware infrastructure for data storage and processing.
    - Data collection and monitoring equipment, including sensors and surveillance systems.

- Implementation services for system setup, configuration, and integration.
- Training programs for personnel involved in safety data collection, analysis, and response.
- Ongoing system maintenance, technical support, and data management.

Indirect costs should also be considered, such as:

- Allocation of staff resources for data collection, analysis, incident response, and system administration.
- Potential opportunity costs resulting from diverting resources from other safety initiatives or projects.

3. Benefit quantification: Quantifying the benefits of a transportation data management system for a government entity involves considering the specific safety-related advantages it can deliver:
    - Enhanced transportation safety: Accurate and timely data on road conditions, crash occurrences, and hazardous areas enable targeted safety measures, infrastructure enhancements, and proactive enforcement activities.
    - Improved decision-making: Real-time and historical safety data support informed decisions related to incident response, emergency management, and the allocation of safety resources.
    - Faster incident response: Streamlined data collection processes and automated incident reporting systems facilitate quicker identification and response to safety incidents, reducing incident durations and minimizing their impact on road users.
    - Collaboration and coordination: A centralized data management system enables seamless data sharing and collaboration among different government departments

responsible for transportation safety and emergency services, promoting effective coordination and joint safety initiatives.

- Regulatory compliance: Implementing a data management system that ensures compliance with safety regulations and reporting requirements reduces the risk of legal and regulatory penalties for the government entity.

4. Timeframe considerations: The timeframe for realizing safety-related benefits from a transportation data management system includes both short-term and long-term gains:
    - Short-term benefits: Immediate access to real-time safety data, enabling quick identification and response to safety incidents, and prompt implementation of safety measures.
    - Long-term benefits: Improved safety planning and infrastructure investments based on historical safety data trends, long-term reduction in crash rates, enhanced emergency management capabilities, and continuous improvement of safety policies and measures.
5. Risk analysis: A thorough risk analysis is essential to address potential challenges associated with implementing a transportation data management system:
    - System downtime: Risks related to system failures or technical issues leading to data unavailability and potential delays in safety incident response.
    - Data security: Risks associated with data breaches or unauthorized access to sensitive safety data, potentially compromising emergency response efforts or safety-related decision-making processes.

- Financial risks: The potential need for future investments in system upgrades, additional hardware or software licenses, and ongoing maintenance costs to ensure continued safety benefits.

1.2.4.1 Cost characterization of data collection, storage, and dissemination

Within the cost-benefit analysis of data management systems, it is crucial to consider the components and associated costs related to data collection, storage, and dissemination. Understanding the business models underlying these components helps in characterizing the costs accurately and evaluating their impact on the overall cost-benefit analysis. This section explores the key components involved in establishing the cost and the business models associated with data collection, storage, and dissemination.

Data collection is a fundamental component of a data management system, and it encompasses various activities, each contributing to the overall cost. Key cost components related to data collection include:

- Infrastructure: The costs associated with establishing the necessary hardware, software, and network infrastructure for data collection, such as sensors, data collection devices, communication systems, and data acquisition software.
- Personnel: The costs of hiring and training personnel responsible for data collection activities, including data analysts, field workers, surveyors, or technicians.
- Data Acquisition: The expenses incurred in acquiring data from external sources, such as purchasing datasets from third-party providers, licensing data from data aggregators, or collaborating with other organizations for data sharing initiatives.

- Maintenance: The ongoing costs of maintaining and calibrating data collection equipment, performing regular quality control checks, and ensuring data integrity and accuracy.

Business models associated with data collection include:

- In-house data collection: Organizations establish their own data collection capabilities, investing in infrastructure and personnel to gather the required data internally.
- Outsourced data collection: Organizations rely on external contractors or specialized agencies to collect data on their behalf. This model involves contracting the services of data collection experts, leveraging their expertise and resources.
- Collaborative data collection: Organizations engage in partnerships or collaborations with other entities, sharing resources and costs to collect and share data jointly. This model promotes data sharing and cost sharing among participating organizations.

Efficient and secure data storage is critical for a data management system. The cost characterization of data storage involves several components, including:

- Infrastructure: The expenses associated with establishing and maintaining the hardware infrastructure required for data storage, such as servers, data centers, cloud storage services, and backup systems.
- Storage Capacity: The costs related to acquiring and scaling the necessary storage capacity to accommodate the anticipated data volume, including the purchase or rental of storage devices or cloud storage subscriptions.
- Data Security: The investments required to ensure data security, including firewalls, encryption, access control mechanisms, and cybersecurity measures to protect against data breaches or unauthorized access.

- Data Backup and Disaster Recovery: The costs associated with establishing backup mechanisms and disaster recovery plans to safeguard against data loss, including regular backups, redundant storage systems, and backup infrastructure.

Business models associated with data storage include:

- On-premises storage: Organizations establish and maintain their own data storage infrastructure on their premises, investing in servers, storage devices, and IT personnel to manage data storage operations.
- Cloud-based storage: Organizations leverage cloud service providers to store their data, paying for storage capacity and related services based on usage. This model offers scalability, flexibility, and cost efficiency as organizations only pay for the storage they consume.
- Hybrid storage: Organizations adopt a combination of on-premises and cloud-based storage solutions, leveraging the advantages of both models based on their specific requirements. This approach offers flexibility, allowing organizations to optimize costs and data accessibility.

Data dissemination involves making data accessible and usable, and it encompasses various cost components, including:

- Data Processing and Analysis: The costs associated with transforming raw data into usable formats, performing data cleaning, aggregation, integration, and analysis to generate meaningful insights.
- Data Visualization: The expenses related to presenting data in a visually appealing and understandable format, including the development of data visualization tools, dashboards, or interactive interfaces.

- Data Sharing Platforms: The costs associated with implementing and maintaining platforms or systems for sharing data with internal or external stakeholders, including website development, API integration, and user access management.
- Data Privacy and Compliance: The investments required to ensure data privacy and compliance with relevant regulations, such as implementing data anonymization techniques, obtaining necessary permissions for data sharing, or securing user consent.

Business models associated with data dissemination include:

- Open data: Organizations make their data freely available to the public, often adopting an open data policy or providing data through public portals or APIs. This model encourages transparency and allows external users to access and utilize the data without significant restrictions.
- Subscription-based access: Organizations offer data access through subscription models, where users pay a recurring fee to access specific datasets or data services. This model provides a revenue stream for organizations while ensuring controlled access to data.
- Data licensing: Organizations monetize their data by licensing them to external parties, enabling third-party organizations to access and use the data for specific purposes in exchange for licensing fees or royalties.

Characterizing the costs associated with data collection, storage, and dissemination is essential within the cost-benefit analysis of data management systems. Considering the components and business models associated with these activities helps organizations accurately assess the financial implications of data management. By understanding the costs involved in data collection, storage, and dissemination, organizations can make informed decisions about optimizing their data management strategies, ensuring cost-effectiveness, and maximizing the benefits derived from their data assets.

1.3. Examples of traffic management software

The traffic management software such as SunGuide offers a comprehensive set of tools to the traffic management centers (TMCs), including managing Intelligent Transportation Systems (ITS) devices, incident detection, and assisting with event management. TMCs manage traffic flow along the roadway network by monitoring closed-circuit television (CCTV) cameras, road sensors/detectors, video wall, and other ITS devices, and coordinating with law enforcement agencies, and road ranger service patrols. Since SunGuide is an open architecture-based software, it enables users to manage multiple subsystems. Operators can use the software to perform incident management tasks, obtain real-time traffic data from vehicle detection systems, and display videos from roadside cameras, and then alert motorists using DMS messages and the highway advisory radio. These activities are fairly time consuming. If the roadway network has too few ITS devices, TMC operators must depend heavily on the law enforcement officers and road rangers, spending a significant portion of their time to coordinate. However, if the roadway network has a significant penetration of the ITS devices, then TMC operators could be overwhelmed with information from each of these devices. Installing and managing this system is costly, hence only covers some targeted areas and make freeway incident detection unreliable in many areas (Imani, 2019).

1.3.1 NOEMI (Normalized Operational Equipment Management Initiative)

The Florida Department of Transportation (FDOT) District 5 has many tools and data that can be used to understand and improve traffic operation and safety. One of the tools created is called the Normalized Operational Equipment Management Initiative application 1). NOEMI is designed to simplify the process of planning and budgeting smart intersection projects by compiling, normalizing, and mapping signalized intersection data. The application receives data from the Signalized Intersections Inventory Application (SIIA), the FDOT G1 Tentative Work Program, user-submitted spreadsheets, and manual entry in the application UI.

The NOEMI application's initial view, "Smart Signal Completion", represents each intersection as a pie chart. Within each chart, the light blue portion represents progress that has been made toward making the intersection smart (i.e., "Complete" work), while the dark blue portion represents work that must still be done (i.e., "Incomplete" work). Under current standards, the following five conditions must be met for an intersection to fully meet the definition of "smart":

- The intersection is connected to other intersections in some way, whether through optical fiber, radio link, or other means.
- The intersection collects Automated Traffic Signal Performance Measures (ATSPM) data.
- The intersection collects Intersection Movement Counts (IMC) data.
- The intersection uses an Advanced Transportation Controller (ATC).
- The intersection detects vehicles in every lane of every approach to the intersection, both in advance and at the stop bar.

Accordingly, each satisfied condition causes a 20 percent "slice" to be added to the "Completed" portion of the chart:

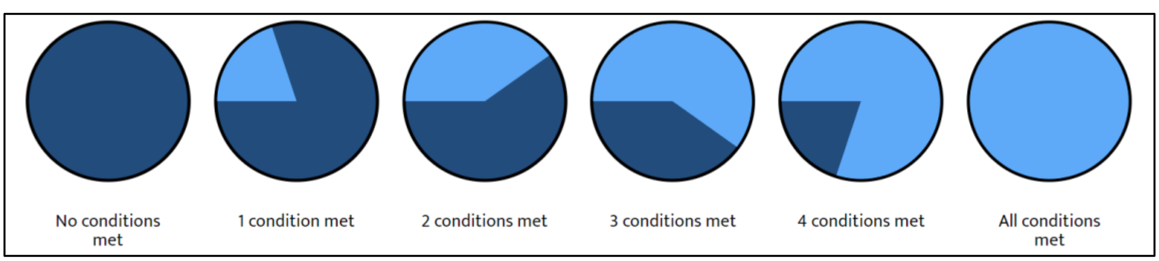

Figure 3. Various Samples of Pie Charts for Signalized Intersections

The application also overlays the existing Routes of Significance and Priority Corridors. Routes of Significance are tied to FHWA Realtime System Management Information System (RTSMIS). Priority Corridors represents the corridors of focus for Florida's Statewide Arterial Management Program (STAMP). The system follows the business rules displayed in its interface to translate data collected and maintained by the Signalized Intersection Inventory Application, or SIIA, into the conclusions shown on the site.

As the user first opens the NOEMI – Smart Signal View application, they can select up to 10 layers to overlay on the base map. The 10 layers that can be overlayed are:

- Municipalities – Layer which shows the GIS boundary of each municipality.
- Strategic Intermodal System – Layer which shows a network of high priority transportation facilities that seamlessly flows from one mode to the next with the goal of providing the highest degree of mobility for people and goods.
- FDOT Fiber Optic Network – Layer which shows location of fiber optic cables.
- Routes of Significance – Layer which shows the routes in Orlando Metropolitan Area based on the criteria in Table 2.
- Detour Routes – Layer which shows the detour routes.
- ICM Implemented Routes – Layer which shows routes that integrate management of freeway, transit, arterial, and parking systems within a corridor using ITS technologies and innovative practices.
- Pepwave Communications – Layer showing the locations of Pepwave (wireless router).
- Evacuation Routes – Layer shows the evacuation routes that may be utilized in the event of an emergency.
- Event Management Routes - Layer shows the event management routes.

- Wrong Way Driving Detection – Layer showing the locations of wrong way driving detection devices. Table 1 below presents routes of significance selection criteria.

Table 1 Routes of Significance Selection Criteria

Parameters	**Criteria**
Roadway Safety	Roadway safety issues include crash rate, crash frequency, etc. Does the route have more than county average crash rate?
Environmental Safety Events	Does this route experience environmental safety events including floods, fog, etc.?
Traffic Volume	Is AADT greater than 50,000 or a range defined by the region?
Congestion	Does this route have recurring or non-recurring congestion?
Economic Productivity	Is this a major economic corridor?
	Is it defined as a route that the overweight/over height permits would allow a vehicle to travel?
	Is this a route requiring CVO permits to travel?
	Is this route with more than 10% of truck AADT? Or define per your requirements.
	Does this route serve major public venue/facility?
Severity and Frequency of Congestion	Does this route experience frequent and severe congestion?
Diversion Route or Evacuation Route/Public Safety	Is this corridor used as diversion or evacuation route?
ITS Infrastructure	Is there ITS infrastructure in these corridors - CCTV, Bluetooth readers, etc.?
	Is there local agency agreement to access CCTVs?
Corridor Connectivity	Does this route connect to major interstates or limited access state highways?
Regional Connectivity	Does this route connect major cities?

Note: AADT = Average Annual Daily Traffic; CVO = Commercial Vehicle Operations; CCTV = Closed Circuit Television

In addition to the various layers a user can overlap to the base map. The user can apply many filters that can narrow down the specific intersection that meets the requirements that can been inputted. The various filters available to the user is shown in Figure 2.

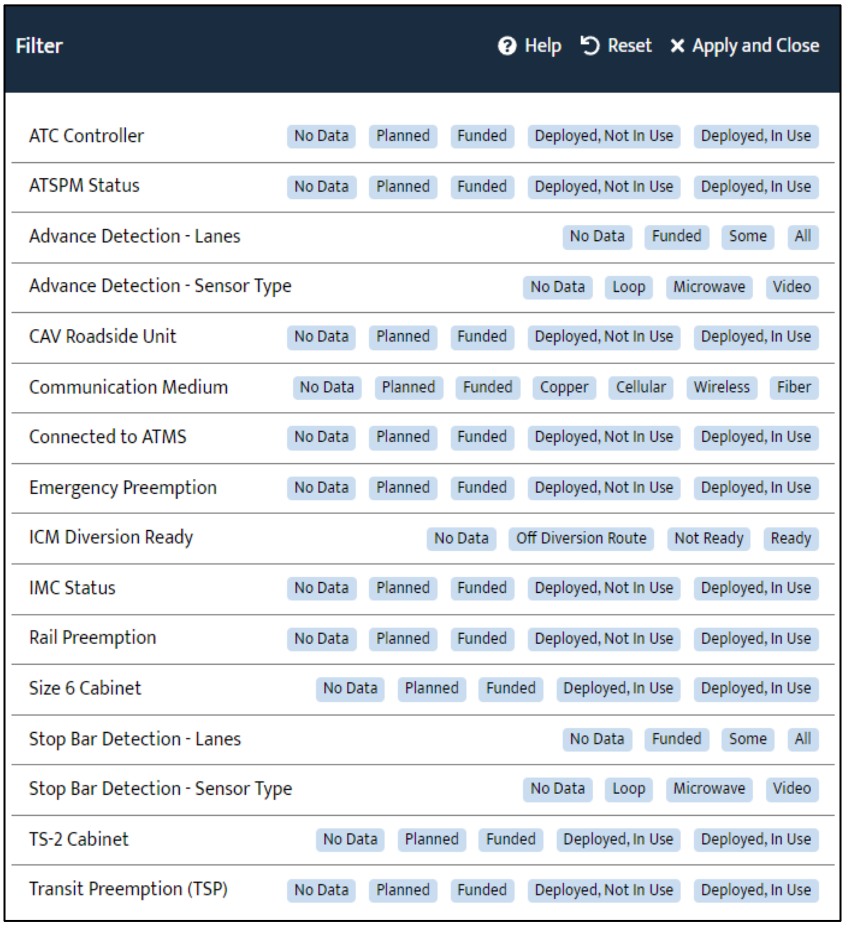

Figure 4. Various Filters That Can Been Applied to Intersections

Below are some definitions of each of the filter:

- ATC Controller – Is an Advanced Transportation Controller (ATC) present?
- ATSPM Status – Does the intersection generate Automated Traffic Signal Performance Measures (ATSPM) data?

- Advance Detection (Lanes) – How many lanes that can detect vehicles in advanced of the intersection?
- Advance Detection (Sensor Type) – What form of technology is used to detect vehicles in advance of the intersection?
- CAV Roadside Unit – Are Roadside Units (RSUs) present to communicate with connected and autonomous vehicles?
- Communication Medium – What technology or material is used to connect the intersection to a network?
- Connect to ATMS – Does a connection exists to an Advanced Traffic Management System (ATMS)?
- Emergency Preemption – Can approaching emergency vehicles (e.g. ambulance, fire, police) influence the signal timing of the intersection?
- ICM Diversion Ready – Can the RICMS remotely configure movement timings for signals on diversion routes?
- IMC Status – Does the intersection generate Intersection Movement Counts (IMC) data?
- Rail Preemption – Can approaching trains influence the signal timing of the intersections?
- Size 6 Cabinet – Is the signal cabinet at least Size 6?
- Stop Bar Detection (Lanes) – How many lanes that can detect vehicles immediately before the intersection?
- Stop Bar Detection (Sensor Type) – What form of technology is used to detect vehicles immediately before the intersection?
- TS-2 Cabinet – Is the signal cabinet compliant with the NEMA TS-2 specification?

- Transit Preemption (TSP) – Can approaching transit vehicles (e.g. buses) influence the signal timing of the intersection?

1.3.2 Automated traffic signal performance measures (ATSPM)

Traffic signal management is a critical aspect of urban transportation systems, aimed at improving traffic flow efficiency and reducing congestion. Traditional traffic signal systems operate on pre-timed signal plans that are fixed regardless of the real-time traffic conditions, which may result in suboptimal performance. To address this issue, Automated Traffic Signal Performance Measures (ATSPM) systems have been developed as an advanced traffic signal control strategy. ATSPM systems use real-time data from various sources to dynamically adjust signal timings based on current traffic conditions, aiming to optimize signal coordination and reduce delays at signalized intersections. In this literature review, we will discuss the data involved in ATSPM systems, the types of reports generated for the users, and studies that have validated the data used in ATSPM systems.

1.3.2.1 Data involved in ATSPM systems

ATSPM systems rely on two main categories of data: traffic data and signal data. Traffic data are collected from various sources, including detectors at signalized intersections, in-roadway sensors, connected vehicles, and other traffic monitoring systems. These data encompass parameters such as traffic volume, speed, occupancy, and other relevant information. They play a crucial role in allowing ATSPM systems to determine the current traffic conditions and make necessary adjustments to signal timing. Signal data, on the other hand, provide information about the traffic signal timings, such as cycle length, durations of green, yellow, and red phases for each signal phase. These data are typically obtained from traffic signal controllers that are connected to the ATSPM system. The signal data is essential for ATSPM systems to dynamically adapt signal timings based on real-time traffic conditions.

PennDOT's unique approach to ATSPM involves incorporating third-party probe data in addition to these traditional sources of traffic and signal data. By leveraging probe data from mobile connected sources such as cell phones, automatic vehicle location equipment, and connected navigation devices, PennDOT aims to evaluate arterial performance on a corridor level. This approach allows for a broader understanding of traffic patterns and performance metrics, enabling more comprehensive analysis and optimization of arterial roadways.

1.3.2.2 Reports generated by ATSPM systems

ATSPM systems provide various types of reports to the users for performance evaluation and decision-making. These reports can include:

- Performance Metrics: ATSPM systems generate performance metrics that quantify the performance of traffic signal operations, such as intersection delay, level of service, and queue length. These metrics provide insights into how well the traffic signal system is performing and help identify areas for improvement.
- Timing Plans: ATSPM systems can generate reports that show the current and historical signal timing plans for each intersection. These reports provide information on the specific timings of green, yellow, and red phases for each signal phase at different times of the day or days of the week.
- Event Logs: ATSPM systems can log events, such as changes in signal timings, detector failures, or other system-related events. These logs can be used to track changes in signal timings, diagnose issues, and assess the effectiveness of signal adjustments.

1.4. Practices and knowledge generated from select DOTs

This report offers a deep dive into the data collection methodologies of different state Departments of Transportation (DOTs), primarily focusing on strategies associated with intersection control and management. Drawing from discussions with state DOT representatives, it unravels intersection prioritization strategies, data collection typologies, data utilization and dissemination policies, and cutting-edge developments in traffic data collection. The successful orchestration of intersections is critical for any transport network's seamless operation, and various DOTs leverage distinctive strategies for this purpose. The essence of these strategies is data derived from a plethora of sources, driving decision-making and traffic management technologies' deployment.

To get an understanding of how other DOTs are dealing with data management, various meetings were scheduled to get more insights into their state of practice. Below is a list of questions that were initially asked, but more questions were asked depending on how advanced the DOT was in data management.

- What are the main tools and data that your district has and uses to manage arterials?
- How do the districts within your DOT store data?
- Which technologies are primarily used to collect the data?
- Are there data applications developed and available to the public?
- Do you collect everything in house or also use vendor data?

1.4.1 Minnesota DOT

The first meeting was held with the TSMO Director of Minnesota DOT (MnDOT). It was found that MnDOT does not generally practice defining smart intersections, as the five criteria for a smart intersection in FDOT District 5. There are some intersections that are connected to a centralized hub, which the DOT can get the data from. These intersections do have ethernet connections and fiber networks, but there was not a GIS map showing the locations of these connections, networks, or intersections. MnDOT does not prioritize any intersection over another in terms of data collection, all the intersections are collecting the same data.

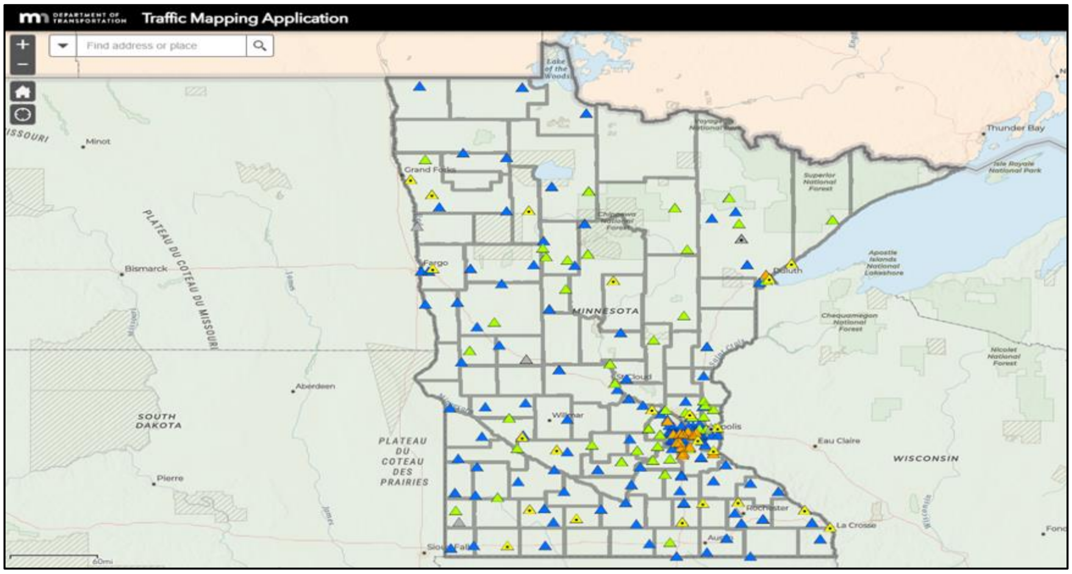

Figure 5. Map of Minnesota Showing the Automatic Traffic Recorders

Currently, MnDOT is not opening the turning movement counts data to the public, but there are plans to open the data to the public in the future. In terms of the pedestrian detection data, MnDOT used to have pedestrian data when they worked with Utah Department of Transportation (UDOT), but currently does not collect these data. MnDOT stated that "UDOT is at the forefront of this [Pedestrian Detection] and they're the ones who have been producing and modifying this open-source software [ATSPM]". MnDOT does not use any real-time data in any of the applications, but they have access to the data.

One of the probe vehicles data that MnDOT utilizes is Iteris ClearGuide™. The collected data are primarily used for monitoring arterial roadways. Another type of data used by the MnDOT is StreetLight, however this is typically primarily used for planning. One of the challenges that the team faces is lack of funding to subscribe to many of the third-party applications that collect and provide the data. Another challenge is related to the StreetLight data. Since the data are primarily based on applications and smart phones and because the users are becoming more security conscious, the scale of the data and their quality have changed. Closed-circuit television (CCTV) video data were initially thought as appropriate method to collect turning movement counts, but since the traffic management center may need to use them for incident management, such approach may introduce some problems.

MnDOT does record the videos from the PTZ camera they have, but the videos are only kept for two to three days, due to the amount of storage space needed for videos that are recorded in 1080P or 720P. Having these recordings allows MnDOT to clearly evaluate road incidents. Since MnDOT records the videos from the PTZ camera and they are required by law to provide the videos if requested, they currently receive around 1,800 requests for the PTZ videos a year.

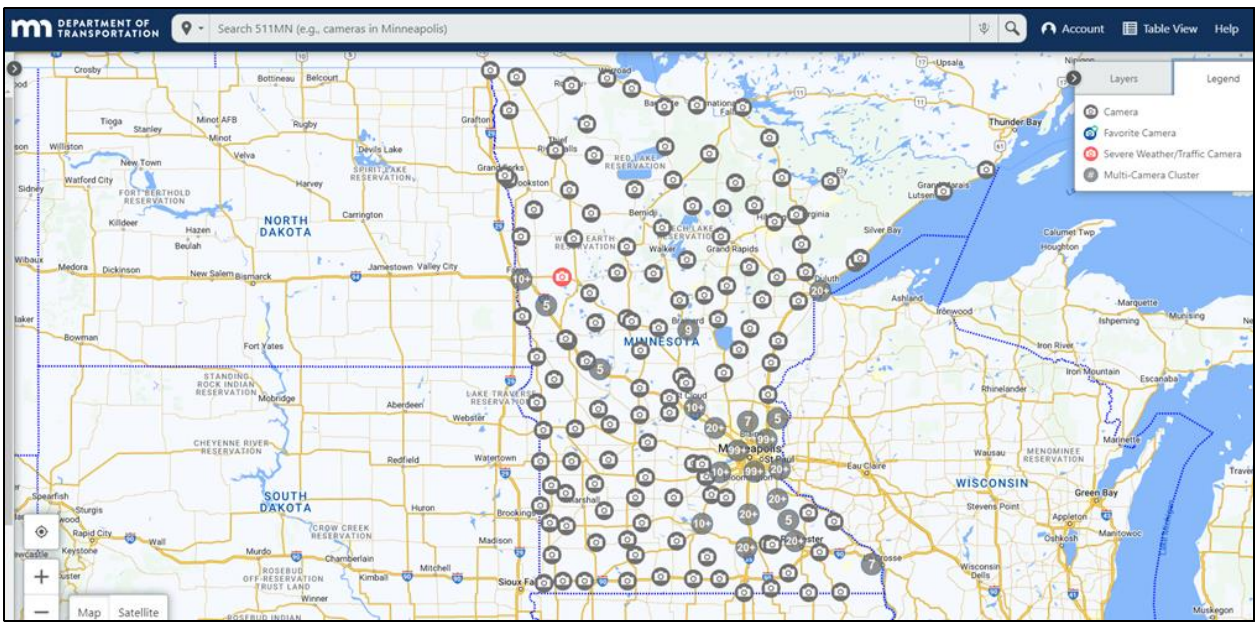

Figure 6. Traffic Cameras (Minnesota)

1.4.2 Colorado DOT

The second meeting was with the traffic operations and technology manager for the Colorado Department of Transportation (CDOT), who has been working in the transportation industry for 24 years and has experience in various areas such as design, construction, materials, estimating, and project management. He has also been involved in connected autonomous vehicles and currently works in traffic operations at CDOT. His group conducts field studies and management, and he is involved in statewide efforts such as training and work zones. He works with the TSMO (Transportation Systems Management and Operations) group and is involved in funding for TSMO applications, ITS (Intelligent Transportation Systems), and limited mobility. CDOT's TSMO group was formalized in 2016 but was dispersed in 2019, and now they are working towards putting together a new TSMO Executive Governance Council to bring it back together in terms of collaboration and coordination.

CDOT is organized into five regions instead of districts. Each region is responsible for arterial management, which includes signal timing and coordination with the Council of Governments. In Denver, the Denver Regional Council of Governments (DRCOG) handles a lot of the arterial management due to the complexities of coordinating traffic flow through multiple cities and counties along a single corridor. For example, one corridor, Wadsworth Rd., goes through six different counties and seven different cities, each with a different traffic engineer. Denver Regional Council of Governments (DRCOG) plays a significant role in managing traffic flow in such areas. CDOT mainly relies on the DRCOG for arterial management due to the cities' jurisdiction over signals on their corridors. CDOT helps put in the signals, but the cities operate and maintain them. DRCOG gathers the data through their instruments and passes them along to CDOT, which has a data management group responsible for documenting where the data are stored and who the owner is. The data management group is starting to work on a data governance plan. CDOT mainly uses speed and volume data to look at bottlenecks and congestion.

Signal data collection is a relatively new area for CDOT, and CDOT is beginning to capture signal data in different ways. They plan to put out LiDAR units to collect the data, and they have a pilot starting in a month to collect bike and pedestrian data as well as the vehicle speed and data at select intersections. They currently use automatic traffic recorders, microwave radar units, and cameras to collect data, and while cameras are mainly used for spotting road incidents and crashes, the images are not used for data analytics or used by computer vision algorithms. They use INRIX, Wejo data, and Streetlight data to evaluate traffic. They also rely on the third-party data as it would require the ITS group to expand if more in-house data were collected. They collect various data types such as stormwater, air programs, and fire data, but they don't integrate them with third-party data sources. They are working on a universal Colorado TMC segmentation system to make it easier to receive real-time data.

1.4.3 Utah DOT

In the realm of traffic data collection and application, Utah's Department of Transportation (DOT) leads the way with innovative strategies and forward-thinking partnerships, which has driven notable advancements in the implementation of smart intersections and connected vehicles. This report dives into Utah DOT's data-centric methods, its exploration of emerging technologies, and the ways in which it leverages the data it collects to enhance intersection management and the overall traffic flow.

Utah DOT primarily employs radar detection technology for both signal detection and freeway mainline detection. While other technologies like in-pavement loops are used in select locations, particularly on ramps, the preponderance of their detection infrastructure relies on radar. The data procured from these systems are integrated into an in-house system, the Performance and Event Management System (PEMS). Further, Utah DOT leverages a system called Clear Guide, which functions as an all-encompassing platform that combines internal and external detection data into a single cohesive system.

Interestingly, Utah DOT phased out camera detection, a decision spurred by the limitations of camera technology in extreme weather conditions such as snow and fog. Instead, they are considering the implementation of Lidar technology. This innovative technology provides a 3D rendering of detected objects, enabling it to measure speeds, presence, and even the height of vehicles, which is particularly useful for detecting vulnerable road users such as pedestrians and cyclists.

Looking towards the future, Utah DOT has been progressive in the realm of smart intersections and connected vehicles. As early as 2017, they started deploying Dedicated Short-Range Communications (DSRC) units. However, keeping pace with the evolution of technology, the DOT has shifted towards a technology known as CV2X, or Connected Vehicle Detection and Applications. The Utah DOT achieved this technological transformation through strategic collaborations with firms like Panasonic.

CV2X equipment has been deployed along various corridors and routes. The primary use of these units is in cooperation with the transit agency for transit signal priority, enabling a more efficient transit system. Moreover, this technology has been incorporated into the operations of snowplows, allowing for signal preemption and thereby facilitating the plows to function without interruption.

Regarding the data sharing policies, Utah DOT promotes openness and transparency. While they impose no external restrictions on data sharing from their systems, they do maintain certain self-imposed limitations on the sharing of specific types of data. This balance ensures data protection while promoting cooperative problem-solving and research.

In conclusion, the contrasting strategies employed by different state DOTs highlight the fundamental importance of data collection in achieving effective intersection management. With technologies such as radar and Lidar becoming more prevalent, the future of intersection management is data-driven, leaning heavily on the implementation of sophisticated technologies and systems.

1.4.4 Bellevue DOT

As cities worldwide grapple with the challenges of burgeoning urban populations and the consequent strain on traffic management, this case study offers a compelling exploration of an advanced traffic management system. This system uniquely employs artificial intelligence (AI) and camera data to drive strategic optimization of traffic signals, with a strong emphasis on bolstering pedestrian safety.

At the heart of this system is a data collection strategy that leverages video footage obtained from cameras stationed at intersections across the city. These cameras serve dual purposes– they detect the presence of pedestrians and also track the time taken by each pedestrian to cross the intersection. One of the striking aspects of this approach is its broad inclusivity; the system does not discriminate between different types of pedestrians, such as children, adults, or elderly individuals. This ensures that all pedestrians, regardless of age or physical ability, are treated equitably, with their safe passage across intersections being the foremost concern.

The AI technology incorporated within the system creates bounding boxes around pedestrians captured in the video footage, playing a pivotal role in their detection. This feature aids in optimizing traffic signal timings in real-time, allowing for intervention and adjustments as necessary to ensure safe pedestrian crossing, which has delayed conflicting traffic phases, underscoring the system's commitment to protecting the most vulnerable road users. In a pilot project, which used video analytics to evaluate footage from intersection traffic cameras, showed a 42% reduction in vehicle-pedestrian close calls after pedestrian intervals were introduced.

Based on the findings, Bellevue began a gradual expansion of the intervals to 41 downtown intersections.

Camera coverage within this traffic management system is extensive, with approximately five cameras installed at each intersection. Remarkably, within a span of just three years, the system has achieved nearly 100% camera coverage of all signalized intersections, translating to over 220 intersections.

Complementing the camera data, the system also taps into third-party data sources. A notable contributor is Iteris ClearGuide, which supplies HERE data. These data are instrumental in evaluating traffic patterns over time and gauging the impact of traffic calming measures. Furthermore, collaborations with T-Mobile and Qualcomm are in progress, with the intent of exploring cellular vehicle-to-everything (C-V2X) solutions. The aim here is to amass data between nodes and harmonize them with the intersection data to streamline and enhance traffic management.

Drone technology also forms a part of the system's data collection arsenal. However, the primary application of drones is for forensics at crash scenes, offering valuable insights to improve safety measures. Continuous monitoring at multiple locations using drones is currently deemed impractical due to the associated operational challenges.

Despite its considerable strengths, the traffic management system acknowledges room for improvement. Key areas include better differentiation between various types of road users, such as bikers, scooter riders, or wheelchair users, and enhancing the AI's capabilities to independently intervene when conflicts are detected. Additionally, the system is exploring other data sources such as mobile LIDAR data and TomTom data, though these have not yet been actively pursued.

In conclusion, this advanced traffic management system embodies a forward-thinking approach to enhancing traffic signal optimization and pedestrian safety. It showcases the transformative potential of AI, camera data, and the integration of diverse data sources in the realm of traffic management. However, it also recognizes the need for future refinement, particularly in differentiating between road user types more effectively and bolstering the system's capability for autonomous conflict resolution.

1.5. Best data practices

This section encapsulates a series of comprehensive discussions conducted with the Florida Department of Transportation (FDOT) District 5 team, who are entrusted with the onerous responsibility of managing traffic and promoting urban development amidst a rapidly changing technological landscape. In an era marked by the data-driven decision making, the task of implementing robust data management strategies to enhance traffic management has never been more imperative.

During the meeting, various crucial facets like managing the sheer volume and variety of data, the necessity for real-time data analysis, and adapting to constant changes in system configurations were discussed. A significant challenge identified was balancing data granularity with the feasibility of storage. Despite these complexities, recognizing the potential benefits that can be harnessed from improved traffic signal performance and efficient planning for urban growth. The following sections delve into these topics in detail, providing an illuminating perspective on the opportunities and challenges inherent in managing and leveraging vast data resources.

1.5.1. The dangers and potential of vast data

Amid the rapidly changing technological landscape, the FDOT District 5 team grapples with the task of managing an extensive volume of data. Daily, the team deals with approximately 3.5

gigabits per second of the video data alone, which poses significant challenges from the data storage perspective. Storing these data for an extended period is not only economically burdensome but also leads to an inundation of requests for specific information. This includes requests from various stakeholders, such as police departments and lawyers, seeking video footage from specific intersections at certain times to investigate incidents like car crashes.

Yet, the abundance of data holds an enormous potential. In an intriguing case, it could be possible to conduct anomaly detection using the publicly available feeds and storing data related to these anomalies. As a result, legal professionals may then use this information for their cases, proving that with the right approach, valuable insights can be gleaned from the seemingly overwhelming data streams.

Indeed, a prevalent sentiment within the FDOT team is that similar techniques could be employed to turn the challenge of the vast data into an opportunity. However, limitations in resources and capabilities currently prevent the team from building their own system to harness these possibilities. As a result, the team is more inclined towards a service-based model, where they offer their data to other entities and allow them to develop accurate systems for the FDOT team as a service.

The above discussion underscores the intricate relationship between the potential and the challenges associated with the vast amounts of data. Though managing such data can be daunting, the right approach can transform them into invaluable resources.

1.5.2. The shift towards real-time and historical data

In the realm of transportation data analysis, there is an observable shift towards integrating real-time data with historical data. The FDOT team finds that different branches of data are essential for different purposes, and that the interplay between these branches can yield valuable insights.

Real-time data, which can be immediately used for decision-making and forecasting, can also be stored for historical purposes, thereby serving multiple offices and functions. The granular nature of this real-time data facilitates system training and allows for accurate time series projections sensitive to new changes. However, the FDOT team faces challenges with incorporating real-time changes into demand models in a timely manner, particularly for significant infrastructure developments.

For instance, take the case of a new park of Universal Studios. Despite being aware of the park's construction and its potential impact on traffic flow, the team projects that it would take a substantial amount of time before these data are accurately incorporated into the demand models. Such delays could lead to unexpected congestion and frustration among the public and elected officials.

Conversely, leveraging technology such as ATSPM data to observe the changes in traffic patterns within weeks of the park's opening is found to have an enormous potential. These real-time data could be incorporated into machine learning models, which would then accurately project the traffic situation for the upcoming years. Such a system could also be beneficial in identifying and reacting to smaller-scale developments like the opening of new stores that impact traffic patterns.

The team aspires to using real-time data not only for re-timing signals but also for planning. They believe that minor investments in intersection modifications based on real-time data could yield substantial benefits. Yet, the actualization of this approach continues to be a challenging endeavor.

1.5.3. Challenges in configuration data storage and data security

During the discourse, an additional imperative concern was spotlighted, namely, the storage of historical Automated Traffic Signal Performance Measures (ATSPM) data and the associated configuration data. The team frequently encounters dilemmas pertaining to the precise location and operational status of specific traffic management apparatuses, such as flashing arrow indicators, on a statewide scale. As it stands, there is an absence of a unified statewide repository for this configuration data, impeding prompt and accurate response to these inquiries. Further, the lack of a holistic, multi-dimensional data set— one that captures not just ATSPM data but also safety data —may pose a potential impediment. A comprehensive data set, in this context, refers to a broad-spectrum data source that integrates the ATSPM data with safety data, thereby facilitating deeper insights and stronger correlations between traffic management strategies and safety outcomes.

An additional point of discussion that arose in the meeting relates to the storage of Personally Identifiable Information (PII). The team highlighted that the PII stored in their databases predominantly originates from MAC address information, preserved only when matches occur, and from details captured by license plate readers. Despite the concerns often associated with the PII storage, the experts reassured that this does not pose as substantial a risk as it may seem. Moreover, they acknowledged that video data, which could potentially capture legible license plates and which some stakeholders might consider as PII, is indeed stored, albeit for a limited duration.

Building on the previously discussed issue of Personally Identifiable Information (PII) storage, the team acknowledges the broader subject of data security. The importance of this topic becomes particularly noticeable given the significant influence these systems exert on decision-making processes. They underscored the need for robust data validation procedures and the essentiality of preserving the integrity of their "systems of truth." It is critical to recognize when external entities have introduced information into the system, and comprehending the data's provenance is paramount to avoid any misinterpretations or mishandlings. They advocated for rigorous change tracking and strict maintenance of information sources. The team also noted that a statewide consensus and collaboration on these matters could significantly enhance the overall data security landscape.

1.5.4. Navigating the complexities of data storage

While addressing the challenges surrounding data storage, the FDOT District 5 team conveyed an interesting perspective. Initially, the idea of storing duplicate data may seem unnecessary, but the team highlighted the benefits of doing so. For instance, storing both: the original and the modified data is valuable when identifying errors, validating data, or enforcing contracts. Contrary to the common belief, the cost of data storage for such tabular data is minimal compared to its benefits.

Data storage is inexpensive when dealing with tabular data. However, it becomes significantly more costly when storing video feeds due to the extensive storage requirements and limited compression options. Nevertheless, the team stressed the worthiness of the investment, noting that the benefits derived from this data management strategy far outweighs the associated costs.

Moreover, the team brought to light the complexities of presenting large amounts of stored data. While Application Programming Interfaces (APIs) work well for transferring small amounts of real-time data, they are not as efficient when it comes to managing voluminous stored data. Thus, the team is exploring cloud migration as a potential solution.

Nonetheless, the team emphasized the need for a clear use case before transitioning to the cloud. States that have moved to the cloud without a defined purpose have experienced challenges during the migration process. The FDOT District 5 team, in its quest for efficient and effective data management, is carefully considering these complexities before making any strategic shifts.

1.5.5. The critical importance of data provenance and security

A prominent theme that surfaced was the crucial role of data provenance and security. The team emphasized the necessity of knowing when and how the data have been changed, asserting that the absence of such information can result in valuable details being overlooked.

In continuation of the discourse, the representatives reiterated that while apprehensions about Personally Identifiable Information (PII) might arise, these are often misplaced. They clarified that the PII data stored in their databases primarily originates from two sources: MAC address information, which is preserved only when matches occur, and details obtained from license plate readers. Moreover, they acknowledged that video data, potentially capturing legible license plates and perceived by some stakeholders as PII, is another component of the stored information. Regardless of the source, the team assured that all these forms of data are scrupulously managed, thereby reinforcing the importance of stringent data handling practices.

Data provenance is also critical when other parties introduce information into the system. Maintaining a sense of control and awareness of such external inputs is key to maintaining data integrity. The FDOT District 5 team is highly aware of the need to keep track of all changes made to the data. This vigilance ensures that they maintain accurate records and can respond appropriately when an issue arises.

Simultaneously, the team highlighted the importance of data security, particularly in a world where data-driven decision making is increasingly becoming the norm. As more stakeholders rely on these systems to make critical decisions, it is crucial to ensure that the data and the systems that house them are secure and valid. As a result, the FDOT District 5 team places high importance on system security and data validation to mitigate any potential risks.

1.5.6. The challenges and solutions in data storage and presentation

A particular challenge that FDOT District 5 faces is related to the storage and presentation of large volumes of data. It was highlighted that while storing duplicate records can seem redundant initially, it holds substantial value in the long term. This practice enables diagnostic capability, allows quality measures and validation, and provides a base for contractual enforcement. While data storage in terms of tabular data is inexpensive, video storage proves to be a significant cost. Yet, the cost of the data could be lesser than the cost of storage, which could justify the investment.

Another challenge arises in the form of how to best present these data to partners, such as universities. Application Programming Interfaces (APIs) have proved to be efficient for transferring small amounts of real-time data but not for moving large amounts of stored data. Therefore, the team has been moving towards cloud storage for providing such functionality. However, the representatives warned against migration to cloud without a clear reason, citing experiences of other states struggling with such transitions.

In the quest for efficiency, the FDOT District 5 team applies compression techniques for long-term storage where possible. Nonetheless, they concede that compression opportunities are limited, particularly for the video feeds which are already compressed to a high degree.

1.5.7. Conclusions: Embracing the future of data collection in transportation planning

The Florida Department of Transportation's District 5 team demonstrates a forward-thinking approach towards incorporating the utility of the real-time data in modern transportation planning. They are uniquely pioneering the merging of traditional transportation planning methods with contemporary data-driven strategies, which promise to revolutionize the field.

In a landscape where historical data were previously dominant, the District 5 team recognizes the value of real-time data and how they can complement historical data for a more accurate, predictive, and responsive transportation planning process. The team has proactively harnessed the power of data, applying it to complex problems such as tracking traffic patterns around new developments, adjusting signals based on traffic demands, and accurately predicting future transportation needs.

The team also appreciates the importance of maintaining data quality and integrity, taking thoughtful precautions in data collection and storage. By storing multiple records, they safeguard against potential inaccuracies, provide means for diagnostics and quality checks, and ensure that their original data remains untampered. The FDOT District 5 team not only collects the data, but also emphasizes maintaining their "provenance," or history of changes, acknowledging the criticality of traceability in data-driven decision-making processes.

Moreover, the District 5 team is strategic in their approach to data presentation, considering the best ways to share large volumes of data and making the valuable transition to cloud storage for this purpose. In doing so, they display an awareness of emerging trends in technology and data management, effectively marrying it with their traditional practices.

1.6. Summary

A Data Management Platform (DMP) is crucial for transportation agencies to collect and utilize audience data from different sources, enabling them to enhance operations, make informed decisions, and comply with regulations. By leveraging a well-structured DMP, transportation agencies can improve decision-making, efficiently manage resources, provide better public services, and ensure regulatory compliance. In the realm of Transportation Systems Management and Operations (TSM&O), data-driven strategies play a significant role, with real-time data supporting TSM&O strategies, performance measurement, and procurement processes. Extensive research has been conducted to identify best practices and implementations of data-driven strategies, performance measures, and procurements at various levels, providing valuable insights for transportation agencies.

From the Department of Transportation (DOT) meetings from the Minnesota Department of Transportation (MnDOT), Colorado Department of Transportation (CDOT), Utah Department of Transportation (UDOT), and Bellevue Department of Transportation highlighted several important points. MnDOT currently lacks a defined practice for smart intersections but has some connected intersections with data collection capabilities. While data collection is uniform across all intersections, there are plans to make turning movement counts data accessible to the public in the future. Limited funding and reliance on third-party applications present challenges for data collection and utilization. CDOT is relatively new to signal data collection but employs various methods such as automatic traffic recorders and cameras. They are exploring the use of LIDAR units for improved data collection. CDOT also utilizes third-party data sources like INRIX and Wejo for data evaluation and is working on a universal Colorado Traffic Management Center (TMC) segmentation system for real-time data integration. UDOT leads in innovative traffic data collection strategies and partnerships. They primarily use radar detection technology and have phased out camera detection due to the weather limitations. UDOT has been proactive in deploying Connected Vehicle Detection and Applications (CV2X) technology for transit signal priority and snowplow operations. They promote openness and transparency in data sharing with limited self-imposed restrictions. The Bellevue Department of Transportation employs an advanced traffic management system that utilizes AI and camera data for signal optimization and pedestrian safety. Cameras detect pedestrians and adjust signal timings in real-time. The system aims for comprehensive camera coverage of intersections and integrates third-party data sources like Iteris ClearGuide and HERE data. Collaboration with T-Mobile and Qualcomm is ongoing to explore cellular vehicle-to-everything (C-V2X) solutions. Although drone technology is used for crash scene forensics, it is not currently used for continuous monitoring.

The Florida Department of Transportation (FDOT) District 5 showed significant progress in data collection, storage, and processing for their traffic management system. Through a meeting with the district, the team gained insights into the system's design and framework, focusing on the pathway from detector to data storage. The analysis reveals that the system utilizes multiple data sources, including controllers and detectors, with each controller storing local information in specific file formats. Efforts are being made to enable on-premises decoding for all controllers, ensuring efficient data conversion. The decoded data are then pushed into Kafka, a distributed streaming platform, where they are made available to various endpoints, including cloud-based instances and regional integrated corridor management systems. The system also incorporates cloud-based services from different providers, offering distinct functionalities such as analytics and error detection in data streams. Additionally, the system features a local data repository called Sun Store, which serves as a reliable source for accessing historical data, facilitating research projects and public requests.

FDOT District 5's traffic management system demonstrates significant advancements in data collection, processing, and storage. By leveraging multiple data sources, decoding processes, cloud-based services, and a local data repository, the system ensures data availability, accuracy, and accessibility. The utilization of Kafka as a streaming platform and the integration of various cloud-based services further enhances the system's capabilities. Continued improvements in the data handling and analysis are expected to enhance traffic management, leading to an improved urban mobility and transportation efficiency in the future.

Chapter 2

2.1. Introduction and overview

The Florida Department of Transportation (FDOT), recognizing the critical role of effective traffic management in ensuring the safety and efficiency of its roadway initiated a project aiming to examine traffic systems and their management across all seven districts.

In this chapter we aim to gather and analyze detailed survey data from each district, focusing on their current practices, challenges, and innovations in traffic management. This data is used to gain insights and identify best practices that can be applied statewide. This component involves evaluation of the existing arterial management systems, exploration of data sources and management techniques, and the assessment of collaborative efforts with other agencies.

The primary objectives of this initiative are as follows:

- To conduct a thorough evaluation of survey responses from each district and identify effective data and management strategies.
- To recommend data management techniques that enhance accuracy and completeness, thus facilitating better decision-making.
- To achieve uniformity in data collection and utilization across all districts and improve the efficiency and consistency of traffic management strategies.
- To utilize the gathered data for a comprehensive analysis and provide a state-wide perspective on traffic management strategies.

The survey is segmented into eight parts, each addressing a unique aspect of traffic management. Accompanying each part in this report is a visualization created from the survey results, providing a clear and concise graphical representation of the findings. The full survey is included in the appendix section for reference.

Here's a breakdown of each part:

1. Respondent information: This part gathered essential information about the survey participants, including their names, titles, and affiliations. It aimed to understand the diverse range of professionals contributing to traffic management across the districts.
2. Existing arterial management systems and infrastructure: This section was designed to assess the current state and efficacy of arterial management systems in place. It inquired about the quality of Intelligent Transportation Systems (ITS) equipment and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation. Visualization under this section (Figure 7 & 8) reflects the variance in equipment quality and ATSPM status across districts.

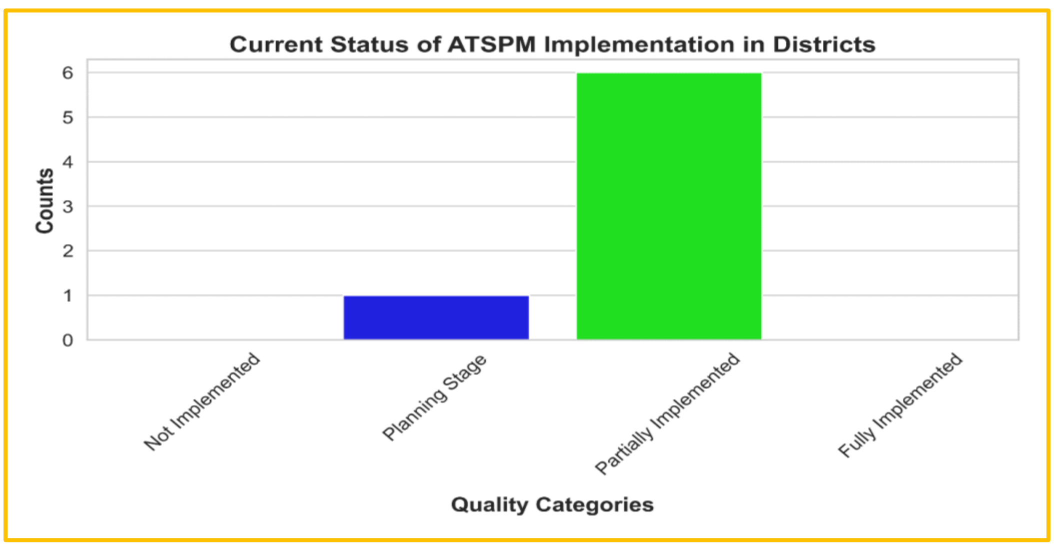

Figure 7. Current Status of ATSPM Implementation by Districts

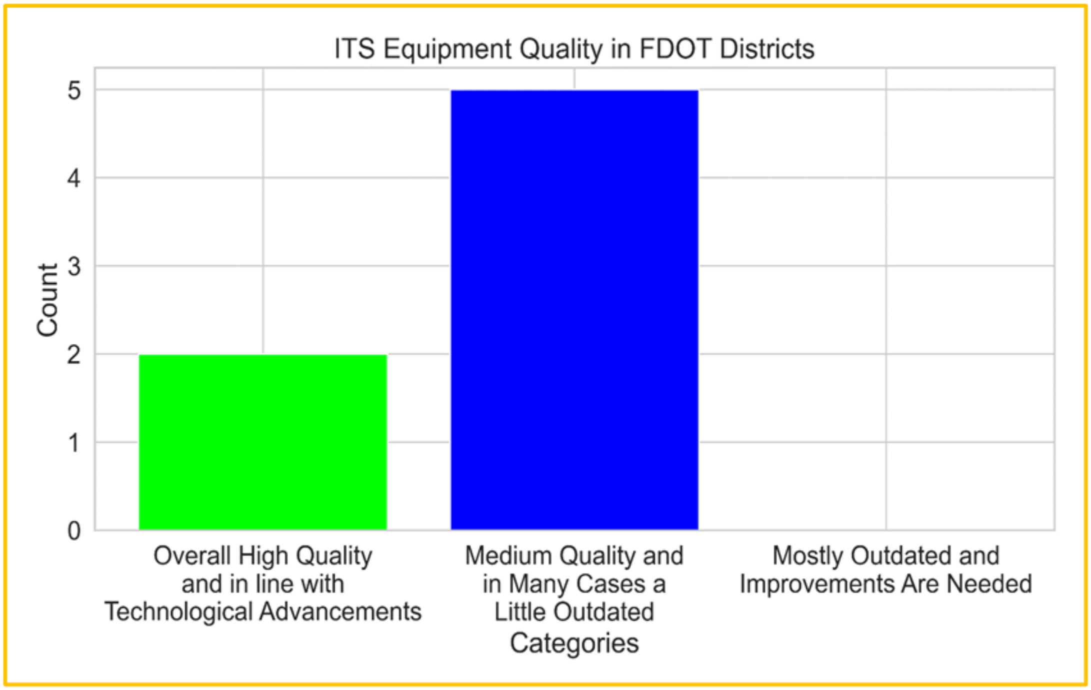

Figure 8. ITS Equipment Quality in Districts

3. Data sources and management: This part explored the types and sources of data used in each district, their accessibility, and the confidence level in the reliability of these data sources. Visualization here (Figure 9) illustrates the diversity and reliability of data sources used in traffic management.

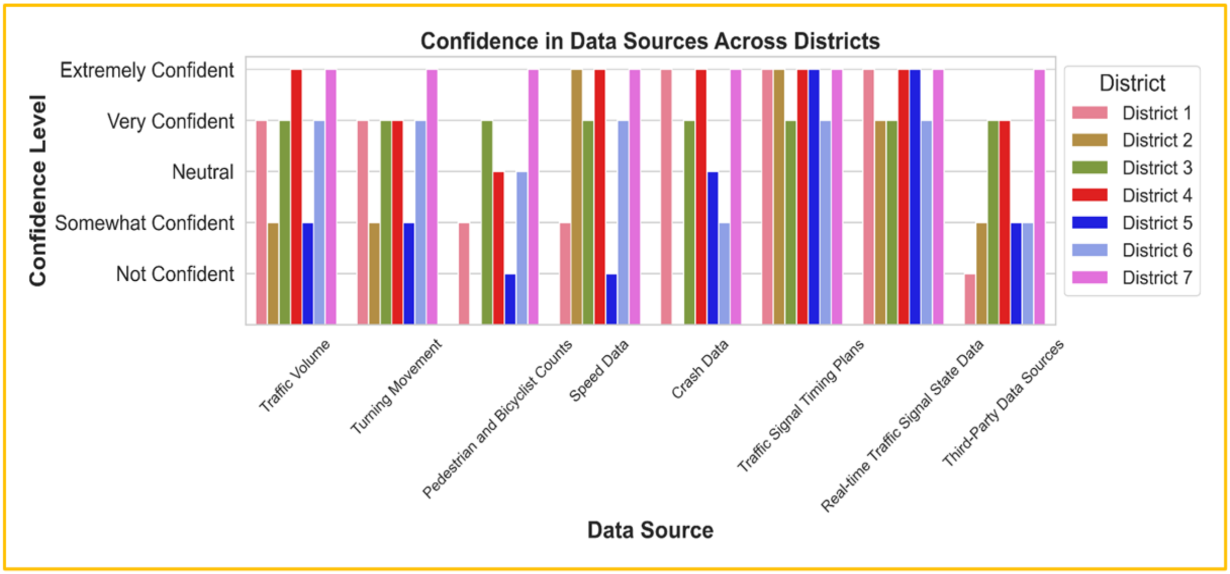

Figure 9. Confidence in Data Sources across the Districts

4. Agencies involved: Focusing on partnerships, this section evaluated the nature of collaboration between districts and other agencies, including law enforcement and planning organizations. Visuals in this section (Figure 10) highlight the extent and nature of these collaborations.

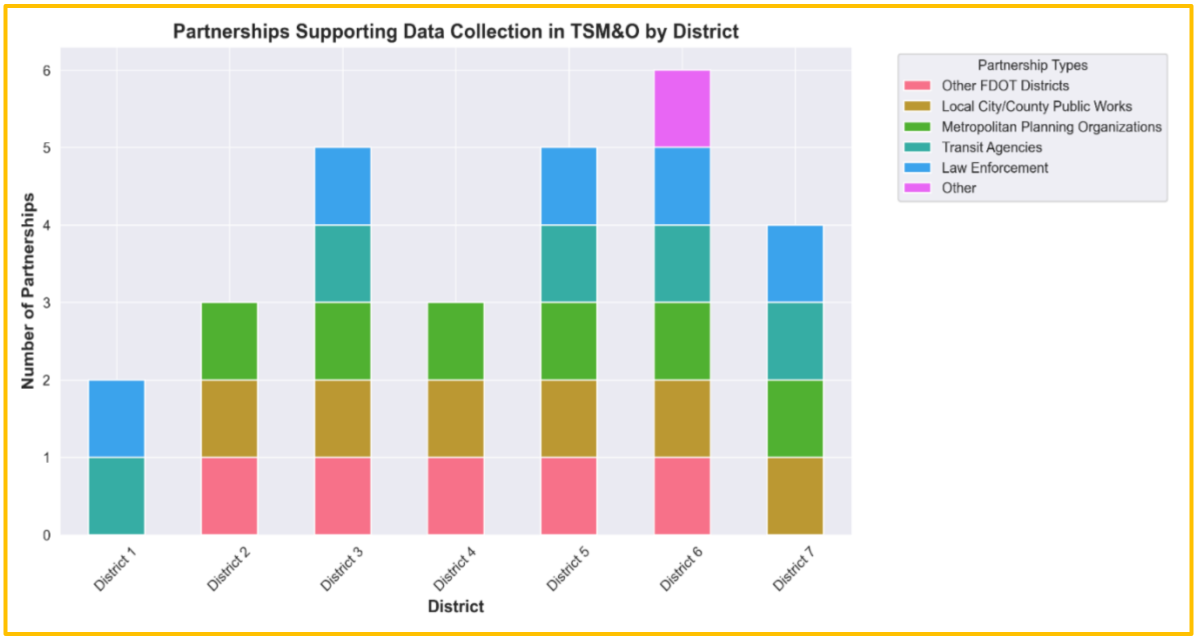

Figure 10. Partnerships Supporting Data Collection in TSMN&O by Districts

5. Uses of data (performance measures and decision support systems): This segment investigated how data influences both short-term and long-term decision-making processes, including the evaluation frequency of performance measures. The accompanying visualization (Figure 11) encapsulates the use of data in decision-making across districts.

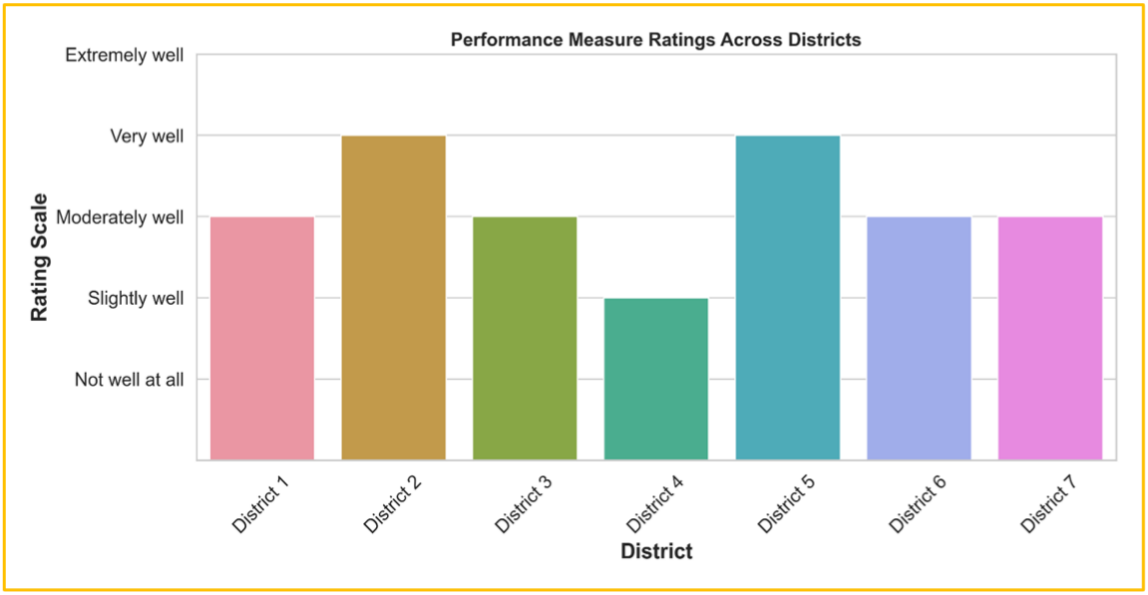

Figure 11. Performance Measure Ratings Across Districts

6. Minimum requirements: Surveying the standards for data accuracy and granularity, this part delved into how districts establish, review, and adhere to these requirements.
7. Non-traditional data sources: This part examined the adoption and effectiveness of unconventional data sources like drone data and Bluetooth detectors. The visualization (Figure 12) shows the usage and usefulness associated with these data sources.

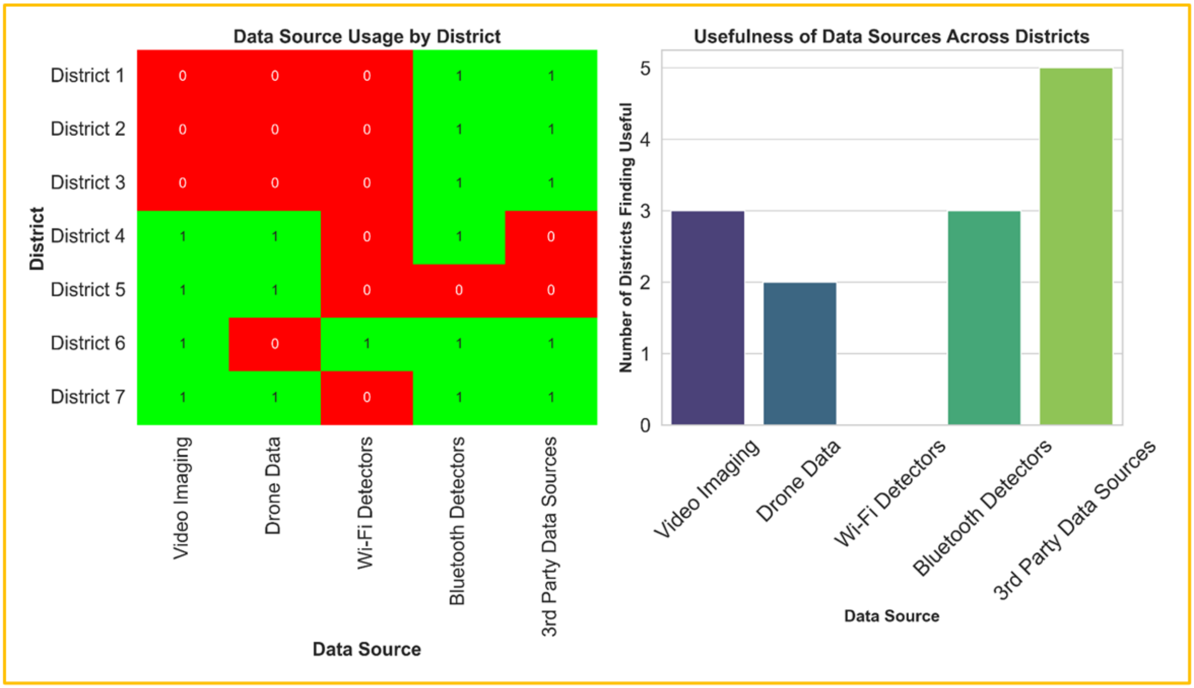

Figure 12. Data Sources Usage by District (the data sources used ('1', in green) and not used ('0', in red) by each district) and Usefulness of Data Sources across District

8. Coordination, statewide system, failure detection, costs, and vendor selection: The final part assessed the systems and procedures in place for detecting failures or issues in transportation management. The visual representation under this section (Figure 13) provides insights into the methods and effectiveness of failure detection and issue resolution.

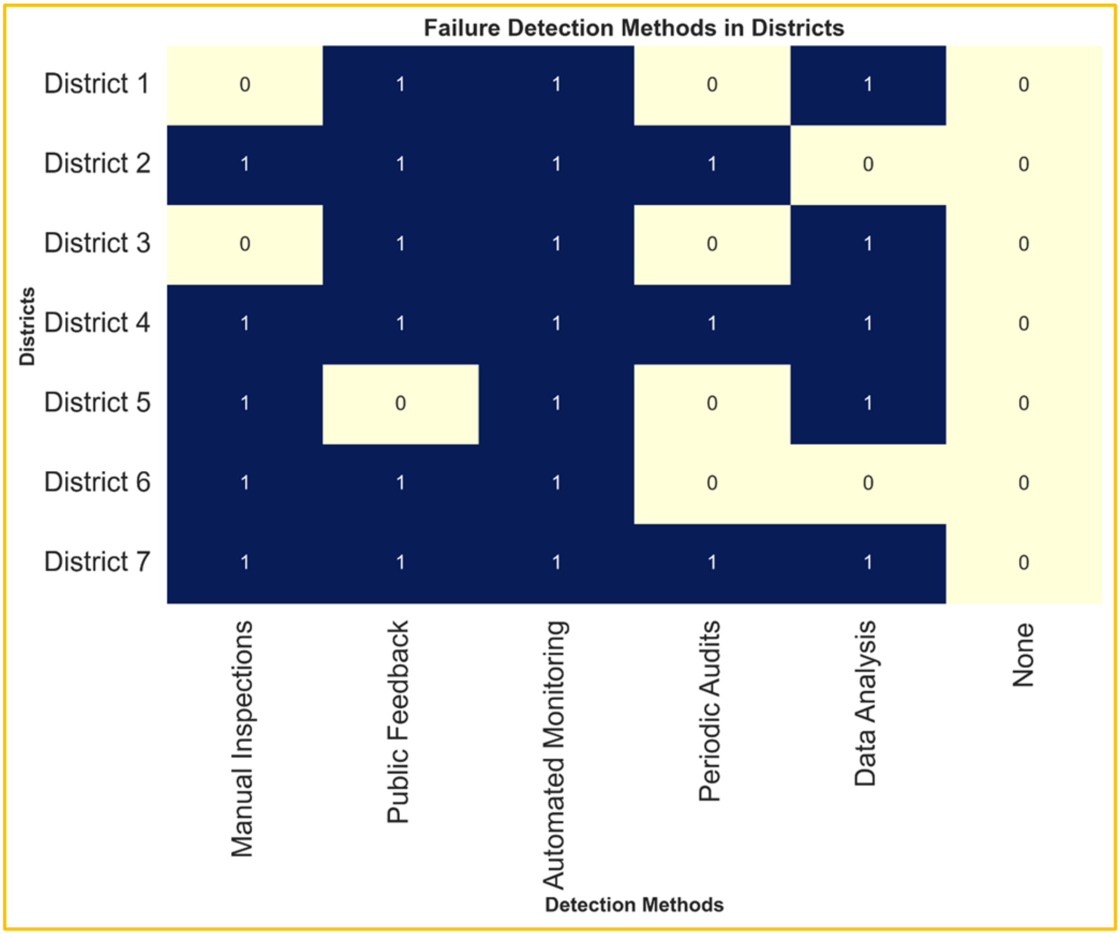

Figure 13. Failure Detection Methods in Districts

The forthcoming sections of this report will examine how the FDOT is updating its approach to traffic systems management, leveraging cutting-edge, data-centric methodologies and fosters cooperative relationships among its various districts. To provide a thorough and insightful analysis, the report will elaborate on the survey results from each district. The first part predominantly captures respondent information, and each subsequent section will offer a comprehensive view of the current state of traffic management across Florida's districts, highlighting potential areas for improvement and standardization. These insights will serve as a foundation for developing strategies that can be effectively implemented across the different districts, fostering a more unified and efficient approach to traffic management in Florida.

2.2. Comprehensive survey summary and key findings

2.2.1 District 1

2.2.1.1 Part-2: existing arterial management systems and infrastructure

In Part-2 of the survey for Florida Department of Transportation (FDOT) District 1, we focus on the existing arterial management systems, the quality of ITS (Intelligent Transportation Systems) equipment, and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation.

Presence of arterial management systems

District 1 confirms the existence of arterial management systems, which indicates that the district has an established framework for managing traffic flow, safety, and operational efficiency on arterial roads.

Quality of ITS equipment

The quality of ITS equipment installed along arterial corridors in District 1 is described as medium quality and, in many cases, a little outdated. This assessment points to a need for technological upgrades and modernization within the district's traffic management infrastructure. While the current systems are functional, there is room for improvement, particularly in adopting newer technologies to enhance traffic control and safety measures.

ATSPM implementation status

The current status of ATSPM implementation in District 1 is partially implemented. Partial implementation of ATSPM reflects a step towards adopting advanced traffic management techniques. ATSPM enables data-driven management of traffic signals, which can improve traffic flow and reduce congestion. The partial implementation indicates progress in this area but also suggests that further work is needed to fully implement this technology across the district.

In summary, Part-2 of the survey provides insight into the current state of arterial management in FDOT District 1. It highlights the presence of fundamental management systems, the need for updates in ITS equipment, and the ongoing process of implementing ATSPM.

2.2.1.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 1 focuses on data source accessibility, beneficial data types that are currently inaccessible, confidence in routinely collected data sources, and privacy issues related to data handling.

Accessibility of data sources across departments

In District 1, the Planning department has access to various data sources, and the TSM&O (Traffic Systems Management & Operations) team actively accesses and shares data upon request. This setup indicates a targeted approach to data access meaning that only relevant departments have the data they need for effective planning and traffic management.

Beneficial data types and accessibility

District 1 identifies turning movement counts, pedestrian and bicycle counts, and speed data as beneficial but currently not readily accessible through ATSPMs. The district has to actively collect these data, suggesting a gap in their existing data collection framework. While average speed data is available, spot speed data are not, indicating a limitation in the speed data collection capabilities.

Confidence in routinely collected data sources

The district reports very high confidence in traffic volume data and turning movement counts, reflecting robust collection and analysis systems for these data types. Confidence in pedestrian and bicyclist counts and speed data indicates room for improvement in the accuracy and comprehensiveness of these data. Crash data and traffic signal timing plans are areas of extremely high confidence, suggesting effective systems and processes for data collection and management in these aspects. However, the district is not confident in commonly used third-party data sources such as Here, Inrix, Waze, etc., highlighting a potential area for improvement in integrating external data sources into their traffic management system.

Privacy issues and data handling

District 1 reports no applicable privacy issues or challenges related to data handling, suggesting effective management and adherence to privacy standards in their data handling processes. In summary, Part-3 of the survey for District 1 reveals that while the district has access to and high confidence in certain key data types, there are gaps in their access to and confidence in other critical data types, such as pedestrian and bicycle counts and specific speed data.

2.2.1.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 1 focuses on the partnerships that support data collection for Traffic Systems Management & Operations (TSM&O) and the benefits of these collaborations.

Partnerships supporting TSM&O

District 1 engages in partnerships with a variety of agencies to support data collection in TSM&O. These include:

- Transit agencies: Their involvement indicates a focus on integrating public transportation data into overall traffic management.
- Law enforcement (Florida Highway Patrol, Police Departments, Sheriff's Offices): Collaboration with law enforcement is critical for obtaining traffic incident and enforcement-related data.

- Other collaborations with local city/county public works departments, Metropolitan Planning Organizations (MPOs), technical schools/universities, and access management/developers are also noted but not detailed in the response.

Primary data providers for TSM&O

The primary partners that rely on data in TSM&O activities in District 1 are law enforcement, technical schools/universities, and access management/developers. This reliance underscores the importance of diverse data sources, including traffic incident data, academic research, and development-related traffic information.

Benefits of collaborations

The primary benefits of these collaborations for TSM&O in District 1 include:

- Different/additional perspectives: Engaging with a variety of partners provides a broader range of insights and viewpoints, enhancing the understanding of traffic patterns and needs.
- Additional data sources: Collaborations expand the range of data available for analysis, allowing for more comprehensive traffic management strategies.
- Identify additional needs/considerations: These partnerships help in recognizing broader or previously unconsidered traffic management needs and challenges.

The survey responses for Part-4 indicate that District 1 benefits from a diverse range of partnerships, each contributing unique data and insights to the district's traffic management strategy.

2.2.1.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 1 covers the frequency of reviewing performance measures, their reflection on ground situations, and how data is used for both short-term and long-term decision-making, as well as the advantages of operational strategies employed.

Review and update of performance measures

For district management, performance measures in District 1 are reviewed and updated quarterly. This indicates a structured approach, ensuring that the measures are reassessed periodically to remain relevant and effective. For staff supporting arterial operators, performance measures are reviewed and updated weekly. This more frequent review cycle allows for rapid adjustments in response to changing conditions.

Reflection of performance measures on ground situations

The district considers that current performance measures moderately well reflect the situation on the ground. This rating suggests that the measures are reasonably effective but may benefit from further refinement to closely align with real-world traffic conditions.

Short-term data use

In the short term, data are used for making decisions in areas such as traffic signal timing adjustments, incident management, and communication to the public. These applications demonstrate an emphasis on responding to immediate needs and managing day-to-day traffic scenarios.

Long-term strategic data use

For long-term strategic decisions, the district employs data in the identification of signal retiming needs. This long-term focus is crucial for maintaining effective traffic flow and optimizing traffic signals over time.

Benefits of employing operational strategies

The advantages observed from employing strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM) include improved signal coordination, reduced travel time, enhanced traffic flow, better incident management, and improved decision-making processes. These benefits highlight the effectiveness of these strategies in optimizing traffic management and improving overall traffic conditions.

In summary, Part-5 of the survey for District 1 indicates a structured yet dynamic strategy for reviewing performance measures. It is combined with the effective use of data in both short-term and long-term decision-making, demonstrates a robust traffic management system.

2.2.1.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 1 focuses on the establishment, review, adherence to standards, challenges, and resources related to meeting minimum requirements for data accuracy and granularity.

Establishment of minimum requirements

Minimum requirements in District 1 for data accuracy and granularity are significantly influenced by signal retiming needs. This indicates a focused approach where specific operational requirements drive the standards for data quality.

Review and update of requirements

These minimum requirements are reviewed and updated annually. This periodic review ensures that the standards remain relevant and effective in the face of evolving traffic conditions and technological advancements.

Adherence to standards and regulations

Specific standards or regulations adhered to by District 1 in setting these minimum requirements are not specified, as the response was N/A. This could imply that district-specific guidelines are followed, or standard industry practices are not employed.

Challenges in meeting minimum requirements

District 1 reports no challenges or issues in adhering to these minimum requirements, indicating effective management and processes in place for data handling and quality control.

Systems and procedures for compliance

The survey response does not specify the systems or procedures in place to check that data meets these minimum requirements, as the response was N/A. This could mean that standard validation tools and procedures are employed but not detailed in the survey.

Implications of non-compliance

In instances where data did not meet these minimum requirements, the primary implication identified was limitations of the data provider to provide the data. This suggests that external sources of data might sometimes not comply with the district's standards.

Resources and tools for meeting requirements

To consistently meet these minimum requirements, District 1 identifies a need for better data collection tools/equipment and improved/increased data aggregation. This indicates a recognition of the evolving nature of traffic management and the need for advanced tools to keep up with these changes.

In summary, Part-6 of the survey for District 1 reveals a structured approach to establishing and reviewing minimum data requirements, with a particular focus on signal retiming needs. While the district effectively adheres to these standards without significant challenges, there is an acknowledgment of the need for enhanced data collection tools and aggregation methods to maintain and improve data quality.

2.2.1.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 1 addresses the use of non-traditional data sources for transportation management, their usefulness, challenges, and potential areas for future exploration.

Usage of non-traditional data sources

District 1 actively uses various non-traditional data sources, including Bluetooth detectors and third-party data sources such as Here, BlueTOAD, and Smats (iNode).

Most useful non-traditional data sources

Among these, third-party data sources, particularly Smats (iNode), are identified as the most useful. This indicates their significant contribution to traffic management, likely providing valuable insights into traffic patterns and behaviors.

Frequency of data updates

Data from these alternative sources are updated in real-time, which is crucial for making immediate and informed traffic management decisions.

Effectiveness of alternative data sources

The effectiveness of these data sources is rated as moderately effective. This rating suggests limitations such as data quality issues, limited coverage areas, or cost implications.

Challenges and issues

Challenges associated with these data sources include data quality issues, limited coverage areas, and cost implications. These challenges highlight areas where improvements could enhance the overall utility of these data sources for traffic management.

Interest in exploring additional data sources

No specific additional alternative data sources are identified for exploration, indicating either satisfaction with current sources or an area for potential future consideration. The findings show that District 1 is effectively utilizing a range of non-traditional data sources to enhance its traffic management capabilities. While these sources are proving to be moderately effective, the district faces challenges related to data quality, coverage, and costs. Addressing these challenges could further enhance the effectiveness of these tools in traffic management.

2.2.1.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 1 explores the methods used for detecting failures or issues in transportation management, highlighting a comprehensive and multi-faceted approach.

Methods for detecting failures or issues

District 1 employs several methods to identify and address failures or issues in transportation management, ensuring thorough coverage and responsiveness:

- Manual inspections and reports by transportation staff: These traditional methods remain essential for identifying issues that automated systems might not detect, providing a better understanding of situation of the ground.
- Feedback and complaints from the public or users: Incorporating public input is significant for identifying potential issues and allow for engagement with community.
- Automated monitoring systems and sensors**:** Utilizing technology for failure detection is crucial for real-time or near-real-time identification of issues, enabling prompt and effective responses.

- Analysis of data and trends from transportation management software: This data-driven approach underlines the importance of analyzing patterns and trends for proactive traffic management and issue resolution.

These diverse methods ensure a robust and responsive system for identifying and addressing transportation management failures or issues in District 1. By integrating manual inspections, public feedback, automated systems, and data analysis, the district effectively monitors and manages its transportation system.

2.2.1.8. Learning from best implementations and recommendations for District 1 learning from best implementations

The Florida Department of Transportation (FDOT) District 1 showcases several effective practices in traffic systems management and operations (TSM&O) that can be considered by other districts. Their approach is marked by a robust integration of technology and community engagement, ensuring comprehensive traffic management.

A key strength of District 1 lies in its utilization of various non-traditional data sources, such as Bluetooth detectors and third-party data providers like Here, BlueTOAD, and Smats (iNode). Furthermore, combining manual inspections, feedback from the public, automated monitoring systems, and data analysis, District 1 ensures a thorough and responsive approach to identifying and addressing transportation issues.

Recommendations for District 1

- Enhance data source integration and coverage: While District 1 effectively uses various data sources, expanding the coverage and further integrating these sources can provide a more comprehensive traffic management overview. Addressing challenges related to data quality and coverage will enhance the effectiveness of these tools.

- Invest in data quality improvement: Given the moderate effectiveness of alternative data sources and issues with data quality, investing in systems or technologies that improve data accuracy and resolution would be beneficial.
- Frequent review of performance measures**:** Implementing a more frequent review process for performance measures, especially at the arterial operator level, can ensure that these metrics are continuously aligned with real-world traffic conditions.
- Resource allocation for advanced traffic management: The district could benefit from allocating resources towards advanced traffic management strategies, such as Integrated Corridor Management (ICM) or Active Arterial Management (AAM), and tools like decision support systems (DSS) or automated traffic signal performance measures (ATSPM).
- Community engagement and transparency: Continuing to engage with the community and ensuring transparency in traffic management processes can build public trust and support. Active communication strategies and public involvement in traffic management initiatives should be emphasized.
- Exploration of new data sources: District 1 could explore additional data sources, such as environmental sensors or more advanced third-party navigation apps, to gain a more nuanced understanding of traffic patterns and environmental impacts.

2.2.2. District 2

2.2.2.1. Part-2: Existing arterial management systems and infrastructure

In Part-2 of the survey for Florida Department of Transportation (FDOT) District 2, we assess the existing arterial management systems, the quality of ITS (Intelligent Transportation Systems) equipment, and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation.

Presence of arterial management systems

District 2 confirms the presence of arterial management systems. This indicates an established framework for managing traffic flow, safety, and operational efficiency on arterial roads within the district.

Quality of ITS equipment

The quality of ITS equipment installed along arterial corridors in District 2 is rated as medium quality and, in many cases, a little outdated. This assessment points to a need for technological upgrades and modernization in the district's traffic management infrastructure.

ATSPM implementation status

The current status of ATSPM implementation in District 2 is partially implemented. Partial implementation of ATSPM reflects a step towards adopting advanced traffic management techniques. ATSPM enables data-driven management of traffic signals, which can improve traffic flow and reduce congestion. The partial implementation indicates progress in this area but also suggests that further work is needed to fully implement this technology throughout the district.

In summary, Part-2 of the survey for District 2 provides insights into the current state of arterial management. It highlights the presence of essential management systems, the need for updates in ITS equipment, and the ongoing implementation of ATSPM.

2.2.2.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 2 focuses on the accessibility of data sources across departments, beneficial data types currently inaccessible, confidence in routinely collected data sources, and privacy issues related to data handling.

Accessibility of data sources across departments

In District 2, traffic engineers, TSM&O consultants, and RTMC Operations have access to various data sources. This diverse range of departments and teams having access indicates efficient data sharing and utilization, which are essential for effective traffic management.

Beneficial data types and accessibility

The district identifies traffic volume data, turning movement counts, speed data, and traffic signal timing plans as beneficial but currently not accessible. They specifically mention the use of Iteris BlueToad BT devices. The lack of access to these data types suggests a gap in the district's data collection capabilities, potentially affecting the effectiveness of traffic management strategies.

Confidence in routinely collected data sources

Confidence levels vary among the different data sources:

- Traffic volume data and turning movement count: Somewhat confident, indicating a need for improvement in data accuracy or comprehensiveness.
- Speed data and traffic signal timing plans: Extremely confident, suggesting robust and reliable systems for collecting these types of data.
- Real-time traffic signal state data: Very confident, indicating a high degree of trust in this data's reliability.

- Third-party data sources (Here, Inrix, Waze, etc.): Somewhat confident, highlighting potential areas for improvement in integrating and utilizing external data sources.

Privacy issues and data handling

The district reports encountering challenges with anonymizing data and concerns about data security. These issues indicate the need for enhanced data privacy and security measures to protect sensitive information and comply with privacy standards.

The varied levels of confidence in different data sources suggest areas for improvement in data collection and integration. Additionally, the reported privacy issues highlight the importance of strengthening data security and anonymization practices.

2.2.2.3. Part-4: Agencies involved – District 2 summary

Part-4 of the survey for Florida Department of Transportation (FDOT) District 2 addresses the partnerships that support data collection for Traffic Systems Management & Operations (TSM&O) and the benefits of these collaborations.

Partnerships supporting TSM&O

District 2 collaborates with various agencies to support data collection for TSM&O, enhancing the effectiveness of their traffic management strategies. These partnerships include:

- **Other FDOT Districts:** Collaboration with other districts allows for sharing best practices and learning from each other's experiences.
- **Local city/county public works departments:** Working with local public works departments ensures access to detailed, area-specific traffic data.
- **Metropolitan Planning Organizations (MPOs):** Engagement with MPOs indicates integration of broader regional planning considerations in traffic management.

Primary data providers for TSM&O

Local agencies are primarily relied upon to provide data for analysis in TSM&O activities. This reliance underscores the importance of local-level data in understanding and managing traffic within the district.

Benefits of collaborations

The primary benefits of these collaborations for TSM&O in District 2 include:

- Different/additional perspectives: Collaboration with various agencies brings diverse viewpoints and insights, enhancing the understanding of traffic patterns and needs.
- Identify additional needs/considerations: Engaging with different partners helps in recognizing broader traffic management needs and challenges.
- Increased accuracy of aggregated data: Collaborative efforts contribute to a more comprehensive and accurate dataset, essential for effective traffic analysis and management.

2.2.2.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 2 covers the frequency of reviewing performance measures, their reflection on ground situations, and how data are used for both short-term and long-term decision-making, as well as the advantages of operational strategies employed.

Review and update of performance measures

For district management, performance measures are reviewed and updated monthly. This frequency suggests a balance between responsiveness and practicality, allowing for timely adjustments based on changing traffic conditions. For staff supporting arterial operators, performance measures are reviewed and updated weekly, indicating a dynamic approach to managing arterial traffic and the ability to quickly respond to immediate conditions.

Reflection of performance measures on ground situations

The current performance measures are considered to reflect the situation very well on the ground, indicating that they are effective and closely aligned with real-world traffic conditions.

Short-term data use

In the short term, data is used for making decisions primarily in incident management and resource allocation for immediate issues. These uses highlight a focus on addressing urgent traffic management needs and maintaining operational efficiency.

Long-term strategic data use

For long-term strategic decisions, the district employs data in the identification of signal retiming needs and operations and maintenance needs. This long-term focus is essential for maintaining effective traffic flow and optimizing traffic signals over time.

Benefits of employing operational strategies

The specific advantages observed from employing strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM) include enhanced traffic flow, better incident management, more efficient resource allocation, and improved decision-making processes. These benefits underscore the effectiveness of these strategies in optimizing traffic management and improving overall traffic conditions.

Overall, the district's strategy for reviewing performance measures, combined with the effective use of data in both short-term and long-term decision-making, demonstrates a robust and responsive traffic management system.

2.2.2.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 2 focuses on the establishment, review, adherence to standards, challenges, and resources related to meeting minimum requirements for data accuracy and granularity.

Establishment of minimum requirements

Minimum requirements in District 2 are established based on historical data, operational needs, maintenance needs, and signal retiming needs. This indicates a comprehensive approach, considering various aspects of traffic management to ensure data accuracy and relevance.

Review and update of requirements

These requirements are reviewed and updated annually, ensuring that standards remain current and effective in light of changing traffic dynamics and technological advancements.

Adherence to standards and regulations

The district adheres to industry standards when setting minimum data requirements. This adherence suggests a commitment to maintaining high-quality data management practices in line with recognized benchmarks.

Challenges in meeting minimum requirements

The primary challenges faced include the need for stakeholder coordination and collaboration and lack of data aggregation. These challenges highlight areas where improvements are needed to enhance data management capabilities.

Systems and procedures for compliance

To ensure data meets minimum requirements, District 2 employs manual evaluations and comparisons with other performance measures. These methods allow for validating data accuracy and applicability.

Implications of non-compliance

When data did not meet minimum requirements, the implications included the need for additional resources or tool development and limitations of the state of technology. These instances highlight areas for potential enhancement in data collection and processing technologies.

Resources and tools for meeting requirements

The district identifies a need for improved/increased data aggregation to meet minimum requirements consistently. This indicates a recognition of the evolving nature of traffic management and the importance of advanced tools for effective data handling.

In summary, Part-6 of the survey for District 2 reveals a structured approach to establishing and reviewing minimum data requirements, with particular attention to operational, maintenance, and signal retiming needs. While the district effectively addresses these standards, it acknowledges the need for improved stakeholder collaboration and data aggregation to enhance its data management capabilities.

2.2.2.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 2 delves into the use of non-traditional data sources for transportation management, their effectiveness, potential challenges, and areas of interest for future exploration.

Usage of non-traditional data sources

District 2 employs various non-traditional data sources, including Bluetooth detectors and third-party data sources such as Here Data. This adoption highlights the district's commitment to leveraging advanced technologies for comprehensive traffic analysis.

Most useful non-traditional data sources

Among these, Bluetooth detectors and third-party data sources like Smats (iNode) are identified as the most useful. These tools provide valuable insights into traffic patterns and behaviors, contributing significantly to traffic management.

Frequency of data updates

Data from these alternative sources are updated in real-time. Real-time data is crucial for making immediate traffic management decisions and responding effectively to changing traffic conditions.

Effectiveness of alternative data sources

These data sources are rated as extremely effective in managing transportation in District 2. This high level of effectiveness suggests that they significantly contribute to the district's traffic management capabilities.

Challenges and issues

No specific challenges or issues associated with these data sources are reported, indicating that District 2 effectively manages and utilizes these tools in its traffic management system.

Interest in exploring additional data sources

District 2 expresses interest in exploring environmental sensors as an additional alternative data source. This interest indicates a desire to further enhance their traffic management system by incorporating data on environmental factors, potentially to better understand and mitigate environmental impacts on traffic.

In summary, Part-7 of the survey shows District 2's effective utilization of a range of non-traditional data sources to enhance its traffic management capabilities. The extremely effective rating of these tools, combined with the district's interest in exploring environmental sensors, underscores the need for innovative and comprehensive traffic management solutions.

2.2.2.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 2 explores the methods utilized for detecting failures or issues in transportation management, highlighting a comprehensive and multi-layered approach.

Methods for detecting failures or issues

District 2 employs a variety of methods to identify and address failures or issues in transportation management:

- Manual inspections and reports by transportation staff: These traditional methods remain vital for identifying issues, particularly those that may not be easily detected by automated systems.
- Feedback and complaints from the public or users: Incorporating public input is significant for identifying potential issues, reflecting a commitment to community engagement and responsiveness.
- Automated monitoring systems and sensors: Utilizing technology for failure detection is crucial for real-time or near-real-time identification of issues, allowing for prompt responses.
- Periodic audits and reviews by external agencies: These reviews provide an external perspective and validation of the district's transportation management practices.

Integrating manual inspections, public feedback, automated systems, and external audits, the district can monitor and manage its transportation system, adapting as necessary to maintain efficiency and safety.

2.2.2.8. Learning from best implementations and recommendations for District 2

Learning from best implementations

Florida Department of Transportation (FDOT) District 2 demonstrates a proactive and multifaceted approach to traffic management, marked by the integration of advanced data sources and a comprehensive strategy for system monitoring. A strength of District 2 lies in its use of various non-traditional data sources, including Bluetooth detectors and third-party data like Here Data and Smats (iNode). These tools, updated in real-time and rated as extremely effective, provide nuanced insights into traffic patterns, and are important for dynamic and responsive traffic management.

The district's approach to failure detection in transportation management combines manual inspections, public feedback, automated monitoring systems, and periodic external audits, ensuring a thorough and responsive identification and resolution of transportation issues.

Recommendations for District 2

- Continuous improvement of data sources: While the current non-traditional data sources are highly effective, continuing to evaluate and improve these tools will ensure they remain relevant and beneficial.
- Enhanced public engagement: Given the importance of public feedback, further enhancing engagement strategies can provide deeper insights into user experiences and expectations.

- Expand data integration and analysis: Strengthening the integration and analysis of data from various sources can provide a more comprehensive understanding of traffic dynamics, aiding in decision-making.
- Investment in technology for failure detection: Continued investment in advanced technologies for failure detection, including automation and AI-driven analytics, can further refine the district's capacity to identify and address issues promptly.
- Exploration of environmental sensors: Given the district's interest in environmental sensors, exploring these technologies can add another layer to traffic management, particularly in understanding environmental impacts on traffic.
- Stakeholder collaboration enhancement: Addressing challenges in stakeholder coordination and collaboration can lead to more streamlined and effective traffic management strategies.
- Resource allocation for data management: Allocating resources for improved data aggregation and tool development, especially in areas where data resolution is inadequate, will enhance the overall data management framework.

2.2.3. District 3

2.2.3.1. Part-2: Existing arterial management systems and infrastructure

The second part of the survey for Florida Department of Transportation (FDOT) District 3 delves into the existing arterial management systems and the quality of infrastructure.

Arterial management systems presence

The survey confirms that District 3 does have arterial management systems in place. The presence of these systems indicates existing framework based on which traffic flow, safety, and operational efficiency are managed.

Quality of ITS equipment

When it comes to the quality of Intelligent Transportation Systems (ITS) equipment installed along arterial corridors the response indicated that they are medium quality (with many cases indicating the system to be little outdated). The district is aware of the need for upgrade, as indicated by the push towards updating signal systems to Advanced Transportation Controllers (ATC) (as controllers and cabinets are updated). The transition to ATC represents a significant step towards enhancing traffic signal operations, offering more sophisticated control and better adaptation to traffic conditions.

Automated traffic signal performance measures (ATSPM) implementation

Regarding the implementation of Automated Traffic Signal Performance Measures (ATSPM), the response indicates a partial implementation in Bay and Leon counties. This partial implementation suggests a progressive approach towards adopting modern traffic management techniques as the ATSPM implementation is a key indicator of a district's commitment to using data-driven strategies to improve traffic signal performance and enhance the overall traffic flow and safety. The partial implementation in specific counties, Bay and Leon Counties, points to the ongoing efforts in this direction, possibly reflecting a phased or trial approach before wider adoption across the district.

2.2.3.2. Part-3: Data sources and management – summary

Part-3 of the survey for Florida Department of Transportation (FDOT) District 3 focuses on data sources and management, revealing significant insights into the availability, access, and confidence in various traffic-related data sets.

Accessibility and centralization of data sources

FDOT District 3 is working towards a centralized approach for data sources and management. This strategy is essential for efficient and effective data handling, ensuring that data sets are accessible to all relevant offices within the district. The fact that some data require access approval while others are openly available suggests a balanced approach to data accessibility and security.

Data types and availability

The survey identifies several types of data that are beneficial to the district. Traffic volume data, speed data, crash data, traffic signal timing plans, and commonly used third-party data sources such as Here, Inrix, Waze, etc., are among the data types already accessible. Interestingly, turning movement counts, pedestrian and bicycle counts, and real-time traffic signal status data are added as essential data types. The district typically collects turning movement and pedestrian/bicycle counts in conjunction with retiming projects, but there is limited sharing of real-time traffic signal status data with the District 3 TSM&O program. This highlights a potential area for improvement in data sharing and integration.

Confidence in data sources

The respondents expressed confidence in the reliability and applicability of various routinely collected data sources, including traffic volume data, turning movement counts, pedestrian and bicyclist counts, speed data, crash data, traffic signal timing plans, real-time traffic signal state data, and third-party data sources.

This high level of confidence suggests that the district has robust systems in place for collecting and managing these data types, which is crucial for informed decision-making and effective traffic management.

Privacy issues and data security

In terms of privacy and data handling challenges, the district experiences low or negligible issues in areas such as anonymizing data, complying with privacy regulations, and data security concerns. Notably, no personally identifiable information (PII) is collected in any FDOT traffic or crash database, which simplifies the privacy considerations.

The findings highlight the need to move towards centralized data sources and confirm confidence in the reliability of various data types with minimal concerns regarding data privacy and security. This part underscores the district's efforts to maintain a comprehensive, accessible, and secure data environment, essential for effective traffic management and planning.

2.2.3.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 3 addresses the various partnerships that support data collection in Traffic Systems Management & Operations (TSM&O) and the nature of these collaborations.

Partnerships in TSM&O

District 3 collaborates with a range of agencies to support TSM&O activities. These partnerships include other FDOT districts, local city/county public works departments, Metropolitan Planning Organizations (MPOs), transit agencies, and law enforcement (including Florida Highway Patrol, police departments, and sheriff's offices). This diverse range of partnerships allows District 3 to leverage the strengths and resources of various stakeholders.

Role of the FDOT Central Office

The FDOT Central Office plays an essential role in the state's data collection and archival. They utilize advanced systems like the SunGuide™ transportation management system software, which is integral to collecting, analyzing, and archiving traffic data. This centralized support is crucial for ensuring consistency and reliability in data management across the state.

Reliance on partners for data

The survey highlights that Florida Highway Patrol and local law enforcement are primarily relied upon for collecting traffic crash data. This reliance is significant as crash data is a critical component of traffic safety analysis and TSM&O strategies. The role of local law enforcement in data collection further emphasizes the importance of collaboration between traffic management authorities and public safety agencies, ensuring comprehensive data collection for informed decision-making in traffic management.

Benefits of collaborations

The primary benefits identified from these collaborations are the provision of different/additional perspectives and additional data sources. These benefits suggest that the partnerships not only expand the scope of data available for TSM&O activities but also provide varied insights that can lead to more effective traffic management strategies. The inclusion of diverse viewpoints and data from multiple sources enhance the district's ability to address complex traffic issues.

In summary, Part-4 of the survey underlines the significant role of various partnerships in supporting TSM&O in FDOT District 3. The collaborations with a wide range of agencies contribute to a more robust, diverse, and comprehensive approach to traffic systems management and operations, with a strong emphasis on traffic crash data collection and the integration of multiple perspectives and data sources.

2.2.3.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 3 explores the application of data in performance measures, decision-making processes, and the use of operational strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM).

Review and update of performance measures

For district management, performance measures are updated on a longer strategic planning cycle rather than a frequent, routine basis. This approach indicates a focus on a long-term strategic planning in traffic management.

For staff supporting arterial operations, since District 3 does not have any Traffic Management Center (TMC) staff for arterial operations and relies on local agencies, the review of performance measures occurs at longer cycles. These cycles are primarily aligned with procurement cycles for updating Advanced Traffic Management Systems (ATMS) software and traffic signal hardware.

Reflecting ground situations in performance measures

The survey response indicates that the current performance measures moderately well reflect the on-ground traffic situations. This suggests a balanced and realistic approach to performance measurement but also indicates potential areas for further refinement.

Short-term and long-term data uses

Short-term decisions, like incident management, are made daily or hourly. However, traffic signal timing adjustments and resource allocations for immediate issues tend to be more long-term than daily or weekly. For long-term strategic decisions, data is used in infrastructure planning and upgrades, identifying signal retiming needs, operations and maintenance needs, as well as funding and budget allocation. These applications demonstrate a comprehensive use of data for strategic traffic management planning.

Operational strategies and their advantages

District 3 acknowledges several advantages from employing strategies like ICM or AAM. These include improved signal coordination, reduced travel time, enhanced traffic flow, better incident management, more efficient resource allocation, enhanced safety measures, and improved decision-making processes.

Barriers to implementing operational strategies

The district is considering developing ICM efforts for corridors like I-10 and US 90. However, challenges such as the need for additional funds to upgrade traffic signals, controllers, cabinets, and communications are notable roadblocks. This insight underlines the challenges faced in implementing advanced traffic management strategies, primarily due to financial and infrastructural constraints.

In summary, Part-5 of the survey provides a comprehensive view of how FDOT District 3 uses data in performance measurement and decision-making for traffic management. It reveals a strategic approach to updating and reviewing performance measures, the effective use of data for short-term and long-term decisions, the benefits of operational strategies like ICM and AAM, and the challenges in implementing these strategies.

2.2.3.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 3 addresses the minimum requirements for data accuracy and granularity, their review, adherence to standards, and the systems in place to ensure compliance.

Establishment of minimum requirements

The minimum requirements for data accuracy and granularity in District 3 are established based on the FDOT Standard Specifications for Road and Bridge Construction. This indicates a structured and standardized approach to setting data requirements, ensuring consistency and reliability across the district.

Review and update of requirements

These specifications are reviewed annually and updated as needed, aligning with the industry standards and operational requirements. The district's adherence to a regular review cycle reflects a commitment to keeping data specifications current and relevant.

Adherence to standards and regulations

The district adheres to state and national industry standards, incorporating specific measures like incident clearance time, roadway clearance time, device uptime, and secondary crashes, as outlined in the TSM&O Strategic Plan.

Challenges in adherence to requirements

Interestingly, the district reports no challenges or issues in adhering to these minimum requirements. The absence of noted challenges suggests a robust framework and adequate resources for managing data requirements effectively.

Systems and procedures for compliance

To ensure data meets these requirements, the district employs automated validation tools and manual evaluations, both conducted at the FDOT Traffic Engineering Research Laboratory (TERL). These procedures indicate a thorough approach to data validation, utilizing both technological and human resources to ensure data integrity.

Instances of non-compliance and implications

There have been no instances noted where data did not meet the minimum requirements. This zero instances of non-compliance are a testament to the district's effective data management practices and adherence to standards.

Resources and tools for meeting requirements

While the district has been successful in meeting data requirements, an increased budget for data collection devices and operations is identified as a beneficial resource. This recognition of the need for financial resources indicates the ongoing requirements for maintaining and improving data collection and management capabilities.

In summary, Part-6 of the survey reveals FDOT District 3's structured approach to establishing, reviewing, and adhering to minimum data requirements. The district employs a combination of standards, regular reviews, and rigorous validation processes to ensure data accuracy and granularity. The absence of significant challenges in this area and the call for increased budgetary resources highlight both the district's current effectiveness and its vision for continued improvement in data management.

2.2.3.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 3 addresses the use of non-traditional data sources for transportation management, their effectiveness, challenges, and potential areas for exploration.

Usage of non-traditional data sources

District 3 currently utilizes non-traditional data sources, specifically Bluetooth detectors and third-party data sources like HERE data from RITIS (Regional Integrated Transportation Information System). RITIS integrates HERE probe data with FDOT detector data, providing a comprehensive view of traffic conditions.

Most useful non-traditional data sources

The district finds Bluetooth detectors and third-party data sources to be the most useful. This indicates their effectiveness in enhancing transportation management through detailed traffic analysis and real-time monitoring.

Frequency of data updates

Data from these alternative sources are updated both in real-time and daily. Such frequent updates ensure that the district has access to the most current traffic information, crucial for making timely decisions and adjustments in traffic management.

Effectiveness of alternative data sources

The overall effectiveness of these alternative data sources is rated as moderately effective. The limitation in effectiveness is attributed to the availability of human resources to utilize the data. This suggests a need for more staffing or improved data management tools to fully leverage these data sources.

Challenges and issues

No specific challenges or issues have been reported regarding the use of these alternative data sources. The absence of reported difficulties indicates a smooth integration and utilization of these data types in the district's traffic management operations.

Interest in exploring additional data sources

The district expresses interest in exploring drone-based monitoring. The potential use of drones to monitor congestion, especially at the end of queues resulting from traffic incidents, reflects an innovative approach to traffic monitoring and management.

In summary, Part-7 of the survey reveals FDOT District 3's proactive use of non-traditional data sources like Bluetooth detectors and third-party data to enhance transportation management. The district is benefiting from these sources, with a focus on more effective utilization through better resource allocation. The interest in exploring drone-based monitoring for congestion assessment further highlights the opportunity for expanding the current data collection efforts.

2.2.3.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 3 explores the methods used for detecting failures or issues in transportation management.

Methods for detecting failures or issues

District 3 employs several methods to detect failures or issues in transportation management. The survey highlights three primary mechanisms:

- Feedback and complaints from the public or users: The district values input from the public and users, utilizing this feedback as a significant method for identifying issues.
- Automated monitoring systems and sensors: The use of technology, such as automated monitoring systems and sensors, plays a critical role in failure detection. These systems likely provide real-time or near-real-time data, enabling prompt identification and response to issues.
- Analysis of data and trends from transportation management software: Data-driven decision-making is evident in District 3's approach, as they analyze data and trends from transportation management software to detect failures. This method suggests a sophisticated approach to transportation management, leveraging data analytics for insights into system performance and potential issues.

These methods collectively provide a comprehensive approach to identifying and addressing transportation management issues in District 3. By combining public feedback, technology, and data analysis, the district can effectively monitor and respond to transportation system failures, ensuring a robust and responsive transportation management system.

2.2.3.8. Learning from best implementations and recommendations for District 3

Learning from best implementations

The Florida Department of Transportation (FDOT) District 3 offers a valuable case study in arterial management through its innovative approaches and strategic use of data. By analyzing their practices, other districts can enhance their own transportation management systems.

One of the key strengths of District 3 lies in its use of performance measures. The district updates these measures strategically, aligning with long-term planning cycles. This approach balances the need for current data with the practicalities of system upgrades and resource allocation. By focusing on a longer strategic planning cycle, District 3 ensures that performance measures are not just reactive but also anticipatory, aiding in identifying future needs and trends. Additionally, the integration of non-traditional data sources, such as Bluetooth detectors and third-party data from RITIS, into their traffic management system, exemplifies innovation in data utilization. These sources provide real-time and daily updates, offering a comprehensive view of traffic conditions that traditional data sources might not capture. The moderate effectiveness of these sources, limited by human resource availability, suggests a potential area of focus for other districts.

Recommendations for District 3

- Enhanced data sharing and centralization: District 3 is moving towards centralized data sources and management. Further enhancing this centralization, particularly in real-time data sharing between local agencies and the District 3 TSM&O program, could streamline operations and decision-making processes.
- Full implementation of ATSPM: The partial implementation of Automated Traffic Signal Performance Measures (ATSPM) in certain counties is a step in the right direction. Expanding this to a full implementation across the district would allow for a more uniform and efficient approach to traffic signal management, leading to improved traffic flow and safety.
- Optimizing use of non-traditional data sources: The current use of non-traditional data sources is an excellent practice. To fully leverage these resources, District 3 could consider increasing human resources or adopting more advanced data processing tools. This would maximize the potential of real-time and daily data updates for traffic management.
- Increased budget allocation for data collection tools: Recognizing the need for an increased budget for data collection devices and operations, exploring avenues for additional funding or reallocation of existing resources could enhance District 3's data collection capabilities. This would support more effective traffic management strategies and the adoption of new technologies.
- Automated data validation and manual evaluations: District 3 employs a combination of automated tools and manual evaluations for data validation. Continuing to invest in these

practices, and possibly incorporating more advanced automated validation technologies, would ensure the ongoing accuracy and reliability of traffic data.

- Exploration of drone-based monitoring: The interest in exploring drone-based monitoring for traffic incident analysis is innovative. Piloting a drone-based monitoring program could provide valuable insights into traffic patterns and incident management, offering a new dimension to traffic data collection.

By adopting these recommendations, District 3 can continue to refine its traffic management strategies, ensuring they remain at the forefront of innovative and effective arterial management. Other districts can learn from these practices, adapting and implementing them according to their unique contexts and needs.

2.2.4. District 4

2.2.4.1. Part-2: Existing arterial management systems and infrastructure

Part-2 of the survey for Florida Department of Transportation (FDOT) District 4 focuses on the current state of arterial management systems, the quality of ITS (Intelligent Transportation Systems) equipment, and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation.

Arterial management systems

District 4 confirms the existence of arterial management systems. This indicates that the district has an established framework for managing traffic flow, safety, and operational efficiency on arterial roads. The presence of these systems allows for effective traffic management.

Quality of ITS equipment

The ITS equipment installed along arterial corridors in District 4 is rated as overall high quality and in line with technological advancements. This assessment indicates that District 4 is well-equipped with modern and effective ITS technologies, which are essential for managing traffic flow, enhancing road safety, and improving overall traffic conditions. It suggests that the district prioritizes staying current with technological advancements in traffic management.

ATSPM implementation status

The current status of ATSPM implementation in District 4 is partially implemented. ATSPM enables data-driven management of traffic signals, which can improve traffic flow and reduce congestion. The partial implementation indicates ongoing efforts to fully integrate this technology into the district's traffic management system.

In summary, Part-2 of the survey for District 4 provides insights into the well-established arterial management systems and the high quality of ITS equipment, indicating a strong foundation in traffic management infrastructure.

2.2.4.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 4 focuses on the accessibility of various data sources, beneficial data types currently not accessible, confidence in routinely collected data sources, and privacy issues related to data handling.

Accessibility of data sources across departments

Data sources in District 4 are available upon request from signal maintaining agencies. .

Beneficial data types and accessibility

The district identifies a need for better access to several data types, including traffic volume data, turning movement counts, pedestrian and bicycle counts, speed data, traffic signal timing plans, and commonly used third-party data sources like Here, Inrix, Waze, etc. District 4 sees the value of a centralized data storage method accessible to all agencies, indicating a desire for more streamlined and efficient data management and sharing practices.

Confidence in routinely collected data sources

The district reports extremely high confidence in traffic volume data, turning movement counts, speed data, crash data, traffic signal timing plans, and real-time traffic signal state data.. Confidence in third-party data sources is very high, reflecting effective use and integration of these external data in traffic management. For pedestrian and bicyclist counts, the confidence level is neutral, indicating room for improvement in data collection or analysis in this area.

Privacy issues and data handling

The district has encountered challenges related to the lack of clear policies for data privacy. This issue highlights the need for more defined and consistent privacy practices in handling and sharing traffic data.

In summary, Part-3 of the survey reveals that District 4 has access to a variety of data sources and high confidence in most of the routinely collected traffic data. However, there is a recognized need for improved access to certain data types and the establishment of more comprehensive data privacy policies. The desire for centralized data storage suggests an area for potential improvement in data management practices.

2.2.4.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 4 addresses the partnerships supporting Traffic Systems Management & Operations (TSM&O) and the benefits of these collaborations.

Partnerships supporting TSM&O

District 4 collaborates with various agencies to enhance its data collection capabilities for TSM&O, including:

- Other FDOT districts: Collaboration with other districts allows for the sharing of best practices and experiences, fostering a more unified approach to traffic management across the state.
- Local city/county public works departments: Engaging with local public works departments ensures access to detailed, area-specific traffic data and insights.
- Metropolitan Planning Organizations (MPOs): Involvement with MPOs is indicative of integrating broader regional planning considerations and strategies in traffic management.

Data sharing practices

Data within District 4 is generally shared freely upon request. However, it is noted that there is no central repository for data, implying a potential area for improvement in data accessibility and management.

Primary data providers for TSM&O

Local agencies are primarily relied upon for providing data for TSM&O activities. This reliance underscores the importance of localized traffic data in understanding and managing traffic within the district effectively.

Benefits of collaborations

The primary benefits of these collaborations include:

- Different/additional perspectives: Collaborating with a variety of partners brings a range of insights and viewpoints, enriching the district's understanding of traffic patterns and needs.
- Additional data sources**:** These partnerships provide access to a broader range of data, contributing to a more comprehensive traffic management strategy.

- More data resolution, additional needs/considerations, and increased accuracy of aggregated data: These benefits reflect the enhanced depth and quality of traffic data analysis made possible through these collaborations, leading to more informed and effective traffic management decisions.

In summary, District 4's approach to partnerships in TSM&O illustrates a comprehensive and collaborative strategy, involving various agencies to improve traffic management. The benefits of these collaborations highlight the district's commitment to leveraging diverse perspectives and data sources for enhanced traffic system management. The absence of a central data repository, however, suggests an opportunity for further improvement in data handling and accessibility.

2.2.4.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 4 addresses the frequency of reviewing performance measures, their alignment with ground realities, short-term and long-term data usage, and benefits of operational strategies.

Review and update of performance measures

For district management, performance measures are reviewed and updated quarterly. This frequency suggests a balance between the need for timely adjustments and the practicalities of thorough evaluation. For staff supporting arterial operators, performance measures are reviewed and updated weekly.

Reflection of performance measures on ground situations

The current performance measures are perceived to reflect the situation slightly well on the ground, showing that while they are somewhat effective, there may be room for improvement to ensure they are more closely aligned with actual traffic conditions.

Short-term data use

District 4 uses data for short-term decisions in several key areas:

- Traffic signal timing adjustments: Adjusting traffic signals based on current traffic conditions.
- Incident management: Responding effectively to traffic incidents.
- Resource allocation for immediate issues: Addressing immediate maintenance and patrol needs.
- Communication to the public: Providing real-time updates and alerts.

Long-term strategic data use

For long-term strategic decisions, the district uses data for:

- Infrastructure planning and upgrades: Guiding decisions on infrastructure changes and enhancements.
- Identification of signal retiming needs: Continuously optimizing traffic signals.
- Operations and maintenance needs: Planning for operational efficiency and maintenance requirements.
- Funding and budget allocation: Informing financial planning and resource distribution.

Benefits of operational strategies

The advantages noticed from employing strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM) include improved signal coordination, reduced travel time, enhanced traffic flow, better incident management, more efficient resource allocation, enhanced safety measures, and improved decision-making processes. These benefits underscore the effectiveness of these strategies in optimizing traffic management.

In summary, Part-5 of the survey for District 4 reveals a structured approach to using data in traffic management. The district employs data effectively in both short-term and long-term decision-making, although there may be opportunities to improve the alignment of performance measures with on-ground situations.

2.2.4.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 4 focuses on the establishment, review, and adherence to minimum requirements for data accuracy and granularity, along with challenges and resources needed to meet these standards.

Establishment of minimum requirements

District 4 acknowledges the complexity in establishing minimum requirements for data accuracy and granularity, noting the difficulty in determining the real "ground truth." They typically select a single data source as the standard for accuracy, such as using Freeway Express Lane volume counts from FTE gantry counts versus MVDS.

Review and update of requirements

Minimum requirements are reviewed and updated quarterly, ensuring that standards are kept current and effective in response to changing traffic conditions and technological advancements.

Adherence to standards and regulations

The district adheres to industry standards when setting minimum data requirements. The response indicates no specific knowledge of adherence to federal guidelines or state mandates.

Challenges in meeting minimum requirements

Challenges faced include inadequate data resolution and data in different formats. These issues highlight areas where improvements in data collection and processing are needed.

Systems and procedures for compliance

Automated validation tools are used for freeways, but there are no specific procedures mentioned for arterials. This suggests a potential area for development in terms of establishing systematic checks for arterial data.

Implications of non-compliance

Instances where data did not meet minimum requirements resulted in limitations of the data provider to provide the data, indicating reliance on external sources for accurate data.

Resources and tools for meeting requirements

To consistently meet these requirements, District 4 identifies the need for better data collection tools/equipment and improved/increased data aggregation. This indicates a recognition of the evolving nature of traffic management and the importance of advanced tools for effective data handling.

In summary, Part-6 of the survey for District 4 reveals a nuanced approach to establishing and reviewing minimum data requirements, with an emphasis on selecting appropriate "ground truth" standards. While the district faces challenges in data resolution and format, there is an acknowledged need for enhanced data collection tools and aggregation methods to maintain and improve data quality.

2.2.4.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 4 explores the use of non-traditional data sources for transportation management, their effectiveness, challenges, and potential areas for future exploration.

Usage of non-traditional data sources

District 4 utilizes various non-traditional data sources, including video imaging, drone data, and Bluetooth detectors. This adoption indicates a commitment to leveraging modern technologies for comprehensive traffic analysis.

Most useful non-traditional data sources

The most useful non-traditional data sources identified are video imaging, drone data, and iNode. These tools provide valuable insights into traffic patterns and behaviors, contributing significantly to traffic management.

Frequency of data updates

Data from these alternative sources are updated in real-time, emphasizing the district's focus on timely and responsive traffic management.

Effectiveness of alternative data sources

The effectiveness of these data sources is rated as very effective in managing transportation in District 4. This high level of effectiveness suggests that they significantly contribute to the district’s traffic management capabilities.

Challenges and issues

The district has faced challenges with integration difficulties and lack of standardization in using these alternative data sources. Addressing these challenges could further enhance the effectiveness of these tools in traffic management.

Interest in exploring additional data sources

District 4 expresses interest in exploring additional data sources such as drone-based monitoring and environmental sensors.

In summary, Part-7 of the survey shows District 4's effective utilization of a range of non-traditional data sources to enhance its traffic management capabilities. The very effective rating of these tools, combined with the district's interest in exploring environmental sensors and drone-based monitoring can improve understanding of traffic patterns.

2.2.4.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 4 covers the various methods employed by the district to detect failures or issues in transportation management, highlighting a comprehensive and multifaceted approach.

Methods for detecting failures or issues

District 4 uses a combination of techniques to identify and address failures or issues in transportation management, which ensures a robust system:

- Manual inspections and reports by transportation staff: These traditional methods provide direct, on-the-ground insights into the state of transportation infrastructure and operations.
- Feedback and complaints from the public or users: Public feedback is crucial for identifying issues that may not be immediately apparent to transportation staff, offering a user-centric perspective.
- Automated monitoring systems and sensors: Technology plays a key role in real-time or near-real-time monitoring of the transportation network, allowing for prompt detection and response to issues.
- Periodic audits and reviews by external agencies: External audits offer an objective assessment of the transportation system's health and compliance with standards.

- Analysis of data and trends from transportation management software: Data-driven approaches enable the district to identify trends and potential issues before they escalate, facilitating proactive management.

These methods ensure a thorough and proactive approach to identifying and addressing transportation management failures or issues in District 4. The combination of manual and technological strategies, along with public input and external reviews, provides a well-rounded system for maintaining and improving transportation efficiency and safety.

2.2.4.8. Learning from best implementations and recommendations for District 4

Learning from best implementations

Key strengths of District 4 include:

- Utilization of non-traditional data sources: The district effectively uses video imaging, drone data, and Bluetooth detectors, which are rated as very effective in enhancing traffic management. These tools provide crucial insights into traffic patterns, contributing significantly to dynamic traffic management.
- Comprehensive failure detection methods: District 4 employs a combination of manual inspections, public feedback, automated monitoring, external audits, and data analysis. This multi-layered approach ensures thorough detection and quick response to transportation issues.

Recommendations for District 4

- Enhance data integration and management: While effective at using various data sources, further integration and management of these sources could provide a more comprehensive traffic analysis, leading to more informed decision-making.

- Expand public engagement: Given the importance of public feedback, enhancing engagement strategies could provide deeper insights into user experiences, potentially uncovering areas for improvement.
- Investment in advanced monitoring technologies: Continued investment in advanced technologies, such as AI-driven analytics and more sophisticated drone capabilities, could further refine the district's ability to monitor and manage traffic.
- Standardization and privacy solutions: Addressing integration difficulties and lack of standardization in data usage will enhance efficiency. Implementing robust privacy solutions will also be vital as data sources become more diverse and complex.
- Exploration of additional data sources: Interest in environmental sensors indicates an opportunity to incorporate more holistic traffic management strategies, considering environmental impacts on traffic.
- Resource allocation for data challenges: Addressing challenges like inadequate data resolution and diversity in data formats will require targeted resource allocation, including funding for new tools and training programs.

The district's practices, along with suggested improvements, can serve as a benchmark for other districts aiming to enhance their traffic management systems.

2.2.5. District 5

2.2.5.1. Part-2: Existing arterial management systems and infrastructure

Part-2 of the survey for Florida Department of Transportation (FDOT) District 5 covers the presence of arterial management systems, the quality of ITS (Intelligent Transportation Systems) equipment, and the implementation status of Automated Traffic Signal Performance Measures (ATSPM).

Arterial management systems

District 5 confirms the presence of arterial management systems. This indicates a structured approach to managing traffic flow, safety, and efficiency on arterial roads.

Quality of ITS equipment

The ITS equipment installed along arterial corridors in District 5 is rated as overall high quality and in line with technological advancements. This assessment implies that District 5 is well-equipped with modern and effective ITS technologies, crucial for managing traffic flow, enhancing road safety, and improving overall traffic conditions.

ATSPM implementation status

ATSPM in District 5 is partially implemented. Partial implementation indicates ongoing efforts to fully integrate this advanced traffic management technology. ATSPM enables data-driven management of traffic signals, improving traffic flow and reducing congestion.

In summary, Part-2 of the survey for District 5 reveals a well-established arterial management system and high-quality ITS equipment, indicative of a strong foundation in traffic management infrastructure.

2.2.5.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 5 delves into data access across various departments, the need for certain data types, confidence in the reliability of routinely collected data, and challenges related to data handling and privacy.

Access to data across departments

Multiple departments within District 5, including Planning, Design, Consultant Project Management, Public Information Office, and Maintenance, have access to traffic data. These data are available upon request from signal maintaining agencies.

Need for additional data types

The district identifies a need for access to several data types, including traffic volume data, pedestrian and bicycle counts, and speed data, which are not currently fully accessible. The acknowledgment of incomplete data sets points to a need for enhanced data collection and completeness.

Confidence in data sources

The district expresses varying levels of confidence in different data sources:

- High confidence: Extremely confident in traffic signal timing plans and real-time traffic signal state data.
- Moderate confidence: Somewhat confident in traffic volume data, turning movement counts, and third-party data sources like Here, Inrix, and Waze.
- Low confidence: Not confident in pedestrian and bicyclist counts and speed data, indicating areas where data collection and analysis could be improved.
- Neutral: Neutral confidence in crash data.

Challenges in data handling and privacy

District 5 faces challenges with firewall rules making data gathering difficult and a lack of understanding between the IT and traffic groups regarding the business case for data access. This situation suggests a need for better coordination and understanding of the mutual benefits of data access and use. Additionally, the lack of clear policies for data privacy is a concern that needs to be addressed to ensure data security and compliance with privacy regulations.

In summary, Part-3 of the survey for District 5 highlights the need for improved access to certain types of traffic data and an increase in data completeness. The district shows strong confidence in some data sources but recognizes areas for improvement in others. Challenges related to data handling, particularly in terms of IT coordination and data privacy, suggest areas for potential development.

2.2.5.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 5 explores the partnerships supporting Traffic Systems Management & Operations (TSM&O) and the benefits derived from these collaborations.

Partnerships supporting TSM&O

District 5 has established a network of partnerships with various agencies and organizations that play a significant role in supporting data collection for TSM&O, including:

- Other FDOT districts: Collaboration with other districts enables the sharing of best practices and experiences, contributing to a more unified state-wide approach to traffic management.
- Local city/county public works departments: These partnerships ensure access to detailed, area-specific traffic data, crucial for localized traffic management.
- Metropolitan Planning Organizations (MPOs): Working with MPOs reflects the integration of regional planning considerations into traffic management strategies.
- Transit agencies and law enforcement: Collaboration with these agencies provides critical data and insights, particularly in areas like transit operations and incident management.
- Third-party sources (HERE, Waze): Utilization of data from these sources indicates an openness to leveraging advanced and diverse data sets for traffic analysis and decision-making.

Primary data providers for TSM&O

Key partners primarily relied upon for data include law enforcement, local agencies, school districts, and technical schools/universities.

Benefits of collaborations

The primary benefits of these collaborations for District 5's TSM&O are:

- Additional data sources: Accessing a wide range of data types enhances the district's ability to manage traffic effectively.
- More data resolution: The collaborations provide a deeper level of detail in traffic data, enabling more nuanced traffic analysis and decision-making.
- Increased accuracy of aggregated data: This benefit points to improved overall data quality and reliability, a crucial factor in effective traffic management.

In summary, Part-4 of the survey for District 5 highlights a comprehensive and collaborative approach to traffic management. The district's partnerships with a variety of agencies and organizations, including third-party data providers, contribute significantly to its traffic systems management and operations, providing access to diverse data sources and enhancing the resolution and accuracy of traffic data.

2.2.5.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 5 addresses the frequency of reviewing performance measures, their reflection of on-ground situations, and the use of data for both short-term and long-term decision-making in traffic management.

Review and update of performance measures

- For district management**:** Performance measures are reviewed and updated weekly, indicating a proactive approach in adapting to changing traffic conditions and needs.

- For staff supporting arterial operators: The review and update of performance measures occur monthly, suggesting a balance between responsiveness and the practicality of implementing changes in arterial traffic management.

Reflection of performance measures on ground situations

The current performance measures are rated as reflecting the situation on the ground very well. This high rating suggests that the measures are effectively aligned with actual traffic conditions, contributing to accurate and responsive traffic management.

Short-term data usage

District 5 utilizes data for short-term decision-making in the following ways:

- Incident management: Prompt response to traffic incidents based on real-time data.
- Communication to the public: Utilizing data for public alerts and real-time updates, possibly through Advanced Traffic Management Systems (ATMS).
- Traffic signal timing adjustments**:** Dynamically adjusting traffic signals based on current traffic conditions.

Long-term strategic data usage

For long-term strategic decision-making, the district employs data in areas such as:

- Infrastructure planning and upgrades: Guiding decisions on infrastructure changes to improve traffic flow and safety.
- Signal retiming needs identification: Ensuring optimal traffic signal operations.
- Operations and maintenance needs: Planning for efficient operations and maintenance activities.
- Funding and budget allocation: Allocating resources effectively based on data-driven insights.

- Public communication strategies: Developing strategies for public engagement and information dissemination.

Benefits of operational strategies

District 5 has observed specific advantages from employing operational strategies like ICM or AAM, which include improved signal coordination, more efficient resource allocation, and an enhanced decision-making process. These benefits highlight the effectiveness of these strategies in optimizing traffic management and response.

In summary, Part-5 of the survey for District 5 reveals a strategic and dynamic use of data in traffic management. The district demonstrates a high alignment of performance measures with real-world conditions and effectively employs data in both short-term responsiveness and long-term planning.

2.2.5.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 5 covers the establishment, review, and adherence to minimum requirements for data accuracy and granularity in traffic management, including the challenges faced and resources needed.

Establishment of minimum requirements

District 5 utilizes a combination of factors to establish minimum data requirements:

- University research and specific use cases: These inputs help in tailoring the data requirements to the specific needs and challenges of the district.
- Reasonable inspection: This suggests a pragmatic approach, likely involving on-the-ground assessments.
- Operational, maintenance, signal retiming, and design needs: These considerations ensure that the data requirements align with various practical aspects of traffic management.

Review and update frequency

The minimum requirements are reviewed and updated on an ad-hoc basis, indicating a flexible approach that likely responds to changing needs and situations.

Adherence to standards and regulations

The district adheres to the industry standards, supplemented by university research and use case needs. This approach demonstrates a commitment to maintaining high-quality data standards that are both practical and research-informed.

Challenges in meeting minimum requirements

District 5 faces several challenges:

- Lack of appropriate tools: This issue can hinder effective data collection and analysis.
- Lack of orthogonal datasets: The absence of diverse, independent datasets can limit the depth of analysis and insights.
- Other challenges are not specified but may relate to the dynamic nature of traffic patterns and data management.

Systems and procedures for compliance

Systems in place include automated validation tools, manual evaluations, and comparisons with other performance measures. These methods help ensure data quality and reliability.

Implications of non-compliance

Not meeting these minimum requirements has led to paralyzed decision-making, highlighting the critical importance of reliable data in informed traffic management.

Resources and tools needed

To consistently meet these requirements, the district identifies the need for better data collection tools/equipment and new data sources. This recognition points towards an ongoing effort to enhance the district's data collection and analysis capabilities.

In summary, Part-6 of the survey for District 5 highlights a detailed and research-informed approach to establishing data requirements. While the district faces challenges in data collection and diversity, there is a clear recognition of the need for enhanced tools and new data sources to support effective traffic management.

2.2.5.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 5 focuses on the use of non-traditional data sources for transportation management, their effectiveness, and any potential challenges or future interests in additional data sources.

Usage of non-traditional data sources

District 5 is utilizing non-traditional data sources such as video imaging and drone data. The use of these advanced tools indicates a commitment to incorporating innovative approaches to traffic management.

Most useful non-traditional data sources

The survey does not specify which of the non-traditional data sources have been most useful. However, the inclusion of video imaging and drone data suggests these may be among the valuable tools for the district's traffic management needs.

Frequency of data updates

The frequency of updates from these alternative data sources is not specified, implying variability based on the source or use case.

Effectiveness of alternative data sources

The effectiveness of these data sources in managing transportation was not specifically rated, leaving it unclear how significantly these tools are impacting traffic management in the district.

Challenges and issues

The district did not specify any particular challenges or issues associated with the use of these alternative data sources.

Interest in exploring additional data sources

District 5 shows interest in exploring additional alternative data sources, such as third-party navigation apps and drone-based monitoring.

In summary, Part-7 of the survey for District 5 reveals an openness to adopting innovative data collection methods like video imaging and drones. While the effectiveness and challenges of these tools are not explicitly detailed, the district's interest in exploring additional technologies demonstrates a commitment to enhancing their traffic management capabilities through modern solutions.

2.2.5.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 5 addresses the methodologies used to detect failures or issues in transportation management.

Methods for detecting failures or issues

District 5 utilizes several methods to identify and address transportation management failures or issues, reflecting a comprehensive and proactive approach:

- Manual inspections and reports by transportation staff: This traditional approach allows for direct observation and immediate reporting of issues on the ground.

- Automated monitoring systems and sensors: Utilizing technology for real-time or near-real-time monitoring, these systems enable the district to quickly identify and respond to transportation issues as they occur.
- Analysis of data and trends from transportation management software: Employing data-driven strategies, the district can identify trends and potential issues, facilitating a more proactive approach to traffic management.

These methods collectively ensure a thorough and responsive approach to detecting and addressing transportation management issues in District 5. The integration of manual, technological, and data-driven strategies provide a robust framework for maintaining and improving the efficiency and safety of the transportation network.

2.2.5.8. Learning from best implementations and recommendations for District 5

Learning from best implementations

District 5 of the Florida Department of Transportation (FDOT) showcases a dynamic approach to traffic systems management and operations (TSM&O), integrating modern technologies and diverse data sources for effective transportation management.

Key Strengths of District 5:

- Advanced data utilization: The district effectively employs video imaging and drone data, demonstrating an innovative approach to traffic analysis.
- Comprehensive failure detection: Utilizing manual inspections, automated systems, and data analysis, District 5 ensures timely identification and response to traffic issues.
- Collaborative approach: Partnerships with local agencies, MPOs, law enforcement, and third-party sources like HERE and Waze enhance data richness and decision-making accuracy.

- Proactive performance measurement**:** Regular reviews of performance measures (weekly for management and monthly for staff) indicate a commitment to maintaining up-to-date and responsive traffic strategies.

Recommendations for District 5

- Enhanced integration of non-traditional data: While using innovative data sources, further integration and analysis could provide deeper insights, especially for pedestrian and bicycle traffic management.
- Improvement in data confidence levels: Addressing the reported lack of confidence in pedestrian, bicyclist counts, and speed data through advanced data collection and validation tools could enhance overall traffic management efficiency.
- Expansion in data source utilization: Exploring additional non-traditional data sources like third-party navigation apps and environmental sensors could offer more comprehensive traffic management solutions.
- Addressing data handling hallenges: Resolving identified challenges like firewall restrictions and coordination issues between IT and traffic groups could streamline data access and usage.
- Standardization and privacy enhancement: Implementing standardized data handling practices and robust privacy policies would further secure and optimize data utilization.
- Resource allocation for data challenges**:** Investing in better tools and new data sources, as indicated by the district's interest, would address current limitations in data resolution and aggregation.

2.2.6. District 6

2.2.6.1. Part-2: Existing arterial management systems and infrastructure

In Part-2 of the survey for Florida Department of Transportation (FDOT) District 6, we examine the state of existing arterial management systems and infrastructure, with a focus on the quality of ITS equipment and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation.

Arterial management systems presence

District 6 confirms the existence of arterial management systems. The presence of these systems indicates a fundamental framework for managing traffic flow, safety, and operational efficiency across the district.

Quality of ITS equipment by county

The quality of Intelligent Transportation Systems (ITS) equipment varies by county within District 6:

- Monroe County: The ITS equipment is rated as overall high quality and in line with technological advancements. This suggests a strong alignment with current technology standards and indicates a proactive approach to maintaining state-of-the-art traffic management infrastructure.
- Miami Dade County: The equipment is described as medium quality and somewhat outdated. However, a significant update is underway through a countywide project focusing on traffic signal infrastructure and central software.

Automated traffic signal performance measures (ATSPM) implementation

The status of ATSPM implementation also varies between the counties:

- Monroe County: ATSPM is fully implemented, with some parts still under construction. This demonstrates a forward-thinking approach in adopting advanced traffic management techniques, contributing to more efficient and responsive traffic signal operations.
- Miami Dade County: ATSPM is in the planning stage. This indicates an acknowledgment of the importance of ATSPM and a move towards implementing these measures to improve traffic signal performance and overall traffic management.

The survey responses for Part-2 highlight District 6's efforts to maintain and upgrade its arterial management systems and infrastructure. The contrast in ITS equipment quality and ATSPM implementation between Monroe County and Miami Dade County showcases the district's varied approaches to traffic management, reflecting different stages of technological adoption and infrastructure development.

2.2.6.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 6 provides insights into data source accessibility, beneficial data types currently inaccessible, confidence in data sources, and privacy challenges.

Accessibility of data sources by departments

Multiple departments within District 6, including Planning, Design, Consultant Project Management, Public Information Office, Maintenance, and TSM&O, have access to various data sources. In Monroe County, ATSPM data is accessible by SunGuide TMC and support staff, while in Miami Dade County, there is no access to ATSPM data. This disparity highlights differences in data accessibility and the implementation stage of ATSPM between counties.

Beneficial data types and accessibility

District 6 identifies traffic volume data, turning movement counts, and pedestrian and bicycle counts as beneficial data types that are currently inaccessible. The D6 TSM&O office and supporting consultant staff have access to RITIS, INRIX IQ, real-time traffic signal status data, and Signal4Analytics. However, these sources are predominantly vehicle-centric. The district expresses a need for multimodal data sources, particularly for pedestrian and bicycle performance measures, to support context-sensitive efforts. Also, expanding ATSPM access to include live data could enhance performance measures and traffic data collection.

Confidence in routinely collected data sources

The district exhibits high confidence in the reliability and applicability of traffic volume data, turning movement counts, speed data, and traffic signal timing plans. For pedestrian and bicyclist counts, the district remains neutral, indicating a need for improved data collection methods in these areas. Confidence in crash data is somewhat moderate, suggesting room for improvement in the accuracy and comprehensiveness of this data. The district is very confident in real-time traffic signal state data in Monroe County, but there's a somewhat lower confidence in commonly used third-party data sources like Here, Inrix, Waze, etc.

Privacy issues and data handling

District 6 has not yet encountered significant challenges related to privacy issues such as data anonymization, clear policies for data privacy, compliance with privacy regulations, or data security concerns. This absence of reported difficulties suggests effective management and adherence to privacy standards in their data handling processes.

In summary, Part-3 of the survey for District 6 reveals a well-structured approach to data management, with varied levels of data accessibility across different departments and counties.

The district shows strong confidence in most of its routinely collected data sources but acknowledges the need for more multimodal data to support comprehensive traffic management. The lack of significant privacy challenges indicates a strong framework for data security and privacy compliance.

2.2.6.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 6 focuses on the partnerships that support data collection for Traffic Systems Management & Operations (TSM&O) and the benefits of these collaborations.

Partnerships supporting TSM&O

District 6 engages in partnerships with a variety of agencies for data collection in TSM&O. These partners include other FDOT districts, local city/county public works departments, Metropolitan Planning Organizations (MPOs), transit agencies, and law enforcement (Florida Highway Patrol, police departments, sheriff's offices). A specific collaboration is highlighted with Miami-Dade County, where District 6 has access to their traffic signal system. This partnership allows for monitoring signalized intersections along state roads and is a vital part of managing the traffic system efficiently.

Nature of data collection and collaboration

The district retrieves data from available sources from the Florida Highway Patrol (FHP), which indicates a reactive rather than a proactive collaborative approach. They also have access to Advanced Traffic Management Systems (ATMS) for signal timing data and real-time traffic data. This access is crucial for real-time traffic management and for adjusting strategies based on current traffic conditions.

Primary data providers for TSM&O

Law enforcement and local agencies, such as Miami-Dade County, are primarily relied upon for data provision. These agencies play a critical role in incident management resources. TSM&O or other Traffic Operations groups are also involved in traditional data collection activities, like turning movement counts, demonstrating a multifaceted approach to data gathering.

Benefits of collaborations

The primary benefits of these collaborations for TSM&O in District 6 include access to additional data sources and the ability to identify additional needs and considerations. These collaborations allow for a more comprehensive data collection, which is essential for effective traffic management. The access to diverse data sources and insights helps in enhancing the accuracy of aggregated data and in understanding the broader traffic management needs.

The survey responses for Part-4 underscore the importance of collaborative efforts in TSM&O for District 6. These partnerships not only facilitate a more comprehensive approach to data collection but also contribute to a more nuanced understanding of traffic management requirements and strategies.

2.2.6.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 6 examines how data are used in performance measures and decision support systems, reflecting on both short-term and long-term strategies as well as the benefits of employing operational strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM).

Frequency of review and update of performance measures

In District 6, performance measures are reviewed and updated at various intervals, including daily, weekly, monthly, quarterly, and annually. This approach ensures a constant evaluation and adjustment of traffic management strategies, allowing for responsiveness to changing conditions and needs. Additionally, District 6 posts performance measures data and reports online for public access, indicating transparency and community engagement.

Reflection of on-ground situations in performance measures

The performance measures are considered to reflect the on-ground traffic situations moderately well. This rating suggests a balanced approach but also indicates room for further refinement to more closely align performance metrics with actual traffic conditions.

Short-term data use

For short-term decisions, District 6 utilizes data for traffic signal timing adjustments, incident management, resource allocation for immediate issues, and communication to the public. These applications demonstrate a dynamic use of data to address day-to-day and weekly operational needs effectively.

Long-term strategic data use

For the long-term strategic decisions, the district employs data in various areas, including infrastructure planning and upgrades, signal retiming needs, operations and maintenance, funding and budget allocation, policy or strategy formulation, and public communication strategies. The district is currently planning a retiming program for dashboard support, indicating an ongoing effort to enhance traffic flow and management.

Benefits of employing ICM or AAM

District 6 recognizes several advantages of using operational strategies like ICM or AAM. These benefits include improved signal coordination, reduced travel time, enhanced traffic flow, better incident management, more efficient resource allocation, enhanced safety measures, and an improved decision-making process. The implementation of these strategies reflects a comprehensive approach to traffic management, leveraging advanced tools and techniques to optimize traffic flow and safety.

In summary, Part-5 of the survey reveals District 6's multifaceted approach to using data in traffic management. The district's frequent review and updating of performance measures, along with the application of data in both short-term and long-term decision-making, demonstrate a robust and dynamic traffic management strategy. The benefits realized from employing advanced operational strategies like ICM or AAM further allow for effective and efficient traffic management.

2.2.6.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 6 focuses on the establishment, review, adherence to standards, and challenges of meeting minimum requirements for data accuracy and granularity.

Establishment of minimum requirements

In District 6, minimum requirements for data accuracy and granularity are primarily established based on operational and signal retiming needs. In Monroe County, Automated Traffic Signal Performance Measures (ATSPM) detector configurations are set up to meet these requirements, with data accuracy based on specifications and granularity varying by configuration. However, in Miami Dade County, specific processes or standards for establishing these requirements are not applicable (N/A).

Review and update of requirements

District 6 does not have a current established review cycle for these minimum requirements. The lack of a regular review process suggests an area for improvement in ensuring that data standards are consistently up-to-date and responsive to changing needs.

Adherence to standards and regulations

The district adheres to federal guidelines, state mandates, and industry standards when setting minimum data requirements. This adherence supports maintaining high-quality data standards that align with broader regulatory and industry practices.

Challenges in meeting minimum requirements

Challenges faced by the district include funding for hardware/software storage and lack of data aggregation. These challenges highlight resource limitations and the need for more effective data management strategies.

Systems and procedures for compliance

To ensure data meets these minimum requirements, District 6 employs third-party evaluations and comparisons with other performance measures. These methods suggest a comprehensive approach to validate data accuracy and relevance.

Resources and tools for meeting requirements

Identified resources and tools that could aid in consistently meeting these requirements include better data collection tools/equipment, improved/increased data aggregation, training programs, and an increased budget. These needs point towards a desire to enhance the district's data collection and analysis capabilities.

In summary, Part-6 of the survey reveals District 6's structured approach to establishing minimum data requirements, primarily driven by operational and signal retiming needs. While the district adheres to various standards and employs methods to ensure compliance, challenges in funding and data aggregation persist. The identification of needed resources and tools indicates an awareness of areas for improvement.

2.2.6.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 6 also examines the use of non-traditional data sources for transportation management, as well as their effectiveness, challenges, and areas of potential exploration.

Usage of non-traditional data sources

District 6 actively uses a variety of non-traditional data sources, including video imaging, Wi-Fi detectors, Bluetooth detectors, and third-party data sources such as WAZE, Google Traffic, RITIS, and INRIX Signal Analytics.

Most useful non-traditional data sources

Among these, third-party data sources, particularly WAZE and RITIS, are identified as the most useful. These platforms likely provide real-time traffic updates and analytics, crucial for dynamic traffic management.

Frequency of data updates

Data from these sources are updated in real-time, though the frequency may vary depending on the assignment. Real-time data are essential for immediate traffic management decisions and incident responses.

Effectiveness of alternative data sources

The effectiveness of these data sources is rated as moderately effective, which suggests they provide valuable insights but may have limitations or areas for improvement.

Challenges and issues

The primary challenge associated with these data sources is their limited coverage area. This limitation could impact the comprehensiveness of the data collected and potentially affect the district's ability to manage traffic effectively across all areas.

Interest in exploring additional data sources

District 6 shows interest in exploring additional alternative data sources, such as third-party navigation apps, drone-based monitoring, and environmental sensors. Specifically, they are interested in multimodal data for non-motorized traffic (pedestrians and bicycles), other micro-mobility modes (scooters), and transit. The interest in expanding to these areas highlights a desire to enhance the district's understanding of various traffic components, especially those related to non-motorized and micro-mobility traffic, which are becoming increasingly important in urban traffic management.

In summary, Part-7 of the survey illustrates District 6's efforts to incorporate a range of non-traditional data sources in its traffic management strategies. While these sources are proving beneficial, the district recognizes the need to expand their data coverage and explore new areas to enhance their transportation management capabilities further.

2.2.6.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 6 explores the methods used to detect failures or issues in transportation management and any additional information the district wishes to share regarding system-level data.

Methods for detecting failures or issues

District 6 employs a variety of methods to detect failures or issues in transportation management, ensuring a multi-faceted approach to maintaining system integrity and responsiveness:

- Manual inspections and reports: Transportation staff conduct manual inspections and generate reports, which are crucial for identifying issues that automated systems might not detect.

- Feedback and complaints from the public or users: The district values input from the public and users, utilizing this feedback as a significant method for identifying issues..
- Automated monitoring systems and sensors: The use of technology, such as automated monitoring systems and sensors, plays a critical role in failure detection. These systems likely provide real-time or near-real-time data, enabling prompt identification and response to issues.

Consideration of system-level data

District 6 highlights the importance of considering system-level data in their transportation management strategy. Specifically, they mention that currently, RITIS (Regional Integrated Transportation Information System) only provides access to SHS (State Highway System) data. By considering broader system-level data, District 6 can develop more comprehensive strategies that address the interconnected nature of transportation networks. The survey responses for Part-8 indicate that District 6 utilizes a comprehensive approach to detect transportation system failures, combining manual inspections, public feedback, and automated systems.

2.2.6.8. Learning from best implementations and recommendations for District 6

Learning from best implementations

A notable strength of District 6 is its dynamic use of non-traditional data sources, such as video imaging, Wi-Fi detectors, Bluetooth detectors, and third-party sources like WAZE and RITIS. These tools provide a broad view of traffic conditions, crucial for real-time decision-making and long-term planning. Particularly, the effective use of third-party data sources like WAZE for real-time updates and RITIS for comprehensive traffic analytics shows are noteworthy. The district's commitment to frequent review and update of performance measures – daily, weekly, monthly, quarterly, and annually – ensures a continuous assessment of traffic management strategies.

Recommendations for District 6

- Enhance data coverage and integration: While District 6 effectively uses various data sources, expanding coverage areas and further integrating these data can provide a more comprehensive traffic management overview. Addressing the challenge of limited coverage in alternative data sources will enhance the effectiveness of these tools.
- Establish a review cycle for minimum requirements: Currently, there is no established review cycle for minimum data requirements. Implementing a regular review process will ensure that data standards remain relevant and responsive to evolving traffic management needs.
- Focus on system-level data analysis: The district's consideration of system-level data is worth nothing. The scope of data analysis beyond SHS to include broader transportation network data can improve the existing management strategies.
- Invest in resource allocation for data management: Addressing the challenges of funding for hardware/software storage and data aggregation requires targeted investment. Exploring avenues for additional funding or reallocating existing resources can support the district's data management capabilities.
- Multimodal data expansion: District 6's interest in exploring multimodal data for non-motorized traffic and micro-mobility modes requires additional investments.
- Public engagement and transparency: The practice of posting performance measures data online for public access is important to highlight. Continuing to enhance public

engagement and transparency in traffic management processes will foster community trust and support.

By implementing these recommendations, District 6 can further strengthen its traffic management system, ensuring it remains efficient, responsive, and innovative. Other districts can also learn from these practices, adapting them to their unique contexts.

2.2.7. District 7

2.2.7.1. Part-2: Existing arterial management systems and infrastructure

In Part-2 of the survey for Florida Department of Transportation (FDOT) District 7, the focus is on the existing arterial management systems, the quality of ITS (Intelligent Transportation Systems) equipment, and the status of Automated Traffic Signal Performance Measures (ATSPM) implementation.

Arterial management systems presence

District 7 confirms the presence of arterial management systems, indicating that there is an established framework for managing traffic flow, safety, and operational efficiency on arterial roads within the district.

Quality of ITS equipment

The quality of the ITS equipment installed along the arterial corridors in District 7 is rated as medium quality and, in many cases, a little outdated. This assessment points to a need for technological upgrades and modernization in the district's traffic management infrastructure. It suggests that while the current systems are functional, there is room for improvement, particularly in adopting more advanced technologies to enhance traffic control and safety measures.

ATSPM implementation status

The status of ATSPM implementation in District 7 is described as partially implemented. This partial implementation reflects a progressive step towards adopting more sophisticated traffic management systems.

The findings highlight the presence of essential management systems, the need for updates and enhancements in ITS equipment, and the ongoing implementation of ATSPM. These elements collectively show the efforts towards modernizing and improving traffic management capabilities in the district.

2.2.7.2. Part-3: Data sources and management

Part-3 of the survey for Florida Department of Transportation (FDOT) District 7 focuses on data source accessibility within various departments, the beneficial data types that are currently inaccessible, confidence in routinely collected data sources, and privacy issues related to data handling.

Accessibility of data sources across departments

Accessibility to different data types within District 7 varies depending on the type of data. This suggests a tailored approach to data access, where specific departments or teams have access to data relevant to their functions. Such an approach can be beneficial for focused data analysis and usage but may require effective inter-departmental communication to ensure a comprehensive understanding of the traffic system.

Beneficial data types and accessibility

Notably, District 7 does not identify any specific data types as beneficial but currently inaccessible. This response indicates that the district either has access to all the data types it needs or has not identified additional data types that could further enhance its traffic management strategies.

Confidence in routinely collected data sources

The district expresses extremely high confidence in the reliability and applicability of all the routinely collected data sources listed, including traffic volume data, turning movement counts, pedestrian and bicyclist counts, speed data, crash data, traffic signal timing plans, real-time traffic signal state data, and commonly used third-party data sources.

Privacy issues and data handling

District 7 reports having encountered none of the listed privacy issues or challenges related to data handling. This absence of reported difficulties implies effective management and adherence to privacy standards in their data handling processes, ensuring data security and compliance with relevant regulations.

In summary, Part-3 of the survey reveals that District 7 has tailored access to various data types across different departments, ensuring that data usage is relevant and effective. The district's extremely high confidence in its routinely collected data sources and the absence of significant privacy challenges highlight a strong framework for data accuracy, reliability, and security.

2.2.7.3. Part-4: Agencies involved

Part-4 of the survey for Florida Department of Transportation (FDOT) District 7 addresses the partnerships that support data collection for Traffic Systems Management & Operations (TSM&O) and the benefits of these collaborations.

Partnerships supporting TSM&O

District 7 collaborates with a range of agencies to support data collection in TSM&O. These partnerships include:

- Local city/county public works departments: Their involvement suggests a strong connection with local infrastructure management, crucial for detailed and area-specific traffic data.
- Metropolitan Planning Organizations (MPOs): Collaboration with MPOs indicates an integration of broader regional planning considerations in traffic management.
- Transit agencies: This partnership is likely key to understanding and managing traffic flows related to public transportation systems.
- Law enforcement (Florida highway patrol, police departments, sheriff's offices): Engagement with law enforcement agencies ensures access to crucial data like traffic incident reports and enforcement-related information.

Primary data providers for TSM&O

Among these partners, local agencies are primarily relied upon to provide data for analysis in TSM&O activities. The reliance on local agencies underlines the importance of ground-level data and insights in traffic management strategies.

Benefits of collaboration

The primary benefits identified from these collaborations for TSM&O in District 7 include:

- Different/additional perspectives: Collaboration with various agencies brings diverse viewpoints and insights, enhancing the understanding of traffic patterns and management needs.

- Additional data sources: Access to data from multiple sources allows for a more comprehensive analysis and informed decision-making.
- Identify additional needs/considerations: These partnerships help in recognizing broader or previously unconsidered traffic management needs and challenges.

2.2.7.4. Part-5: Uses of data (performance measures and decision support systems)

Part-5 of the survey for Florida Department of Transportation (FDOT) District 7 covers the frequency of reviewing performance measures, the reflection of these measures on ground situations, and how data are used for both short-term and long-term decision-making.

Review and update of performance measures

For district management, performance measures in District 7 are reviewed and updated quarterly. This periodic review suggests a balance between responsiveness and the practicality of implementing changes based on these measures. In contrast, for staff supporting arterial operators, performance measures are not regularly reviewed. This absence of routine review may indicate a potential area for improvement to ensure more dynamic and responsive traffic management at the arterial level.

Reflection of performance measures on ground situations

The current performance measures are considered to reflect the situation moderately well on the ground. This rating indicates that while the measures provide a reasonable representation of traffic conditions, there is an opportunity to align them more closely with actual situations.

Short-term data use

District 7 utilizes data for making short-term decisions in areas such as traffic signal timing adjustments, resource allocation for immediate issues, and communication to the public. These applications highlight a focus on addressing immediate traffic management needs and enhancing public information dissemination.

Long-term strategic data use

For long-term strategic decisions, the district employs data in infrastructure planning and upgrades, identification of signal retiming needs, operations and maintenance needs, funding and budget allocation, and policy or strategy formulation.

Implementation of operational strategies

District 7 is in the process of implementing operational strategies like Integrated Corridor Management (ICM) or Active Arterial Management (AAM). Although specific advantages of these strategies are not yet reported, the move towards their implementation indicates an ongoing progress to enhance traffic management effectiveness.

Lastly, Part-5 of the survey for District 7 reveals a structured approach to using data in traffic management, with an emphasis on quarterly review of performance measures and applications in both short-term and long-term decision-making. The ongoing implementation of advanced operational strategies further underscores the district's dedication to improving traffic system efficiency and responsiveness.

2.2.7.5. Part-6: Minimum requirements

Part-6 of the survey for Florida Department of Transportation (FDOT) District 7 focuses on the establishment, review, adherence to standards, and challenges of meeting minimum requirements for data accuracy and granularity.

Establishment of minimum requirements

Minimum requirements for data accuracy and granularity in District 7 are established based on a combination of factors: operational needs, maintenance needs, signal retiming needs, and design needs. This multi-faceted approach indicates that the district considers various aspects of traffic management to ensure comprehensive and accurate data collection.

Review and update of requirements

These minimum requirements are reviewed and updated according to the industry standards and as needed. The flexible approach of updating as needed, combined with adherence to industry standards, ensures that data requirements remain relevant and effective over time.

Adherence to standards and regulations

District 7 adheres to federal guidelines, state mandates, and industry standards when setting minimum data requirements. This commitment to following higher-level guidelines and standards underscores allows District 7 to maintain high-quality data management practices**.**

Challenges in meeting minimum requirements

Notably, District 7 reports having faced no challenges or issues in adhering to these minimum requirements. The lack of significant challenges suggests that the district has effective systems and processes in place for managing data requirements.

Systems and procedures for compliance

To ensure that data meet these minimum requirements, District 7 employs manual evaluations, third-party evaluations, and comparisons with other performance measures. These varied methods of validation are used to ensure data accuracy and relevance.

Resources and tools for meeting requirements

The only resource identified as beneficial for consistently meeting these requirements is an increased budget. This suggests that while the district is managing well with its current resources, additional funding could further enhance its data management capabilities.

In summary, Part-6 of the survey reveals District 7's structured approach to establishing, reviewing, and adhering to minimum data requirements, primarily driven by operational, maintenance, signal retiming, and design considerations. The district's successful adherence to standards without significant challenges and its reliance on various methods for data validation reflect an effective and comprehensive approach to data management.

2.2.7.6. Part-7: Non-traditional data sources

Part-7 of the survey for Florida Department of Transportation (FDOT) District 7 investigates the use of non-traditional data sources for transportation management, their effectiveness, challenges, and areas of potential exploration.

Usage of non-traditional data sources

District 7 actively uses various non-traditional data sources, including video imaging, drone data, Bluetooth detectors, third-party data sources, and GPS probes. The adoption of these diverse sources aims to capture a comprehensive and nuanced view of traffic conditions.

Most useful non-traditional data sources

The district finds video imaging, drone data, and Bluetooth detectors particularly useful. These tools provide unique insights into traffic conditions, from ground-level traffic flow to aerial views for broader traffic management perspectives.

Frequency of data updates

Data from these alternative sources are updated in real-time. Real-time data are essential for immediate traffic management decisions and incident responses.

Effectiveness of alternative data sources

These data sources are rated as very effective for managing transportation in District 7, suggesting that they significantly contribute to the district’s traffic management capabilities.

Challenges and issues

The primary challenge associated with these data sources is their limited coverage area and access. These limitations could impact the comprehensiveness of the data collected and potentially affect the district's ability to manage traffic effectively across all areas.

Interest in exploring additional data sources

District 7 shows interest in exploring additional data sources, such as third-party navigation apps, drone-based monitoring, and video analytics. The interest in these areas highlights a desire to further enhance the district's understanding of various traffic components and incorporate advanced analytics into traffic management.

District 7's incorporates a range of non-traditional data sources in its traffic management strategies. While these sources have proven very effective, the district recognizes the need to expand their data coverage and explore new data collection methods.

2.2.7.7. Part-8: Coordination, statewide system, failure detection, costs, and vendor selection

Part-8 of the survey for Florida Department of Transportation (FDOT) District 7 explores the methods used to detect failures or issues in transportation management, indicating a comprehensive approach to maintaining system integrity and efficiency.

Methods for detecting failures or issues

District 7 employs a multi-faceted approach to detect failures or issues in transportation management:

- Manual inspections and reports by transportation staff: These traditional methods remain vital for identifying issues, particularly those that may not be easily detected by automated systems.

- Feedback and complaints from the public or users**:** The district values public input as a significant source for identifying potential issues.
- Automated monitoring systems and sensors: The use of technology in failure detection is crucial for real-time or near-real-time identification of issues, allowing for prompt responses.
- Periodic audits and reviews by external agencies: These reviews provide an external perspective and validation of the district's transportation management practices.
- Analysis of data and trends from transportation management software: This approach underscores the importance of data-driven strategies in identifying and addressing transportation system issues.

The combination of these methods in District 7 aims to deliver a responsive approach to identifying and addressing transportation management failures or issues. By integrating manual inspections, public feedback, automated systems, external audits, and data analysis, the district can effectively monitor and manage its transportation system.

2.2.7.8. Learning from best implementations and recommendations for District 7

Learning from best implementations

Florida Department of Transportation (FDOT) District 7 has been shown to integrate diverse data sources and a multi-layered strategy for system monitoring and issue detection. The district's use of a variety of non-traditional data sources, including video imaging, drone data, Bluetooth detectors, GPS probes, and third-party data, allows District 7 to leverage the latest technologies for traffic analysis. These tools provide real-time insights and broad traffic perspectives, crucial for effective traffic management.

Another notable aspect is the district's rigorous approach to failure detection. By combining manual inspections, public feedback, automated monitoring systems, external audits, and data analysis, District 7 ensures a thorough and responsive system for identifying and addressing transportation issues.

Recommendations for District 7

- Expand data source coverage: Addressing the limited coverage area of alternative data sources can further enhance the effectiveness of these tools. Expanding coverage and access to these data sources will provide a more comprehensive understanding of traffic conditions across the district.
- Enhance data integration and analysis: While the district is effectively using various data sources, there is an opportunity to further integrate and analyze this data for more nuanced traffic management strategies. This could involve advanced data analytics techniques to synthesize information from different sources.
- Regular review of performance measures: Instituting a more frequent review process for performance measures, especially for staff supporting arterial operators, can ensure that these metrics are continuously aligned with ground realities and changing traffic patterns.
- Invest in resource allocation for data management: Considering the high effectiveness of alternative data sources, investing in resource allocation for better data management, including tools for data aggregation and analysis, can be beneficial.
- Further develop operational strategies: As District 7 works on implementing strategies like ICM and AAM, focusing on their development and integration into the

existing traffic management system will be key. Identifying specific objectives and expected outcomes from these strategies can guide their effective implementation.

- Community engagement and transparency: Continuing to engage with the community and ensuring transparency in traffic management processes can build public trust and support. This can include more active communication strategies and public involvement in traffic management initiatives.

By adopting these recommendations, District 7 can further strengthen its traffic management system, ensuring it remains innovative, efficient, and responsive.

2.3. Detailed recommendations for FDOT districts based on survey responses

Utilizing data for strategic decision making

- Long-term planning: Use data-driven insights for infrastructure planning, identifying areas needing upgrades or new installations.
- Performance metrics development: Develop and regularly update performance metrics that accurately reflect current traffic conditions and system performance.

Cross-district collaboration and knowledge sharing

- Regular workshops and meetings: Organize regular workshops and meetings where districts can share their challenges, successes, and learn from each other.
- Joint projects: Initiate joint projects or pilot studies involving multiple districts to tackle common issues, such as congestion management or incident response strategies.

Addressing specific needs and gaps identified in districts

- For districts with lower data confidence**:** Focus on enhancing data collection methods, especially for pedestrian and bicyclist counts where confidence is low. Utilize advanced sensors and machine learning algorithms to improve accuracy.

- For districts considering non-traditional data sources**:** While maintaining a focus on uniform data sets, we recommend evaluating and, where appropriate, adopting innovative data collection methods like drones and Bluetooth detectors. This adoption should be guided by a framework that ensures data compatibility and consistency across all districts.
- For districts facing data integration challenges: Provide technical support and resources to overcome integration difficulties, including software that can handle diverse data formats.

Enhanced data analysis capabilities

- Advanced analytics tools: Invest in advanced data analytics tools that leverage AI and machine learning to predict traffic patterns, identify potential bottlenecks, and suggest optimization strategies.
- Increased staffing: Recruit and train additional data analysts and traffic engineers specializing in big data analytics and machine learning. This will enhance the capability to analyze complex datasets and derive actionable insights.
- Training programs: Develop continuous training programs for existing staff to keep them updated on the latest data analysis techniques and tools.

Centralized data management system

- Implementation: Adopt a cloud-based, centralized data management system like Amazon Web Services (AWS) for all districts. AWS can offer scalable storage, high availability, and robust data security.
- Integration: Ensure this system integrates data from various sources (traffic counts, signal timing, incident reports) and allows for real-time data processing and analysis.

- Accessibility: Create a unified dashboard accessible to all districts, enabling real-time monitoring and comparison of traffic conditions, trends, and system performance.
- Data standardization: Establish standard data formats and protocols to ensure seamless data integration and comparability across districts.

Summary and key takeaways for FDOT's traffic management enhancement

By integrating advanced technology and data analytics into its Traffic Systems Management and Operations (TSM&O) the Florida Department of Transportation (FDOT) can significantly enhance traffic management across its districts. The comprehensive analysis of survey responses from all seven districts highlights a shared need for more unified, efficient, and innovative approaches to traffic data management and analysis.

A central theme emerging from the districts' feedback is the necessity of a centralized data management system. Adopting a cloud-based platform like Amazon Web Services (AWS) across all districts would standardize data collection, storage, and processing. This unification will not only bring consistency in data handling but also facilitate real-time monitoring and decision making. Moreover, it would enable the seamless integration of data from diverse sources, ensuring a comprehensive view of traffic scenarios across the state.

However, the implementation of such a system requires more than just technological upgrade. There is a clear need for an increase in specialized personnel skilled in data analytics. Districts would greatly benefit from additional data analysts and traffic engineers who are adept in big data analytics and machine learning. These professionals could gain insights into complex traffic datasets and develop recommendations that could inform decisions relating to daily traffic management as well as long-term infrastructural planning.

Addressing specific needs identified in the districts forms another crucial aspect of the proposed enhancement. Districts expressing low confidence in certain data types, like pedestrian and bicyclist counts, need targeted initiatives to improve data accuracy. Utilizing advanced sensors and AI algorithms can significantly boost the precision of these counts. Similarly, districts that have already embraced non-traditional data sources should be encouraged to share their experiences and best practices, paving the way for others to follow suit.

A collaborative framework is essential for realizing these enhancements. Regular workshops, meetings, and joint projects involving multiple districts would not only facilitate knowledge sharing but also foster a culture of collective problem-solving. Such collaboration can lead to innovative solutions to common traffic management challenges, benefiting the state as a whole.

Lastly, the strategic use of data in long-term planning cannot be overstated. Data-driven insights should be the cornerstone of infrastructure development, maintenance scheduling, and resource allocation. Continuously updated performance metrics reflecting real-time traffic conditions will ensure that traffic management strategies remain relevant and effective.

FDOT's efforts towards a more data-driven, collaborative, and technologically advanced traffic management system is both necessary and timely. By centralizing data management, enhancing analytics capabilities, addressing district-specific needs, fostering collaboration, and strategically using data for planning and decision making, FDOT can significantly improve traffic operations, not just in individual districts but across the stat

Chapter 3

3.1. Introduction and overview

The evolution of transportation systems into increasingly complex networks necessitates a parallel advancement in their management and operation. The Florida Department of Transportation (FDOT) recognizes this and aims to use the potential of technology innovation and data-driven decision making. This initiative aims to significantly enhance the efficiency, safety, and sustainability of Florida's transportation infrastructure through the strategic application of data-driven strategies.

This initiative is underpinned by the Cloud-Based Arterial Management (CBAM) Program from District 4 and insights derived from collaborative efforts between FDOT districts and key stakeholders, including academic partners such as the University of Central Florida (UCF). The CBAM Program, initiated by FDOT District Four’s Transportation Systems Management and Operations (TSM&O), represents a significant step towards remote arterial management support. Utilizing a combination of hardware, software, and professional services, the program leverages the existing communications infrastructure to improve signal communication and traffic management across the Treasure Coast region. This initiative is part of a broader effort to modernize and optimize Florida’s arterial management through cloud-based solutions and advanced data analytics.

This chapter outlines a series of detailed recommendations developed through a comprehensive process of surveys, workshops, stakeholder meetings, and feedback collection. The recommendations are designed to address the needs of FDOT’s districts, drawing on the rich insights gathered from direct engagements with district representatives, traffic engineers, data analysts, and other stakeholders. These engagements have highlighted the diverse challenges and opportunities across the districts, informing a set of tailored strategies to enhance data management, analysis capabilities, and the overall transportation system performance.

The chapter is structured to provide FDOT and its stakeholders with a roadmap for implementing these strategies. It encompasses a wide array of focus areas, including strategic decision making, cross-district collaboration, specific district needs, enhanced data analysis, and the adoption of a centralized data management system. Each section offers detailed, actionable recommendations, grounded in the collective expertise and experiences of FDOT's partners and stakeholders.

By implementing these recommendations, FDOT aims to set a new standard for intelligent transportation management, one that not only addresses current challenges but also anticipates future developments in transportation technology and data analytics. This forward-looking approach is crucial for maintaining and enhancing the resilience, safety, and efficiency of Florida's transportation network, ensuring it can meet the evolving needs of the communities it serves.

3.2. Methodology

The methodology employed in developing the detailed recommendations for the Florida Department of Transportation (FDOT) involved a multi-step approach, designed to gather comprehensive insights into the data management and operational needs of FDOT's districts. This process was instrumental in identifying specific areas for enhancement within the scope of the Statewide Arterial Management Program (STAMP) and broader Transportation Systems Management and Operations (TSM&O) strategies. The following subsections outline the steps taken to ensure that the recommendations are both evidence-based and aligned with the real-world needs of the FDOT and its stakeholders.

3.2.1 Survey distribution and collection

The initial phase of the methodology involved the distribution of surveys across Florida's various districts. These surveys were meticulously crafted to capture a wide range of information, including current data management practices, perceived gaps in technology or processes, and specific needs related to active arterial management (AAM), integrated corridor management (ICM), and automated traffic signal performance measures (ATSPM). The survey aimed to gather quantitative and qualitative data that could inform the subsequent phases of recommendation development.

3.2.2 Stakeholder workshops and meetings

Following the survey phase, a series of workshops and meetings were conducted. These gatherings served as platforms for deeper engagement with a diverse group of stakeholders, including FDOT district representatives, traffic engineers, data analysts, consultants, and representatives from Signal Maintaining Agencies (SMAs) within the Treasure Coast region. The workshops facilitated a detailed discussion on the Cloud-Based Arterial Management (CBAM) Program, among other topics, allowing for the exchange of challenges, successes, and best practices across districts.

3.2.3 Analysis of feedback and meeting minutes

Feedback received during the workshops and meetings, as well as the detailed minutes documenting these discussions, underwent a thorough analysis. This step was crucial in synthesizing the diverse perspectives and insights shared by the participants, ensuring that the recommendations reflect the collective expertise and experiences of the stakeholders involved.

The analysis focused on identifying common themes, specific technological and operational needs, and potential areas for innovation and improvement within FDOT's arterial management strategies.

3.2.4 Integration of STAMP and TSM&O objectives

The recommendations were developed with a keen awareness of the existing STAMP action plan and the broader objectives of the TSM&O program. This integration ensured that the proposed enhancements are not only in line with FDOT's strategic directions but also contribute to achieving the high-level goals of improved safety, efficiency, and multimodal operation of Florida's transportation network. Special attention was given to the program's emphasis on data management, performance assessment, and operational and maintenance needs, as these areas were identified as critical to the success of TSM&O strategies.

3.2.5 Iterative review and refinement

The draft recommendations underwent an iterative process of review and refinement, incorporating feedback from FDOT and stakeholders to ensure relevance, feasibility, and alignment with the evolving needs of the transportation system. This iterative approach allowed for continuous improvement of the recommendations, ensuring they remain adaptive to feedback and reflective of the latest in transportation management and technology trends.

3.3. Utilizing data for strategic decision making

The critical role of data in strategic decision making for Florida's transportation system is underscored by insights drawn from the CBAM Stakeholder Workshop and the integration and optimization discussions with District 5. These discussions highlighted the necessity for advanced data analytics and performance metrics that can adapt to the dynamic needs of transportation management.

3.3.1. Enhanced infrastructure planning through data analytics

Case study implementation

Inspired by the CBAM discussions, a recommendation is to pilot advanced data collection technologies, such as FLIR cameras and Wavetronix sensors, as explored by Indian River County and St. Lucie County. These technologies have shown promise in improving traffic monitoring and control, suggesting a broader applicability for statewide traffic management strategies.

Adaptive signal technologies

Martin County's transition from induction loops to more sophisticated data-driven traffic management solutions like camera and adaptive signal technologies should be considered a model for other districts. This move towards granular data collection facilitates more nuanced traffic flow analysis and optimization, directly contributing to the goals of STAMP by enhancing traffic safety and efficiency.

3.3.2 Development and regular update of performance metrics

Granular traffic data analysis

The significance of ATSPM, as discussed in the District 5 meeting, demonstrates the value of obtaining granular, unbiased traffic data. By implementing ATSPM across more districts, FDOT can enhance its ability to develop performance metrics that accurately reflect real-world conditions, enabling more informed decision making.

Use of third-party data

The more exploration of third-party data sources, such as Google Maps and Waze, during the District 5 discussions, offers a pathway to augment FDOT's existing data collection efforts. Integrating this data can provide a richer, more comprehensive view of traffic patterns, aiding in the development of more responsive and adaptive performance metrics. The team finds varied performance and granularity of the third-party data. While INRIX has 30 second granularity, HERE offered 60 second granularity (in the last two years). Both of them are much smaller compared to WAZE, that appears to be at 2 minutes. Although all of them are acceptable for travel time and speed identification, none of them is useful for safety applications, namely near misses. Depending on the needs of the stakeholders, the most appropriate one can be selected to ingest in the platform. Lastly, another noteworthy source of data that could be worth investigating in the future has been recently made available through StreetLight.

3.3.3 Practical examples from the UCF SST's previous work

3.3.3.1 Automated traffic signal performance measures (ATSPM) and equipment optimization

Integrating recent advances in deep learning and high-resolution traffic data, we propose enhancements to the ATSPM systems that are aligned with emerging research in real-time signal timing prediction. The research by Islam et al., (2022) underscores the potential for leveraging Convolutional Neural Network-Long Short-Term Memory (CNN-LSTM) models to forecast signal phasing and timing with considerable precision, using traffic flow metrics derived from detector data.

Incorporating CNN-LSTM for predictive signal timing

The innovative application of CNN-LSTM models, as demonstrated by Islam et al. (2022), can facilitate the prediction of signal timing and phasing for subsequent cycles, significantly reducing the manual efforts associated with signal retiming processes. The implementation of such models, validated across both adaptive and actuated signal control corridors, suggests a path toward optimizing traffic flow and safety with reduced hardware dependency and cost.

- Predictive accuracy**:** Adopting the CNN-LSTM model for cycle length prediction, with a reported Mean Absolute Error (MAE) as low as 6.06 seconds, and phase duration prediction with MAE as low as 2.73 seconds, could dramatically enhance the responsiveness of traffic signal adjustments in real-time.
- Operational integration: The model's ability to predict Signal Phase and Timing (SPaT) up to six cycles ahead can be integrated into ATSPM platforms to improve traffic flow predictions and support advanced mobility features, such as route planning and trajectory estimation, with a forward-looking approach to signal control.
- Transferability and replication: The demonstrated transferability of the trained model to other intersections with similar traffic patterns offers a promising opportunity for FDOT to streamline signal timing performance across multiple corridors, suggesting that a model well-performing in one context may be effectively applied in another.

Supporting broader traffic management goals

The utility of CNN-LSTM models extends to various traffic management applications, from reducing the carbon footprint through optimized vehicle velocity to enhancing pedestrian safety by predicting vehicle conflicts. By embracing such deep learning models, FDOT can advance toward a more predictive and adaptive traffic signal control system that proactively responds to the dynamic state of urban traffic flows, as suggested by Islam et al. (2022).

proactive approach aligns with the broader goals of enhancing real-time safety and mobility features. Knowing the future state of traffic signals enables smarter route planning, helps vehicles navigate through intersections efficiently, and supports efforts in reducing the carbon footprint by minimizing idle times and stop-and-go traffic.

In conclusion, integrating deep learning algorithms for signal timing optimization can revolutionize the way traffic signal systems are managed within FDOT, paving the way for a transition from periodic, reactive signal retiming to a more continuous, data-driven, and proactive management paradigm.

Continuing from the integration of deep learning approaches to predict traffic signal timing, the study by Yuan et al. (2021) introduces a pivotal advancement in real-time crash risk assessment at signalized intersections. This research not only complements the predictive modeling of signal phasing and timing but also introduces a crucial safety dimension to ATSPM optimization efforts. By employing high-resolution event-based data to model real-time crash risk, the study offers insights into cycle-level factors that significantly influence crash occurrences.

Real-time crash risk assessment

- Cycle-level risk factors: Yuan et al. (2021) emphasize the importance of considering cycle-level variables, such as traffic volume, signal timing, headway, occupancy, and shockwave characteristics, in assessing crash risk. This granular approach enables a more accurate prediction of crash probabilities, which can inform signal timing adjustments and other traffic management interventions.
- Traffic volume and signal timing: The study found that higher traffic volumes and specific signal timing patterns, such as longer cycle lengths and higher arrivals on yellow ratios, could increase crash risks. These findings suggest that optimizing signal timing to reduce these risks could be a vital component of traffic safety strategies.
- Shockwave analysis for safety enhancements: Shockwave characteristics, including maximum queue length and shockwave speed, were identified as significant predictors of

crash occurrences. Incorporating shockwave analysis into ATSPM systems could thus enhance the predictive accuracy of safety interventions, allowing traffic managers to proactively address conditions likely to lead to crashes.

Integrating safety into ATSPM optimization

Building upon the predictive capabilities highlighted by Islam et al. (2022) and the safety-oriented findings from Yuan et al. (2021), a comprehensive approach to ATSPM optimization emerges—one that not only aims to improve traffic flow and reduce delays but also prioritizes the reduction of crash risks through data-driven insights.

- Safety-oriented signal timing adjustments: Leveraging the predictive models, traffic signal programs can be adjusted in real-time to mitigate identified crash risks, optimizing the balance between efficiency and safety at signalized intersections.
- Enhanced traffic management strategies: By integrating the cycle-level crash risk models with existing ATSPM frameworks, FDOT can develop a more detailed traffic management strategy that responds not only to traffic conditions but also to the dynamic risk landscape of its signalized intersections.
- Policy implications and future directions: The work of Yuan et al. (2021) underscores the potential for significant safety improvements through the strategic application of ATSPM data. This requires policy support for the implementation of advanced analytical techniques and the development of infrastructure capable of supporting these sophisticated systems.

In summary, the integration of real-time crash risk assessment models into ATSPM systems represents a significant step forward in enhancing the safety and efficiency of signalized intersections. By adopting these advanced analytical tools, FDOT can lead the way in proactive traffic management, setting a new standard for the integration of safety and operational efficiency in traffic signal optimization efforts.

Building on the foundation of integrating predictive modeling for traffic signal timing and real-time crash risk assessment, the incorporation of pedestrian safety models represents a critical advancement in comprehensive traffic management systems. The study by Zhang and Abdel-Aty (2022) specifically addresses the gap in real-time pedestrian safety models by leveraging machine learning models to predict pedestrian conflicts at signalized intersections. This approach not only enhances traffic safety for vehicular traffic but also places a pivotal emphasis on vulnerable road users.

Real-time pedestrian conflict prediction

- Integration of pedestrian safety: Integrating real-time pedestrian conflict prediction models, as developed by Zhang and Abdel-Aty (2022), into the ATSPM system enhances the system's capability to proactively manage pedestrian safety at signalized intersections. By using conflict indicators like Post Encroachment Time (PET) and Time to Collision (TTC) derived from high-resolution traffic data and CCTV footage, these models offer a detailed understanding of pedestrian-vehicle interactions.
- Machine learning models for safety enhancement**:** The application of Extreme Gradient Boosting (XGBT) models, noted for their high accuracy (AUC value of 0.841) and significant recall value (0.739), demonstrates the potential of machine learning in predicting pedestrian conflicts ahead of each signal cycle. This predictive capability allows for timely adjustments in signal timing and the issuance of pre-warnings, particularly beneficial in Connected and Automated Vehicles (CAV) environments.

Proactive traffic management strategies

- Signal timing adjustments for pedestrian safety: The ability to predict pedestrian conflicts one cycle ahead introduces a proactive component to traffic signal management, enabling adjustments to signal timing that prioritize pedestrian safety without compromising vehicular flow efficiency.
- Extending the model's application: While the initial study focused on suburban areas with lower pedestrian volumes, the potential to apply these models in urban settings with higher pedestrian activity underscores the scalability of this approach. Future investigations into the model's transferability across different traffic and pedestrian conditions will be crucial in broadening the impact of real-time pedestrian safety models.

Policy implications and future initiatives

The integration of pedestrian conflict prediction models into existing traffic management systems calls for policy support and infrastructure adaptation to accommodate the data requirements of these advanced models. Furthermore, extending research to urban areas with diverse traffic compositions will enhance the model's applicability and effectiveness in improving pedestrian safety at a wider scale.

Incorporating these advanced predictive models not only aligns with the goals of enhancing traffic flow and safety but also significantly contributes to the protection of vulnerable road users. By adopting a holistic approach to traffic management that includes vehicular, cyclist, and pedestrian safety, FDOT can set new benchmarks in creating safe, efficient, and inclusive urban transportation networks.

3.3.3.2 The role of third-party data in traffic management

Incorporating insights from recent advancements in real-time crash prediction models, especially those utilizing connected vehicle trajectory data, provides a detailed perspective on enhancing traffic management strategies through third-party data. The use of trajectory data, as explored in the study utilizing an ensemble of Transformer and Conformer models Islam et al. (2023b), demonstrates a significant step forward in utilizing external data sources to improve traffic safety and management.

Enhancing crash prediction with connected vehicle data

The innovative approach of employing connected vehicle trajectory data, as detailed in the recent study Islam et al. (2023a), showcases the potential of third-party data in augmenting traditional traffic management systems. This data, characterized by its wide coverage and the granularity of trajectory insights, including speed, acceleration, and yaw rate, can substantially improve crash prediction models. The model's performance, achieving a recall of 76% and a false alarm rate of 30%, highlights the viability of integrating such data into Advanced Traffic Management Systems (ATMS).

Challenges and opportunities

While the integration of third-party data like connected vehicle trajectories offers unique insights into traffic dynamics, it also presents challenges in data interpretation and potential biases. Ensuring the reliability and privacy of this data while minimizing biases necessitates careful calibration of the predictive models and adherence to robust data processing standards.

Leveraging data for maintenance and skill enhancement

The operational maintenance of traffic management systems, including the upkeep of sensor technologies and the development of predictive models, benefits significantly from the insights gained through connected vehicle data. Training programs for traffic management personnel can incorporate case studies and scenarios derived from such data, enhancing their ability to interpret and act on traffic patterns and crash predictions.

Systemic adoption of advanced predictive models

The conversation around data integration emphasizes the need for systemic adoption of advanced predictive models that leverage third-party and connected vehicle data. This adoption requires standardized practices across districts for data processing and model integration, ensuring a unified approach to traffic management that is both proactive and responsive to real-time conditions.

Infrastructure for data-intensive models

The backend infrastructure, particularly cloud storage solutions like AWS or Azure, plays a critical role in supporting the data-intensive requirements of advanced predictive models. The selection of cloud services must consider the scalability, security, and compatibility with existing traffic management systems, facilitating the seamless integration of third-party data sources and the deployment of sophisticated predictive algorithms.

Policy and infrastructure readiness

The effective implementation of these technologies and methodologies necessitates not only technological readiness but also policy frameworks that support data sharing, privacy, and security. Enhancing traffic management systems with connected vehicle data and predictive modeling requires a collaborative effort among traffic authorities, vehicle manufacturers, data providers, and policy makers to address these challenges comprehensively.

In conclusion, the integration of connected vehicle trajectory data into traffic management strategies offers a promising way for enhancing real-time safety and efficiency. As these models continue to evolve, they will likely become integral components of future traffic management ecosystems, driving improvements in operational maintenance, skill development, and overall traffic safety.

Building upon the foundation laid by the integration of connected vehicle data for crash prediction, the study by Islam and Abdel-Aty (2023) introduces a novel approach to traffic conflict prediction using Long Short-Term Memory (LSTM) models. This approach significantly expands the capabilities of traffic management systems to proactively address potential safety issues, offering a method to predict conflicts before they escalate into crashes.

Real-time conflict prediction using LSTM

The LSTM-based conflict prediction framework developed by Islam and Abdel-Aty (2023) demonstrates the potential of connected vehicle data to predict traffic conflicts 9 seconds into the future with a recall of 81% and a false alarm rate of 28%. This model represents a shift towards more proactive traffic safety interventions, where potential conflicts can be anticipated and mitigated through timely alerts to drivers.

Integration with onboard units (OBUs)

The potential application of this conflict prediction system in OBUs of connected vehicles introduces a new dimension to Advanced Driver Assistance Systems (ADAS), allowing for real-time warnings to drivers about impending safety concerns. This technology not only enhances individual vehicle safety but also contributes to overall traffic flow optimization by preventing conflicts that could lead to congestion or accidents.

Leveraging connected vehicle data for conflict analysis

The utilization of connected vehicle data for traffic conflict prediction underscores the importance of third-party data in enhancing traffic management strategies. By integrating this data with traditional traffic management systems, authorities can gain deeper insights into traffic dynamics, enabling more nuanced and effective interventions.

Skill development for advanced predictive models

The successful implementation of LSTM models for traffic conflict prediction highlights the need for continuous skill development among traffic management professionals. Training programs should include modules on machine learning and data analysis, equipping staff with the knowledge to leverage advanced predictive models for traffic safety and efficiency.

Data-driven decision making

Islam and Abdel-Aty (2023)'s work illustrates the critical role of data integration in modern traffic management, emphasizing the shift towards data-driven decision making. This shift necessitates systemic changes in how traffic data is collected, analyzed, and acted upon, highlighting the need for standardized practices and definitions to ensure the effective use of predictive models in traffic management.

Infrastructure for high-volume data processing

The processing requirements for real-time conflict prediction models call for robust technological infrastructure, capable of handling high volumes of data with minimal latency. Cloud storage solutions must be evaluated for their ability to support these advanced models, ensuring flexibility, scalability, and compatibility with existing traffic management frameworks.

In conclusion, the integration of advanced predictive models for traffic conflict prediction represents a significant advancement in traffic management, promising to enhance safety, efficiency, and responsiveness. By adopting these models, traffic management authorities can move towards a more proactive and predictive approach to traffic safety, leveraging the full potential of connected vehicle data and advanced analytics to preemptively address traffic conflicts and improve roadway safety for all users.

Integrating insights from the exploration of speeding effects using connected vehicle trajectory data, as conducted by Ugan et al. (2024), provides significant insights on the multifaceted nature of speed management and its critical role in traffic safety. This study's innovative use of machine learning models to analyze individual journeys and predict speeding levels underscores the importance of nuanced, data-driven strategies in traffic management, particularly when addressing the complex behaviors associated with speeding.

Predictive analysis of speeding behaviors

The application of Extreme Gradient Boosting (XGBoost) to predict speeding levels based on journey-specific variables, such as time spent at intersections and the environmental context of the journey, illustrates the potential of third-party data to enhance traffic management strategies. This predictive approach allows for a more targeted intervention, potentially mitigating speeding by addressing its underlying causes.

Integrating environmental and journey-specific data

Ugan et al. (2024)'s findings highlight how environmental features and the dynamics of individual journeys contribute to speeding behavior. The integration of this data into traffic management systems could lead to the development of more sophisticated models that account for the influence of residential and commercial areas on speeding, as well as the impact of time spent at signalized intersections.

Enhancing traffic system reliability through data analytics

The study further emphasizes the need for operational maintenance and skill development in leveraging advanced data analytics for traffic safety. Training traffic management personnel in machine learning and predictive modeling can equip them with the tools necessary to interpret complex data sets and implement effective speed management solutions.

Systemic adoption of predictive speed management models

The insights from this research necessitate systemic changes in traffic management practices, particularly in integrating predictive speed management models that utilize connected vehicle data. These changes require standardized practices across districts to ensure the effective use of predictive models in managing speeding and enhancing road safety.

Supporting predictive models with robust technological infrastructure

The predictive modeling of speeding behaviors requires a robust technological infrastructure capable of processing large volumes of data. Cloud storage solutions, such as AWS or Azure, must be evaluated for their ability to support the data-intensive needs of these models, ensuring the flexibility, scalability, and compatibility required for effective traffic management.

In conclusion, the study by Ugan et al. (2024), provides compelling evidence of the value of connected vehicle trajectory data in understanding and predicting speeding behaviors. By incorporating these insights into traffic management strategies, agencies can move towards a more proactive, data-driven approach to speed management, enhancing the safety and efficiency of transportation systems. Predictive analytics integration into traffic management techniques presents a viable approach to tackling the problems of speeding, highlighting the significance of ongoing innovation and the uptake of cutting-edge technical solutions in traffic safety initiatives.

3.4. Addressing specific needs and gaps identified by the districts to enhance data analysis

The varied landscapes and operational challenges across Florida's transportation districts necessitate a flexible yet standardized approach to data management and analytical capabilities. Reflecting on the feedback received, our recommendations are crafted to respect district autonomy in selecting ATSPM vendors, ensure interoperability of data sets, and emphasize the practicality of data processing and anomaly detection. The recommendations aim to enhance both the technical and administrative aspects of data management across FDOT districts. To support the Florida Department of Transportation's (FDOT) strategic goals and address the detailed feedback received, enhancing data analysis capabilities across its districts is vital. This section outlines recommendations for advancing FDOT's analytical capabilities through technology, staffing, and training, ensuring the agency can effectively leverage data to improve traffic management, safety, and mobility.

3.4.1 Flexibility in ATSPM vendor selection

Districts should have the autonomy to select the ATSPM vendor or solution that best fits their operational needs and interface preferences. This flexibility encourages innovation and allows districts to leverage local knowledge and relationships to optimize traffic management outcomes. Despite this flexibility, it's imperative to establish technical minimums and preferred data formats for ATSPM solutions to ensure national industry standards are met. This approach guarantees that, regardless of the vendor selected, the granularity of data elements and computations will maintain low risk for interoperability issues across the central office database.

3.4.2 Data integration and application programming interface (API) requirements

Solutions adopted by the districts must provide an API that facilitates seamless data ingestion into the central office database. This requirement ensures that data collected by various ATSPM systems can be integrated efficiently, supporting statewide analytics and decision making processes.

The data platform needs to have a server setup for data ingestion from various APIs. It should also have a database to store the data received from the APIs. Additionally, a data visualization frontend can also be proposed.

3.4.3 Distinguishing between administrative and technical needs

While acknowledging the importance of data management administration and soft skills, the primary focus should remain on addressing the technical needs of analytical storage, platform visualization, and data processing. This distinction emphasizes the necessity for a solid technical foundation to support effective data analysis and application in traffic management strategies.

3.4.4 Practical considerations in anomaly detection and data processing

Anomaly detection timelines

The system should allow districts to define the activation times for anomaly detection based on their specific operational realities. This flexibility ensures that anomaly detection algorithms are tuned to the temporal patterns relevant to each district's traffic conditions. Implement data processing and anomaly detection protocols that reflect the operational realities and expectations of different districts, as highlighted in the feedback. This means establishing systems that can offer both rapid analysis for immediate needs and deeper, strategic analysis for long-term planning, ensuring that data processing times are aligned with the specific requirements of each district.

Realistic expectations for data processing

Recognizing the varied expectations across districts regarding the timeliness of data processing, the recommendations advocate for a pragmatic approach. Not all districts require or expect immediate (same day or next day) data analysis. As such, the system design should accommodate diverse needs, with some districts focusing on rapid response while others prioritize strategic, longer-term analyses.

Equity in safety and mobility analysis

Equip data analysis tools with the capability to measure safety and mobility outcomes equally, ensuring that the insights generated contribute to the holistic improvement of Florida's transportation network (discussed in more detail below in Section 4.5). This will address feedback calling for tangible measurements that support both safety and mobility, reinforcing FDOT's commitment to serving all road users effectively.

3.4.5 Ensuring equity in safety and mobility metrics

The platform must provide tangible measurements that equally cover safety and mobility, ensuring that both aspects have full independent utility. This dual focus guarantees that traffic management strategies comprehensively address the well-being and efficiency of all road users. In addition to crash numbers and their severity, there are several safety metrics available to consider. Surrogate safety measures often used in road safety analyses in order to quantify various unsafe traffic events include TTC (defined as time to collision, which is time required for two vehicles to collide if they continue at their present speed vehicles to collide if they continue at their present speed and along the same path), PET (defined as post-encroachment time, which is the time difference between the first vehicle leaving the course of the second vehicle, and the second vehicle reaching the course of the first vehicle), deacceleration rate, as well as modified time to collision (MTTC) or deceleration rate to avoid collision (DRAC). While different metrics are appropriate in different contexts and environments, the above-mentioned factors are considered some of the most frequently used with TTC (time to collision) being particularly relevant for the rear end crashes often taking place at intersections on arterial roads.

3.4.6 Investment in advanced analytics tools

Utilize advanced data analytics tools that incorporate artificial intelligence (AI) and machine learning algorithms. These tools will enable predictive analysis of traffic patterns, bottleneck identification, and optimization strategies, aligning with feedback emphasizing the need for sophisticated analytics to support decision making. Machine learning can help with anomaly detection and predicting traffic patterns. The developer needs to keep an eye on the performance on the machine learning algorithms since with changes in traffic, the models can become obsolete. Therefore, there might be performance degradation. The developer needs to compare predicted data with real-time data to draw such conclusions.

API for seamless data integration

Ensure these analytics tools are equipped with robust APIs that facilitate the integration of diverse data sources. This capability is crucial for aggregating and analyzing data across different ATSPM systems and ensuring compatibility with the central office database, addressing feedback regarding interoperability and data ingestion.

3.4.7 Increasing specialized staffing

Expand the team of data analysts and traffic engineers who specialize in big data analytics and machine learning. This initiative will enhance FDOT's capacity to manage and analyze complex datasets, providing actionable insights for traffic management and infrastructure planning.

In response to feedback, differentiate roles between data management administration and the technical analysis needs. By recruiting staff with specific skill sets aligned with these roles, FDOT can ensure that both administrative functions and technical analysis are optimally supported.

3.4.8 Continuous training programs

Establish ongoing training programs for existing staff to ensure they remain proficient in the latest data analysis techniques and tools. This effort will address feedback on the necessity for continuous learning and adaptation among FDOT personnel, maintaining a workforce that is agile and informed about emerging technologies and methodologies.Tailor training programs to cater to the diverse needs and skill levels within FDOT, ensuring that all staff, from administrative to technical roles, have opportunities for development. This approach will facilitate a comprehensive uplift in data analysis capabilities, fostering a culture of excellence and innovation within the organization.

3.5. Centralized data management system

Implementing a cloud-based data management system is vital for the Florida Department of Transportation (FDOT) to elevate its transportation network's efficiency, safety, and reliability. This section delves into the specific technical requirements and strategies essential for establishing a robust, interoperable, and accessible centralized data management platform, emphasizing the criticality of data standardization, integration, and accessibility. These recommendations incorporate feedback from stakeholders, emphasizing the necessity for a flexible yet standardized approach to data management that supports the varied needs of FDOT districts. By focusing on technical specifications, data standardization, integration strategies, and enhancing system accessibility, FDOT can establish a centralized data management system that not only meets current operational demands but is also scalable to future advancements in transportation technology and analytics.

3.5.1 Technical specifications for cloud-based data management

For cloud service provider selection, we recommend adopting a cloud service platform that offers scalability, reliability, and security, aligning with FDOT's operational requirements. Platforms like Amazon Web Services (AWS) or Microsoft Azure should be evaluated for their capabilities in supporting large-scale transportation data analytics and storage. For system architecture and security the system architecture should be designed to support high availability, data redundancy, and disaster recovery. Data security protocols must comply with national cybersecurity standards, ensuring data integrity and protection against unauthorized access.

3.5.2 Data standardization and formats

ATSPM data formats

Adhere to the national industry standards for ATSPM data elements and computations to ensure consistency and interoperability across different systems and vendors. This adherence supports the integration of ATSPM data into the centralized system without significant modifications.

Preferred data formats

We recommend the use of widely accepted data formats such as JSON for data interchange and SQLite or PostgreSQL for database management. These formats facilitate easy data sharing and manipulation, supporting diverse analytical needs.

Granularity and computation standards

Specify technical minimums regarding the granularity of data collection (e.g., vehicle counts, speeds, and signal phase and timing data) and the computations required (e.g., travel times, queue lengths). This specificity ensures that the data collected is actionable and meets FDOT’s analytical requirements.

3.5.3 Integration strategies

API development and documentation

Develop comprehensive API documentation to standardize how external systems and applications interact with the centralized data management system. APIs should support a wide range of functions, including data ingestion, query, and retrieval, facilitating seamless data exchanges between district-level systems and the central platform. In addition to the outlined requirements in Section 4.3, the system requirements would vary depending on how the server is setup for the data platform. Usually NodeJS (for both backend and frontend) and MongoDB (for database) are standard across industries.

Interoperability testing

Implement rigorous testing protocols to ensure that data from various ATSPM solutions and other traffic management systems can be integrated efficiently. This testing should cover different scenarios and data formats to verify system readiness and interoperability.

3.5.4 Enhancing accessibility and usability

Design a user-friendly portal that provides centralized access to the cloud-based data management system. This portal should cater to a wide range of users, from traffic engineers to administrative staff, offering customizable dashboards, real-time data visualization, and analytical tools. Design the system with role-based access controls to ensure that users have appropriate access levels based on their roles and responsibilities. This approach enhances data security while ensuring that stakeholders across different districts can access the data and analytics tools relevant to their operational needs.

To pilot testing and iterative deployment, begin with pilot testing of the centralized data management system in selected districts (such as District 5) to gather insights and identify potential issues before a statewide rollout. This phased approach allows for iterative improvements, ensuring the system is robust, user-friendly, and fully aligned with FDOT's operational requirements.

To support training, develop a comprehensive training program to equip FDOT staff with the skills necessary to utilize the centralized data management system effectively. Ongoing support and updates should be provided to ensure users can adapt to system enhancements and emerging data analytics techniques.

3.6. Feedback from CBAM stakeholder workshop

To complement the derived from the project findings with some practical components, the team participated in the Cloud-Based Arterial Management (CBAM) Stakeholder Workshop, an informative gathering hosted by the Florida Department of Transportation (FDOT) District 4. It offered a unique platform for collaboration and knowledge exchange among FDOT, consultants, and Signal Maintaining Agencies (SMAs) from the Treasure Coast region. This workshop provided additional insights into the current state and future direction of traffic management within the district, highlighting the critical areas of cybersecurity, aging infrastructure, and workforce development. Below is a summary of the key points, actions, and feedback from the workshop, emphasizing the collective drive towards innovation and enhanced traffic management.

3.6.1 Collaboration and innovation in traffic management

A significant outcome of the workshop was the consensus on the need for a common platform to facilitate resource sharing among Treasure Coast SMAs and FDOT. Such a platform would enhance communication, allow for the pooling of resources, and enable the sharing of best practices and innovative solutions to common traffic management challenges.

The workshop underscored the importance of initiating joint projects or pilot studies to address widespread issues like congestion management and incident response strategies. These collaborative efforts are seen as vital for developing and testing innovative traffic management solutions that could be scaled and applied across the state.

3.6.2 Addressing cybersecurity concerns

Feedback from the workshop highlighted cybersecurity as an important concern, especially with the increasing reliance on digital and cloud-based solutions for traffic management. The need for robust cybersecurity protocols and the integration of these protocols into the design and operation of traffic management systems was emphasized. This includes regular security assessments and the adoption of best practices in data protection and system security.

The critical role of collaboration between IT departments and traffic engineering teams was discussed, with an aim to ensure that cybersecurity measures are effectively implemented and maintained. This collaboration is essential for safeguarding the integrity and availability of traffic management systems and data.

3.6.3 Tackling aging infrastructure

Aging infrastructure emerged as a significant concern, with a call for comprehensive assessments to identify and prioritize areas needing upgrades or replacement. This strategy aims to enhance the reliability and efficiency of traffic management systems, ensuring they are capable of supporting modern traffic management technologies and approaches.

Stakeholders advocated for targeted investments in infrastructure modernization, including the adoption of advanced detection technologies and communication systems. These investments are crucial for overcoming the limitations of aging infrastructure and ensuring the transportation network can meet current and future demands.

3.6.4 Workforce development initiatives

The workshop identified workforce development as a key challenge, with a specific focus on the need for ongoing training and skill development in emerging traffic management technologies and cybersecurity. Developing a comprehensive training program for both new and existing staff was highlighted as a priority to build a skilled workforce capable of navigating the complexities of modern traffic management systems.

Discussions also touched on the difficulties in recruiting and retaining qualified personnel for traffic management roles. Innovative recruitment and retention strategies, including competitive compensation, career development opportunities, and a positive work environment, were suggested as essential for addressing this challenge.

3.7. Integration and optimization insights from District 5 meeting

To further provide additional context for the current project, the team met with several key personnel from District 5. District 5's approach to arterial management presents a structured framework for implementing and optimizing traffic operations and its operations have been shown to be some of the most advanced in the state. The "Five Levels of Arterial Management" shared by District 5 serve as a guiding principle for the development of FDOT's arterial systems. This layered approach includes a progression from basic operations to an integrated network, advocating for advancements in technical capabilities, workforce development, and operational strategies. Here, we elaborate on how these levels inform and align with broader strategies for traffic management.

3.7.1 Basic signal operations

Optimization of isolated intersections

For intersections operating in free or isolated mode, FDOT should consider leveraging data analytics for timing optimization to improve flow, even without high-level integration. Periodic, data-informed retiming, more frequent than the typical 3-5 years, could enhance responsiveness to changing traffic patterns.

Upgrade to closed loop systems

Encourage upgrades from non-communicative signals to basic closed-loop systems where feasible. This would serve as a foundation for more advanced coordination and would be beneficial even before full corridor retiming efforts are undertaken.

3.7.2 Arterial coordination and monitoring

Monitoring for maintenance and alarms

Establish protocols for regular monitoring of systems to preemptively address potential issues such as communication loss or signal malfunctions, reducing the incidence of reactive maintenance.

Incremental improvement over periodic retiming

Instead of relying solely on infrequent corridor retiming, consider smaller, more frequent adjustments based on real-time data and stakeholder feedback to gradually refine signal timings.

3.7.3 Arterial management by corridor

Implement real-time traffic condition monitoring tools, like Bluetooth and big data analytics, to facilitate case-by-case management of corridors and enable quick adjustments to optimize traffic flow.

Utilize corridor reporting not just for performance evaluation, but as a tool for proactive management, addressing issues before they escalate into larger problems.

3.7.4 Active arterial management by area

Expansion of management to multiple corridors

Active management should extend beyond individual corridors to consider area-wide traffic flow, integrating major routes into a cohesive management strategy.

Use of dynamic messaging

Explore the deployment of Arterial Dynamic Message Signs (ADMS) for real-time traffic guidance, complementing the physical traffic control infrastructure with digital capabilities.

3.7.5 Integrated corridor management (ICM)

Seamless integration with freeway management

Strive for full integration between arterial and freeway management systems, enabling coordinated response strategies, such as flush plans during peak congestion or incidents.

Centralized retiming and analysis

Centralize retiming efforts within the Regional Traffic Management Center (RTMC), leveraging SPM data to guide decisions and enhance the overall efficiency of the arterial network.

Please refer to Figure 1, which delineates the "Five Levels of Arterial Management" concept provided by District 5. This visual representation aids in understanding the progression and integration of traffic management strategies across different levels of arterial operations.

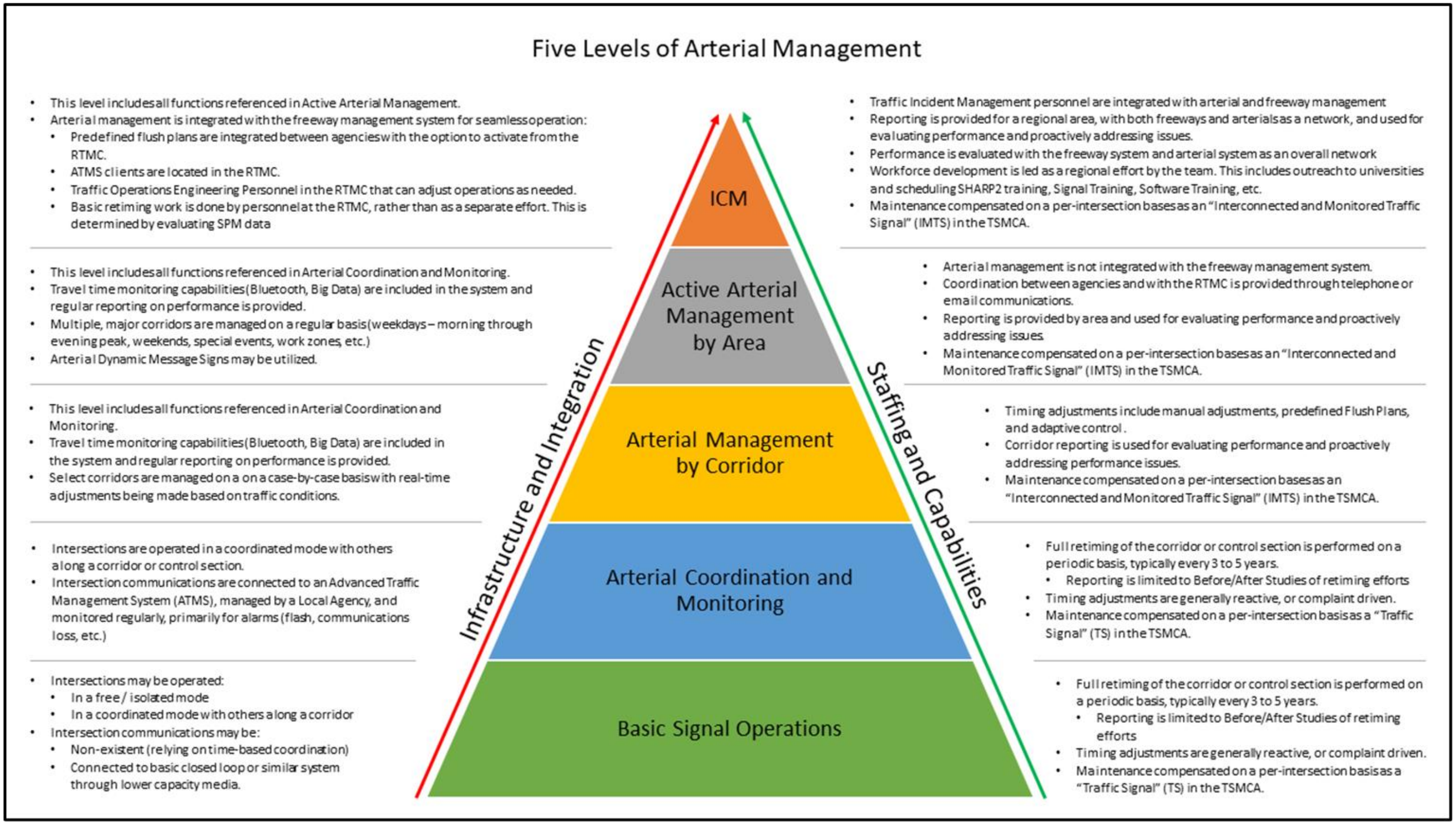

Figure 14. Five Levels of Arterials Management (Source FDOT District 5)

3.8. Cross-district collaboration and knowledge sharing

The meetings with FDOT D5 and workshops highlighted the value of cross-district collaboration and knowledge sharing in uncovering common challenges and pooling resources and expertise to address these issues collectively.

3.8.1 Establishing regular inter-district communication channels

The CBAM Stakeholder Workshop emphasized the importance of creating a common platform for resource sharing among the Treasure Coast SMAs and FDOT. Implementing a similar platform on a statewide level could enhance collaboration, allowing districts to share insights on innovative technologies and successful traffic management strategies.

Based on feedback from the workshops, developing a centralized repository of best practices, technological evaluations, and case studies could significantly benefit all districts. This repository would facilitate quicker adoption of successful strategies, such as the use of wireless signal communication technology and remote staffing services discussed during the CBAM workshop.

3.8.2 Promoting joint initiatives for unified traffic management

Unified signal preemption devices

The agreement on installing common signal preemption devices for emergency vehicles, as highlighted in the CBAM workshop, should be expanded into a statewide initiative. This would ensure a unified approach to enhancing response times and safety across all FDOT districts.

Cloud-based traffic data service

Inspired by the CBAM suggestion to provide access to a cloud-based traffic data service like ClearGuide, a recommendation is to evaluate and potentially implement such a service statewide.

This would enable real-time traffic management and analysis, fostering a more proactive and data-driven approach across districts.

3.9. Recommendations

In addressing the feedback we received, it's essential for us to provide recommendations that not only align with the technical requirements of the Florida Department of Transportation (FDOT) districts but also with their operational dynamics. This encompasses the selection of Automated Traffic Signal Performance Measures (ATSPM) vendors, the use of standardized data formats, and API requirements, as well as anomaly detection protocols and data processing timelines.

The chapter is divided primarily in two parts; the first one relates to data and administrative suggestions, and the second one to the system requirements and its direction. This chapter also serves as a summary and overview of previously mentioned recommendations.

3.9.1 Data related

3.9.1.1 Safety metrics

To be able to evaluate safety on the roadways, numerous safety metrics might be considered in developing the data platform. Surrogate safety measures that are often employed in transportation safety analysis include TTC (time to collision), PET (post-encroachment time), deceleration rate, modified time to collision (MTTC) or deceleration rate to avoid collision (DRAC). Selecting a couple of them or their combination is needed to best aid the stakeholders as well as support safe and efficient traffic operations in the state.

3.9.1.2 Potential of artificial intelligence (AI) and machine learning (ML)

In order to leverage emerging methods as well as their predictive capabilities it is recommended to use advanced data analytics tools that incorporate artificial intelligence (AI) and machine learning algorithms. These tools will enable predictive analysis of traffic patterns, bottleneck identification, and optimization strategies, as well as provide real time safety analysis.

Machine learning can help with anomaly detection (discussed below) and predicting traffic patterns. The developer needs to keep an eye on the performance of the machine learning algorithms since with changes in traffic, the models can become obsolete. Therefore, there might be performance degradation. The developer needs to compare predicted data with real-time data to draw such conclusions.

3.9.1.3 ATSPM vendor selection and data format standardization

Vendor flexibility with standard compliance

FDOT districts should retain the flexibility to select ATSPM vendors that suits their local requirements, ensuring these systems adhere to national data format standards. This balance will support interoperability across the state while enabling customization for district-specific needs.

Standardized data protocols

Standardized data protocols allow to better assess larger geographical regions and ensure more seamless collaborations between the districts. Establishing a statewide standard for data formats that all ATSPM systems must follow, such as adopting the National Transportation Communications for ITS Protocol (NTCIP) or an equivalent is recommended. These standards ensure that irrespective of the vendor, the data can be seamlessly integrated and processed within the statewide system.

3.9.1.4 API design and system integration

Universal API specifications

Define and implement a universal set of API specifications for all traffic management systems within FDOT's network. This should enable efficient data ingestion from various ATSPM vendors and support the consolidation of data into the central office database.

Integration support

Provide technical support to districts for integrating different systems, ensuring that even when the vendors might be different, the quality and reliability of the data will remain consistent across the entire network.

3.9.1.5 Balancing safety and mobility metrics

Equitable focus on safety and mobility

Ensure that the traffic management platform's metrics equally prioritize safety and mobility. Each district should have the tools to measure and improve both aspects, reflecting the dual mandate of ensuring safe travel and efficient movement across the transportation network. Some of the additional measures that could be considered include expanding the S4A database with trajectory data to capture conflicts (even if for select locations only or whenever the data are feasible to collect). Nevertheless, caution must be exercised in order to most accurately reflect safety. The equitable component could also be incorporated by using Census spatial data to map locations to capture equity related considerations.

Independent utility of metrics

Design metrics that provide standalone insights into safety and mobility, allowing for independent assessments and targeted improvements in each area without sacrificing one for the other.

3.9.2 System requirements and platform direction

3.9.2.1 Cloud service provider selection

Due to the importance of seamlessly integrating the platform into the current systems the Department uses, selecting appropriate cloud service provider is needed. Because the Department is currently using Microsoft Azure, it is likely that retaining this system for the future use could be the most beneficial due to its familiarity and integration with the existing systems and components.

3.9.2.2 Preferred data formats

To ensure a wide use and flexibility of the platform for its users, selected data format must provide broad functionality. Given that JSON is an open standard file format that uses human-readable text to store and transmit data objects with different attributes, it has become commonly used. It allows diverse uses in electronic data interchange that include, for example, data exchange between web applications with respective servers. It is also widely accepted for data interchange and SQLite or PostgreSQL for database management. These formats allow for data sharing and manipulation as well as support diverse analytical tools.

3.9.2.3 Granularity and computational power

For the platform to be user friendly and offer desired functionality, context specific technical minimums must be designed. The granularity of the data collection should be based on the overall traffic metrics and/or be location specific (rural versus urban). Specify technical minimums regarding the granularity of data collection (e.g., vehicle counts, speeds, and signal phase and timing data) and the computations required (e.g., travel times, queue lengths). At the end of each day, the platform should allow for easy and general access to basic data such as vehicle counts and delays. Additionally, there should be weekly and monthly trends that would include some general trends of daily data. The platform should allow to adjust the granularity of outputs to accommodate the evolving needs of the Department and its districts. Finally, tradeoffs between real time and delayed approach (daily, weekly, monthly) must be considered. The final granularity should be consulted with the traffic operations office. Based on the needs and how much real versus historical computations are needed, the computation power necessary must be decided.

The trends recently lean toward more granular and real-time proactive solutions. As data, AI/ML, and GPUs become adequately available, applications such as computer vision to identify vehicle and VRU trajectories become possible and thus near misses are captured. Even data such as ATSPM become more useful for cycle based metrics rather than at 15 min intervals, etc.

3.9.2.4. Role-based access control

To protect sensitive data while supporting different stakeholders, design a user-friendly portal that provides centralized access to the cloud-based data management system. This portal should cater to a wide range of users, from traffic engineers to administrative staff, offering customizable dashboards, real-time data visualization, and analytical tools. Design the system with role-based access controls to ensure that users have appropriate access levels based on their roles and responsibilities. This approach enhances data security while ensuring that stakeholders across different districts can access the data and analytics tools relevant to their operational needs. Provide an opportunity and user friendly access option to navigate and grant control to the appropriate stakeholder.

3.9.2.5 Anomaly detection and data processing timeliness

Anomaly detection framework

Because the platform users are not able to manually and/or visually examine the entire network to screen for disruptions in the traffic flow, the platform must have an anomaly detection framework. Developing an anomaly detection framework that is configurable to the specific temporal patterns of traffic operation and safety in each district is important to be able to identify issues in the network in a timely manner. The employed framework should allow districts to set thresholds and detection intervals that align with their traffic management strategies. The system should allow districts to define the activation times for anomaly detection based on their specific operational realities. Designing systems that offer both rapid analysis for immediate needs and deeper, strategic analysis for long-term planning will ensure that that data processing times are aligned with the specific requirements of each district.

Timeliness of data processing

Establish clear expectations for the timeliness of data processing and balance the need for immediate answers with computational limitations. While rapid, near-real-time processing may be necessary for active traffic management, other scenarios may benefit from longer intervals of data analysis. This distinction should be clearly communicated to ensure resources are allocated effective. It is recommended that the Department confirm the intended concept of operation to help set the user data processing need with the detailed requirement to provide traceability and verification (as well as be executed by the system).

3.9.2.6 Platform design

The data platform needs to have a server setup for data ingestion from various APIs. It should also have a database to store the data received from the APIs. Additionally, a data visualization frontend must also be considered.

Finally, APIs should support a wide range of functions, including data ingestion, query, and retrieval, facilitating seamless data exchanges between district-level systems and the central platform. Usually NodeJS (for both backend and frontend) and MongoDB (for database) are standard across industries.

3.10. Conclusions

The strategic enhancement of Florida's transportation systems through intelligent transportation systems (ITS) and active arterial management (AAM) is a multi-faceted endeavor that requires a comprehensive approach. This chapter outlines detailed initial recommendations informed by a robust analysis of survey data, stakeholder workshops, and direct feedback, particularly from the FDOT’s District 5 and the Cloud-Based Arterial Management (CBAM) workshops by District 4. Key findings have emphasized the need for data-driven decision making, the importance of cross-district collaboration, and the adoption of a centralized data management system. These are underpinned by the necessity to select flexible yet interoperable ATSPM solutions, standardize data formats and ensuring that APIs facilitate seamless data integration.

Recommendations have been formulated to reflect the Five Levels of Arterial Management, advancing from basic signal operations to integrated corridor management (ICM). These recommendations advocate for:

- The empowerment of districts to select ATSPM vendors aligned with national data standards to ensure system compatibility.

- The advancement of system architecture to support interoperability, robust API development, and comprehensive security measures.
- The adoption of granular data analysis and proactive anomaly detection strategies tailored to the unique temporal traffic patterns within each district.
- A balanced prioritization of safety and mobility metrics, ensuring that both are addressed with equal rigor and sophistication.

As FDOT moves forward, it is essential to maintain the continuous improvement and active stakeholder engagement. The transportation landscape is perpetually evolving with the involvement of artificial intelligence, and as such, the systems and strategies we implement must be adaptable and responsive to new challenges and innovations.

We encourage ongoing dialogue among FDOT, district representatives, traffic engineers, data analysts, and other key stakeholders. By fostering this collaborative environment, Florida can ensure its transportation systems not only meet current demands but are also poised to handle future growth and technological advancements.

This document serves as an initial step towards a more integrated, efficient, and user-centric transportation network and data management in the state of Florida.

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Appendix

This Appendix serves as a comprehensive repository of the survey questions.

- **Survey Questions:** The survey, designed to capture a wide range of data and management strategies, encompasses various aspects of traffic systems management and operations (TSM&O) across the state. The questions aimed to gather insights into current practices, challenges, innovations, and perspectives on traffic management within each district.

Dear FDOT District Representative,

As part of our partnership with the Florida Department of Transportation, we are working on a project titled "Developing Data Sources and Standards for Supporting Arterial TSM&O Implementation of the Statewide Arterial Management Program (STAMP)" **(BED26-977-06).** The objective is to gain more insights into the complexities of transportation infrastructure, data management practices, performance measures, and decision-support systems across Florida's districts.

The uniqueness of your role and your expertise are critical for the success of this research. Given the limited number of individuals possessing such specialized knowledge, your participation is greatly appreciated.

This survey, which should take approximately 15 minutes to complete, is designed to:

- Capture the strengths and challenges within your district's arterial system and data management.
- Formulate statewide recommendations for a comprehensive data analytics platform.

We have aimed to make this survey concise and have included multiple-choice components for efficiency and guidance. However, where possible, we encourage you to provide additional context or details, as these will enrich our understanding. Please be assured that your responses are confidential and will be used solely for research purposes. No identifiable information will be released.

Should you have queries or need further clarification regarding this survey or the project, please contact Prof. Mohamed Abdel-Aty at m.aty@ucf.edu.

On behalf of **Edith Wong, P.E.** and Traffic Engineering and Operations Office.

Thank you for your time.

PART-1: Respondent Information

1. Name:
2. Position/Title:
3. Department/District:
4. Email Address:
5. Contact Phone Number:

Please confirm your name and your association with the district.

PART-2: Existing Arterial Management Systems and Infrastructure

6. Does your district have any arterial management systems in place? **(Options: Yes, No)**

7. How would you rate the quality of the ITS equipment installed along the arterial corridors in your district? (**Please select one:** overall high quality and in line with technological advancements, medium quality and in many cases a little outdated, mostly outdated and improvements are needed)

8. What is the current status of Automated Traffic Signal Performance Measures (ATSPM) implementation in the district? (Options: Not implemented, Planning stage, Partially implemented, Fully implemented)

PART-3: Data Sources and Management

9. Which departments or teams within the district have access to these data sources? **(Select all that apply**)

- Planning
- Design
- Consultant Project Management
- Public Information Office
- Maintenance
- Other (Please clarify below)

……..

10. Which of the following data types would your team find beneficial but currently do not have access to? **(Select all that apply)** (please select the relevant options and provide additional details in the textbox below)

- Traffic volume data
- Turning movement counts
- Pedestrian and bicycle counts
- Speed data
- Crash data
- Traffic signal timing plans
- Real-time traffic signal status data
- Commonly used third-party data sources such as Here, Inrix, Waze, etc.?
- **Please provide more details/background to your answer below**

………

11. Please rate your confidence in the reliability and applicability of the following routinely collected data sources. If a data source is not available or not routinely collected in your district, please select "Not Available". (For each data source **please select one of the options:** Not Confident, Somewhat Confident, Neutral, Very Confident, Extremely Confident, Not Available)

- Traffic volume data
- Turning movement count
- Pedestrian and bicyclist counts
- Speed data
- Crash data
- Traffic signal timing plans
- Real-time traffic signal state data

- Commonly used third-party data sources such as Here, Inrix, Waze, etc.?

12. Which of the following privacy issues or challenges related to data handling have you encountered? **(Select all that apply)** (please select the relevant options and provide additional details in the textbox below)

- Difficulty anonymizing data
- Lack of clear policies for data privacy
- Challenges complying with privacy regulations
- Concerns about data security
- **Please provide more details/background to your answer below**

……..

PART-4: Agencies Involved

13. With regards to Traffic Systems Management & Operations (TSM&O), which specific partnerships support data collection in your district? (Please **select all the relevant agencies** and elaborate on the nature of the collaboration in the textbox below.)

- Other FDOT districts
- Local city/county public works departments
- Metropolitan Planning Organizations (MPOs)
- Transit agencies
- Law Enforcement (Florida Highway Patrol, police departments, sheriff's offices)
- Other (please provide specific details below)

………

14. Which partners are primarily relied upon to provide data for analysis in TSM&O activities? **(Select all that apply)**

- Law enforcement
- Local agencies
- School districts
- Community organizations
- Technical schools/universities
- Access management/developers
- Other (please specify below)

……….

14.1. What are the primary benefits of these collaborations or reliance on certain partners for TSM&O? **(Select all that apply)**

- Different/additional perspectives
- Additional data sources
- More data resolution
- Identify additional needs/considerations
- Increased accuracy of aggregated data,
- Other (Please specify below)

………

PART-5: Uses of Data (Performance Measures and Decision Support Systems)

15.1. For district management: How frequently are performance measures reviewed and updated? **(Select one)**

- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- Other (Please specify below)

………..

15.2. For staff supporting arterial operators: How frequently are performance measures reviewed and updated? **(Select one)**

- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- Other (Please specify below)

....

16. On a scale of 1 to 5, how well do the current performance measures reflect the situation on the ground? **(Select one option)**

- Not well at all
- Slightly well
- Moderately well
- Very well
- Extremely well

17. How does your district use the data to make short-term (day-to-day or weekly) decisions? **(Please select the most relevant options and provide any additional details in the textbox below)**

- Traffic signal timing adjustments
- Incident management
- Resource allocation for immediate issues (e.g., maintenance, patrols)
- Communication to the public (e.g., real-time updates, alerts)
- Other (Please specify below)

………

18. How does your district use the data to make long-term (monthly or yearly) strategic decisions? **(Please select the most relevant options and provide any additional details in the textbox below)**

- Infrastructure planning and upgrades
- Identification of signal retiming needs
- Operations and maintenance needs
- Funding and budget allocation
- Policy or strategy formulation
- Training and capacity building
- Public communication strategies
- Other (please specify below)

………..

19. If you employ operational strategies like ICM (integrated corridor management) or AAM (active arterial management), which may utilize tools like decision support systems (DSS) or automated traffic signal performance measures (ATSPM), what specific advantages have you noticed? **(Select all that apply)**

- Improved signal coordination
- Reduced travel time
- Enhanced traffic flow
- Better incident management
- More efficient resource allocation
- Enhanced safety measures
- Improved decision making process
- Other (Please provide more details/background to your answer below)

……….

20. If your district doesn't currently employ operational strategies like ICM or AAM, or utilize tools such as DSS within these frameworks, what are the reasons or obstacles? **(Please provide details below)**

………..

PART-6: Minimum Requirements

21. How are the minimum requirements for data accuracy and granularity established in your district? **(Select all that apply)**

- Based on historical data
- Industry benchmarks
- Stakeholder feedback
- Operational needs
- Maintenance needs
- Signal retiming needs
- Design needs
- Other (Please specify below)

………..

22. How often are these minimum requirements reviewed and updated? **(Select one answer)**

- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- Other (Please specify below)

……….

23. Are there any specific standards or regulations that your district adheres to when setting these minimum requirements? **(Select all that apply)**

- Federal guidelines
- State mandates
- Industry standards
- Other (Please specify below)

………….

24. Has your district faced any challenges or issues in adhering to these minimum requirements? **(Select all that apply)**

- Lack of appropriate tools
- Changing traffic patterns
- Need for stakeholder coordination and collaboration
- Funding for hardware/software storage
- Inadequate data resolution
- Lack of data aggregation
- Data in different formats
- Other (Please specify below)

………..

25. What systems or procedures are in place to check that data meets these minimum requirements? **(Select all that apply)**

- Automated validation tools
- Manual evaluations
- Third-party evaluations
- Comparison with other performance measures
- Other (Please specify below)

………..

26. If there have been instances when data did not meet these minimum requirements, what were the implications? **(Select all that apply)**

- Need for additional resources or tool development
- Tool Development

- Limitations of equipment in data collection
- Limitations of the state of the technology
- Limitations of the data provider to provide the data
- Other (Please specify below)

…………

27. What resources or tools could help your district in meeting these minimum requirements consistently? (**Select all that apply)**

- Better data collection tools/equipment
- Improved/increased data aggregation
- Training programs
- Increased budget
- Other (Please specify below)

………..

PART-7: Non-Traditional Data Sources

28. Does your district currently use any non-traditional data sources for transportation management? **(Select one answer)**

- Yes
- No

If 'Yes', proceed to the following questions, otherwise, please select N/A for those that do not apply:

29. Which of the following non-traditional data sources does your district use**? (Check all that apply)**

- Video imaging
- Drone data
- Wi-Fi detectors
- Bluetooth detectors
- Third-party data sources (please specify)

  ……….
- Other (please specify)

  ………..
- N/A

30. Which of them have been found the most useful? **(Check all that apply)**

- Video imaging
- Drone data
- Wi-Fi detectors
- Bluetooth detectors
- Third-party data sources
- If third party data, which one?

  ……….

- Other (Please specify)

  ………..
- N/A

31. How frequently are data from these alternative sources updated?
- Real-time
- Daily
- Weekly
- Monthly
- Annually
- If varies by source, please specify below

  ………
- N/A

32. Overall how effective have these alternative data sources been for managing transportation in your district?
- Not Effective
- Slightly Effective
- Moderately Effective
- Very Effective
- Extremely Effective
- If varies by source, please specify below

  ………..
- N/A

33. Have there been any challenges or issues associated with the use of these alternative data sources? (**Select all that apply and provide additional details in the textbox below**.)
- Data quality issues
- Integration difficulties
- Limited coverage area
- Lack of standardization
- Privacy concerns
- Cost implications
- Other (Please provide a justification to your answer)

  ………….
- N/A

34. What additional alternative data sources, if any, would your district be interested in exploring? (**Select all that apply)**
- Third-party navigation apps
- Drone-based monitoring

- Environmental sensors
- Other (Please specify below)

…………

PART-8: Coordination, Statewide System, Failure Detection, Costs, and Vendor Selection
35. How does your district currently detect failures or issues in transportation management? **(Select all that apply)**

- Manual inspections and reports by transportation staff
- Feedback and complaints from the public or users
- Automated monitoring systems and sensors
- Periodic audits and reviews by external agencies
- Analysis of data and trends from transportation management software,
- None of the above; we do not have a specific system in place
- Other (Please specify below)

PART-9:
36. Is there any additional information you would like to share with us?