Connecticut Department of Transportation

Connecticut's Transportation Enterprise Data

SAFETY DATA CASE STUDY

FHWA-SA-22-008

Federal Highway Administration Office of Safety

Roadway Safety Data Program

http://safety.fhwa.dot.gov/rsdp

U.S. Department of Transportation
Federal Highway Administration

CONNECTICUT DEPARTMENT OF TRANSPORTATION

Notice

Quality Assurance Statement

Technical Documentation Page

1. Report No. FHWA-SA-22-008	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Connecticut's Transportation Enterprise Data		5. Report Date September 2022 6. Performing Organization Code	
7.Author(s) Michael Dunn and Ian Hamilton		8. Performing Organization Report No.	
9. Performing Organization Name and Address Vanasse Hangen Brustlin, Inc (VHB) 940 Main Campus Drive Raleigh, NC 27606		10. Work Unit No. 11. Contract or Grant No. DTFH61-16-D-00052	
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Safety 1200 New Jersey Ave., SE Washington, DC 20590		13. Type of Report and Period Case Study, January 2020-November 2022 14. Sponsoring Agency Code FHWA	
15. Supplementary Notes The contract manager for this report was Jerry Roche. Sarah Weissman Pascual provided editorial review and support for technical content.			
16. Abstract This case study highlights the Connecticut Department of Transportation's (CTDOT's) recent advancements in its enterprise data systems and processes. The Moving Ahead for Progress in the 21st Century Act (MAP-21) established several requirements to help States advance their roadway safety data development and analysis capabilities. Two key requirements for States were to: 1) collect Model Inventory of Roadway Elements (MIRE) Fundamental Data Elements (FDE) data for all public roads, and 2) develop safety data management systems to support the Highway Safety Improvement Program, Strategic Highway Safety Plan, and data driven safety analysis (DDSA) and evaluation. The need to meet Federal requirements and develop an enterprise-level approach to safety analysis on all public roads drove many of the recent advancements in CTDOT's data infrastructure. CTDOT created the Transportation Enterprise Data (TED) warehouse to meet the need for enterprise data specifically supporting robust safety management, but also meeting other critical department data analysis needs. The safety data systems are managed under formal data governance policies expressed in the Data Governance Charter drafted by CTDOT alongside implementation of the TED warehouse. These advancements have helped CTDOT scale its data infrastructure and meet emerging needs for robust roadway safety management on all Connecticut roads.			
17. Key Words: Data governance, enterprise data, TED, linear referencing system, capability maturity model	18. Distribution Statement No restrictions.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 18	22. Price

Acronyms

Acronym	Description
AASHTO	American Association of State Highway and Transportation Officials
ARNOLD	All Roads Network of Linear Referenced Data
CRSMS	Connecticut Roadway Safety Management System
CTDOT	Connecticut Department of Transportation
DDSA	Data Driven Safety Analysis
DOT	Department of Transportation
ETL	Extract, Transform, and Load
FDE	Fundamental Data Element
FHWA	Federal Highway Administration
FME	Feature Manipulation Engine
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
IT	Information Technology
KPI	Key Performance Indicator
LRS	Linear Referencing System
MAP-21	Moving Ahead for Progress in the 21st Century
MAVRIC	Mobile Asset Verification & Roadway Inventory Collection
MIRE	Model Inventory of Roadway Elements
RACI	Responsibility, Accountability, Consulted, Informed
RIS	Roadway Information System
SME	Subject Matter Expert
TED	Transportation Enterprise Data
TDS	Transportation Data Server
UCONN	University of Connecticut
XSP	Cross-Sectional Positioning

Table of Contents

Introduction....... 1
Data Governance in Connecticut 2
TED and Enterprise Data 5
Conclusions....... 9
References 11

List of Figures

Figure 1. Graphic. Change request workflow. 3
Figure 2. Graphic. TED operational model. 4
Figure 3. Graphic. Example of XSP data visualization. 7
Figure 4. Graphic. Roadway safety management process (FHWA, 2013). 9

Executive Summary

This case study highlights the Connecticut Department of Transportation's (CTDOT's) recent advancements in its enterprise data systems and processes. The Moving Ahead for Progress in the 21st Century Act (MAP-21) established several requirements to help States advance their roadway safety data development and analysis capabilities. Two key requirements for States were to: 1) collect Model Inventory of Roadway Elements (MIRE) Fundamental Data Elements (FDE) data for all public roads, and 2) develop safety data management systems to support the Highway Safety Improvement Program, Strategic Highway Safety Plan, and data driven safety analysis (DDSA) and evaluation. The need to meet Federal requirements and develop an enterprise-level approach to safety analysis on all public roads drove many of the recent advancements in CTDOT's data infrastructure. CTDOT created the Transportation Enterprise Data (TED) warehouse to meet the need for enterprise data specifically supporting robust safety management, but also meeting other critical department data analysis needs. The safety data systems are managed under formal data governance policies expressed in the Data Governance Charter drafted by CTDOT alongside implementation of the TED warehouse. These advancements have helped CTDOT scale its data infrastructure and meet emerging needs for robust roadway safety management on all Connecticut roads.

Introduction

In 2019, the Federal Highway Administration (FHWA) completed the second U.S. Roadway Safety Data Capabilities Assessment (FHWA, 2019). This nationwide effort documented the safety data processes, policies, and procedures of all 50 States plus Washington D.C. and Puerto Rico. This effort not only highlighted the current state of practice with respect to all phases of safety data collection, management, integration, and analysis, but it also revealed that State departments of transportation (DOTs) were eager to improve their capacity for data management and integration.

This case study highlights the Connecticut DOT's (CTDOT's) recent advancements in its enterprise data systems and processes. CTDOT's coordination of data infrastructure, such as the Transportation Enterprise Data (TED) warehouse, and internal processes, such as the TED Data Governance Charter and supporting teams, have greatly enhanced the State's safety data management and analysis capabilities (CTDOT, 2020). This includes the collection of many Model Inventory of Roadway Elements (MIRE) data elements recommended by FHWA to support States' roadway safety management processes.

Purpose and Need

The Moving Ahead for Progress in the 21st Century Act (MAP-21) established several requirements to help States advance their roadway safety data capabilities (MAP-21, 112-141). Two key requirements for States were to:

1. Collect MIRE Fundamental Data Elements (FDE) data for all public roads.
2. Develop safety data management systems to support the Highway Safety Improvement Program, Strategic Highway Safety Plan, and data driven safety analysis and evaluation.

FHWA introduced the MIRE policy in 2010 and updated it in 2017 (Lefler et al., 2017). MIRE is a list of roadway characteristic and traffic inventory data elements that can support agencies as they conduct data driven safety management, analysis, and decision making. It includes 205 elements, 37 of which are FDEs on non-local[1] paved roads, 9 on local paved roads, and 5 on unpaved roads. States are required to have access to the requisite FDEs for all public roads by September 30, 2026 (23 CFR § 924.11). States are encouraged to collect, maintain, and facilitate access to the full MIRE as applicable to specific locations.

CTDOT is responsible for over 21,000 miles of public roads throughout the State. Connecticut does not have county government agencies and, as a result, CTDOT maintains both the State and local road network linear referencing systems (LRS) and roadway attribution. This involves collecting and maintaining safety-related data (i.e., MIRE) for these roadways. The need to meet Federal requirements and develop an enterprise-level approach to safety analysis on all public roads drove many of the recent advancements in CTDOT's data infrastructure.

[1] Defined by functional classification.

Target Audience

- State transportation agencies.
- Information Technology (IT) staff.
- Data managers, analysts, and stewards.
- Roadway safety practitioners and safety data users.

Data Governance in Connecticut

The Data Governance Charter is the core document supporting CTDOT's data program. It clearly outlines the responsibilities of individual roles and working groups (e.g., the Change Management Team, Data Governance Team, and TED-IT Planning Team). It describes the flow of data throughout the organization.

Roles and Teams in Data Governance

The list of roles in CTDOT's data governance structure includes:

- General Geographic Information System (GIS) Users.
- Advisors from the University of Connecticut (UConn).
- Data Stewards and Data Owners/Custodians.
- GIS Lead.
- GIS Subject Matter Experts (SMEs).
- Bureau (e.g., Public Transportation, Maintenance and Highway Operations, etc.) SMEs.
- Bureau Leads.
- IT Lead.

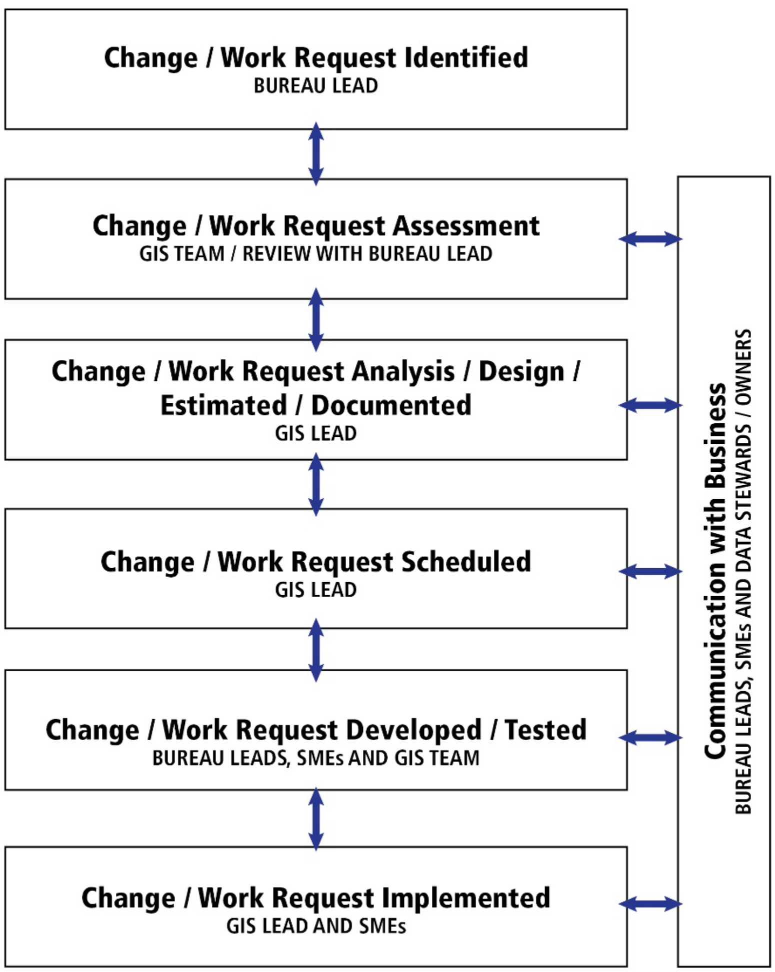
Each role has a formal definition and a list of activities that cover day-to-day operations, as well as planning-level coordination. CTDOT outlines the individual responsibilities of each role using a Responsibility, Accountability, Consulted, Informed (RACI) Chart. The RACI Chart documents the following for each activity under data governance:

- Responsibility (R): The staff in this role are responsible for performing the specific task.
- Accountability (A): The staff in this role are accountable for ensuring the specific task is completed by those responsible.
- Consulted (C): The staff in this role are consulted as the specific task is performed.
- Informed (I): The staff in this role are kept informed during task execution.

In addition to individual responsibilities, the Data Governance Charter organizes the staff associated with these roles into three different teams:

1. Change Management Team.
2. Data Governance Team.
3. TED-IT Planning Team.

The **Change Management Team** meets weekly. It is responsible for tactical and technical management of TED and associated data and applications. This team is responsible for programming software and application updates and changes to, or initiating and monitoring development of, enterprise data in TED. Figure 1 shows how the individual activities relate in the change management sequence reflecting the formal data governance process.



© CTDOT

Figure 1. Graphic. Change request workflow.

The **Data Governance Team** meets quarterly (or as needed), and it is responsible for programmatic management across CTDOT. This includes monitoring key performance indicators (KPIs) and applying a GIS Capability Maturity Model to assess KPIs (Green et al., 2018). The **TED-IT Planning Team** meets weekly and is responsible for project-level management and resource allocation of IT and business resources for TED. The TED-IT Planning Team conducts the activities planned and initiated through the Change Management Team and relies on the Change Management Team for working-level data governance.

Data Flows

The Data Governance Charter diagrams how data flows through the organization using the TED Operational Model (figure 2). This diagram distinguishes between individual bureau-level activities (e.g., Policy & Planning, Maintenance, Highway Operations, etc.) and enterprise-level activities. Although these activities support different objectives within the DOT, figure 2 shows how data flows from collectors and stewards to internal and external users, as well as the positions responsible for each step in the TED Operational Model.

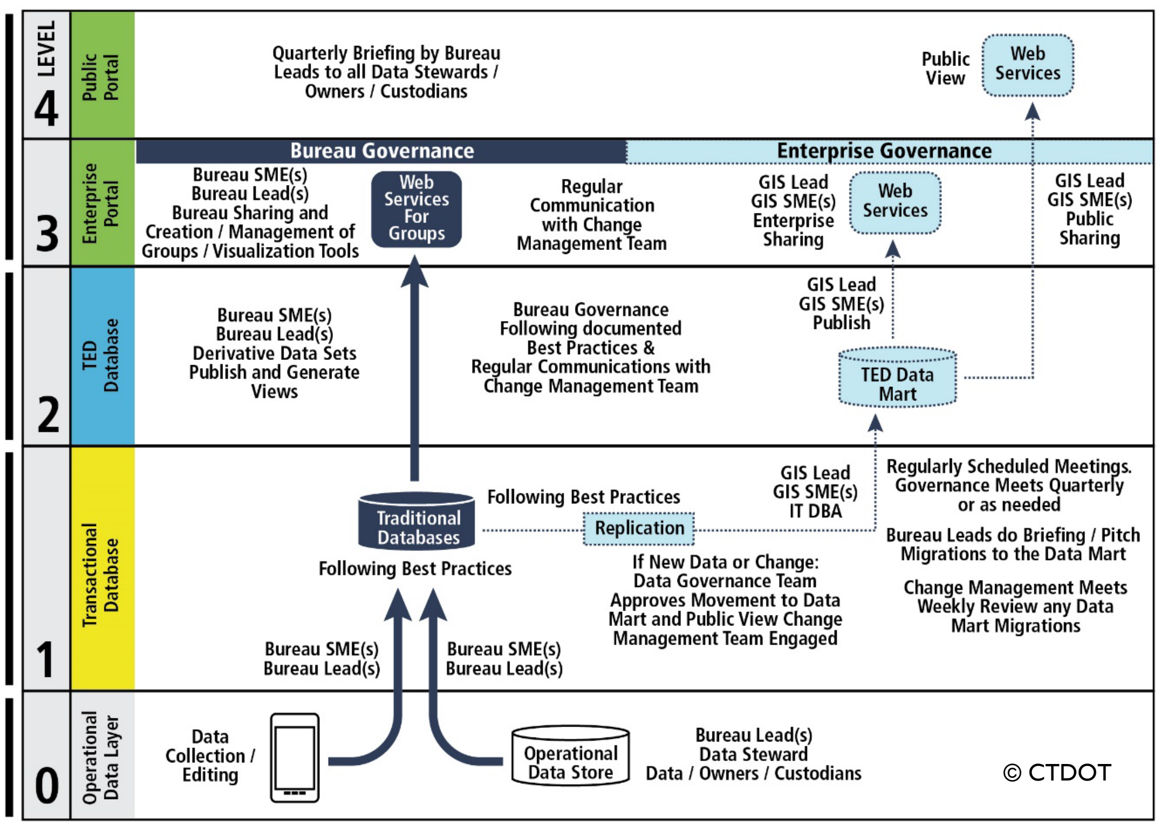


Figure 2. Graphic. TED operational model.

TED and Enterprise Data

CTDOT efficiently collects and integrates large amounts of data through the agency's enterprise approach, specifically through the "backbone" of its enterprise data platform, the geospatially located authoritative public road network. Prior to CTDOT's enterprise data advancements, Connecticut relied on a Microsoft Access™-based application to manage the State's public road network and inventory data on a non-geospatial LRS. This application had limited scalability due to character limits, data entry methodology, and time-consuming post-processing requirements. The MIRE FDE requirement (23 CFR § 924.11) greatly expanded the amount of data to be collected on all paved public roads, as well as documenting specific relationships between types of data. In response, CTDOT identified a need for a more comprehensive solution to data management.

TED is a centralized and accessible, authoritative source for timely data, linking data geospatially from a variety of business units within CTDOT. It is the result of a collaborative effort among engaged stakeholders, each using their particular expertise in transportation data management, and the development of a collective mission and vision for enterprise data. It also builds on the creation of a formal data governance structure to aid in consistent data delivery and use. TED improves two key components of CTDOT's overall safety data program: scalability and accessibility. Scalability refers to TED's capacity to standardize and integrate new datasets while avoiding redundancy across the agency. Accessibility refers to CTDOT's ability to collaborate with internal and external partners as it develops, maintains, and uses its safety and asset data.

Safety Data Collection and Scalability

Historically, CTDOT had managed its existing roadway characteristic and limited asset location information using a non-geospatial LRS, the Roadway Information System (RIS), as a system of record. This legacy system was only able to manage a limited number of datasets compatible with the LRS, and it was not consistent nor compatible with the requirements of the All Roads Network of Linear Referenced Data (ARNOLD) guidance (FHWA, 2014), the Highway Performance Monitoring System (HPMS), or MIRE. The programmatic changes required to accommodate ARNOLD, HPMS, and MIRE data elements meant that these systems could no longer expand to meet the DOT's needs. TED and supporting data systems helped CTDOT address Federal requirements (23 CFR § 924.11) and advance the State's safety data capabilities. CTDOT's development of a geospatial LRS with roadway characteristics was critical to supporting safety data and the TED effort.

An example of CTDOT expanding its capabilities under TED includes the development of the Mobile Asset Verification & Roadway Inventory Collection (MAVRIC) tool. The introduction of MAVRIC has significantly improved CTDOT's data collection capabilities, allowing the agency to expand its compliance with Federal data collection recommendations (Lefler et al., 2017) and improve the efficiency and reliability of statewide safety analysis.

MAVRIC is a browser-based roadway and asset data collection application initially customized to meet field data collection requirements. CTDOT has since repurposed the application to also support office editing of LRS-based data (e.g., speed limits, passing zones, use restrictions, etc.). CTDOT staff can access the tool anywhere, in either a connected (i.e., "live") or disconnected (i.e., "check-out") environment. This means that field data collectors do not require internet or cellular reception to use the application, a critical component in areas of Connecticut that have limited cellular service or "urban canyon" downtown areas in cities. In the absence of an internet connection, data can be cached on a user's device and manipulated in the field through a standard browser interface.

MAVRIC also allows data collectors to create new segments of the road network and add substantial geospatially accurate asset data immediately without having any additional processing steps. This removes the need for multiple trips into the field to review the same areas. These features greatly improve efficiency and safety for data collectors. Additionally, MAVRIC supports parallel data collection where the user can collect multiple linear or point assets (e.g., lanes, curbing, shoulders, intersections, etc.) simultaneously during a single review path. This also offers a considerable efficiency improvement for both field and office data collection.

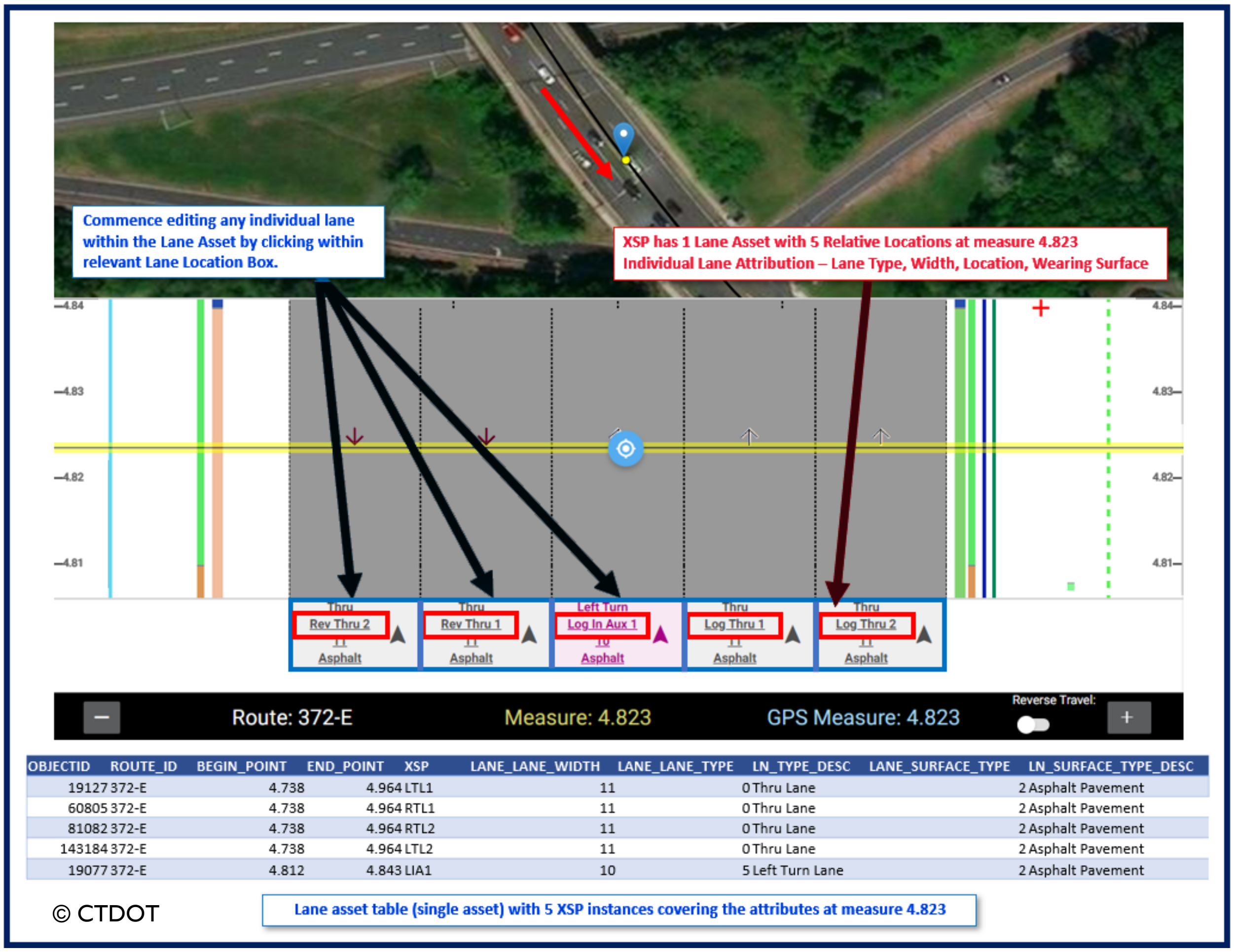
CTDOT houses MAVRIC within the Transportation Data Server (TDS), an administrative application which provides a way to control access to view and edit specific assets. This is critical to maintain high data quality and integrity. Field crews, office crews, administrators, and other users each have set permissions to edit their own assets and attributes. Data collectors can sync data up with the MAVRIC database upon returning from the field if working in a disconnected environment. Office-based editors/connected users can sync edits after they are satisfied with completing an editing session. The agency performs an extract, transform, and load (ETL) process nightly to repopulate the MAVRIC database feeding the application, which improves the timeliness of data sharing between field crews, office personnel, and enterprise data custodians.

Integrate Cross-Sectional Data, Parallel Collection, and MAVRIC

CTDOT's legacy collection systems allowed collectors to update cross-sectional data along the non-spatial LRS for the State-owned portion of the network. Cross sectional positional (XSP) data allows for a single asset to be fully attributed multiple times at the same location without having to maintain separate individual assets for each location. This valuable component of CTDOT's legacy data collection tools has been expanded as the agency advanced its capabilities into the geospatial environment.

An example of this type of data is the Roadway Inventory Unit's maintenance of individual lane information on the road network. "Lanes" is a single geospatial data asset, but by using the XSP approach, the Roadway Inventory Unit can maintain a full set of attributes for each individual lane based upon its location and lane type relative to their position on the route. Travel lanes, slow vehicle lanes, acceleration lanes, deceleration lanes, and turn lanes are all managed as their own entity within the single lane asset. Shoulders (i.e., inside shoulder, outside shoulder), rumble strips (inside shoulder, outside shoulder, centerline), curbing (log direction and reverse direction), and many other assets that may occur multiple times in multiple relative locations at the same measure are all managed similarly using XSPs.

Critical to fully utilizing the XSP approach is the ability to edit multiple data assets simultaneously, known as "parallel data collection." This approach supports CTDOT's application of XSPs in its inventory data (i.e., an individual asset can have multiple measurements at the same point). For example, the through lane asset can have XSP locations for both the log direction and reverse log direction all within the same asset class. This cross-sectional view provides a more holistic visualization of the transportation system (figure 3).



OBJECTID	ROUTE_ID	BEGIN_POINT	END_POINT	XSP	LANE_LANE_WIDTH	LANE_LANE_TYPE	LN_TYPE_DESC	LANE_SURFACE_TYPE	LN_SURFACE_TYPE_DESC
19127	372-E	4.738	4.964	LTL1	11	0	Thru Lane	2	Asphalt Pavement
60805	372-E	4.738	4.964	RTL1	11	0	Thru Lane	2	Asphalt Pavement
81082	372-E	4.738	4.964	RTL2	11	0	Thru Lane	2	Asphalt Pavement
143184	372-E	4.738	4.964	LTL2	11	0	Thru Lane	2	Asphalt Pavement
19077	372-E	4.812	4.843	LIA1	10	5	Left Turn Lane	2	Asphalt Pavement

Figure 3. Graphic. Example of XSP data visualization.

Advancing Data Capabilities

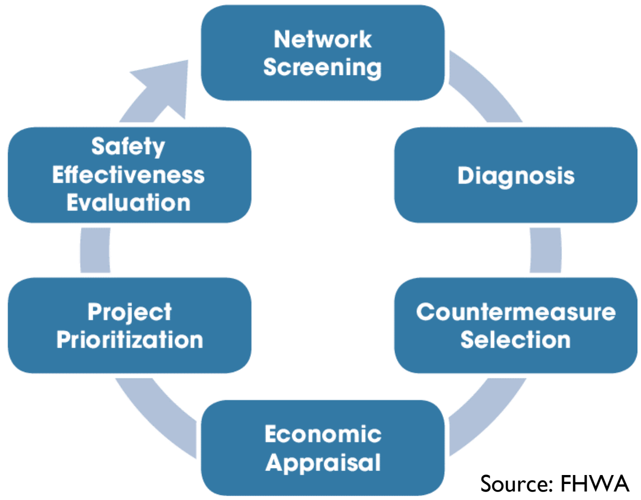
CTDOT has used TED and MAVRIC to manage MIRE attribution along the network, as well as the State's HPMS data. Based on advancements in its enterprise approach, CTDOT collects, maintains, or derives 93 MIRE data elements across its entire network, including all MIRE FDEs. Furthermore, integration of other enterprise data assets has allowed CTDOT to add new non-public road networks (e.g., private roads, commercial driveways, etc.) and mileage to the network model, as well as expand assets and attributes with improved scalability and precision. Legacy data systems could only maintain extensive data on State-owned roads, with only limited data on local roads. Maintenance of a complex geospatial road network, along with MAVRIC editing capabilities and TED integration, accommodates a much larger data model that includes fully attributed State and local roads. It also supports expanded access to other multimodal networks with cross integration (e.g., trail networks) that intersect and share geometry with the road network). This institutional approach has positioned CTDOT to follow Federal guidance more efficiently.

An additional benefit from CTDOT's enterprise systems has been the adaptation of varied datasets from within the DOT as assets along the LRS, leveraging the management of the geometry and route designations to easily locate other department assets to a single LRS with shared geometry and measures. CTDOT plans to expand its capabilities to use the LRS for several diverse applications, such as maintenance of regulatory data (e.g., posted speed limits, no thru truck prohibitions, and highway restrictions) and trails of regional or statewide significance. CTDOT has leveraged Esri's Hub platform to create an Open Data access point for the public and other critical partners, where many of these authoritative and maintained datasets are accessible. These can be integrated into external applications through public web services.

Data Accessibility: Partnerships and Safety Analysis Capabilities

Enterprise data supports several bureau-level business needs within CTDOT, as well as key partnerships outside of the organization. CTDOT developed the Connecticut Roadway Safety Management System (CRSMS) in coordination with UConn's Transportation Safety Research Center. CRSMS is a web-based enterprise application designed to implement the roadway safety management process defined in the First Edition of the American Association of State Highway and Transportation Officials' (AASHTO) (2010) Highway Safety Manual (figure 4). The tool enables CTDOT to make data driven decisions regarding safety investments, particularly with respect to developing refined costs and potential benefits associated with improvements.

A key contributor to the success of CRSMS is its linkage to TED and the State's enterprise data structure. The LRS and roadway attribute data model provided to the CRSMS through TED is compatible with the CRSMS's data management module, enabling the CRSMS to ingest TED data relatively simply. This allows users to dynamically define roadway segments based on identified homogenous attributes and ingest data that are native to the LRS, as well as additional data provided through other means (i.e., not ingested from TED). CTDOT uses a Feature Manipulation Engine (FME) to manage business data in its native format before linking to the system geospatially.



Source: FHWA

Figure 4. Graphic. Roadway safety management process (FHWA, 2013).

CRSMS enables safety analysis on all public roads, and data collected and integrated in TED support these methods. For instance, CTDOT used to rely solely on frequency-based methods for network screening; crash rates formed the foundation for Suggested List of Surveillance Study Sites. With the advent of CRSMS and this data partnership, advanced methods that incorporate detailed MIRE data support safety performance functions and empirical Bayes analysis methods can be applied to all State-maintained roads. To account for locations where there is only basic roadway data available (i.e., locations where traffic counts do not exist), CRSMS can perform a planning-level analysis that involves historic crash frequency and severity. As CTDOT collects more data across a greater share of the road network, more advanced methods can be applied to local facilities. The data accessibility, reliability, and quality supported by TED improves safety decision-making for the State's entire program.

An additional benefit of this DOT and university collaboration is the ability to greatly expand State-specific safety research. This helps improve the ability of robust safety analysis methods to capture Connecticut-specific trends and refine expected performance across the entire State road system.

Conclusions

CTDOT's advancements in the State's enterprise data began as a need to meet Federal requirements (23 CFR § 924.11) and improve the State's analysis capabilities. This enterprise data approach has allowed CTDOT to expand its capabilities and analytical capacity across the entire network. Data governance clearly assigns roles and responsibilities to each stakeholder in the data collection, management, and consumption process. This framework allows CTDOT to effectively manage change and scale its technology to meet new challenges and use cases. The MAVRIC data collection application and CRSMS are great examples of comprehensive data collection and analysis capabilities, but these tools are only possible because data governance and TED are in place. Intra- and inter-agency partnerships, most notably between the DOT and the University of Connecticut, showcase what is possible when data are readily accessible to each stakeholder, collector, analyst, and custodian alike.

References

- Federal Highway Administration. (2019). *Second U.S. Roadway Safety Data Capabilities Assessment*, Report No. FHWA-SA-19-018, Washington, D.C. Available online: https://safety.fhwa.dot.gov/rsdp/downloads/rsdp_usrsdca_final.pdf.
- American Association of State Highway and Transportation Officials. (2010). *Highway Safety Manual: 1st Edition*, Washington, D.C. Resources available online: http://www.highwaysafetymanual.org/Pages/default.aspx.
- Connecticut Department of Transportation. (2020). *TED Data Governance Charter*.
- Federal Highway Administration. (2013). *Quantifying Safety in the Roadway Safety Management Process*, Federal Highway Administration, Report No. FHWA-SA-13-010, Washington, D.C. Available online: https://safety.fhwa.dot.gov/tools/crf/resources/cmfs/docs/management.pdf.
- Federal Highway Administration. (2014, September 1). All Road Network of Linear Referenced Data (ARNOLD) Reference Manual. https://rosap.ntl.bts.gov/view/dot/56299
- Green, M., Lucivero, A., Reovan, A., & Quinton, D. (2018). *Slimgim-T: GIS Capability Maturity Model For State Departments of Transportation*. Available online: https://www.gis.fhwa.dot.gov/documents/Slimgim-T_GIS_Capability_Maturity_Model.pdf.
- Lefler, N., Zhou, Y., Carter, D., McGee, H., Harkey, D., and Council, F. (2017). *Model Inventory of Roadway Elements – MIRE 2.0*, Report No. FHWA-SA-17-048, Washington, D.C. Available online: https://safety.fhwa.dot.gov/rsdp/downloads/fhwasa17048.pdf.
- Moving Ahead for Progress in the 21st Century Act. Public Law 112-141. (2012, July 6). https://www.congress.gov/bill/112th-congress/house-bill/4348/text
- Phone Interview on October 27, 2021, with Greg Ciparelli and Shanshan Zhao.
- *23 CFR § 924.11 - Implementation.* (n.d.). Code of Federal Regulations. https://www.ecfr.gov/current/title-23/chapter-I/subchapter-J/part-924/section-924.11.

Contact

Connecticut Department of Transportation

Enterprise GIS Unit

DOT.EnterpriseGIS@ct.gov

Roadway Inventory Unit

DOT.RoadInfo@ct.gov

University of Connecticut

Shanshan.H.Zhao@uconn.edu