Northern Kentucky

ATDM

FINAL

Northern Kentucky
ATDM Feasibility Study

Concept of Operations

October 2023

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1. Scope

The Northern Kentucky Interstate system consists of three highways: I-71/ I-75, I-471, and I-275 (**Figure 1**). Each Interstate has its own unique characteristics regarding function, traffic patterns, configuration, geometry, speeds, congestion, and queues. The I-71/I-75 corridor extends through the study area from the merge point of the two facilities south of Florence in Boone County into Ohio via the Brent Spence Bridge in Covington. The I-471 corridor runs north and south from US 27 in Highland Heights across the Ohio River via the Daniel Carter Beard Bridge to junction with Columbia Parkway and I-71. The I-275 corridor traverses around the Northern Kentucky and Cincinnati area providing connectivity to both local arterials and other interstate systems.

The purpose of this Concept of Operations (ConOps) is to clearly convey a high-level view of how a proposed set of Active Transportation and Demand Management (ATDM) and Transportation System Management and Operations (TSMO) strategies could be deployed to address system-wide mobility, congestion, and safety needs identified for the corridor. ATDM strategies would allow the Kentucky Transportation Cabinet (KYTC) to dynamically manage recurring congestion (e.g., consistent peak period congestion caused by traffic delays and bottlenecks) and non-recurring congestion (e.g., inconsistent congestion caused by accidents, weather, large local events, among other situations) based on prevailing traffic conditions. Focusing on trip reliability, ATDM strategies are designed to maximize the effectiveness and efficiency of both individual facilities and/or corridors made up of parallel and connecting roadway facilities. ATDM strategies also help to increase safety and throughput using integrated systems and advanced technologies. This includes the use of automated dynamic deployments designed to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually.

This document presents the functionality of the proposed system of strategies and associated deployments for the Northern Kentucky ATDM project and forms the basis of the project's system engineering, design, and implementation phases. This ConOps also serves to communicate user needs and expectations for the proposed integrated system. This document offers stakeholders the opportunity to provide input on how the proposed system would function and to help build consensus to create a single vision for the region moving forward.

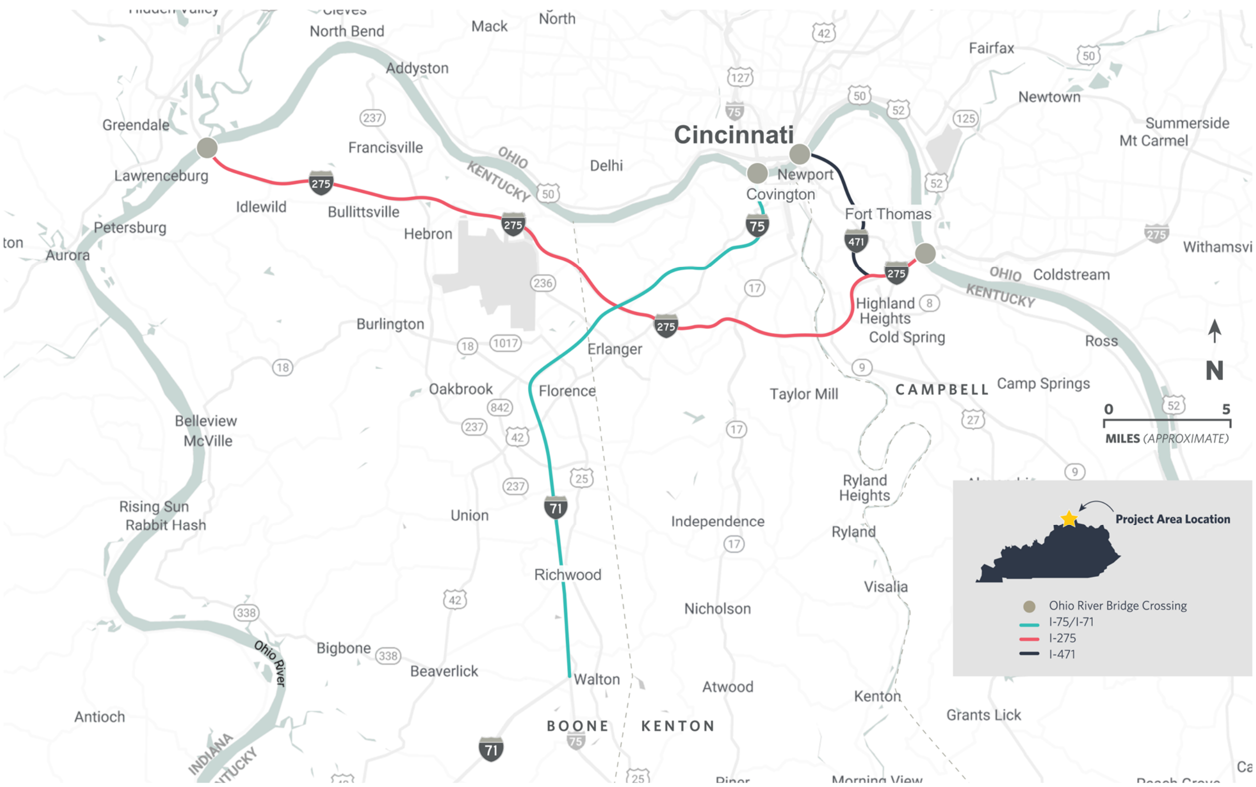

Figure 1. Study Region for the Northern Kentucky ATDM

1.1. Identification

This document provides an overview of the ATDM concepts; describes current conditions; how the deployment strategies would function in the near-term once the system concept is operational; and identifies current and future responsibilities of project stakeholders. By providing a user-oriented view of the potential for integrated management in the region, the ConOps presents the region's needs and problems, goals and objectives, proposed operational approaches, strategies for attaining goals and meeting objectives, the institutional framework in which the proposed ATDM systems would operate, and the associated operational, technical, and institutional issues.

1.2. System Overview

Northern Kentucky is an economic driver for the state and the three interstates in the region are some of the busiest and most congested. I-71/I-75 has eight mainline lanes from the merge point to I-275 and seven mainline lanes north of I-275 to the Ohio River (three northbound and four southbound). There are numerous auxiliary lanes that increase the number of lanes further between interchanges. The 2019 average daily traffic (ADT) volumes on I-71/I-75 ranged from approximately 104,000 to 210,000 vehicles per day. I-471 varies between three and four lanes each direction and carries approximately 100,000 ADT. The Kentucky portion of I-275 is three lanes in each direction with additional lanes just east of I-71/I-75. Traffic on the corridor varies from 50,000 to 107,000 ADT. **Figure 1** illustrates the geographical relationship of the interstates in the study region.

Following detailed analyses[1], dynamic message signs were proposed for each of the three interstate corridors to provide travelers with comparative route travel times and queue warnings. These systems could be complemented by the deployment of ramp metering at selected locations to manage traffic load and flow on the interstates.

1.3. Goals, Objectives, and Needs

The purpose of the Northern Kentucky ATDM Project was to identify and evaluate a range of ATDM/TSMO strategies and concepts to improve capacity, safety, reliability, and travel time on I-71/75, I-275, and I-471. The study focuses on short and long-term improvements that could be implemented by KYTC, Ohio-Kentucky-Indiana Regional Council of Governments (OKI), KYTC's Traffic Response and Incident Management Assisting the River Cities (TRIMARC), or other entities.

1.4. Proposed Integrated Strategies

Three ATDM strategies were determined to be feasible and are proposed for further consideration and potential deployment in Northern Kentucky:

- **Comparative Travel Time System:** This system automatically determines the travel times for alternative routes and posts messages with the travel times for these routes to travelers. These signs are recommended to supplement existing dynamic message sign (DMS) "Smart Boards" along the Interstate corridors and on arterials leading up to interstate on-ramps.
- **Traffic Queue Warning System:** This automated system uses existing data, such as HERE© or WAZE© information to identify when a traffic queue is forming. Once a queue has been identified, the system automatically generates and posts warning messages on roadside DMS to warn drivers.
- **Ramp Metering System:** This system uses dedicated traffic signals on interstate on-ramps near the merge with the mainline to regulate the influx of new vehicles onto the interstate. This system responds to traffic conditions with respect to the metering rates.

1.5. Document Overview

This document follows the IEEE Standard 1362-1998, Guide for Information Technology – System Definition – Concept of Operations (ConOps) Document, 19 March 1998 and as replaced by ISO/IEC/IEEE 29148:2011. The document presents the following sections:

1. **Scope:** Presents an overview, purpose of improvements, and description of the study area.
2. **Referenced Documents:** Identifies supporting documents useful in understanding the project background and development of this document.

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[1] "Northern Kentucky ATDM Feasibility Study: Concepts, Feasibility, Benefits, and Costs," KYTC. October 2022 Draft (Final October 2023)

3. **Current System or Situation:** Describes the current system, how it is used, and needs and problems to be addressed.
4. **Justification and Nature of Changes:** Presents the reasons for and general approach of the proposed improvement strategies.
5. **Concept for the Proposed System:** Provides a high-level description of the proposed system (program) of strategies and rationale for the selected approach.
6. **Operational Scenarios:** Presents how the proposed program is envisioned to operate, its strategies for implementation, and descriptions of users.

2. Referenced Documents

The following documents were referenced in the preparation of this report:

- FHWA Systems Engineering Guidebook for ITS version 3.0
- "Northern Kentucky ATDM Feasibility Study: Concepts, Feasibility, Benefits, and Costs" HDR and WSP. Prepared for KYTC. October 2022 Draft. (Final version released October 2023)
- "Active Traffic Management and Transportation Systems Management and Operations Best Practices Technical Memorandum" WSP and HDR. Prepared for KYTC. October 25, 2021.
- "Northern Kentucky ATDM: Impact of Potential ATM Strategies to State and Regional ITS Architectures, Technical Memorandum" WSP and HDR. Prepared for KYTC. September 1, 2021.
- TRIMARC Webpage: www.trimarc.org

3. Current System or Situation

KYTC has previously deployed a version of comparative travel times, queue warning systems, and other ATDM strategies. However, the Intelligent Traffic System (ITS) equipment remains sparse in the Northern Kentucky region with limited deployment of DMS and Closed-Circuit Television (CCTV). There are also no active vehicle detection units that have been deployed on the interstate corridors in the region. Traffic operations were managed by ODOT prior to 2017 when KYTC reassigned the task to TRIMARC. TRIMARC Traffic Operations Center (TOC) operators in Louisville, KY manage traffic operations with support from local TRIMARC field technicians, who are responsible for maintaining the ITS equipment in the region.

3.1. Background and Objectives

The area described as Northern Kentucky typically refers to Boone, Kenton, and Campbell counties. This region is home to roughly 400,000 persons who work, live, and travel throughout the region. It is the third most populated region in Kentucky behind Lexington and Louisville.

The Northern Kentucky Interstate system consists of three highway corridors: I-71/ I-75, I-471, and I-275. Each interstate corridor has unique characteristics including the number of mainline lanes, use of auxiliary lanes, etc. The I-71/I-75 interstate has eight mainline lanes from the merge point to I-275 and seven mainline lanes north of I-275 to the Ohio River (three northbound and four southbound). There are also numerous auxiliary lanes that increase the number of lanes between interchanges. The 2019 average daily traffic (ADT) volumes on I-71/I-75 ranged from approximately 104,000 to 210,000 vehicles per day. I-471 runs north and south from US 27 in Highland Heights across the Ohio River via the Daniel Carter Beard Bridge to junction with Columbia Parkway and I-71. The existing facility varies between three and four lanes in each direction and carries approximately 100,000 ADT. I-275 is primarily three lanes in each direction, with additional lanes just west of I-275. Traffic on I-275 varies between 50,000 and 107,000 ADT (see **Figure 2** and **Figure 3**).

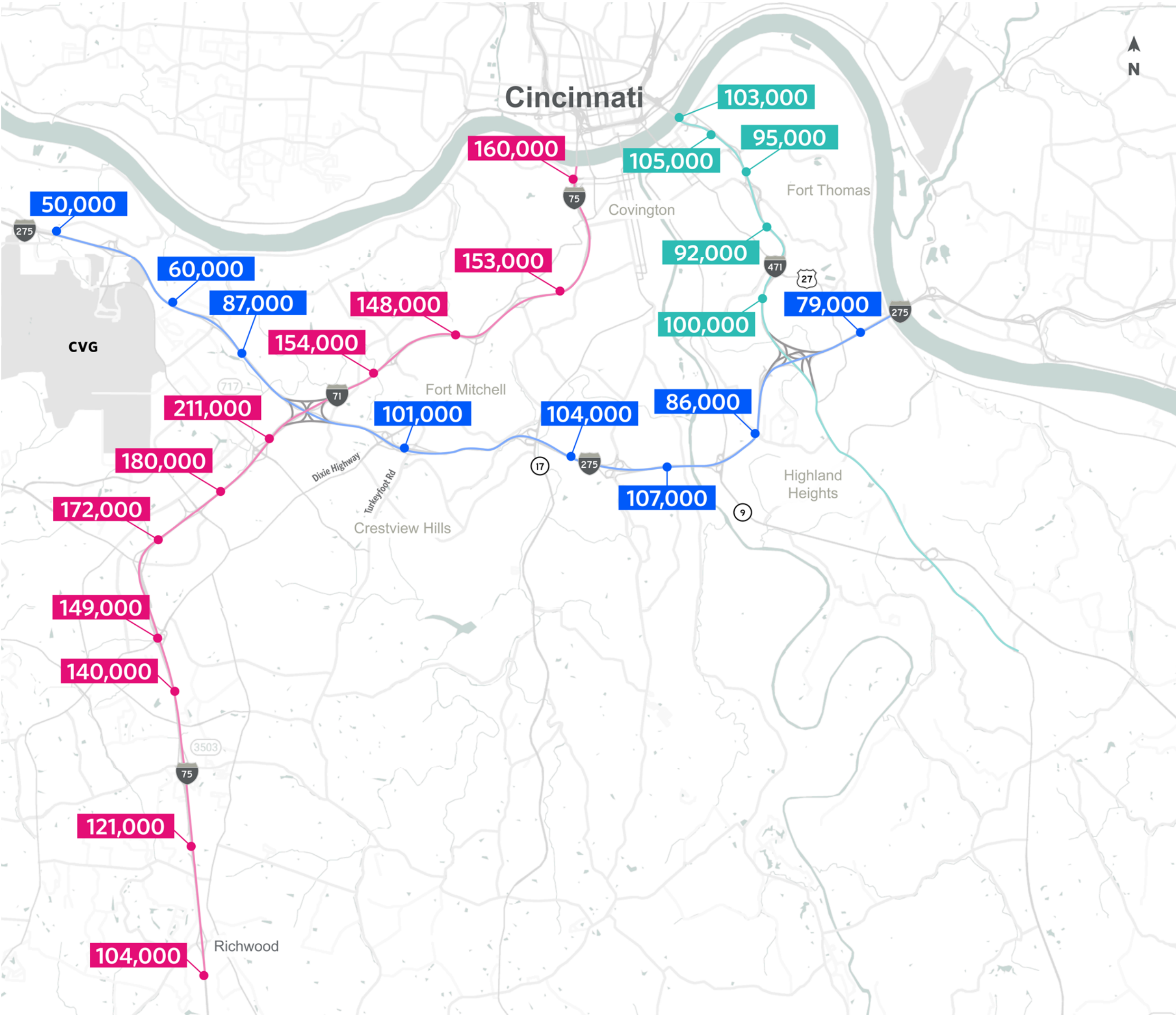

FIGURE 2. ADT ON INTERSTATE SEGMENTS IN NORTHERN KENTUCKY

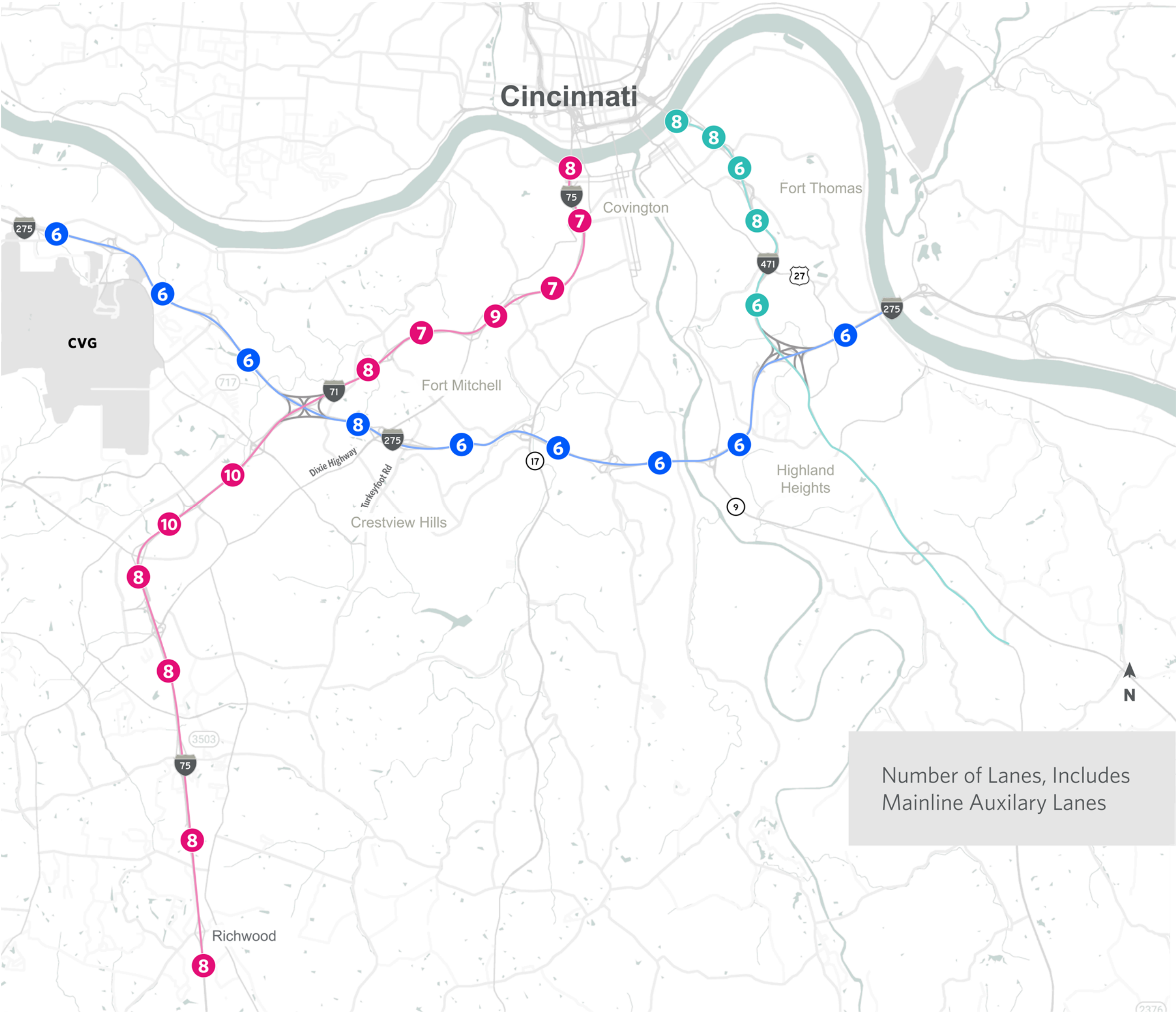

FIGURE 3. NUMBER OF LANES ON INTERSTATE SEGMENTS IN NORTHERN KENTUCKY

All three interstates are heavily traveled and experience frequent, and sometimes severe, congestion and travel time delays. This study was conducted to:

- Assess the feasibility of ATDM strategies to improve capacity, safety, reliability, and travel time on the interstate system of Northern Kentucky.
- Identify locations where ATDM strategies are practical and can be implemented and consider how these strategies could be implemented alongside committed projects.
- Identify opportunities for improved incident detection and management.
- Quantify planning-level benefits of the proposed improvements, including safety and travel time.
- Prioritize the proposed improvements.

3.2. Stakeholder and Institutional Partners

Stakeholders and agency partners actively involved are presented in **Table 1**. These stakeholders were assembled by KYTC to support all required coordination and communications needed to successfully implement and provide ongoing support.

TABLE 1. LIST OF AGENCY STAKEHOLDERS

Stakeholder	Current Roles and Responsibilities
KYTC Central Office	KYTC Central Office is the sponsor of the study and provides management and oversight of the implementation of ITS and ATDM strategies throughout the State.
KYTC District 6	KYTC District 6 staff are responsible for maintaining the roadway, determining where needs exist, recommending plans/projects to improve safety and reduce congestion, providing signal timing, etc..
OKI	Responsible for regional transportation planning and programming of all federal transportation dollars.
TRIMARC	Operates the TOC in Louisville, KY with responsibilities for monitoring and managing traffic in Northern Kentucky and Louisville Metro. Would be responsible for day-to-day monitoring and implementation of the system components. TRIMARC is currently funded to staff the Northern Kentucky desk for 12 hours each weekday. The funding also provides for two Freeway Safety Patrol (FSP) units during peak periods (6 hours each weekday). TRIMARC technicians are also responsible for maintaining the deployed ITS equipment. TRIMARC is a project of the KYTC.
FHWA	Responsible for oversight of federally funded projects to encourage best practices, use of national standards, etc.
ODOT	State DOT partner who owns and operates transportation infrastructure on the Ohio side of the Ohio River.
Kentucky State Police (KSP)	Responsible for enforcement of traffic regulations and laws.
Local Law Enforcement	Responsible for enforcement of traffic regulations and laws.
Cities/municipalities of Covington, Newport, Fort Thomas, Fort Mitchell, Florence, Erlanger, Highland Heights, Wilder, Fort Wright, Lakeside Park	Each municipality monitors and manages the local transportation infrastructure within its own jurisdiction.

Other stakeholders include those who are users of the roadway systems such as the traveling public, commercial freight owner/operators, and business and commercial entities.

3.3. Operational Policies and Constraints

Northern Kentucky is bounded to the north by the Ohio River and is connected to Ohio through several bridges, most notably the Brent Spence Bridge (I-71/I-75) and the Daniel Carter Beard Bridge (I-471). These bridges are potential pinch points for traffic entering and leaving the state.

Kentucky does not have an extensive deployment of Integrated Corridor Management, ATDM, or Transportation System Management and Operations (TSMO) strategies in the state. There have been some deployments of ITS equipment during the past decade, including some associated with Comparative Travel Time, Queue Warning, and other traveler information mechanisms. TRIMARC's TOC staff in Louisville, Kentucky monitor and manage traffic and ITS equipment on Interstates in the Northern Kentucky area (KYTC District 6). TRIMARC monitors and manages traffic and ITS equipment in KYTC Districts 5 and 6. Lexington-Fayette Urban County Government (LFUCG) monitors and manages traffic and ITS equipment in District 7, with support from KYTC's State Traffic Operations Center (STOC) in Frankfort, Kentucky. The STOC also monitors and manages traffic and ITS assets in the remainder of the state. Other constraints or operational conditions include:

- **Backhaul Connectivity:** The region does not have an active fiber network and relies upon cellular connectivity to ITS devices.
- **Vehicle Detection Devices:** There are no existing vehicle detection devices deployed along the interstate corridors in the region. All traffic monitoring is performed through the use of third-party data providers such as HERE© and WAZE© along with available CCTV camera coverage.
- **Existing Advanced Traffic Management System (ATMS):** TOC Operators utilize an existing, centralized ATMS to manage traffic along with a video system that enables access to the traffic cameras.
- **Signal Operations:** TOC Operators currently do not have the authorization, access, training, or mandate to manage traffic signals. Signals are managed by KYTC central office and District staff using a separate management software system. TOC Operators communicate traffic conditions to KYTC using an Application Programming Interface (API) or through personal communications.
- **CCTV Coverage:** CCTV coverage of the interstate system is not ubiquitous and there are significant gaps in coverage.

3.4. Description of the Current System

There are a number of different ATMS that have been deployed in the Northern Kentucky region primarily those that utilize DMS and CCTV cameras. The active ATMS system has been centralized and is used by the TOC Operators in Louisville, to manage traffic conditions. **Figure 4** and **Table 2** summarize the currently deployed DMS and CCTV cameras. There are no vehicle detection units present along the three interstates. All CCTV and DMS utilize a cellular back-haul to exchange information with the Louisville TOC.

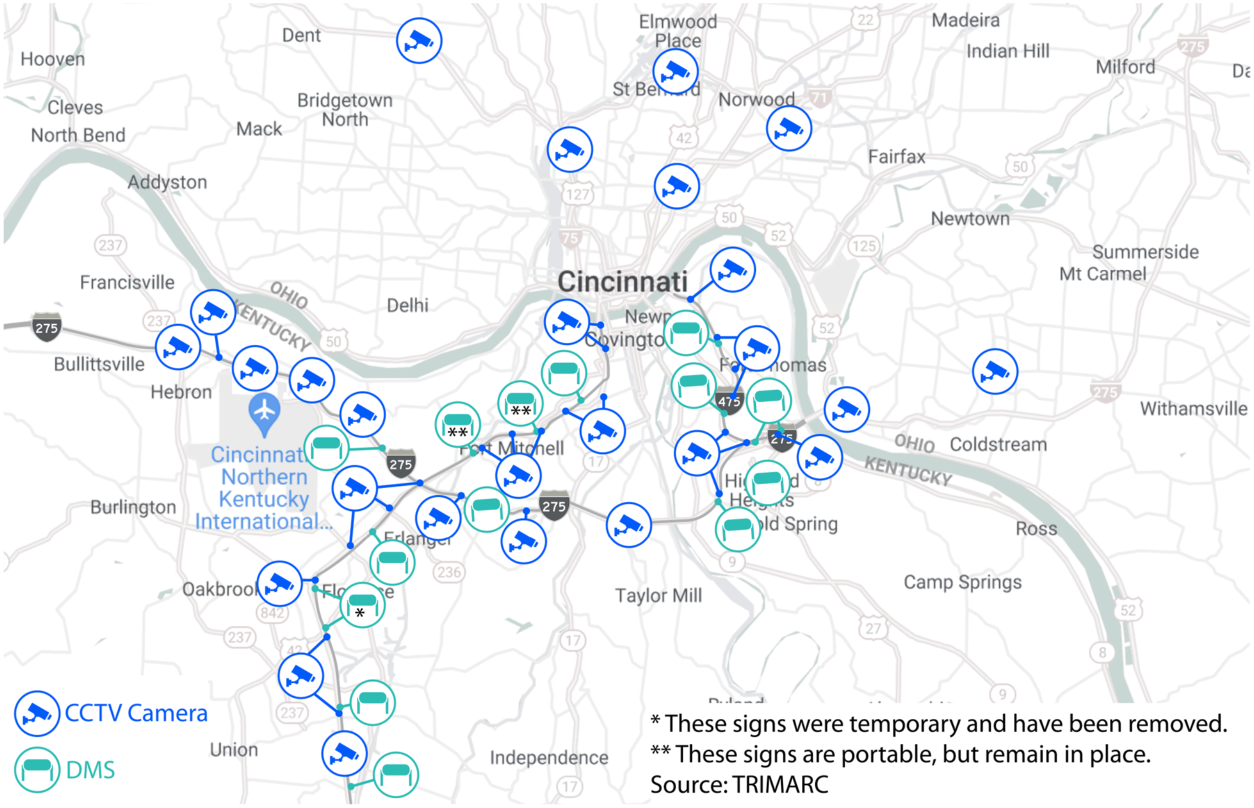

FIGURE 4. CURRENT LOCATIONS OF DMS AND CCTV CAMERAS DEPLOYED IN NORTHERN KENTUCKY ON INTERSTATES

TABLE 2. EXISTING ITS DEVICES IN THE REGION

Device Type	I-71/I-75	I-471	I-275
CCTV Cameras	16*	5	11
Dynamic Message Signs	8**	3***	5
Traffic Sensors	0	0	0

* Two are south of the map area; ** two are portable DMS and two are south of the map area; *** one is south of I-275

The DMS are typically monochrome and mounted on an overhead gantry spanning the interstate. These DMS are used for multiple purposes including general traveler information messages, comparative travel time messages, time-and-distance messages, queue warnings, and other uses. **Figure 5** illustrates a typical DMS on the interstate corridors in Northern Kentucky.

FIGURE 5. EXISTING "SMART BOARD" DMS DEPLOYED IN THE REGION

FIGURE 6. PORTABLE DMS USED ON NORTHBOUND I-71/I-75

3.5. Ongoing Implementation of ATDM Strategies

Messages such as queue warning and comparative travel times are automatically generated and posted by the ATMS from a list of pre-defined messages. The TOC Operator has the ability to override the automatic messages and post more detailed information as desired. Priority is given to operator generated messages, queue warning messages, and comparative travel times in order of priority. Most of the queue warning and comparative travel time messages are associated with north-bound/east-bound traffic. There are two portable DMS that are currently in use in the northbound lanes of I-71/I-75 between I-275 and the Brent Spence Bridge. The portable signs supplement the two overhead DMS (**Figure 5**) in this heavily traveled corridor as all four units are also used to alert drivers of potential traffic queues as illustrated in **Figure 6**.

FIGURE 7. TRIMARC FREEWAY SERVICE PATROL VEHICLE

TRIMARC operates two Freeway Service Patrol (FSP) vehicles in the Northern Kentucky region to provide motorists with roadside assistance and to help improve safety during incidents and other traffic conditions. The two FSP units in NKY provide service Monday to Friday from 6:30 to 9:30 AM and from 3:30 to 6:30 PM. These vehicles operate during periods of heavy traffic and include an arrow board to alert oncoming vehicles of potential hazards (see **Figure 7**).

KYTC no longer provides traveler information via a 511 system as this has been replaced with GoKY, which is "KYTC's Real-Time Traffic Information site that provides an interactive traffic map to provide information regarding traffic incidents, congestion and weather activity for roadways across the Commonwealth." GoKY uses state TOC operators, Waze, HERE data, and other inputs to support GoKY.[2] TRIMARC runs the Notify Every Truck (NET) service which uses SMS texts and/or emails to alert commercial vehicle operators about closures in excess of two hours on Interstate Highways and parkways throughout the state. TRIMARC also actively utilizes social media such as Facebook and Twitter to provide traffic alerts.

3.6. Regional ITS Architecture

Current (as well as future proposed) ITS strategies/deployments operating in Northern Kentucky would need to be consistent with both regional and national ITS Architectures defined by KYTC and the Federal Highway Administration (FHWA). The National ITS Architecture is federally mandated to provide a common framework for states and regions to plan, define, and integrate ITS deployments as an integral component of its transportation system. Regional ITS architecture:

- Defines the system and its components
- Identifies the specific services to be provided by participating transportation agencies
- Identifies the specific users of the services
- Describes how information flows between the different components of the system
- Identifies the deployment standards

[2] Source: www.TRIMARC.org (February 2022)

A major update to the National ITS Architecture was last conducted in July 2017 when the ITS National Reference Architecture was merged with the Connected Vehicle Reference Implementation Architecture (CVRIA). This new version of the National ITS Architecture was renamed to the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT).

The OKI Regional ITS Architecture was recently updated (August 2022) and serves as the roadmap for transportation systems integration into the OKI Regional Council of Government tri-state area over the next 10 years. This Regional ITS Architecture covers the entirety of the project area. The OKI Regional ITS Architecture was updated to reflect the latest National Architecture.

The Kentucky Statewide ITS Architecture document was developed in February 2015 and provides an overarching framework that spans all the region's transportation organizations and individual transportation projects. This architecture is currently out-of-date and does not reflect the structure of the National Architecture.

A detailed review of all three architectures was performed as part of this study and this analysis was provided in a project Technical Memorandum[3]. This review, while not exhaustive, revealed that the ITS elements within the current system are generally covered by these architectures and that proposed systems such as those associated with comparative travel times, ramp metering, and queue warning systems are also generally covered although the state architecture is inconsistent with the current National ITS Architecture framework.

3.7. Modes of Operation for the Current System

Modes of operation for ITS devices include normal, unmonitored, and failure/maintenance operations. As discussed above, most of the DMS messages, particularly those associated with comparative travel times and queue warnings are automatically generated and posted by the ATMS. TRIMARC is funded to provide dedicated operations personnel to monitor/manage traffic in Northern Kentucky for 12 hours per day Monday through Friday. Outside of the designated hours, TRIMARC operations staff juggles monitoring Northern Kentucky traffic and ITS assets with other responsibilities.

3.8. User Classes

Existing users may have their roles impacted as planned improvements are deployed. As presented earlier in this section, **Table 3** lists the project stakeholders and their roles and responsibilities related to the current system. User classes based upon these and other stakeholders are defined in **Table 3**.

TABLE 3. CURRENT SYSTEM USER CLASSES

User Class	Members
Infrastructure Owners	KYTC Central Office, KYTC District 6
Infrastructure Maintenance	KYTC District 6, TRIMARC
Traffic Monitoring and Management	TRIMARC
Transportation Planners	OKI, KYTC
Roadway Users	Commercial Vehicle Operators, private vehicle owners/operators, commercial businesses, etc.

[3] "Northern Kentucky ATDM: Impact of Potential ATM Strategies to State and Regional ITS Architectures, Technical Memorandum" WSP and HDR. Prepared for KYTC. September 1, 2021.

4. Justification for and Nature of Changes

The Northern Kentucky region continues to experience travel delays and extreme variability in travel times due to congestion and travel demand. There are current operational deficiencies throughout each of the three interstate corridors present in the region. Congestion during peak travel times is of particular concern as it has led to reduced travel speeds, travel time variability, and additional traffic-related crashes.

4.1. Justification for Changes

Key measures of congestion include the travel time index (TTI), the planning time index (PTI), and the level of travel time reliability (LOTTR). The TTI represents the ratio of the actual travel time to the travel time experienced under free-flow speed. The PTI is the 95th percentile of the TTI and represents the amount of time that a traveler has to "plan" for to have a reasonably high chance of arriving on time. Finally, the LOTTR is the ratio of the 80th percentile of TTI to the 50th percentile. This measure represents a measure of "how bad" travel time is impacted on a "bad" day compared to a "normal" travel day. **Figure 8** illustrates the PTI for the interstate corridors during the PM peak while **Figure 9** illustrates the LOTTR during this same time period. As observed in both figures, there are a significant number of interstate segments with high levels of PTI and LOTTR as indicated by the red shading.

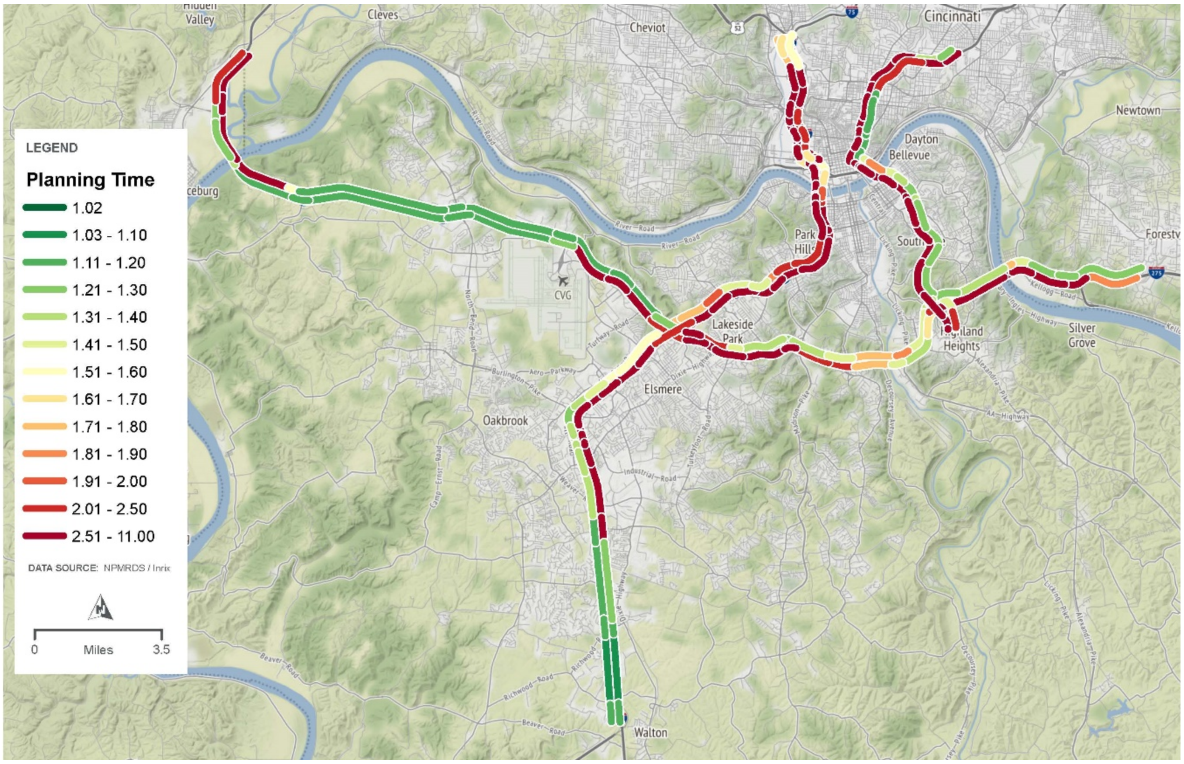

FIGURE 8. PLANNING TIME INDEX DURING PM PEAK TRAVEL IN THE REGION (4 TO 5 PM)

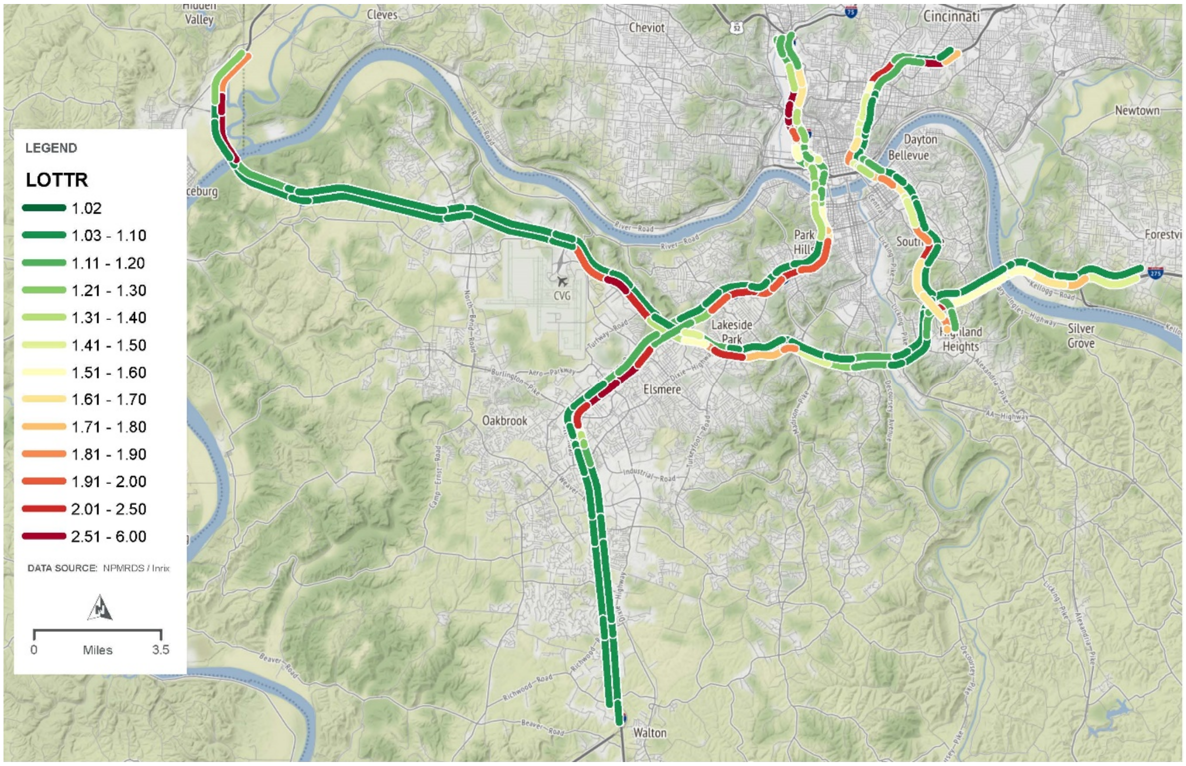

FIGURE 9. LEVEL OF TRAVEL TIME RELIABILITY DURING PM PEAK IN THE REGION (4 TO 5 PM)

Each interstate corridor has unique needs and challenges. Within the I-71/I-75 corridor, the average peak period travel speeds for typical weekdays are shown in **Figure 10**. As shown, the current congestion throughout the corridor extends northbound (NB) from the I-275 interchange through the Brent Spence Bridge during the AM peak. The current congestion SB is in the PM peak and is primarily between the downtown Cincinnati area and Kyles Lane where the travel speeds return to typical operating speeds[4].

With I-471, there are operational needs during the peak periods related to congestion in the NB direction approaching the bridge over the Ohio River and in the SB direction approaching the system interchange with I-275. **Figure 11** shows the current congestion with regard to travel speeds during the peak periods in each direction.

Figure 12 shows the existing peak congestion with regard to travel speeds along I-275 in both directions for AM and PM peak periods. On average the travel speeds along I-275 remain fairly consistent during the peak periods in either direction; however, the I-275 EB corridor has significant variability in congestion between the CVG area to the Combs-Hehl Bridge as noted by the wider pink band in the figure. This variability is present primarily during the PM peak but is also present during the AM peak.

[4] Pre-Covid data is being used for this study. Traffic volumes have returned to near 2019 levels in portions of the project area.

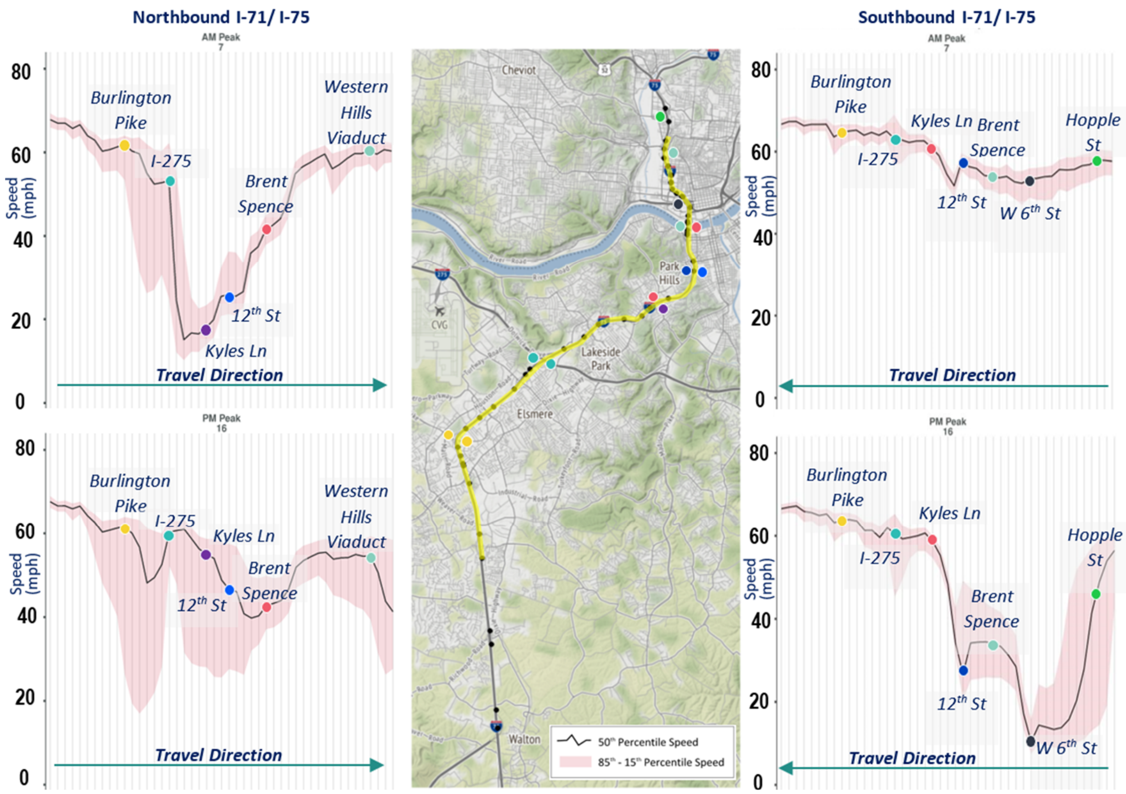

FIGURE 10. I-71/I-75 EXISTING PEAK PERIOD TRAVEL SPEEDS

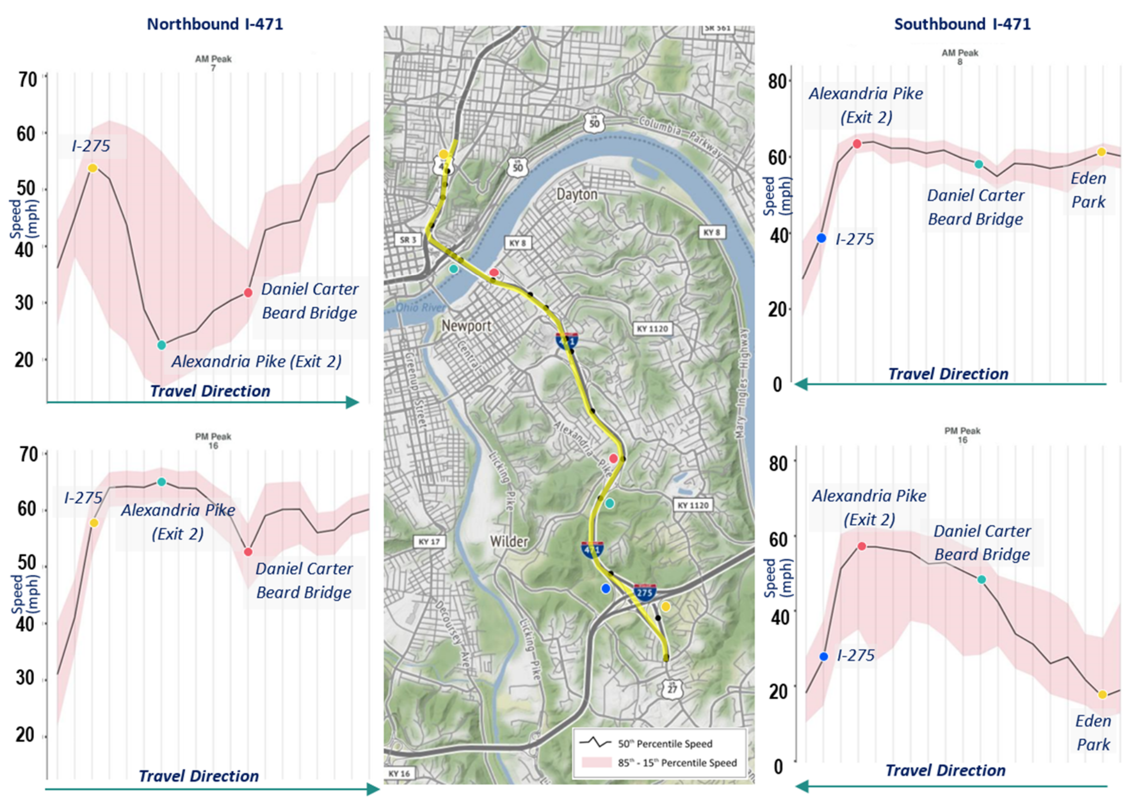

FIGURE 11. I-471 EXISTING PEAK PERIOD TRAVEL SPEEDS

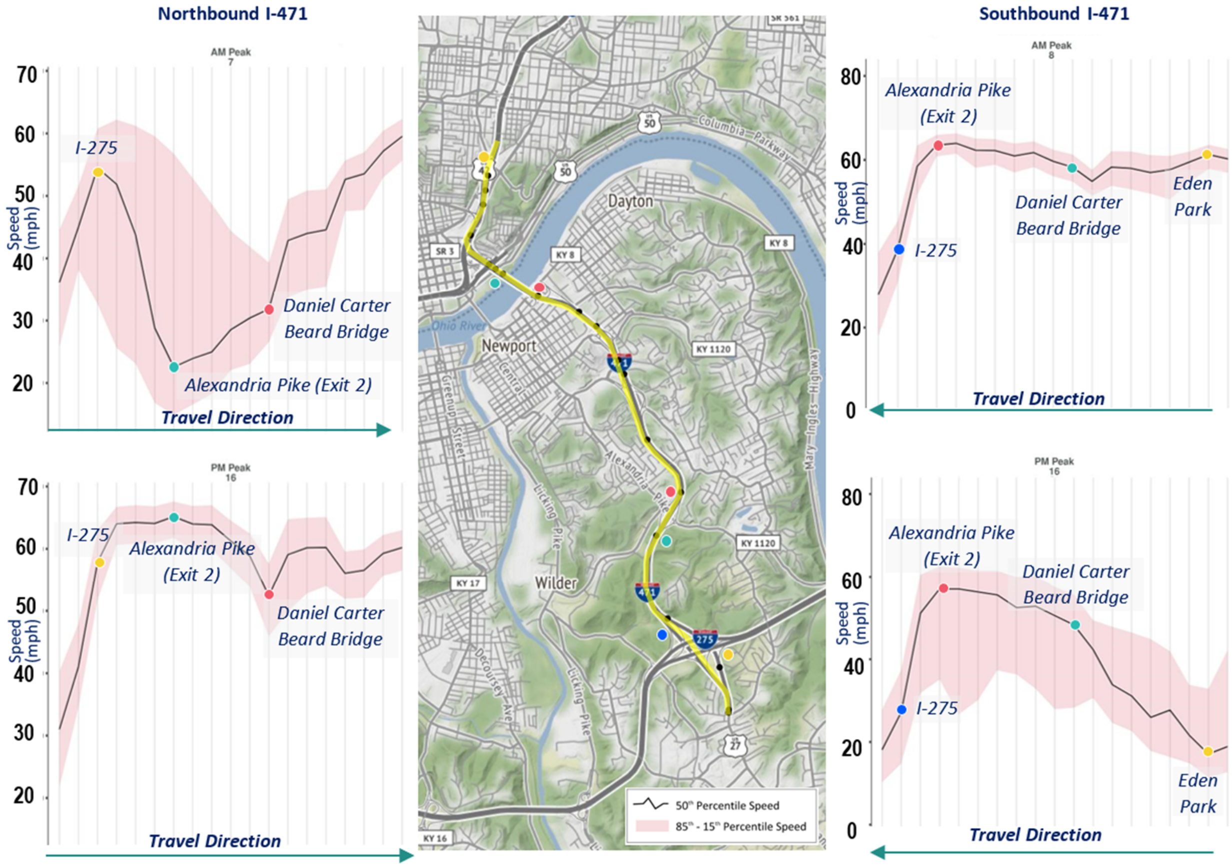

FIGURE 12. I-275 EXISTING PEAK PERIOD TRAVEL SPEEDS

With respect to crashes, there are some locations along the three interstate corridors where crashes concentrate as illustrated in **Figure 13**. Crashes tend to have increased density near major interstate interchanges and preceding heavily congested areas such as those immediately adjacent to the Ohio River. The density of Fatal and Serious Injury crashes follows a similar density as does rear-end crashes. This suggests that crashes are, in part, a result of increased congestion within the region and may be a result of the stop-and-go nature of the traffic flows during congested periods. As the severity of the crashes increases as measured by the degree of the crash and the number of involved vehicles, speed and capacity in the region are further reduced.

The system interchanges connecting the interstate corridors in the region are key focus areas as their capacity can dictate the existing operations and travel conditions. The I-75/ I-71 and I-275 interchange is a four-level fully directional interchange between the two interstate systems. The mainline on both corridors is three-lanes in each direction. The system ramps vary between one and two-lane configurations. The I-75 NB to I-275 EB ramp, I-275 WB to I-75 SB ramp, I-275 EB to I-75 NB, and I-75 SB to I-275 EB ramp are all two-lanes. The remaining ramps are all one lane.

The current configuration provides adequate capacity to serve many of the movements through the interchange. However, one notable exception is along the I-75 NB approach to the interchange. The current diverge on I-75 NB is a four-lane typical configuration that diverges as a standard 3-2 diverge with two lanes going to the ramp. One of the ramp lanes serves I-275 EB and the other lane serves I-275 WB. The KY 236 collector-distributor adds a third lane to the ramp. This third lane does little to add capacity because it connects a short distance before the lane to I-275 EB diverges. Another exception is the reverse movement from I-275 westbound to I-71/I-75 southbound. This two-lane ramp becomes congested due to the restricted capacity in the southbound collector-distributor on the west side of I-71/I-75. This collector-distributor carries a high volume of weaving traffic from both directions on I-275 as well as southbound exiting traffic from I-71/I-75.

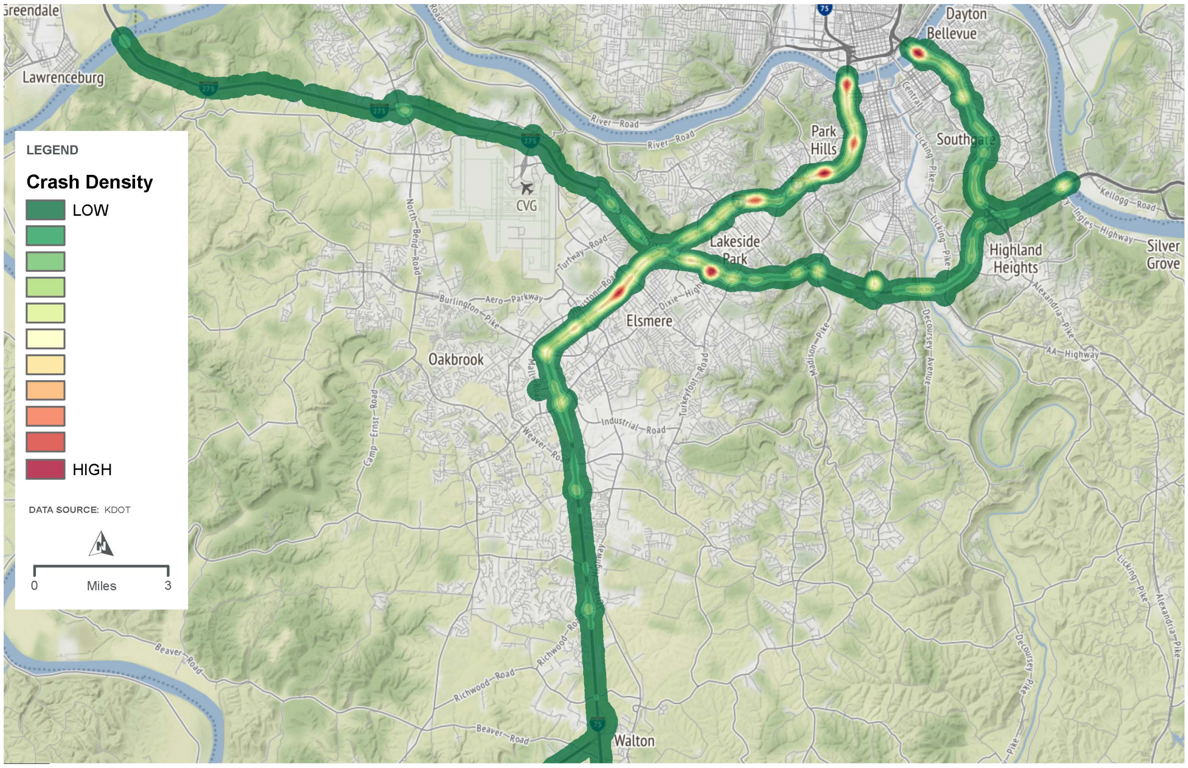

FIGURE 13. CRASH DENSITY IN THE NORTHERN KENTUCKY REGION

The I-275 and I-471 interchange is a three-level fully directional interchange between the two interstates. Through the interchange I-275 mainline is three-lanes in each direction while I-471 is two-lanes in each direction. The system ramps vary between one and two-lane configurations. The I-275 WB to I-471 NB ramp, I-471 SB to I-275 EB ramp, and I-471 SB to I-275 WB ramp are two-lanes while all others are one lane. The current configuration and capacity are adequate to accommodate the existing traffic volumes with a few caveats. While the I-471 SB to I-275 WB ramp is two lanes to provide additional capacity, both lanes drop once they merge with I-275 WB. The outside lane merges within the first 1,000 ft. after the merge gore and the inside ramp lane subsequently merges within approximately 2,000 feet after the merge gore point. This creates additional merging conflicts and poor lane utilization on the ramp. The mirror ramp (I-275 EB to I-471 NB) is the other capacity constraint. It is currently a one-lane, left-sided, flyover exit from I-275 EB. It is near capacity and is a source of recurrent congestion due to the ramp geometry (horizontal and vertical). Traffic on the ramp is operating at a lower speed. This causes some queuing in the I-275 EB left lane in conflict with higher speed traffic attempting to utilize the left mainline lanes for passing.

4.2. Description of Desired Changes

Six Active Traffic Demand Management (ATDM) strategies were determined to have the potential to improve traffic operations, safety, and reliability on the Interstate system in Northern Kentucky. The deployments include: Comparative Travel Time, Queue Warning, Ramp Metering, Dynamic Shoulder Use, Dynamic Speed Advisories, and Dynamic Lane Use Control. Of those strategies the first four were identified as preferred for the Northern Kentucky system and were evaluated from an operational and safety perspective to determine the anticipated benefits associated with their deployments. The four strategies examined in this document are described below.

Comparative Travel Time

Comparative travel time messaging is the use of DMS or hybrid static signs with DMS panels to display travel times for two or more unique but comparable routes to a common destination. Based on the times displayed, motorists can easily gauge travel and traffic conditions for the signed routes and select in real-time the route with the least delay. Comparative travel time can improve a driver’s travel experience by allowing better enroute decision making. It also improves traffic operations by spreading demand across multiple routes; more effectively using available capacity, reducing congestion, and improving safety.

Queue Warning

Queue warning systems alert drivers about slowed or stopped traffic to prevent sudden slowing and to reduce the number and severity of rear-end or erratic lane change crashes. These systems often have sensors along freeways that are regularly congested or experience frequent crashes, incidents, adverse weather, or construction activity. However, algorithms using third party speed data (such as HERE© or WAZE©) can also be used to identify the congested areas and automatically populate the queue warning messages. When slowed or stopped traffic is detected, a warning message is displayed on a DMS, possibly coupled with flashing lights to indicate that the warning is in effect.

Ramp Metering

Ramp metering is the use of traffic signals, installed on freeway entrance ramps, that control the rate that vehicles enter the freeway. Ramp metering reduces the impact that traffic entering the freeway has on mainline traffic flow by storing vehicles (i.e., excess demand) on the ramp and releasing them one at a time rather than allowing closely spaced vehicle platoons to enter the freeway. By managing the rate that traffic can enter the freeway, vehicles can merge more smoothly with mainline traffic reducing merge related congestion.

Dynamic Shoulder Use

Dynamic shoulder use is an active traffic management approach for dynamically opening the shoulder to traffic on a temporary basis in response to increasing congestion, incidents, or special events. Dynamic shoulder use can temporarily increase roadway capacity and postpone or eliminate the onset of congestion and its effects on travel time reliability and safety. Dynamic shoulder use can also be restricted to particular classes of vehicles, such as HOVs or transit, to increase person throughput and encourage mode shift. Dynamic shoulder use deployments typically use overhead DMS to indicate whether the shoulder is open to traffic. These signs would be in conjunction with the other DMS and/or static signs needed to support the deployment. For deployments where the shoulder use times are fixed (not dynamic), static signs can be used to display the times of operation.

4.3. Priorities Among Changes

Traffic conditions discussed previously are only worsening as the region recovers from the impacts of Covid-19 and returns to pre-pandemic travel volumes. Increased pressure from a growing demand is only contributing to the need for improvements. Detailed analyses were performed[5] for all the identified strategies, with priority given to those strategies that:

- Could be implemented within a relatively short duration (1-2 years).
- Have favorable benefit/cost ratios.
- Would have a measurable impact on congestion with respect to travel time and safety.

Among the strategies that were evaluated, three strategies were determined to meet these criteria and were prioritized for deployment. These strategies, discussed in detail in Chapter 5 of this document, include:

- Comparative Travel Time Traveler Information
- Traffic Queue Warning Systems
- Ramp Metering Systems

4.4. Changes Considered but Not Included

Two common ATDM systems that were considered but not selected for deployment as part of the project include Dynamic Speed Advisories and Dynamic Lane Use Control.

Dynamic Speed Advisories

Incidents, weather conditions, or other unexpected events as well as bottlenecks may create congestion and variability in prevailing driving speeds on the interstate. If drivers are not expecting the resulting slowdown, collisions may result. These situations can be mitigated, in part, through advanced warning of conditions, and provision of recommended driving speeds. With

[5] "Northern Kentucky ATDM Feasibility Study: Concepts, Feasibility, Benefits, and Costs" HDR and WSP. Prepared for KYTC. October 2022. (Final October 2023)

advanced information, drivers can be better informed of conditions that lie ahead of them and can take steps to adjust driving behavior safely before being impacted by downstream events. The intent of a dynamic speed advisory system is to gradually slow traffic as it approaches congestion or slow-moving traffic and in doing so to reduce the frequency and severity of incidents and secondary crashes. (Note: In Kentucky, state law complicates dynamically changing the posted regulatory speed. Therefore, a speed related system could be limited to posting advisory speeds.)

Dynamic Lane Use Control

Dynamic Lane Use Control is a strategy consisting of closing or opening individual traffic lanes as needed and providing advance warning to travelers of the closures, while guiding the safe merging of traffic into adjoining lanes. These actions are performed through the use of specific icons displayed on the message boards above each lane such as a red “X” or a green arrow. When an incident or another need to close a lane is detected, the red “X” would be displayed on the overhead, lane DMS nearest the incident with a yellow “X,” indicating a future lane closure displayed on the second closest gantry. As the queue length grows due to the incident, the use of the yellow “X” would be continued on preceding gantries to warn travelers of an impending merge.

4.5. Assumptions and Constraints

Stakeholders in the region would need to commit funding and/or resources to operate and maintain technologies deployed to fully realize the benefits. KYTC staff would have new equipment to maintain, while TRIMARC would have new devices that would have to be monitored and managed as part of daily traffic operations. The local municipalities may encounter changes to the travel patterns on their local roads as a result of the deployed strategies. Travelers may divert from Interstate travel or to different interstate routes as a result of a comparative travel time messages. Drivers may also choose to divert away from the freeway for short trips because of ramp metering or if queues on ramps become excessive. For ramp metering to be effective, it would need to be enforced, which would increase the responsibilities of the Kentucky State Police and local law enforcement. Continued discussion and coordination among the stakeholder groups would be critical during and following the deployments for the long-term success of the project.

5. Concepts for the Proposed System

This chapter describes the overall concepts associated with the three ATDM strategies that are being proposed for deployment. It should be noted that the actual design and final form of each system needed to achieve these concepts would be determined as part of the system design process. Information presented in this section is designed to convey the intent of the system with respect to functionality and not form.

5.1. Comparative Travel Time System

Comparative Travel Time Systems refers to the use of electronic signs to provide comparative travel times for alternate routes as drivers approach decision points. These systems have been deployed using roadside or overhead dynamic message signs, hybrid roadside or overhead fixed signs with pre-printed alternative routes and dynamic inserts for travel times as illustrated in **Figure 14**. These systems provide information to travelers on the interstate as well as to those travelers who are on an arterial roadway leading to an option of merging onto an interstate.

FIGURE 14. ILLUSTRATION OF A TYPICAL COMPARATIVE TRAVEL TIME INFORMATION SYSTEM

Comparative travel time systems work to relieve congestion by providing information to travelers so that they can choose to divert to an alternative route, usually another interstate, during periods of heavy use. The effectiveness of such systems is heavily reliant upon their accuracy and belief by the public that the information presented is current and represents actual conditions. The overarching goal of a comparative travel time system is to effectively distribute traffic demand throughout the system by allowing drivers to choose to divert to other routes that have lower travel times. When traffic volumes increase and/or incidents occur on the interstate (i.e., primary route), congestion may form, and travel times may increase. In these instances, other interstate and/or arterial routes may provide a travel time advantage to travelers. However, drivers are often not aware of these routes or their operational status and cannot effectively decide which route to take, and thus, typically continue to travel on the primary route. The comparative route travel time system would present travel times for the primary route and one or two comparative alternate routes to allow drivers to effectively make travel decisions based on real-time travel time information.

Potential locations for Comparative Travel Time displays are shown in **Figure 15** and listed below. The arterial DMS installations have been divided into two phases to accommodate the possibility that they might not all be implemented at one time. It is assumed that the existing DMS along the corridor could also be utilized for this deployment without incurring additional costs. In total, the deployment includes three new Comparative Travel Time displays on I-75 NB, one new display on I-275 EB, and 17 displays along arterials leading to on-ramps associated with I-75 NB (9 arterial signs), I-471 NB (4 arterial signs), and I-275 EB (4 arterial signs).

1. I-71/I-75 Northbound Mainline South of I-275 - 3 signs
2. I-275 Eastbound Mainline West of I-71/I-75 - 1 sign
3. I-71/I-75 and KY 236 (Commonwealth Avenue) - 3 signs
4. I-275 and US 25 (Dixie Highway) - 2 signs
5. I-275 and KY 1303 (Turkeyfoot Road) - 2 signs
6. I-71/I-75 and KY 371 (Buttermilk Pike) - 2 signs - *Phase II*
7. I-71/I-75 and US 25 (Dixie Highway) - 2 signs - *Phase II*
8. I-71/I-75 and KY 1072 (Kyles Lane) - 2 signs - *Phase II*
9. I-471 and KY 1892 (Grand Avenue) - 2 signs - *Phase II*
10. I-471 and US 27 (Alexandria Pike) - 2 signs - *Phase II*

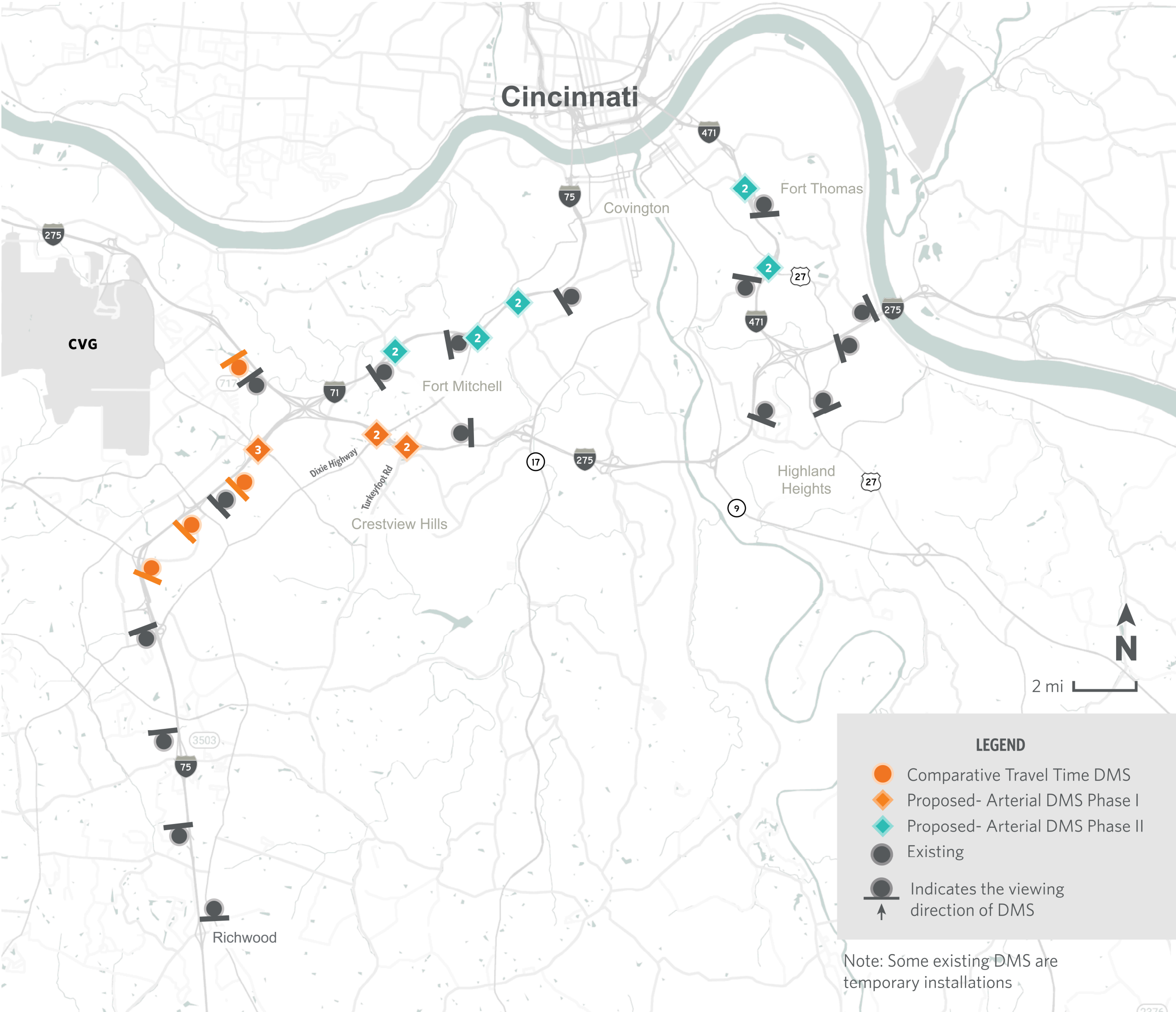

FIGURE 15. POTENTIAL COMPARATIVE TRAVEL TIME SIGN LOCATIONS

Operation of the system could be overseen by operators within the Louisville TOC who could monitor traffic conditions along the interstates using CCTV and third-party data available to KYTC. The system would be managed and controlled using existing ATMS central management and control software that would automatically collect and process data from new and existing data sources and would post travel times to roadside signs associated with the system based on a set of predefined rules entered by KYTC. The system should be configured to display travel times for signed routes on a continuous, 24/7/365 basis unless traffic management personnel manually turn off the system or there is a system malfunction/failure. Therefore, each sign associated with the system should always appear as "on" to the driver. Traffic management personnel should not be required to manually operate the system at any time, outside of initial system configuration. However, operations staff should have the ability to manually operate and manage the system and override system operation as needed. To that end, traffic management personnel would only be required to monitor system operations to make sure that it is displaying travel times that seem appropriate for observed conditions. The system would be capable of being configured to prevent displaying travel times that are less than the free flow travel time that would occur at the posted speed limit.

The comparative route travel time system's central management and control software platform would have a device map that visually displays an icon corresponding to each comparative route travel time sign. From the device map, traffic management personnel would be able to view individual icons to quickly determine the location and operational status of individual signs. KYTC traffic management personnel would be able to click on an icon to retrieve details about the operational status of the selected sign. Status includes if the sign is posting a travel time, the numerical time of the posted and free flow travel time, if there is a problem with the sign, etc. If needed, operations staff would use CCTV cameras to verify travel times are visible to motorists and to verify that the sign is working correctly. The central management software would be capable of displaying text to full matrix DMS and smaller DMS inserts. The new data sources, changes to the graphical user interface, and new device integration described in this section may require modifications to current systems and/or software development.

5.2. Traffic Queue Warning System

The traffic queue warning system would consist of dynamic message signs installed along or over the roadway that would automatically alert drivers to the presence of slow moving or stopped traffic. These displays would be placed at regular increments along the corridor and/or at strategically placed locations in advance of typical congestion hotspots and incrementally spaced as far back as queues normally extend. Existing DMS may also be used to convey this information within the study region. Deployment of displays would be placed predominantly along I-71/I-75 NB, I-471 NB, and I-275 EB within the study region. **Figure 16** illustrates a typical Traffic Queue Warning display. **Figure 17** illustrates potential new queue warning DMS locations. It also shows the arterial DMS discussed with the Comparative Travel Time deployment, which could also be used for queue warning messages.

FIGURE 16. ILLUSTRATION OF THE USE OF DYNAMIC MESSAGE SIGNS FOR QUEUE WARNING

Typically, traffic queue warning systems include fixed or portable dynamic message signs that are digitally controlled from a TOC. The speed and congestion information are often obtained from vehicle detection systems such as video cameras or vehicle radar units, though third-party speed data (HERE or WAZE) can also be used. For Northern Kentucky, queue warning messages would be automatically populated. These alerts would be dynamically updated and adjusted as the end-of-the-queue changes position. TRIMARC staff could monitor conditions and update the messages from the Louisville TOC manually if needed.

By automatically alerting drivers to slowed or stopped traffic, the goal of the system would be to provide quick and accurate alerts to help reduce the number and severity of primary and secondary crashes. The system would require an ample amount of real-time traffic data (such as HERE or WAZE data) to ensure that alerts are accurate and timely. The system would be visible to all traffic regardless of what lane it is traveling in and may require beacons to draw a driver's attention to the sign.

The queue warning system should be operationally ready on a continuous 24/7/365 basis but would only activate and display a queue-warning message when a qualifying queueing event is detected. Central management and control software would automatically generate and remove messages based on real-time data and a set of predefined rules entered by KYTC. Operations staff would, however, have the ability to manually operate and manage the system, override system operation, and post and remove messages as needed. As operations staff become familiar with queue warning operations, they would have the ability to manually edit the predetermined queue warning messages to include incident specific details. This would increase the credibility and usefulness of queue warning messages.

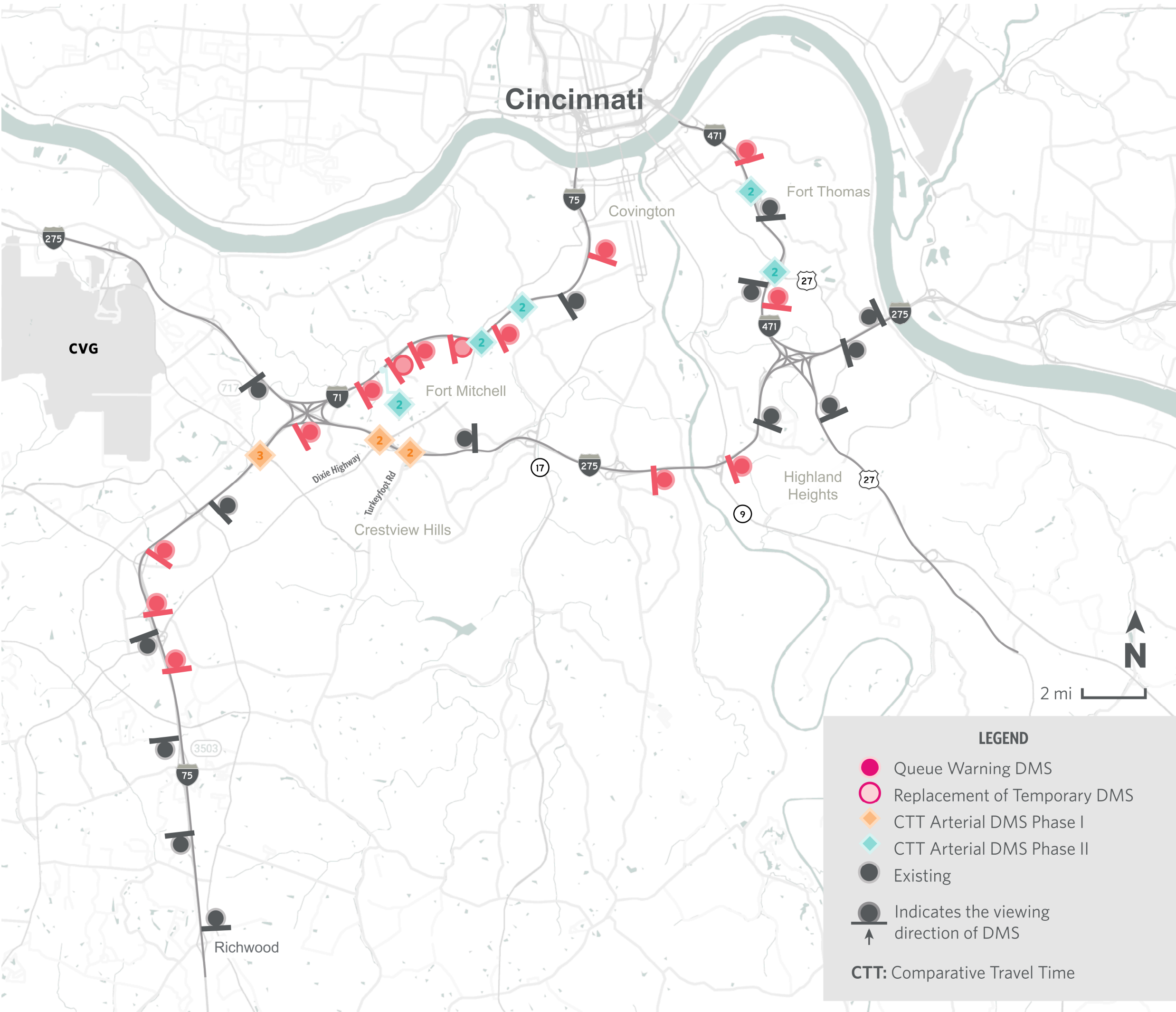

FIGURE 17. POTENTIAL QUEUE WARNING DMS LOCATIONS

The queue warning system's central management and control software platform should have a device map that visually displays an icon corresponding to each queue warning message sign. From the device map, traffic management personnel would be able to view individual icons to quickly determine the location and operational status of individual signs. TRIMARC traffic management personnel would be able to click on an icon to retrieve details about the operational status of the selected sign. Status includes if the sign is posting a message, the type of message the sign is displaying, if there is a problem with the sign, etc. A similar functionality could also be achieved using a device table or list, though the location information would not be mapped/visual. If needed, operations staff could use CCTV cameras to verify sign messages and to verify that the sign is working correctly.

Operations staff would develop and enter specific queue warning messages when the system is configured and before the system is initially turned on. When a slowdown is detected, the central software would automatically select an appropriate queue warning message from the list of user supplied messages based on rules entered into the system by KYTC or TRIMARC. During normal operations, when there are no incidents or congestion, the queue warning system would be capable of displaying a non-queue warning message or may appear blank (no message displayed) per standard operating procedures.

5.3. Ramp Metering

Ramp metering refers to the use of "traffic signals installed on freeway on-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway. Ramp metering reduces overall freeway congestion by managing the amount of traffic entering the freeway and by breaking up platoons that make it difficult to merge onto the freeway."[6] The intent of the ramp metering system is to prevent or delay the onset of mainline traffic congestion and reduce collisions, both in merge areas and other locations on the mainline. For some traffic conditions, ramp metering alone may be sufficient to mitigate traffic impacts. However, in other more severe situations, the comparative route travel time system and/or the queue warning system may yield additional operational benefits.

Ramp metering equipment typically consists of central monitoring and control, communications, and field equipment such as traffic signals, vehicle detection systems, etc. Generally, ramp metering uses vehicle detection equipment to detect current freeway mainline and entrance ramp traffic conditions. Traffic signals are often installed at the side or overhead of the selected freeway ramps to manage the flow of traffic. Vehicles form queues on the ramp behind the stop line and are released onto the freeway at frequencies based upon the current traffic conditions. The system either activates metering by time of day or automatically activates the appropriate ramp meters when congestion thresholds are met. Ideally, vehicles are signaled onto the mainline in a manner that allows for smooth merging and avoids forcing traffic on the freeway to slow down. A series of vehicle loop detectors on both the freeway and the entrance ramps are often used to track the current traffic conditions.

For the Northern Kentucky deployment, vehicle detectors would be installed along the mainline and on ramps in advance of the ramp stop line, at the stop line, and after the stop line. The detectors would continuously track the presence of vehicles traveling through the specified locations. CCTV cameras should also be used along with the proposed detectors to help identify current traffic conditions and determine whether ramp metering operations are performing correctly and whether metering is needed. Each ramp meter should be placed at the location of the associated stop bar in a position that is clearly visible to the drivers and would be accompanied by a sign that clearly communicates its purpose. **Figure 18** shows a graphical representation of a typical ramp metering scenario, including the placement of the ramp metering equipment.

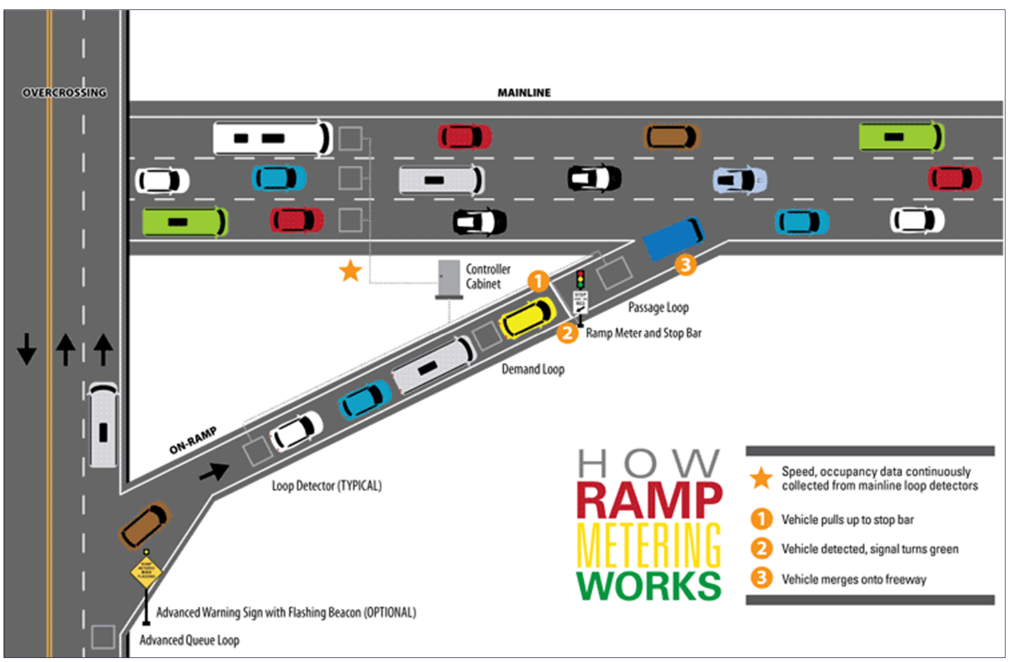

FIGURE 18. A GRAPHICAL REPRESENTATION OF RAMP METERING (SOURCE, FHWA)

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6 https://ops.fhwa.dot.gov/freewaymgmt/ramp_metering/about.htm (February 2022)

The ramp signals would be activated and deactivated according to a fixed timing schedule or when thresholds are met (if the system is set to automatically turn on and off). KYTC or TRIMARC staff could also manually activate or deactivate meters. The system would automatically calculate metering rates reflecting the level of control necessary to support the current traffic conditions. Metered ramps in a freeway system should be coordinated to maximize the traffic flow by controlling the flow of select ramps upstream of a flow breakdown or incident. TOC operators should notify KYTC staff of traffic conditions that may impact ramp metering operations through an Application Programming Interface (API) or through personal communication.

Potential ramp metering installation locations and metering times are presented in **Table 4** and illustrated in **Figure 19**.

TABLE 4. POTENTIAL LOCATIONS FOR RAMP METERING

Corridor and Peak Period	Start of Ramp Metering	End of Ramp Metering	Metered Interchanges
I-75 NB AM Peak	Buttermilk Pike Interchange	Pike Street On-Ramp (Covington)	4*
I-471 NB AM Peak	Alexandria Pike Interchange	KY 8 Interchange	5
I-275 EB PM Peak	Dixie Hwy Interchange	KY 9 Interchange	6

* 4th Street On-Ramp is assumed to be closed, with traffic rerouted to Pike Street; KY 371 (Buttermilk Pike) may require two signals

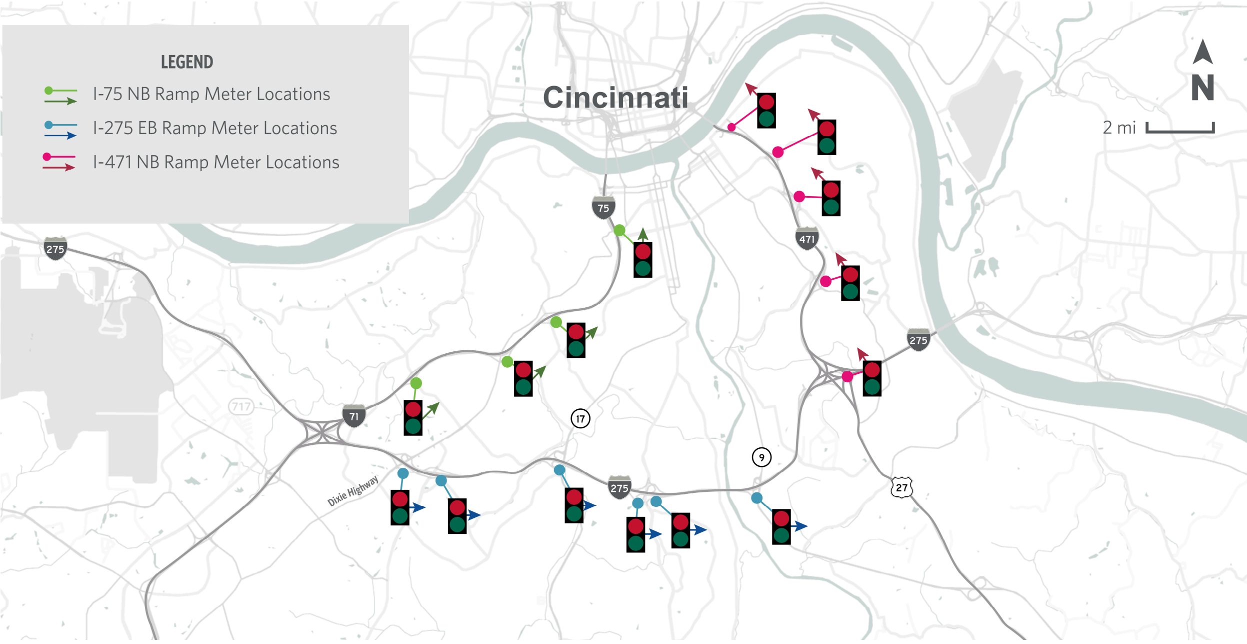

FIGURE 19. POTENTIAL RAMP METERING LOCATIONS

When configured to start at a set time, the signal would begin to meter from that time until the end of the operational window at which time ramp metering operations would cease until the next operational window. When configured to start based on real-time conditions, ramp meters would only start up for the ramp or ramps where real-time traffic data necessitates their use to improve operations. Metering operations at specific ramps would be dependent on and dictated by traffic conditions that can be affected by the specific ramp meter.

Operation of the system would likely to evolve over time and is based on a number of factors including the agency's desired staffing model and its defined operational objectives. Expected near-term and long-term operations are outlined below.

5.3.1. Near-Term Operations

When ramp meters are first implemented, traffic management personnel and drivers would be relatively unfamiliar with their operation. In the near-term, all ramp meters would operate within a specific time-of-day window corresponding to the AM and PM peak periods. Operating during just the AM and PM peak periods would allow operations staff to oversee and gain familiarity with metering operations. It would also lead to more predictable operations and would minimize the potential for surprises. This should lead to more successful operations and public acceptance of ramp metering during the period of initial operations.

In the near term, the operational window would be configured such that it roughly corresponds to the AM and PM peak commute periods. At the beginning of the operational window, all ramp meters would begin their start up sequence if set to initiate at a specific time. If set to start metering when pre-determined conditions are met, the ramp meter controllers would monitor conditions and turn meters on when those conditions are met as needed to effectively manage traffic. KYTC could allow ramp meters to activate individually by location based on real-time traffic conditions as long as the time-of-day is within the operational window. During the operational window, TOC personnel would monitor ramp metering operations throughout the network to verify that all meters are operating as appropriate for real-time conditions. Throughout the operational window, the metering system would monitor queue propagation upstream of the ramp meter stop bar and alert TOC personnel when queues extend beyond specified points. The ramp metering system would be designed to reduce queue lengths if they approach the ramp/arterial intersection. One critical system consideration would be preventing any new impacts to surface arterial highways.

If the system cannot adequately accommodate spikes in demand, operations staff would manually adjust the ramp metering system to contain the queues on the ramp. TOC staff should inform appropriate traffic operations personnel on a daily or weekly basis to alert them of observed conditions and the responses that were taken. TOC staff would follow standard operating procedures (SOP) regarding how and when to communicate with appropriate traffic operations personnel as well as periodic communications regarding system adjustments. Ramp meters would continuously operate until time reaches the end of the user configurable operational window or when pre-determined conditions are met at which time the system would automatically terminate operations of the metered ramps until the beginning of the next operational window.

Within the operational window (AM and PM peak periods), the ramp metering system would meter traffic based on real-time traffic conditions as measured by traffic detectors installed on the interstate and metered ramps. The metering rate would generally become more restrictive as traffic volumes increase on the mainline and less restrictive when traffic volumes decrease. If a central metering algorithm is used, it would monitor conditions throughout the entire network and if needed implement the appropriate metering rate at any given location to help manage expected demand on other parts of the network. Regardless of whether a central algorithm is used, when long queues are detected on a specific ramp, the metering rate on that ramp could become less restrictive to allow the queue to dissipate more quickly. At the same time the ramp metering rate at upstream ramps could become more restrictive to decrease the flow rate on those ramps and counterbalance the additional release of demand on the downstream ramp. The exact number and placement of vehicle detection should be based on, and adequate to support, the approach and algorithm(s) selected for ramp metering during system design. For example, a corridor-based traffic-responsive system using an advanced algorithm requires mainline and ramp traffic flow data from upstream and downstream detectors that is communicated to a central processor at the TOC. In contrast, pre-timed installations can function without extensive vehicle detection. Decisions regarding the range of ramp metering operations and algorithms that could be supported by the software and detection equipment would be made during system design. Commercially available off-the-shelf products are available to support a wide range of operational strategies.

5.3.2. Mid- to Long-Term Operations

Ramp metering operations during the mid- and long-term would be similar to the near-term. However, as ramp metering operations become more familiar to traffic management personnel and drivers, KYTC may expand the operational window beyond the AM and PM peak periods. The extent to which the operational window would be expanded may in part be based on staff knowledge, familiarity, and availability to actively manage, operate, and change ramp metering operational parameters. Eventually, as operations staff become familiar with the ramp metering system and the system is tuned to operate well under a broad range of conditions, it is anticipated that KYTC could allow the system to operate at any time of day, 7 days a week. In the meantime, KYTC's staffing model may dictate if and when ramp meters would be used during off-peak periods so operations staff can monitor the operation. At minimum, KYTC should require that trained (and potentially approved or certified) staff with operational knowledge of ramp meters be on-duty (whether on-site or virtually) at all times when ramp meters are allowed to operate.

Over time, and as operations staff monitor metering operations, they may observe instances of driver non-compliance with ramp signals (driving through a red signal indication). The ramp metering system would detect and log these instances. If non-compliance rates exceed desired thresholds, the TOC staff should inform the Kentucky Office of Highway Safety (KOHS). The KOHS should decide on an appropriate response which could include education, enforcement, or some other response. If additional enforcement is determined to be required, KOHS would contact local and/or state law enforcement personnel to identify the appropriate activities aimed at reducing or preventing non-compliance.

6. Operational Scenarios

This section provides operational scenarios for the proposed system. Scenarios are hypothetical but realistic situations in which the system needs to operate and are used to describe how elements of the system would operate from key stakeholder viewpoints. Scenarios range from typical (i.e., normal) conditions to incidents and system failures. The intent of each scenario is to help stakeholders understand how the system would be operated and what impacts might occur to their existing operations. The range in scenarios provided is intended to represent common situations in which the freeway management system elements are intended to operate. However, the range in scenarios is not intended to be fully comprehensive because the range of possible scenarios is extensive.

Each scenario describes a series of expected interactions between the various user classes and the proposed strategies in response to specified use-cases. The use-cases prepared in support of the Northern Kentucky ATDM Project are presented in **Table 5**. For the peak travel period conditions, the AM peak was selected because that is the critical peak in the study area with heavy northbound traffic flows into Cincinnati. Each of the use-case scenarios are presented in detail below.

TABLE 5. SCENARIO OF USE-CASES

Scenario Name	Description
Scenario 1: Normal Operations Off-Peak	Normal operations during non-peak travel period. No incidents and free-flowing traffic.
Scenario 2: Normal Operations AM Peak	Normal peak travel period conditions in corridor with heavy congestion creating reduced speeds and stop-and-go traffic conditions but no incidents.
Scenario 3: Off-Peak, Minor Incident	Minor incident occurs during off-peak travel with no lane closures.
Scenario 4: AM Peak, Major Incident	Major incident occurs during peak travel period resulting in disabled vehicles with a lane closure and significant congestion.
Scenario 5: System Failure/Maintenance	The system is off-line for maintenance or due to a failure.

6.1. Scenario 1: Normal Operations Off-Peak Travel

This scenario describes the baseline conditions when the corridor is experiencing off-peak travel and all the equipment is operating normally. This scenario would typically be encountered during a non-peak travel period and late evening/early morning hours with a relatively low volume of travelers. There are no incidents, work zones, accidents, abandoned vehicles, etc. This scenario assumes that driving conditions are fair and there are no impacts to travel. During this period, traffic volumes can be expected to be relatively light with no unanticipated conditions occurring. A hypothetical example of a condition representative of the typical operations, off-peak scenario would be a partly cloudy, Saturday morning where there are no incidents or other events that are impacting traffic flow. Traffic is traveling at or near the posted speed limit.

Scenario Assumptions

1. All equipment is operating normally.
2. Comparative route travel time system would be active and calculating travel times for two or three comparative routes to a common downstream destination
3. Estimated travel times are being automatically calculated based on data collected from available sources.
4. Comparative route travel time is displayed in real-time using roadside comparative route travel time signs.
5. Travel times are not permitted to be below the travel time equivalent of the posted speed limit.
6. Queue Warning System is active.

7. The Ramp Metering System is configured to only operate during the peak period and therefore would not be permitted to meter traffic in the off-peak period (i.e., near-term deployment).[7]
8. Scenario Location: I-71/I-75 Northbound between KY 1017 (Turfway Road) and US 25 (Dixie Highway).

Comparative Travel Time System

System View

1. The traffic monitoring systems are detecting that traffic is in a free-flowing, at speed pattern.
2. The Comparative Travel Time System is automatically calculating travel times for alternative routes for the various Comparative Travel Time displays.
3. The comparative travel time is automatically sent to the appropriate displays, which are displaying the information.

Traveler's Perspective

1. A driver bound for the interstate traveling on an arterial highway approaches an I-71/I-75 interchange which has Comparative Travel Time displays.
2. As the driver approaches a Comparative Travel Time display, they observe that the travel times being displayed are consistent with their expectations regarding a typical travel day (i.e., the posted travel times are close to the free flow travel time for each route).
3. The driver chooses to continue to the ramp to I-71/I-75 northbound and merge onto the interstate.
4. A separate driver already driving on I-71/I-75 northbound approaches a Comparative Travel Time display visible from the interstate.
5. As the driver approaches the Comparative Travel Time display, they observe that the travel times being displayed are consistent with their expectations regarding a typical travel day.
6. The driver chooses to continue utilizing I-71/I-75 northbound for their travel.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline as part of revised standard operating procedures.
2. No atypical traffic patterns are observed by the traffic management personnel in this scenario.
3. Traffic management personnel view a confirmation in the ATMS that the posted travel times corresponding to free-flow traffic are being displayed on the Comparative Travel Time displays. This is verified by traffic management personnel using CCTV cameras.

Queue Warning System

System View

1. The Queue Warning System monitors traffic conditions using third party speed and travel time data.
2. The Queue Warning System determines that traffic is in a free-flowing status and that there are no traffic queues forming.
3. The Queue Warning System does not initiate notices to the TOC Operators regarding posting a Queue Warning message.
4. The DMS associated with the Queue Warning System are either blank or being used for other purposes as dictated by KYTC policy.

Traveler's Perspective

1. A driver on I-71/I-75 approaches one of the DMS that is part of the Queue Warning System.
2. The driver notices that the DMS is either blank or is displaying a non-queue warning message.
3. The driver proceeds at speed along the interstate.

[7] In the mid- and long-term, the ramp metering system would be permitted to meter traffic on a traffic responsive basis and would be configured to operate during the peak and off-peak periods.

Traffic Management Personnel Perspective

1. Traffic management personnel observe on their displays that traffic is moving in a free-flow state and there are no traffic queues forming.

Ramp Metering System

System View

1. All ramp meter signals associated with the system appear off (i.e., not lit or displaying a signal indication, like a “Flashing Yellow” as does ODOT). Beacons associated with ramp meter advance warning signs that are located on the adjacent arterial or ramp do not flash, indicating that metering operation on the adjacent ramp is not in effect.

Traveler’s Perspective

1. A driver bound for the interstate travels along an arterial and approaches an interstate entrance ramp that can be metered.
2. As the driver approaches the ramp/arterial intersection the driver notices an advanced warning sign that indicates that the entrance ramp may be metered.
3. The advance warning sign has flashing beacons that would flash if ramp meters were active. In this scenario, the flashing beacons are not activated and appear to the driver as off/not lit.
4. The driver accelerates toward the ramp meter signal, and it appears as “off or not lit”.
5. Driver continues to accelerate past the ramp meter signal without stopping or slowing.
6. Driver merges with interstate mainline traffic in the same manner as they do today.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline and metered ramps as part of revised standard operating procedures.
2. No atypical traffic patterns are observed by the traffic management personnel in this scenario.

6.2. Scenario 2: Normal Operations during AM Peak

This scenario describes the baseline conditions when the corridor is experiencing AM peak travel and all the equipment is operating normally. The typical operations peak period scenario assumes that driving conditions are fair and that traffic volumes are elevated compared to the off-peak scenario. During this period, traffic volumes can be expected to increase toward the height of the peak period and then gradually subside until reaching the off-peak period, when traffic speeds are restored to free flow. A hypothetical example of a condition representative of the typical operations, peak scenario would be the two-to-three-hour AM commute period on a typical Wednesday where there are no incidents or other events that are impacting traffic flow. Traffic transitions from light volumes toward heavy volumes than back to light volumes. Traffic slowdowns and congestion can be expected.

Scenario Assumptions

1. All equipment is operating normally.
2. Driving conditions are fair and traffic volumes are elevated from off-peak conditions.
3. Drivers are experiencing traffic slowdowns and congestion.
4. There are no reported incidents.
5. Comparative route travel time system would be active and calculating travel times for two or three comparative routes to a common downstream destination
6. Estimated travel times are being automatically calculated based on data collected from available sources.
7. Comparative route travel time is displayed in real-time using roadside comparative route travel time signs.
8. Travel times are not permitted to be below the travel time equivalent of the posted speed limit.
9. Queue Warning System is active.
10. The Ramp Metering System is configured and operational during this period.

11. The Ramp Metering System is configured for near-term operations and is based on time-of-day with a fixed metering rate.
12. Scenario Location: I-71/I-75 Northbound between KY 1017 (Turfway Road) and US 25 (Dixie Highway).

Comparative Travel Time System

System View

1. The traffic monitoring systems are detecting that traffic is in a congested condition with speeds lower than free-flowing speed.
2. The Comparative Travel Time System is automatically calculating travel times for alternative routes for the various Comparative Travel Time displays.
3. The Comparative Travel Time System determines that the travel time via I-71/I-75 northbound is greater than for a designated alternative route via I-275 and I-471.
4. The comparative travel time is automatically sent to the appropriate displays, which are displaying the information.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an I-71/I-75 interchange that has Comparative Travel Time displays.
2. As the driver approaches a Comparative Travel Time display, they observe that the times being displayed suggest that the travel time for an alternative route via I-275 is less than the travel time associated with the I-71/I-75 northbound route.
3. The driver decides that they are familiar with the alternative route and the time savings is such that they choose to divert to the alternative route. NOTE: Only a percentage of such travelers will choose to divert their travel.
4. A separate driver already driving on I-71/I-75 northbound approaches a Comparative Travel Time display visible from the interstate.
5. As the driver approaches the Comparative Travel Time display, they observe that the times being displayed suggest that the travel time for an alternative route via I-275 is less than the travel time associated with the I-71/I-75 northbound route.
6. The driver on the interstate is not familiar with the alternative route and decides that they are not comfortable with using the alternative route. NOTE: Only a percentage of such travelers will actually choose to divert their travel.
7. The driver chooses to continue utilizing I-71/I-75 northbound for their travel.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline as part of revised standard operating procedures.
2. No atypical traffic patterns are observed by the traffic management personnel in this scenario.
3. Traffic management personnel view a confirmation in the ATMS that the posted travel times corresponding to congested traffic are being displayed on the Comparative Travel Time displays. This is verified by traffic management personnel using CCTV cameras.
4. Traffic management personnel observe that some traffic is diverting from interstate travel to the alternative routes.

Queue Warning System

System View

1. The Queue Warning System monitors traffic conditions using third party speed and travel time data.
2. The Queue Warning System determines that traffic congestion is increasing resulting in slowing traffic.

3. The Queue Warning System detects that traffic speeds have decreased to the point where a traffic queue has begun to form.
4. The Queue Warning System determines the location of the end of the queue relative to available DMS that are capable of displaying a queue warning message.
5. The Queue Warning System automatically identifies the location and DMS where proposed message(s) would be displayed
6. The Queue Warning System formulates the appropriate messages and automatically distributes these to the DMS for display.
7. The DMS begin to display the Queue Warning System traveler information message similar to “Traffic Stopped Ahead XX Miles.”
   Note: This generic message may be updated with specific details pertaining to the traffic slow down or queue dependent on traffic management personnel workload. Additional details may include the location of the slow down, nature of the slowdown, and other specific details to enhance the credibility of the message and increase driver compliance. Drivers located downstream of the end of the queue but upstream of the bottleneck location (i.e., within the queue) may observe that DMS are blanked out, display an alternate message, or provide more specific details stating the reason for the slowdown and/or location of the incident or bottleneck.
10. The Queue Warning System continues to monitor traffic conditions.
11. Stopped traffic begins to clear and the traffic queue dissipates.
12. The Queue Warning System automatically identifies that the traffic queue is dissipating and automatically removes the Queue Warning System messages.
13. The DMS revert to blank screens or other messages per KYTC policy.

Traveler’s Perspective

1. A driver on I-71/I-75 approaches one of the DMS that is part of the Queue Warning System.
2. The driver notices that the DMS contains a message similar to “Traffic Stopped Ahead XX Miles.”
3. The driver slows their vehicle in anticipation of the stopped traffic.

Traffic Management Personnel Perspective

1. Traffic management personnel observe on their displays that traffic is congested and that a traffic queue has started to form.
2. Traffic management personnel notice that the DMS now is displaying a queue warning message.
3. Traffic management personnel observe that the traffic is beginning to dissipate.
4. Traffic management personnel observe that the DMS are reverting to blank screens or other messages per KYTC policy.

Ramp Metering System

System View

1. The Ramp Metering System determines that the conditions for ramp metering are about to be met (i.e., time-of-day).
2. The ramp meters are automatically activated based upon pre-programmed conditions such as time of day and traffic volumes. Beacons associated with ramp meter advance warning signs that are located on the adjacent arterial or ramp begin to flash indicating that metering operation on the adjacent ramp is in effect.
3. The traffic signal located at the ramp begins to initiate ramp metering at the selected ramps alternating between “red” and “green” according to the metering rate calculated for the particular ramp.
4. The ramp metering continues until the end of the pre-defined window.
5. The Ramp Metering System automatically discontinues ramp metering operations.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an interstate entrance ramp that can be metered.
2. As the driver approaches the ramp/arterial intersection the driver notices an advanced warning sign that indicates that the entrance ramp may be metered. The advance warning sign has flashing beacons that are flashing.
3. The driver approaches the ramp meter signal near the end of the ramp and notices that it appears to be operational and changing between a red and green signal at a steady rate.
4. Driver arrives at the ramp metering signal and waits for the traffic signal to turn green before proceeding.
5. Driver merges with interstate mainline traffic in the same manner as they do today.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline and metered ramps as part of revised standard operating procedures.
2. The ramp metering continues until the end of the pre-defined window.
3. The Ramp Metering System automatically discontinues ramp metering operations.
4. Traffic management personnel observe that ramp metering has been discontinued.

6.3. Scenario 3: Off-Peak, Minor Incident

Incident operations scenarios are representative of situations where incidents occur within the stated time period (e.g., off-peak and peak periods). Incident scenarios could represent numerous situations (e.g., minor lane blocking incidents, major multi-lane or full closure incidents, weather events, or other event that causes disruption to traffic flow). The incident operations off-peak period scenario is representative of a situation where a minor incident occurs at a time when traffic volumes are light such as on a Sunday during the late evening hours. The incident causes minor impacts to traffic flow within the immediate vicinity of the incident but otherwise, driving conditions are generally free flow outside the segment being impacted. As traffic approaches the incident scene prevailing traffic speeds begin to vary across lanes. The greatest speed reductions occur in the lane most impacted by the incident. Higher speeds are maintained in the lanes that are the farthest away from the lane most impacted by the incident. Traffic flow is normal and speeds are near free flow for road segments immediately downstream of the incident.

Scenario Assumptions

1. All equipment is operating normally.
2. There is a traffic incident that causes minor impacts to traffic flow within the immediate vicinity of the incident but otherwise, driving conditions are generally free flow outside the segment being impacted.
3. As traffic approaches the incident scene prevailing traffic speeds begin to vary across lanes with the greatest speed reductions occurring in the lane impacted by the incident. Speeds are the greatest in lanes that are the farthest away from the lane the incident is in. However, the traffic slowdown is minimal and not significantly impeding overall travel times.
4. Traffic flow is normal and speeds are near free flow for road segments immediately downstream of the incident.
5. Comparative route travel time system would be active and calculating travel times for two or three comparative routes to a common downstream destination
6. Estimated travel times are being automatically calculated based on data collected from available sources.
7. Comparative route travel time is displayed in real-time using roadside comparative route travel time signs.
8. Travel times are not permitted to be below the travel time equivalent of the posted speed limit.
9. Queue Warning System is active.

10. The Ramp Metering System is configured to only operate during the peak period and therefore would not be permitted to meter traffic in the off-peak period (i.e., near-term deployment).[8]
11. Scenario Location: I-71/I-75 Northbound between KY 1017 (Turfway Road) and US 25 (Dixie Highway).

Comparative Travel Time System

System View

1. The traffic monitoring systems are detecting that traffic is in a free-flowing, at-speed pattern with the exception of the one segment where the incident has occurred.
2. The Comparative Travel Time System is automatically calculating travel times for alternative routes for the various Comparative Travel Time displays.
3. The comparative travel time is automatically sent to the appropriate displays, which are displaying the information.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an I-71/I-75 interchange that has Comparative Travel Time displays.
2. As the driver approaches the Comparative Travel Time display, they observe that the travel times being displayed are consistent with their expectations regarding a typical travel day although they notice that the travel times for their current route are slightly longer than normal.
3. The driver chooses to continue to the ramp to I-71/I-75 northbound and merge onto the interstate.
4. A separate driver already driving on I-71/I-75 northbound approaches a Comparative Travel Time display visible from the interstate.
5. As the driver approaches the Comparative Travel Time display, they observe that the travel times being displayed are consistent with their expectations regarding a typical travel day, although they notice that the travel times for the Interstate are slightly longer than usual.
6. The driver chooses to continue utilizing I-71/I-75 northbound for their travel.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline as part of revised standard operating procedures.
2. No atypical traffic patterns are observed by the traffic management personnel in this scenario outside of the incident identified in the single segment.
3. Traffic management personnel verify the incident using CCTV.
4. Traffic management personnel enter an incident report in ATMS, activate applicable DMS messaging, and disseminate incident information via social media and other means.
5. Traffic management personnel observe that traffic approaches the incident scene at prevailing traffic speeds, but that speeds decrease in the immediate vicinity of the incident.
6. Traffic management personnel observe that the traffic delays are minimal.
7. Traffic management personnel view a confirmation in the ATMS that the posted travel times corresponding to free-flow traffic are being displayed on the Comparative Travel Time displays. This is verified by traffic management personnel using CCTV cameras.

Queue Warning System

System View

1. The Queue Warning System monitors traffic conditions using third party speed and travel time data.

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[8] In the mid- and long-term, the ramp metering system would be permitted to meter traffic on a traffic responsive basis and would be configured to operate during the peak and off-peak periods.

2. The Queue Warning System determines that traffic is in a free-flowing status for most of the Interstate but has slowed slightly in the segment with the minor incident.
3. The Queue Warning System determines that there are no traffic queues forming, although traffic within the segment where the incident occurred has slowed marginally from free-flow speed.
4. The Queue Warning System does not initiate any queue warning messages.
5. The DMS associated with the Queue Warning System are either blank or being used for other purposes as dictated by KYTC policy.

Traveler's Perspective

1. A driver on I-71/I-75 approaches one of the DMS that is part of the Queue Warning System.
2. The driver notices that the DMS is either blank or is displaying a non-queue warning message.
3. The driver proceeds at speed along the interstate.

Traffic Management Personnel Perspective

1. Traffic management personnel observe on their displays that traffic is generally moving in a free-flow state and there are no traffic queues forming.
2. Traffic management personnel observe that the traffic near the incident is moving slightly slower than a free-flow state.

Ramp Metering System

System View

1. All ramp meter signals associated with the system appear off (i.e., not lit or displaying a signal indication, like a "Flashing Yellow" as does ODOT). Beacons associated with ramp meter advance warning signs that are located on the adjacent arterial or ramp do not flash, indicating that metering operation on the adjacent ramp is not in effect.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an interstate entrance ramp that can be metered.
2. As the driver approaches the ramp/arterial intersection the driver notices an advanced warning sign that indicates that the entrance ramp may be metered.
   a. The advance warning sign has flashing beacons that would flash if ramp meters were active. In this scenario, the flashing beacons are not activated and appear to the driver as off/not lit.
3. The driver accelerates toward the ramp meter signal and it appears as "off or not lit".
4. Driver continues to accelerate past the ramp meter signal without stopping or slowing.
5. Driver merges with interstate mainline traffic in the same manner as they do today.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline and metered ramps as part of revised standard operating procedures.
2. Traffic management personnel verify that the Ramp Metering System is off-line based on the ATMS outputs and CCTV camera observations (when possible, given that priority is being given to the incident related activities).

6.4. Scenario 4: AM Peak, Major Incident

The incident operations peak period scenario is representative of a situation where a lane blocking incident occurs at a time when traffic volumes are elevated such as during the AM or PM peak commuting hours on a typical day. The incident causes major impacts to traffic flow in the vicinity of the incident but otherwise, driving conditions are typical for a peak period outside the segment being impacted. As traffic approaches the incident location, long queues form with all lanes experiencing heavy congestion. Traffic flow is slightly less than normal and speeds are near free flow for the road segment immediately downstream of the incident.

Scenario Assumptions

1. All equipment is operating normally.
2. Driving conditions are fair and traffic volumes are elevated from off-peak conditions.
3. Drivers are experiencing traffic slowdowns and congestion.
4. There is a major incident that is causing a significant traffic slowdown with long queues forming.
5. Comparative route travel time system would be active and calculating travel times for two or three comparative routes to a common downstream destination
6. Estimated travel times are being automatically calculated based on data collected from available sources.
7. Comparative route travel time is displayed in real-time using roadside comparative route travel time signs.
8. Travel times are not permitted to be below the travel time equivalent of the posted speed limit.
9. Queue Warning System is active.
10. The Ramp Metering System is configured and operational during this period.
11. The Ramp Metering System is configured for near-term operations and is activated and deactivated based on time-of-day with metering rates calculated based on real-time conditions.
12. First responders have determined that the ramp immediately upstream of the incident needs to be closed. Local law enforcement or Kentucky State Police are informed, and one or more vehicles are placed to physically block the ramp to prevent its use.
13. Scenario Location: I-71/I-75 Northbound between KY 1017 (Turfway Road) and US 25 (Dixie Highway).

Comparative Travel Time System

System View

1. The traffic monitoring systems are detecting that traffic is in a congested condition with speeds lower than free-flowing speed.
2. The Comparative Travel Time System is automatically calculating travel times for alternative routes for the various Comparative Travel Time displays.
3. The Comparative Travel Time System determines that the travel time via I-71/I-75 northbound is significantly greater than for a designated alternative route via I-275 and I-471.
4. The comparative travel time is automatically sent to the appropriate displays, which are displaying the information.

Traveler’s Perspective

1. A driver bound for the interstate travels along an arterial and approaches an I-71/I-75 interchange upstream of the incident that has Comparative Travel Time displays.
2. As the driver approaches a Comparative Travel Time display, they observe that the times being displayed suggest that the travel time for an alternative route via I-275 is significantly less than the travel time associated with the I-71/I-75 northbound route.
3. The driver decides that they are familiar with the alternative route and that the time savings is such that they choose to divert to the alternative route. NOTE: Only a percentage of such travelers will actually choose to divert their travel.
4. A separate driver already driving on I-71/I-75 northbound approaches a Comparative Travel Time display (south of I-275) that is visible from the interstate and upstream of the incident.
5. As the driver approaches the Comparative Travel Time display, they observe that the times being displayed suggest that the travel time for an alternative route via I-275 is significantly less than the travel time associated with the I-71/I-75 northbound route.

6. The driver on the interstate is familiar with the alternative route and decides that they are comfortable with using the alternative route. NOTE: Only a percentage of such travelers will actually choose to divert their travel.
7. The driver proceeds to use the I-275 exit ramp to divert to the alternative route.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline as part of revised standard operating procedures.
2. A major incident with significant delays and congested traffic is identified by traffic management personnel.
3. Traffic management personnel verify the incident using CCTV if the incident was initially identified by some other means.
4. Traffic management personnel enter an incident report in ATMS, activate applicable DMS messaging, and disseminate incident information via social media and other means.
5. Traffic management personnel dispatch the Freeway Service Patrol (which is operational during this time period). Traffic management personal also contact a Public Service Answering Point (PSAP) if emergency responders are not already on scene.
6. The traffic management personnel confirm that the posted travel times corresponding to severely congested traffic are being displayed on the Comparative Travel Time displays using CCTV cameras.
7. The traffic management personnel observe that some traffic is diverting from interstate travel to the alternative routes.

Queue Warning System

System View

1. The Queue Warning System is monitoring traffic conditions using third party speed and travel time data.
2. The Queue Warning System determines that traffic congestion is increasing resulting in slowing traffic.
3. The Queue Warning System detects that traffic speeds have decreased to the point where a traffic queue has begun to form.
4. The Queue Warning System determines the location of the end of the queue relative to available DMS that are capable of displaying a queue warning message.
5. The Queue Warning System automatically identifies the location and DMS where proposed message(s) would be displayed.
6. The Queue Warning System formulates the appropriate messages and automatically distributes these to the DMS for display.
7. The DMS begin to display the Queue Warning System traveler information message similar to "Traffic Stopped Ahead XX Miles."
   Note: This generic message may be updated with specific details pertaining to the traffic slow down or queue dependent on traffic management personnel workload. Additional details may include the location of the slow down, nature of the slowdown, and other specific details to enhance the credibility of message and increase driver compliance. Drivers located downstream of the end of the queue but upstream of the bottleneck location may observe that DMS are blanked out, display an alternate message, or provide more specific details stating the reason for the slowdown and/or location of the incident or bottleneck.
14. The Queue Warning System continues to monitor traffic conditions.
15. The incident is cleared and stopped traffic also begins to clear and the traffic queue dissipates.
16. The Queue Warning System automatically identifies that the traffic queue is dissipating and discontinues the Queue Warning System display of messages.
17. The DMS revert to blank screens or other messages per KYTC policy.

Traveler's Perspective

1. A driver on the interstate approaches one of the DMS that is part of the Queue Warning System.
2. The driver notices that the DMS contains a message similar to "Traffic Stopped Ahead XX Miles."
3. The driver slows their vehicle in anticipation of the stopped traffic.

Traffic Management Personnel Perspective

1. Traffic management personnel observe that a major incident has occurred that is causing significant queues, congestion, and slow speeds. Traffic management personnel confirm the incident using CCTV. Traffic management personnel enter an incident report in ATMS and disseminate incident information via social media and other means.
2. Traffic management personnel observe on their displays that traffic is congested and that a traffic queue has started to form.
3. Traffic management personnel notice that the DMS now is displaying a queue warning message.
4. Traffic management personnel observe that the traffic is beginning to dissipate.
5. Traffic management personnel observe that the DMS are reverting to blank screens or other messages per KYTC policy.

Ramp Metering System

System View

1. The Ramp Metering System determines that the conditions for ramp metering are about to be met (i.e., time-of-day).
2. The ramp meters are automatically activated based upon pre-programmed conditions such as time-of-day and traffic volumes. Beacons associated with ramp meter advance warning signs that are located on the adjacent arterial or ramp begin to flash indicating that metering operation on the adjacent ramp is in effect.
3. The traffic signal located at the ramp begins to initiate ramp metering at the selected ramps alternating between "red" and "green" at the calculated rate.
4. The Ramp Metering System continuously monitors traffic conditions and changes the metering rate to reflect the traffic conditions.
5. The ramp metering continues until the end of the pre-defined window.
6. The Ramp Metering System automatically discontinues ramp metering operations.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an interstate entrance ramp that can be metered.
2. As the driver approaches the ramp/arterial intersection the driver notices an advanced warning sign that indicates that the entrance ramp may be metered.
   - The advance warning sign has flashing beacons that are flashing.
3. The driver approaches the ramp meter signal near the end of the ramp and notices that the ramp meter signal appears to be operational and changing between a red and green signal at a steady rate.
4. Driver arrives at the ramp metering signal and waits for the traffic signal to turn green before proceeding.
5. Driver merges with interstate mainline traffic in the same manner as they do today.
6. A different driver approaches the ramp immediately preceding the incident.
7. The driver notices traffic queued on the on-ramp.
8. The driver observes that the advanced warning sign has flashing beacons that are flashing.
9. The driver observes that the ramp metering signal is continuously showing "red."
10. The driver observes a first responder closing the on-ramp from travel.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline and metered ramps as part of revised standard operating procedures.
2. The traffic management personnel observe that ramp metering has been initiated by the system.
3. The traffic management personnel confirm the ramp metering is operational in the ATMS. This is verified through CCTV cameras, when possible, given that priority will be given to the incident related activities.
4. Traffic management personnel observe that a major incident has occurred that is causing significant queues, congestion, and slow speeds.
5. Traffic management personnel confirm the incident using CCTV.
6. Traffic management personnel enter an incident report in ATMS, activate applicable DMS messaging, and disseminate incident information via social media and other means.
7. Traffic management personnel observe using CCTV that there are no vehicle using the immediately upstream ramp and that law enforcement has physically blocked the ramp.
8. Traffic management personnel observe using CCTV that vehicle have again begun using the immediately upstream ramp and that law enforcement has reopened blocked the ramp.
9. The ramp metering continues until the end of the pre-defined window.
10. The Ramp Metering System automatically discontinues ramp metering operations.
11. The TOC Operator notices that ramp metering has been discontinued.

6.5. Scenario 5: System Failure/Maintenance

Maintenance and failure scenarios could be numerous and therefore it is difficult to represent all the possible scenarios. For the purposes of simplicity and because the response is somewhat similar for both preventative and responsive maintenance actions, this section presents just one scenario focused on a system failure situation. The system failure/maintenance scenario is representative of a field equipment failure/malfunction that occurs at a specific location. The failure/malfunction impacts normal system operation at the impacted location but does not affect operation of other field equipment. The failed/malfunctioning equipment must be repaired or replaced.

Scenario Assumptions

- The equipment along one segment of the interstate has failed or has been removed for service to perform maintenance. All three systems along this segment are impacted.
- Comparative route travel time system would be active and calculating travel times for two or three comparative routes to a common downstream destination
- Estimated travel times are being automatically calculated based on data collected from available sources.
- Comparative route travel time is displayed in real-time using roadside comparative route travel time signs.
- Travel times are not permitted to be below the travel time equivalent of the posted speed limit.
- Queue Warning System is active.
- The Ramp Metering System is configured to only operate during the peak period and therefore would not be permitted to meter traffic in the off-peak period (i.e., near-term deployment).[9]
- Scenario Location: I-71/I-75 Northbound between KY 1017 (Turfway Road) and US 25 (Dixie Highway).

Comparative Travel Time System

Because the system failure is assumed to be contained within one segment of the interstate, the Comparative Travel Time System is assumed to be able to continue to accurately estimate travel times for alternative routes. However, if the segment undergoing maintenance or experiencing a system failure impacts the ability of the system to determine travel times, the following actions will be observed.

[9] In the mid- and long-term, the ramp metering system would be permitted to meter traffic on a traffic responsive basis and would be configured to operate during the peak and off-peak periods.

System View

1. The traffic monitoring systems are detecting that traffic is in a free-flowing, at-speed pattern.
2. The system identifies that a portion of the system is not responsive and issues a notification to the TOC Operator identifying the systems that are off-line.
3. The Comparative Travel Time System determines that it cannot estimate accurate travel times due to the system failure/maintenance.
4. The Comparative Travel Time System removes travel time information on alternative routes from DMS.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an I-71/I-75 interchange that has Comparative Travel Time displays.
2. As the driver approaches the Comparative Travel Time Display, they observe that the travel times are not being displayed.
3. The driver chooses to continue to the ramp to I-71/I-75 northbound and merge onto the interstate.
4. A separate driver already driving on I-71/I-75 northbound approaches a Comparative Travel Time display visible from the interstate.
5. As the driver approaches the Comparative Travel Time Display, they observe that the travel times are not being displayed.
6. The driver chooses to continue utilizing I-71/I-75 northbound for their travel.

Traffic Management Personnel Perspective

1. Traffic management personnel are monitoring traffic operations on the interstate mainline as part of revised standard operating procedures.
2. The TOC Operator receives a notification from the Comparative Travel Time System that a portion of the system is off-line and that this portion inhibits the system from calculating travel time for one or more of the alternative routes.
3. The TOC Operator confirms the status of the system.
4. The TOC Operator notices that the travel time information has been removed from the Comparative Travel Time DMS displays. TOC Operator notifies systems personnel of the outage.

Queue Warning System

The Queue Warning System is expected to operate normally outside of the segment impacted by the system maintenance/failure.

System View

1. The Queue Warning System is monitoring traffic conditions using third party speed and travel time data.
2. The Queue Warning System determines that the monitoring equipment and/or the DMS are off-line and issues a notification to the TOC Operator.
3. The TOC Operator verifies the system status.
4. The DMS associated with the Queue Warning System in the segment with the off-line equipment is blank or being used for other purposes as dictated by KYTC policy.

Traveler's Perspective

1. A driver on the I-71/I-75 approaches one of the DMS that is part of the Queue Warning System.
2. The driver notices that the DMS is either blank or is displaying a non-queue warning message.
3. The driver proceeds at speed along the interstate.

Traffic Management Personnel Perspective

1. Traffic management personal observe on their displays that traffic is moving in a free-flow state and there are no traffic queues forming.
2. Traffic management personal receives a notification that the Queue Warning System for the impacted segment is off-line.
3. Traffic management personal verifies the system status. TOC Operator notifies systems personnel of the outage.

Ramp Metering System

The Ramp Metering System is expected to operate normally outside of the segment impacted by the system failure/maintenance. Within the segment, the ramp metering system will operate as if it were not active.

System View

1. All ramp meter signals associated with the system appear off (i.e., not lit or displaying a signal indication, like a "Flashing Yellow" as does ODOT). Beacons associated with ramp meter advance warning signs that are located on the adjacent arterial or ramp do not flash indicating that metering operation on the adjacent ramp is not in effect.

Traveler's Perspective

1. A driver bound for the interstate travels along an arterial and approaches an interstate entrance ramp that can be metered.
2. As the driver approaches the ramp/arterial intersection the driver notices an advanced warning sign that indicates that the entrance ramp may be metered.
   a. The advance warning sign has flashing beacons that would flash if ramp meters were active. In this scenario, the flashing beacons are not activated and appear to the driver as off/not lit.
3. The driver accelerates toward the ramp meter signal and it appears as "off or not lit".
4. Driver continues to accelerate past the ramp meter signal without stopping or slowing.
5. Driver merges with interstate mainline traffic in the same manner as they do today.

Traffic Management Personnel Perspective

1. Traffic management personal are notified that the ramp metering system within the segment is not operational.
2. Traffic management personal continue to monitor traffic conditions.
3. Traffic management personal identify that the unmetered ramp in the segment with the maintenance/system failure is causing additional congestion with the influx of vehicles from the ramp.
4. Traffic management personal notifies KYTC traffic signal operations staff regarding the traffic conditions and the potential impact on the upstream ramp.
5. Using their system console, KYTC traffic signal operations staff manually adjust the timing of the upstream ramps to better accommodate the segment with an off-line ramp meter.